GENERAL REPORT

ON THE OPERATIONS

OF THE

GREAT TRIGONOMETRICAL SURVEY OF INDIA,

DURING

1867-68,

Prepared for submission to the Government of India.

BY

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SUPERINTENDENT G. T. SURVEY.

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1868.

THE OPERATIONS OF THE GREAT TRIGONOMETRICAL SURVEY OF INDIA IN 1867-68.

These operations may be classified as follows :—

I. *Trigonometrical;* the Brahmaputra Series of triangles, on the meridian of 90°.

II. *Trigonometrical;* the Eastern Frontier Series.

III. *Trigonometrical;* the Meridional Series connecting Jubbulpore with Madras.

IV. *Trigonometrical;* the Longitudinal Series west of Calcutta.

V. *Trigonometrical;* the measurement of a base-line of verification, at Bangalore.

VI. *Trigonometrical;* the Bangalore Longitudinal Series.

VII. *Topographical;* Himalayan Surveys in the districts of Kumaon and Gurhwal.

VIII. *Topographical;* the Survey of the Province of Kattywar.

IX. *Geographical;* exploration of Trans Himalayan Regions.

X. *Geographical;* a Military Survey in connexion with the operations of the Abyssinian Expedition.

XI. *Astronomical;* observations of the Total Eclipse of the sun on the 18th August 1868.

XII. *Astronomical;* determining the latitudes of certain stations of the triangulation between the meridians of 74° and 76°.

XIII. *Miscellaneous;* Leveling Operations, and arrangements for the future better protection of the stations of this Survey.

XIV. *Geodetic;* determining at certain stations of the Great Arc, the number of diurnal vibrations of two pendulums, the property of the Royal Society.

XV. *Magnetic;* determining the elements of Dip, Declination and Total Force at Dehra Doon and at certain stations of this Survey.

XVI. *Computations;* the final examination, reduction and publication of the Trigonometrical and Astronomical Observations.

XVII. *Cartography;* the preparation and publication of the various Charts and Maps.

(2.) The out-turn of work executed by the Trigonometrical and Topographical parties only, may be briefly summarized as follows:—The measurement of a base-line of verification. Principal triangulation* with the Great Theodolites, 65 triangles, the errors of which, as well as the probable errors of the angles, are shewn in the margin; they cover an area of 8561 square miles, and would if united form a chain of triangles 293 miles in length. Secondary triangulation with theodolites of various sizes, 6300 square miles, defining the positions of 1479 points, of about 400 of which the heights were also determined. Topographical surveying, on the scale of 12 inches to the mile, 378 acres; on the scale of 2 inches to the mile, 800 square miles; and on that of 1 inch to the mile 1348 square miles. Boundary surveys, 620 linear miles.

Series.	Probable Errors of Observed Angles.		Errors of Triangles.	
	Number.	Amount.	Number.	Amount.
II ...	21	±0″·19	7	0″·41
III ...	69	0·19	23	0·27
IV ...	24	0·21	8	0·28
V ...	27	0·19	9	0·77
VI ...	54	0·26	18	0·49
Averages, ...		± 0·21	...	0·42

(3.) Several Officers have been deputed to accompany the Abyssinian expedition as geographical explorers, and to take observations of the great total eclipse of the sun for which the year 1868 will long be celebrated in the annals of Astronomical Science. As the performances of these officers will be described at length in sections X. and XI. of this report, I need not allude to them further in this place than to express my great gratification that the Trigonometrical Survey of India has been able to take a share in the labors of an arduous but most successful military expedition, and to assist in the solution of problems which are of the highest scientific interest, by undertaking investigations of the remarkable but rarely seen phenomena of a total eclipse of the sun.

(4.) I proceed as usual to report on the general operations of the respective Survey Parties and Offices; further details will be given in the Appendices, which contain selections from the annual Narrative Reports of the Executive Officers, and a special Report by Captain T. G. Montgomerie, on the Trans-Himalayan Explorations.

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* The Great Theodolites which are employed for the Principal Triangulation have azimuthal circles of 24 to 36 inches in diameter, which are read by 5 equidistant microscopes, and vertical circles of 15 to 18 inches in diameter, which are read by 2 microscopes. The system of observing the principal horizontal angles is as follows:—The telescope is pointed to some convenient signal, with the zero microscope set to 0° 0′; the surrounding stations are then observed in order round the horizon, an entire revolution of the instrument bringing the telescope back to the referring-mark, which is again observed; this completes a single round of measures, at each of which all the 5 microscopes are read; the round is, as a rule, repeated twice, but if the 3 measures of any angle differ by more than 2″, the observations of that angle are repeated as often as may be considered desirable; the telescope is then turned through a semi-revolution in altitude and in azimuth, and pointed to the referring-mark; the zero microscope is thus brought over 180° on the azimuthal circle, and the face of the vertical circle becomes transposed from the observer's left to his right hand, or *vice versâ*; three rounds of measures are then taken, and this completes an entire group of observations of each signal, on "face right and face left," and on 10 equidistant graduations of the azimuthal circle. Five complete groups of measures are invariably made in a similar manner, the setting of the zero microscope being shifted in each group, so as to bring 50 equidistant graduations under the microscopes, and to vary the position of the axis in its socket as much as possible, in the course of the whole of the observations to each signal. For this purpose the arc, 72°, between the microscopes, is added to the arc, 7° 12′, which expresses the fiftieth part of the circumference of the circle, to obtain the requisite change of graduation; thus the successive settings of the zero microscope are 0°, 79° 12′, 158° 24′, 237° 36′ and 316° 48′. The signals which are employed are invariably luminous, heliotropes by day, and lamps by night, most of the observations being taken by night, when the atmosphere is usually most favorable.

The quality of the principal triangulation with the Great Theodolites is tested by the probable errors of the observed angles, and by the triangular errors. The nature of the probable error may be defined as being such that the chances of the actual error exceeding or falling short thereof are equal; it is determined by a formula which takes into consideration the accidental errors of each single observation, and of the graduations of the circles on which the measures are made. The triangular error is the amount by which the sum of the observed values of the three angles of a triangle exceeds or falls short of 180° + the spherical excess.

No. I.—TRIGONOMETRICAL.

THE BRAHMAPUTRA SERIES, MERIDIAN 90°.

PERSONNEL.

Lieut. H. R. Thuillier, R.E., Surveyor 2nd Grade.
" E. M. Larminie, R.E., Assistant Surveyor 2nd Grade.
Mr. C. J. Neuville, Civil Assistant 4th Grade.
" F. W. Ryall, Sub-Assistant 1st Grade.
" G. A. Harris, Sub-Assistant 2nd Grade.
" W. J. O'Sullivan, Sub-Assistant 3rd Grade.

(5.) From the Longitudinal Series which trends eastwards, on the parallel of 23°, from the meridian of Calcutta to the frontier of British Tipperah, and was completed last year, a new meridional series has been commenced and named as above. It is required in order to complete the basis which is already supplied to a certain extent by the triangulation on the meridians of 88½° and 91½°, and the parallels of 23° and 26°, for the surveys of the districts of Nuddea and Jessore, the divisions of Rajshahee and Dacca, and other portions of Eastern Bengal. Were the triangulation of this tract of country to be made to conform strictly to that of western Bengal and the North-West Provinces, two meridional series would be required for the area remaining to be completed; but the accuracy of the topography of the present day is such that a smaller amount of triangulation will suffice for all practical purposes, and it is no longer necessary to have as many chains of triangles in a given area as were required formerly; the topographical requirements of Eastern Bengal will be amply met by one additional meridional series of triangles, running in the neighbourhood of the Brahmaputra River, though at a sufficient distance to secure the stations from the excursions of the river.

(6.) This series has now been commenced by Lieutenant Thuillier, who was employed during the field season under review in selecting stations of observations, and completing all the necessary preliminaries. His operations lay in the districts of Furreedpore, Dacca, Mymensing, and Pubnah, where the ground is almost perfectly level, covered with immense swamps, and intersected by innumerable nullahs and streams. The villages are generally surrounded by valuable groves of mangoe, palm and other trees, and all ground that is not directly under cultivation is more or less covered by luxuriant vegetation. Roads are very rarely met with, all the traffic of the country being carried on by boats. No hills or mounds exist on which the survey stations might be fixed; each station has therefore to be made by constructing a tower of sufficient height to surmount the curvature of the ground, then the lines between contiguous towers are cleared of trees and jungle, in order to obtain the necessary mutual visibility. Under these circumstances Lieutenant Thuillier and his Assistants were so fully employed in the preliminary operations of building towers and cutting lines, that it was necessary to postpone the measurement of the principal angles until next season.

(7.) The extent of triangulation laid out covers a direct distance of 81 miles, and an area of 1293 square miles, by 22 stations arranged so as to form 4 symmetrical hexagonal figures. This operation involved the clearance of 410 miles of narrow trial lines, and 296 miles of broad final lines, mostly through heavy jungle; 10 towers were completed in readiness for the future observations.

(8.) Lieutenant Larminie was deputed to commence a first class secondary triangulation of the valley of Assam, starting from the principal stations in the

neighbourhood of Gowhatty, which form the eastern extremity of the triangulation already completed on the parallel of 26°. Two Revenue Survey parties are now employed in Upper Assam, and are much in want of trigonometrical points; but the distance which will have to be crossed is so great that some time must elapse before their operations can be reached. Fortunately there are several hills which will serve as convenient sites for the stations, and materially facilitate the progress of the operations; but the difficulties of moving across country are very great; when once the neighbourhood of the Brahmaputra River is left, the surveyor becomes dependent on the very limited resources of the district for the means of carriage, unless he happens to be provided with elephants. These animals could not be obtained last season, and so many difficulties were met with in securing coolies as carriers that Lieutenant Larminie reports that not less than 33 days were spent in total inactivity. Thus the season was entirely devoted to preliminary operations, and the measurement of the angles could not be commenced; but 11 hill stations were selected, 10 of which had to be cleared of more or less dense jungle; and the operations were carried over a direct distance of 80 miles, which under the circumstances is probably as much as could be expected.

No. II.—TRIGONOMETRICAL.

THE EASTERN FRONTIER SERIES.

(9.) By the close of the field season of 1866-67 this triangulation had been brought down from the western extremity of the Assam valley through the Kossia and Tipperah Hills, and along the borders of the districts of Chittagong, Akyab, and Arracan, to the vicinity of Toangoup and Sandoway. During the year under review it was directed into British Burmah, and crossed the difficult range of hills, uninhabited save by dacoits and outlaws, which intervenes between Arracan and Prome.

PERSONNEL.

W. C. Rossenrode, Esq., Assist. Surveyor 1st Grade.
Mr. H. Beverley, Civil Assistant 3rd Grade.
„ W. C. Price, Sub-Assistant 3rd Grade.
„ E. J. Connor, Sub-Assistant 3rd Grade.

(10.) Though the physical difficulties to be overcome do not appear to have been materially greater than in preceding years, and no extraordinary precautions had to be taken to protect the Surveyors from the attacks of the predatory tribes occupying the hill frontier, there has this year been a very marked falling off in the annual out-turn of work, whether measured by the direct progress in linear miles or by the area in square miles covered by the triangulation. This will be seen by the following figures:—

Season.	Direct progress in miles.	Area triangulated in square miles.	District of operation.
1861-62, ..	62 ..	1207 ..	Kossia Hills.
1862-63, ..	49 ..	884 ..	Tipperah, British and Independent.
1863-64, ..	52 ..	764 ..	Ditto.
1864-65, ..	80 ..	1675 ..	Chittagong Hill Tracts.
1865-66, ..	135 ..	2419 ..	Chittagong and Akyab Hill Tracts.
1866-67, ..	166 ..	3314 ..	Akyab Hill Frontier.
Average of 6 seasons,	91 ..	1710	
1867-68, ..	38 ..	573 ..	Sandoway to Prome.

(11.) The falling off in the out-turn of work is entirely due to the difficulties which were met with in obtaining coolies to act as carriers, and to build the stations and clear the lines of forest and jungle. For instance the clearance of one of the lines which with an ordinary supply of labor might have been done in 8 or 10 days, occupied not less than 2½ months. As the province of British Burmah is very thinly inhabited and covered with dense forest, the future progress of the operations must necessarily be slow; but I believe that similar difficulties to those which were encountered this year, in crossing the range between Arracan and Prome, will not be met with again, and I expect that under Mr. Rossenrode's vigorous and judicious management no delays will occur that can possibly be avoided.

(12.) During the season five new principal stations were fixed, forming a hexagon on the terminal side of the preceding triangulation, by which an area of 573 square miles is covered, and the series has been carried forward a direct distance of 38 miles. A line has been selected, with much trouble and after a prolonged and minute examination of the ground, for the measurement of a base of verification, on the parallel of latitude, (18°) in which the base lines of Beder and Vizagapatam are situated ; 22 principal stations have been selected in advance over a direct distance of 116 miles, and 50 miles of lines and 153 miles of road way 6 feet wide, were cleared through more or less dense forest. A series of secondary triangles was carried down the coast of Arracan for a distance of 66 miles, fixing the position of the station of Sandoway en-route; this series will as soon as practicable be extended southwards to Cape Negrais, and the Alguada Reef Lighthouse.

(13.) As this party was located at Akyab during the recess seasons of 1866 and 1867, Mr. Rossenrode was directed to avail himself of the opportunity to take tidal observations for the purpose of verifying his trigonometrical determinations of height, which had been carried over a distance of many hundred miles without having been connected with the sea level. No self registering tide guage being available, it became necessary to take observations of high and low water throughout an entire lunation. The guage was set up in the vicinity of a trigonometrical station at the mouth of the Koladyne river, within half a mile of Akyab Point. The waters washing the guage had a direct communication with the sea, and deepened rapidly from the bank to the guage. The site was sheltered from surf.

(14.) All requisite preliminaries having been completed, observations were commenced on the 24th October, by which time the rains were supposed to be ended and fair weather to have set in. But on the days on which Calcutta was visited by the disastrous Cyclone of 1867, the weather became very boisterous at Akyab, and from the 31st October to the 3rd November observations were impossible, and the gauge could not even be approached without danger. Observations were resumed as soon as the weather improved, but it was not until the 16th of November that they began to be reliable, but from that date to the 16th of December they were carried on without any break or disturbance.

(15.) The average range of the tide was found to be 5·67 feet, the maximum being 8·60 feet and the minimum 2·27 feet. The height of the bench-mark station on the coast near the tide guage, as determined by the preceding triangulation, was found to be only 1·94 feet in excess of the value given by the tidal observations, shewing that very little error had been generated in the course of a chain of triangulation many hundred miles in length.

No. III.—TRIGONOMETRICAL.

THE JUBBULPORE SERIES, MERIDIAN 80°.

PERSONNEL.

Geo. Shelverton, Esq., Assistant Surveyor.
Mr. M. C. Hickie, Civil Assistant 4th Grade.
„ F. Bell, Sub-Assistant 1st Grade.
„ E. P. Wrixon, Probationary Sub-Assistant.
„ A. C. Low, Probationary Sub-Assistant.

(16.) In my last report I shewed that a belt of about 2° 10′, between the parallels of 16° 25′ and 18° 35′, had still to be completed, to connect the northern portion of this chain of triangles, which emanates from a side near Jubbulpore of the Great Longitudinal Series, with the southern portion, which had been carried down to Madras in the course of the triangulation of the east coast. I had not ventured to anticipate that the connection would be completed in a single season, as the distance appeared to be more than could be accomplished in the time; I am therefore all the more gratified to be able to report that it has been completed in a very satisfactory manner by Mr. Shelverton during the field season now under review. The operations embraced the measurement of 23 principal triangles arranged so as to form a double polygon, two quadrilaterals and a pentagon, covering an area of 5634 square miles, and extending over a direct distance of 150 miles. An azimuth of verification was observed at one of the principal stations. The only drawback to these operations is that while the principal triangulation has been carried forward with unusual rapidity, the secondary triangulation has been neglected, and thus the charts are not so full of information as is desirable.

(17.) In the interval which elapsed between the termination of the rainy season, and the time when the unhealthy forest tracts between the Nerbudda and Godavery rivers, through which the triangulation had to be carried, might be safely entered, Mr. Shelverton employed himself in taking a series of observations, for determining the astronomical latitude of a trigonometrical station in the vicinity of Jubbulpore, with the 18-inch vertical circle of Troughton's Great Theodolite. Eleven pairs of north and south stars were selected from the nautical almanac, and 12 circum-meridional observations were made to each star; the agreement between the results of each observation is very satisfactory, and does credit to the observer and the instrument. The final result shows that there is probably about 5″ of southerly attraction at Jubbulpore as compared with Kalianpoor, the station of the Great Arc which is the origin of latitudes of the Indian Survey.

(18.) The future operations on this meridian will comprise the extension of the triangulation southwards along the coast, passing Pondicherry and Tranquebar, until the Straits which separate the Island of Ceylon from the Indian Peninsula, are reached. Here I hope that it will be possible to connect the Indian triangulation with that of Ceylon, for when this is done the combined operations will furnish a meridional arc of about 25° in length, extending from the Himalayas down to the southernmost point of Ceylon, which should be a valuable addition to geodesy. At present however the early completion of the longitudinal series on the parallel of 18°, which will connect the base line at Beder (on the Great Arc) with that at Vizagapatam, is more immediately required for the operations of the Indian Survey. Mr. Shelverton has consequently been instructed to commence this triangulation in the approaching field season.

No. IV.

THE WEST CALCUTTA LONGITUDINAL SERIES.

PERSONNEL.

H. Keelan, Esq., Surveyor 3rd Grade.
Mr. H. E. T. Keelan, Civil Assistant 4th Grade.
„ H. W. Peychers, Sub-Assistant 2nd Grade.
„ J. Trotter, Sub-Assistant 2nd Grade.
„ A. Moore, Sub-Assistant 4th Grade.

(19.) The revision of this chain of triangles, the reasons for which have already been explained in para. 52 of my Administration report for 1864-65, had been so nearly completed when last reported on, that I had reason to hope the operations would be finished in one more field season. I was aware however that it would probably be found necessary to clear the lines of trees which might have sprung up on them since the stations were first built, and also either to raise the stations, to enable them to overtop any houses which might have been subsequently erected, or to remove the houses, in order that the required mutual visibility might be obtained. All such measures would certainly retard the progress of the operations in a much greater degree than is usual, for they would be carried on in districts in the vicinity of Calcutta the inhabitants of which are proverbially litigious and indolent, very ready to take offence at what they may conceive to be an infringment of their rights, and very slow to assist the progress of the operations either by accepting employment as laborers, or by selling materials for the construction of the survey stations.

(20.) Mr. Keelan reached Raneegunge with his assistants early in November, but found the country so flooded by the heavy rains that had fallen during the cyclone which passed over Calcutta and the surrounding country on the 1st of that month, that he was obliged to halt for nearly a fortnight, until the inundation had sufficiently subsided to permit of the field work being commenced. It was long however before the ground was sufficiently dry to enable bricks to be burnt for the construction of stations in places where ready made bricks were not procurable. All the lines between the old stations (built in 1830) were found to be more or less blocked up by trees and houses, and arrangements had to be made for clearing them and raising the heights of the towers; also for constructing the new stations which were required to convert the original series of single triangles into a polygonal series, and clearing the lines to them. Mr. Keelan reports that much passive opposition was encountered, and that on two occasions the brick making was stopped in consequence of the preposterous demands which were made for the materials; fortunately he was cordially assisted by the district authorities, and thus, and by exercising much patience and forbearance, he was able eventually to carry on his operations without any break of continuity. Instead however of the operations being completed in a single field season, there is still work enough left to occupy the party for the greater portion of the coming season.

(21.) The final operations embraced the observation of the angles of 8 principal triangles, covering an area of 1326 square miles, and extending over a direct distance of 72 miles; 6 new tower stations were built, and 2 telegraph towers were raised and converted into stations; 272 miles of lines were cleared, and 111 miles of trial lines were traced.

No. V.—TRIGONOMETRICAL.

THE BANGALORE BASE-LINE.

(22.) The necessary preliminaries for the measurement of a base-line of verification at Bangalore, having been completed during the preceding field season, I was about to proceed to supervise the operation when I was prevented by a severe accident from leaving my head-quarters. Consequently I deputed Mr. Hennessey to take my place, and I have every reason to be well satisfied with the manner in which he has conducted the operations.

PERSONNEL.

J. B. N. Hennessey, Esq., Surveyor 1st Grade.
Lieut. J. Herschel, R.E., Surveyor 2nd Grade.
Captain Branfill, Surveyor 3rd Grade.
Lieut. W. M. Campbell, R.E., Surveyor 3rd Grade.
" M. W. Rogers, Assist. Surveyor 2nd Grade.
Mr. A. W. Donnelly, Civil Assist. 4th Grade.
" J. W. Mitchell, Sub-Assist. 2nd Grade.
" G. Anding, Sub-Assistant 2nd Grade.
" A. Christie, Sub-Assistant 3rd Grade.
" O. V. Norris, Sub-Assistant 4th Grade.
" C. D. Potter, Sub-Assistant 4th Grade.
" J. Bond, Sub-Assistant 4th Grade.

(23.) The measurement was executed with the admirable apparatus of compensated bars and microscopes which was designed by Colonel Colby, and brought out to India by Colonel Everest in 1830, for the operations of the Great Arc; it has been used, ever since, whenever a base-line has been measured in connection with the Indian triangulation; after having been transported over many thousand miles and employed at no less than 9 base-lines, (including Bangalore), it is still in nearly as good working order as when it was landed in India.

(24.) To be efficiently manipulated, it requires as many officers and assistants as suffice for two or three trigonometrical parties, and consequently, whenever a base-line is measured, certain parties have to be diverted from the triangulation, and concentrated on the measurement, and thus the apparent annual out-turn of work, which is usually measured by the progress of the triangulation, is necessarily reduced, as has happened this year.

(25.) The new base-line is situated on the table-lands of Bangalore, at an altitude of about 3030 feet above the level of the sea, and within a short distance of Colonel Lambton's base which was measured in 1804. I had wished to remeasure Colonel Lambton's line, the extremities of which are still in good preservation; but on ascertaining that it is now crossed by a railway on a high embankment, and by several tanks constructed for the purposes of irrigation, I was obliged to have another line selected in the neighbourhood. The two bases have however been carefully connected by triangulation.

(26.) The new base-line is 6·84 miles in length, and divided into 3 sections, which are connected by triangulation on both flanks, in order that the measured length of each section may be tested by comparison with the other sections. Circumstances have interfered to retard the several calculations and reductions, but I have recently been informed, by telegram, that the computed length of the base-line, as derived from the Vizagapatam base and the triangulation down the coast to Madras and thence across to Bangalore, a distance of 630 miles, differs by only a quarter of an inch from the length given by the measurement. A similar minute discrepancy, of a quarter of an inch in 6·55 miles, was found between the measured length of the Vizagapatam base-line, and the length as computed through 480 miles

of triangulation from the Calcutta base-line. Such close agreements between the results of the linear and the angular measurements, though necessarily to some extent fortuitous, are nevertheless very satisfactory indications of the accuracy of the operations.

(27.) Lieutenant Rogers was employed in measuring 18 principal triangles which were required for the mutual verification of the three sections, for connecting the base with the main triangulation, and with Colonel Lambton's base and his astronomical station of Dodagoontah. All these operations were completed to my entire satisfaction, and, as the performances of his first field season, are very creditable to Lieutenant Rogers.

(28.) Meanwhile Captain Branfill proceeded to Cape Comorin, to select a site for a base-line at the southern extremity of the Great Arc, which I am arranging to measure during the coming field season. The selection was found to be a matter of no small difficulty; for the ground in the immediate vicinity of the Cape is either studded with rocky and precipitous hills, or covered with a dense forest of palmyra trees through which a line could not be cleared without great expense. Eventually a practicable line was discovered to the north-east, within a short distance of Colonel Lambton's astronomical station of Punnæ, and after considerable exertions Captain Branfill succeeded in preparing the base-line stations and completing all the requisite preliminaries for the measurement.

No. VI.—TRIGONOMETRICAL.

THE BANGALORE LONGITUDINAL SERIES.

(29.) Little progress could be made in this triangulation because Lieutenant Campbell and his assistants were employed for the greater portion of the field season in the operations connected with the measurement of the Bangalore base-line. But as soon as these were completed, Lieutenant Campbell took up the triangulation at a point about 40 miles west of Bangalore, and carried it 33 miles westwards, completing a hexagonal figure of an area of 925 miles. 11 stations were selected in advance, over a direct distance of about 120 miles, as a preliminary to the operations of next season.

No. VII.—TOPOGRAPHICAL.

THE SURVEY OF KUMAON AND GURHWAL.

(30.) Captain Montgomerie was re-appointed to the charge of this Survey on the 1st May 1867, shortly after his return from furlough to Europe. In May 1868 he was required, in addition to his ordinary duties, to assist me by Officiating as Superintendent of the Topographical Surveys in the Surveyor General's Department, during Col. Thuillier's absence from India. He has further continued to supervise the arrangements in connection with the geographical explorations of the regions beyond the Himalayas. Thus he

PERSONNEL.

Capt. T. G. Montgomerie, R.E., Surveyor 1st Grade.
„ A. Pullan, S.C., Assist. Surveyor 1st Grade.
Lieut. J. Hill, R.E., Assist. Surveyor 2nd Grade.
Mr. W. G. Beverley, Civil Assistant 1st Grade.
„ E. C. Ryall, Civil Assistant 2nd Grade.
„ J. Peyton, Civil Assistant 2nd Grade.
„ J. Low, Civil Assistant 4th Grade.
„ G. W. Atkinson, Sub-Assistant 1st Grade.
„ C. Braithwaite, Sub-Assistant 2nd Grade.
„ L. Pocock, Sub-Assistant 2nd Grade.
„ H. Todd, Sub-Assistant 3rd Grade.
„ C. Bryson, Sub-Assistant 3rd Grade.

has been very fully occupied, and I have every reason to acknowledge his valuable services, both as an Administrative and as an Executive Officer.

(31.) The operations in Kumaon and Gurhwal have proceeded very satisfactorily. The triangulation which is required to furnish a basis for the topographical operations, was pushed to the north of Gurhwal, so as to cover the whole of the very elevated basin of the Kali or Mandagni river, one of the main sources of the Ganges. Eastwards it was extended over a high and rugged range of forest clad mountains near Almorah, and south eastwards to Huldwani, over a tract of country at the foot of the Himalayas, covered with dense jungle which naturally added much to the difficulties of the Surveyors. The triangulation embraces an area of 2315 square miles, fixing the positions and heights of 279 stations, and the positions only of 304 additional stations.

(32.) Meanwhile topographical operations, on the scale of 1 inch to the mile, were being carried on in parts of the Alakanunda and the Pindur valley, in the mountains east of Almorah, and in the vicinity of the site of the new sanatarium of Ranikhet, over ground of every altitude from 2500 to 13000 feet above the sea level. In the higher hills the Surveyors were constantly exposed to snow storms, and the severities of an alpine winter; but arrangements were made to employ them whenever practicable in the ground which happened at the time to be most favorable for field operations, in the higher hills first, then in the lower as the weather became more severe, and finally again in the higher, as the hot season commenced, when the Terai at the foot of the Himalayas becomes unsafe from malaria. The area surveyed topographically during the present year was 1280 square miles.

(33.) Captain Montgomerie reports that the out-turn, both of triangulation and topography, was very creditable, the ground throughout being of an exceedingly precipitous nature, and nearly every day's work a matter of hard climbing from morning to night. He personally examined the work of each detail-surveyor, and invariably found that the ground had been faithfully represented, and generally with considerable artistic ability. Both in quality and quantity the work appears to be entirely satisfactory.

(34.) The elevations of a large number of points, both in the valleys and on the summits of the mountain ranges, have been determined trigonometrically, and the proportion of these to the area under survey is very considerable. It is scarcely possible to shew too many determinations of height in the maps of a mountain region, where the variations of altitude are frequent and often very abrupt; but on the other hand it would be impossible, without greatly retarding the progress of the operations, to determine all these heights trigonometrically; many points are so situated, in the beds of rivers and ravines and in the gorges between mountains, that their heights could not be thus determined without executing a special triangulation for the purpose in each instance, which would be a very laborious proceeding. In order to determine the altitudes of these comparatively depressed localities, Captain Montgomerie has been employing aneroid barometers, instruments whose compactness and portability render them an invaluable adjunct to Surveyors who have the means of controlling the errors to which they are liable. The aneroids are employed so as to give strictly differential results; they are invariably read at a number of high and low trigonometrical points whose heights have been accurately

determined; then the height of any intermediate point is found by interpolation. It appears, from a variety of experiments, that the heights so deduced may be relied on as within 30 or 40 feet of the truth, which will probably be considered sufficiently accurate to give a fair idea of the differences of elevation between peaks, passes and valleys in a mountain tract where the variations of altitude are many thousand feet.

(35.) I cannot conclude this notice of the operations of the Kumaon and Gurhwal Survey party without observing that Captain Montgomerie and some of his assistants have been obliged to devote a good deal of time to the retracing of the original boundary of Mussoorie and Landour, because the simple precaution of demarcating this boundary by building pillars along it had not been taken in the course of the operations of the fiscal settlement. The only information forthcoming on the position of the line of boundary, is given in an old and imperfect map, executed on a small scale many years ago, under the orders of the Board of Revenue of the N.W. Provinces; consequently it was impossible to recover the original boundary exactly. A sufficient approximation has however been made to satisfy the requirements of the Civil authorities; pillars have been built along a portion of the line as now determined, and others will be built along the rest of the line as soon as possible; their positions will be shown on the new maps of Mussoorie and Landour, the publication of which has been delayed, pending the adoption by the Civil authorities of the boundary now under demarcation.

No. VIII.—TOPOGRAPHICAL.

THE SURVEY OF KATTYWAR.

(36.) In my last Administration Report, I described the early operations of this Survey, and the measures that had been taken to increase its utility and accuracy by providing for the execution, *pari passu* with the ordinary operations, of a boundary survey of all the Talookas or chief sub-divisions of the Native and British States in the Province of Kattywar. I also explained the reasons which had induced me to enlarge the plane-table or field survey sections, from the usual scale of 1 inch to that of 2 inches to the mile, in order to meet more adequately the growing requirements of the province.

PERSONNEL.

Captain C. T. Haig, R.E., Surveyor 2nd Grade.
Mr. J. McGill, Civil Assistant 1st Grade.
„ A. D'Souza, Civil Assistant 4th Grade.
„ N. Gwinn, Sub-Assistant 3rd Grade.
„ C. McA'Fee, Sub-Assistant 3rd Grade.
„ T. Rendell, Sub-Assistant 3rd Grade.
„ E. N. Wyatt, Sub-Assistant 3rd Grade.

Native Surveyors.

Wissojee Ragoonath, Gopal Naryen, and 7 others.

(37.) During the present year the operations have proceeded very satisfactorily and made good progress in all respects but as regards the boundary surveys, which have been materially retarded, because proper steps had not been taken by the local authorities to demarcate the boundaries in the first instance. Certain of the Native States do not appear to be very anxious to have their territorial rights exactly defined, and would almost seem to wish to perpetuate the disputes and feuds which have prevailed from time immemorial on these subjects, and have frequently been the cause of violent collisions and bloodshed. On the part of the Gaikwar States no steps whatever have yet been taken towards demarcating their boundaries.

Thus in several instances Captain Haig was compelled to push on the topographical operations in advance of the boundary traverses, in order to provide employment for his field sketchers.

(38.) I have drawn the attention of the Bombay Government to this subject, and pointed out that the boundary surveys should invariably precede the topography, for they then become a most valuable adjunct to the general operations, and form a reticulated frame work within which the topographical details are subsequently fitted; the numerous and accurately fixed boundary stations serving as points from which the field draftsmen can lay down the interior details, and sketch the features of the ground, more rapidly and accurately than they could if no such points were forthcoming. Whereas when the boundary measurements succeed the topographical operations much of their value is lost, and for the purposes of the survey they become quite useless. The Government of Bombay has been pleased to support my views and to move the Gaikwar Durbar to energetic action in the matter; and the Resident at Baroda has recently reported that the "Durbar has been awakened to the importance of the work, and the absolutely necessity of its speedy completion; His Highness the Gaikwar has consequently ordered that officials of weight and experience be entrusted with the duty next season, under the direction of Lieutenant Prideaux."

(39.) The last field season's operations comprise the following amount of work. *Triangulation*; an area of 1041 square miles, in which the positions of 536 points and the altitudes of 83 of these points, were determined by observations at 102 stations; this portion of the operations was almost entirely executed by Mr. McGill. *Topography;* 800 square miles on the scale of 2 inches to the mile, and 260 square miles on the 1 inch scale, the smaller scale being resorted to for a low, marshy and almost uninhabited tract of country lying to the north of the Kalubba River, on the west coast of the Gulf of Cambay. *Boundary traverses, and check lines;* 614 linear miles of the former, and 89 of the latter.

(40.) Captain Haig was employed for the greater portion of the season in instructing the natives newly entertained to be employed as boundary surveyors, and in directing their operations; he placed himself in communication with the committees who were appointed to demarcate the boundaries, and received weekly reports of their progress. He states however that it was not until several weeks had elapsed that he could form any idea of the confusion of subdivision that exists, and of the utter impossibility of getting the boundary survey in advance of the plane-tabling in one season. I have little doubt however that under his thoughtful and zealous supervision, the difficulties that have to be grappled with will soon be satisfactorily disposed of, and the boundary surveys will soon become a useful adjunct to the operations, and cease to be the embarrassment and source of delay that they have been hitherto.

No. IX.—GEOGRAPHICAL.

EXPLORATIONS OF TRANS-HIMALAYAN REGIONS.

(41.) The Trans-Himalayan explorations, under the direction of Captain Montgomerie, have during the last year been extended across the upper basins

of the Sutlej and the Indus to some distance beyond the eastern watersheds, thus penetrating into that portion of Great Tibet which lies between the desert of Gobi and the upper basin of the Brahmaputra river. For this purpose a third Pundit was added to the explorers and trained to the work by Captain Montgomerie. The operations have been successfully carried out, and the results will be found fully detailed in Captain Montgomerie's report.

(42.) The route-surveys extend over a total distance of 850 miles, in the course of which the latitudes of 75 different places were determined, and the heights of 80 places were deduced by the boiling point. By these route-surveys the geography of about 20,000 square miles of Tibet has been roughly determined, a considerable portion of which is entirely new, and the remainder having hitherto depended on a very narrow basis of route-survey. The course of the Sutlej between Shipki and Totling, hitherto unknown, has been roughly determined. The upper course of the river Indus has been traced south from the point where it leaves the Ladak territory nearly to its source. It has been definitely ascertained that there is a great eastern branch of the upper Indus, and that the said branch, known to the natives as the Singh-gi-chû, is the main stream of the Indus, the branch on which Gartok stands being smaller and having a shorter course and being always called the Gartung-chû. Both these branches have had a route-survey carried along them; the portion between Gartok and Ladak though indicated on all maps has never been surveyed in any way, whilst the existence of the great eastern branch has been denied by many geographers.

(43.) The explorations extend up to the western gold fields of great Tibet, the Thok Jalung field, the largest that is worked at present, having been visited by the Pundits. Thok Jalung lies on the northern route from Rudok to Lhasa, and I hope that explorations may ultimately be extended from it along the slopes of the northern water-shed of the Brahmaputra, and that the position and size of some of the great lakes known to exist in that direction may be thereby determined.

(44.) These route-surveys have satisfactorily stood similar tests to those applied to the previous ones and described in para. 46 of my last report; the values of the pace, as derived from the differences of latitude, have been throughout found to be very accordant. A further conclusive test has also been forthcoming, as the routes start from and close on points which had been previously fixed in the course of the regular operations of the survey. The longitude of the terminal point, as derived from the route-survey, only differs from the G. T. Survey value of the same by about 4 miles. This, and other comparisons with points which have been accurately fixed, show that the work, rough though it be, is thoroughly reliable within narrow limits.

(45.) Great credit is due to the Pundits for the way in which they carried out their work; for upwards of three months they were at an elevation of more than 12,000 feet above the sea, they crossed and re-crossed the Himalayan range three times, the Gangri range between the Sutlej and Indus three times, another very lofty range between the two upper branches of the Indus once, and that between the Indus and Thok Jalung twice; each of the crossings involving the ascent of a pass more than 17,000 feet above the sea, the highest being 19,500 feet.

(46.) A map showing the geographical results accompanies this report, from which it will be seen that a very small portion of the upper basins of the Sutlej and

Indus has been left untouched, and that the margin of the vast terra incognita, between the desert of Gobi and Lhasa, has been penetrated. I am not without hope that a considerable portion of this region may ultimately be explored.

GEOGRAPHICAL.

THE MILITARY SURVEY IN CONNEXION WITH THE OPERATIONS OF THE ABYSSINIAN EXPEDITION.

(47.) At the suggestion of Sir Robert Napier, instructions were communicated by the Government of India to the Surveyor General and myself to organize a survey establishment for the Abyssinian expedition. Our instructions were received at Mussoorie at the end of September 1867, and it was intimated that the Surveyors would arrive in good time if they reached Bombay by the 1st December. Three Officers of the Royal Engineers were deputed from the Trigonometrical and Topographical Survey Departments to form the survey party, the charge of which devolved on the senior Officer, Lieutenant Carter. All the Officers reached Bombay by the 1st December, but were detained there until the 13th before an opportunity offered for their embarkation, and then, by an unfortunate oversight on the part of the Quarter-Master General's Department, they were placed on board of a sailing vessel instead of being forwarded by steamer; on reaching Annesley Bay further delays were occasioned in consequence of the difficulties of obtaining carriage; thus it was not until the 15th of January that they were fairly in a position to commence work.

PERSONNEL.
Lieutenant Carter, R.E.
„ Dummler, R.E.
„ Holdich, R.E.

(48.) The instruments with which they were furnished were selected so as to meet the requirements of a military reconnoisance executed in the course of a rapid march, as well as to enable a rough topographical survey to be made of the country around any places in which the army might halt for a few days at a time. A transit instrument was supplied, to be kept at the origin of the survey and employed in determining its longitude; plane-tables were provided for topographical sketching along the line of route; also barometers and chronometers, and 6 inch transit theodolites with complete vertical circles, for triangulation, astronomical observations, and route-surveying.

(49.) The latter instruments had been specially constructed, at my request, by Messrs. Troughton and Simms, to be employed on expeditions of this nature, and deserve a brief description in this place. The eye piece is furnished with a pair of micrometers, fitted into a rectangular frame which is capable of being turned round on a collar, so as to bring the micrometer wires into parallelism with either the horizontal or the vertical wire in the fixed diaphragm plate. The primary object of this arrangement is to enable the angle subtended by a pole of known length, set up either in a vertical or a horizontal position, to be measured by the micrometers, and thus to determine the distance between the pole and the instrument. Knowing the run of the micrometer and the length of the pole, it is easy to prepare a table which will enable the distance corresponding to any angle to be ascertained, with very little labor of calculation and sometimes by mere inspection. In these instruments, a division of the micrometer is equivalent to about 2″, so the angles

may be measured with considerable accuracy, much exceeding what would be possible with ordinary theodolites of the same size. The micrometer and pole can thus take the place of the chain or perambulator which must otherwise be used in a route-survey, while the angles of the traverse can be measured on the azimuthal circle, in the same manner as with an ordinary theodolite. To be able to dispense with a chain is a very great advantage in a route-survey of a tract of rugged hill country, more particularly when the chainmen are liable to be incessantly disturbed and impeded by the movements of a large army on the line of survey. Moreover the micrometers greatly add to the value of the theodolites as astronomical instruments, by furnishing two additional wires to the fixed horizontal and vertical wires, which increase the accuracy of observations of time and longitude, whether by the method of zenith distances, or that of meridional transits, as they may be laid either horizontally or vertically at pleasure.

(50.) Lieutenant Carter's instructions were, if possible, to make a plane-table survey on a trigonometrical basis, fixing the positions and altitudes of all the prominent hill peaks visible from the stations of observation, in order to facilitate the incorporation of geographical details acquired from native information. Should the army advance too rapidly to allow of such operations, he was to carry a route-survey along the line of march, and when the rapidity of the advance rendered even this impossible, he was to fall back on astronomical observations of the latitudes, and either absolute or chronometric differential longitudes, of the principal places along the line of route. All absolute longitudes were to be determined by lunar zenith distances measured with the micrometer theodolites already described, as in intertropical latitudes this method is probably better than any other for the determination of this difficult element. It was expected that differential longitudes might be determined with the aid of the line of telegraph which was to be put up along the route taken by the army, but this expectation was disappointed, as the telegraph wire was not carried beyond the point reached by the topographical survey.

(51.) Operations were commenced by the measurement of a base-line near Koomaylee, the first halting place on the march from Zoola to Senafe, and the determination of its latitude and azimuth; similar operations were subsequently performed at Senafe, Antalo and Ashangi, and the country around each base was triangulated; but the advance of the army was too rapid to permit of the triangulation being connected otherwise than by the route-survey; the latter was fortunately carried without any break of continuity, from Koomaylee to Magdala, and subsequently connected with the port of Zoola, in Annesley Bay, on the return of the force. Up to Antalo, a considerable breadth, 10 to 15 miles of country, on both flanks of the line of march, was surveyed topographically, on the scale of 1 inch to 4 miles, but further on the breadth necessarily diminished as time would not permit of a protracted survey. The plane-tabling ceased altogether a little beyond Ashangi, and it was only after very great exertions that Lieutenant Carter was able to complete the route-survey to Magdala, arriving there on the morning of the 13th of April, the day of the assault.

(52.) While the army remained at Magdala Lieutenant Carter made a survey of about 70 square miles of the surrounding country on the scale of 2 inches to the mile, to accompany Sir Robert Napier's despatches.

(53.) The out-turn of work may be summarized as follows. 6000 square miles reconnoitered and mapped on the scale of ¼ inch to the mile; a survey of Magdala on the scale of 2 inches to the mile; 400 linear miles traversed with the micrometer theodolites; 2 determinations of absolute longitude, 14 of latitude, 5 of azimuth, and 50 time observations; 5 base-lines were measured, 58 points were fixed trigonometrically, 30 heights were determined trigonometrically, and 50 by boiling point observations.

(54.) Performed in the short space of 4 months, by 3 officers only, who labored from the outset under numerous disadvantages, and latterly suffered great privations from the want of proper or even sufficient food, and the absence of all 'stimulants', such an amount of work testifies most forcibly to the energy and ability with which these officers devoted themselves to the arduous duties that fell to their share.

(55.) Lieut.-General Sir Robert Napier, in his despatch of the 1st June 1868, notices their services in the following terms:—

"The Officers of the Trigonometrical Survey, Lieutenants Carter, Director, and Dummler and Holdich, Royal Engineers, Assistants, by the most strenuous exertions, and at the cost of great fatigue and privations, succeeded in surveying nearly 6000 miles, and carried their work from the coast to Magdala. The labour of these officers, two of whom have been obliged to return to England, from loss of health, will prove very valuable."

(56.) On the termination of the expedition, all three Officers went to England where they have been employed hitherto in reducing their observations, drawing maps, and preparing a report of the results of the operations.

No. XI.—ASTRONOMICAL.

OBSERVATIONS OF THE TOTAL ECLIPSE OF THE SUN.

(57.) The year 1868 has been signalized by the occurrence of a total solar eclipse, which had long been looked forward to with peculiar interest, not only because it would be the first opportunity of applying the modern discovery of spectral analysis to investigate the physical nature of the corona around the sun's photosphere, and the red flames which appear to issue forth from the photosphere when the sun is totally eclipsed, but also because the period of totality would be of almost the greatest possible duration, and would afford more leisure than usual for such observations as can only be made during an interval which at its longest is but very brief, not more than 6 to 7 minutes. On the recommendation of the Royal Astronomical Society, Major Tennant was deputed by Government to make observations of the eclipse, and was supplied with all the instruments necessary for the purpose, including a spectroscope, polariscope, and photographic apparatus. Moreover the Royal Society, anxious to make the most of the opportunity and increase the chances of success by multiplying the number of observers, offered to place certain instruments at my disposal to be used by Officers of the Trigonometrical Survey at different places along the central line of the eclipse. I readily accepted this offer, in anticipation of the sanction of Government, which was subsequently

most cordially conceded, with an intimation that the Government "was prepared to do everything in its power towards securing full and accurate observations on this rare and important occasion."

(58.) As none of the officers of this department had ever had an opportunity of acquiring a practical familiarity with the manipulation of spectroscopes and polariscopes, it was fortunate that when I received the proposals of the Royal Society, one of our officers, Lieutenant John Herschel, R.E., was in England, on leave of absence. He placed himself in communication with the Society, and had an opportunity of studying the subject of spectral analysis in the Observatory of Mr. Huggins, whose name is so well known in connection with this most interesting branch of physical science. I determined therefore to entrust him with the duty of carrying out the programme of operations proposed by the Royal Society. While in England he interested himself in the preparation of the instruments, and on his return to India, brought them out with him. They comprised, 1st, an equatorially mounted clock-driven telescope, of 62 inches focal length and 5 inches aperture, with a spectroscope having a single flint glass prism, and a micrometer screw for measuring the position of any lines observed. 2nd, four portable hand-spectroscopes. 3rd, a telescope mounted altazimuthally, and furnished with a double image prism and a Savart's polariscope, for the purpose of analyzing the light of the "corona" and "red flames," for polarization.

(59.) Lieutenant Herschel was to use the equatorial instrument, and he prepared himself for the purpose by examining the spectra of the principal southern Nebulæ, the Royal Society having suggested that these observations would not only enable the observer to acquire the necessary familiarity with the instrument, but "would be of very great value in the present state of our knowledge, and would certainly repay the entire cost of the instrument, should bad weather, or some unforeseen accident, render the primary object, the investigation of the sun, impossible." Lieutenant Herschel's observations of the southern Nebulæ have been published from time to time in the proceedings of the Royal Society. The polariscope was allotted to Lieutenant Campbell, and one of the hand spectroscopes to Captain Haig, the rest being lent to persons who do not appear to have had an opportunity of using them. Captain Branfill was attached to Major Tennant's expedition, where he made the observations for polarization.

PERSONNEL.

Lieutenant J. Herschel, R.E.
Captain C. T. Haig, R.E.
Captain B. R. Branfill.
Lieutenant W. M. Campbell, R.E.

(60.) The eclipse would occur towards the close of the rainy season, in the districts under the path of the total phase across the Peninsula of India. At such a time favorable weather could not be expected; on the contrary there was much reason to fear that clouds would be so prevalent as to conceal the eclipse from view. It was necessary therefore to make minute enquiries regarding the localities along the central line which offered the greatest advantages in point of climate, and the best promise of an unclouded sky. For this purpose a circular was prepared calling for information on the weather to be expected, the average rain-fall in the three first weeks of August in preceding years, and other matters the knowledge of which might influence the selection or rejection of any particular locality. As the path of totality would cross portions of the Madras and Bombay Presidencies, and of the Nizam's Dominions, copies of the circular were sent to the Governments of Madras and Bombay, and to the Resident at the Court of the Nizam, to be transmitted to

the several Officers in charge of Districts, and to all persons who might be able to contribute the necessary information. Enquiries were also made regarding the weather prospects in the Province of Tenasserim, on the east coast of the Bay of Bengal, where the duration of totality would be greatest, and the sun nearly in the zenith.

(61.) From the answers to these enquiries it appeared that very unfavorable weather might be expected at Tenasserim and on the Bombay Coast Line, that the most promising localities lay in the belt of country between the Madras Coast and the Western Ghats, and further that in the neighbourhood of Jamkundi (lat. 16° 30′ long. 75° 22′) and Beejapore (lat. 16° 50′ long. 75° 48′) there was a better prospect of fine weather than any where else; Jamkundi was said to be notorious for its small rain-fall. These places were selected by Lieutenant Herschel and Captain Haig as stations of observation. Major Tennant and Mr. Pogson, the Government astronomer at Madras, had decided on stationing themselves at points on or near the east coast. Thus the observers were distributed along the line of totality, and widely separated, and there was all the more probability that some of them would have an opportunity of making the requisite observations, though others might be unfortunate and see nothing.

(62.) As matters turned out, all the Survey Officers had the good fortune to witness the eclipse, and make the observations which had been specially allotted to each; but clouds prevailed to a greater or less extent in every instance, and it was only through the clouds or openings in them that the phenomena were visible from time to time. The weather was very much more favorable at Guntoor and in the neighbourhood of the east coast of the Peninsula, than at Jamkundi and Beejapore; but it was so unfavorable, at all the stations of observation, on the days immediately preceding the eclipse, as to occasion great anxiety and discouragement.

(63.) Detailed reports of the observations have already been forwarded to the Royal and the Astronomical Societies, by whom they will be published with all the accessories for furnishing complete information of the results which have been secured. I need therefore only quote the descriptions given by each of the Survey Officers of the leading phenomena which they individually observed.

(64.) Lieutenant Herschel, who was stationed at Jamkundi, reports as follows:—

"About ten minutes before totality commenced, I took up my position at the telescope, and occupied the interval in final measures of the solar lines, to which any subsequent measurements might be referred. As I was thus engaged the spectrum of what remained of the sun grew rapidly narrower, and I was watching eagerly, and it may be guessed how intently! for the final disappearance which was to reveal, in place of the solar spectrum, that of the corona, when the latter faded prematurely through the intervention of a cloud, and the precious moment was lost.

I went to the finder, removed the dark glass and waited, how long I cannot say, perhaps half a minute; soon the cloud hurried over, following the moon's direction, and therefore revealing, first the upper limb with its scintillating corona, and then the lower. Instantly I marked a prominence near the needle point, an object so conspicuous that I felt there was no need to take any precautions to secure identification. It was a long finger like projection from the lower left hand portion of circumference. A rapid turn of the declination screw covered it with the needle point, and in another instant I was at the spectroscope. A single glance and the problem was solved. THREE VIVID LINES, RED, ORANGE, BLUE; NO OTHERS, AND NO TRACE OF A CONTINUOUS SPECTRUM.

From that time until the end of the 5 minutes I was endeavoring to seize the fitful glimpses of these lines for purposes of measurement. I succeeded with the orange and blue, but there was not sufficient time for the 3rd. The field became suddenly re-illuminated and the total eclipse was over. Nothing more could be done except to check the measurements against those of the solar spectrum."

(65.) Lieutenant Campbell was with Lieutenant Herschel at Jamkundi; he reports that he only saw the eclipse fitfully through openings in the clouds, for an aggregate period which he estimates at somewhat less than half that of totality. The alternate appearance and disappearance troubled him greatly, but he can still speak with certainty on the following points:—

"1st. When using the double image prism, the strong difference in color of the two images of the corona, and the absence of such difference in the case of the most prominent red flame. 2nd With the Savart's polariscope, the bands from the corona were decided. With a low power, they were wanting in intensity and colour (excepting alternate black and white) making it difficult to specify the nature of the centre,—and their position was at right angles to the limb, extending over a space of about 30° of the circumference; when the polariscope was turned, the band travelled bodily round the limb, without other change in position or arrangement, as if indeed they were revolving round the centre of the sun as an axis. With a higher power, when a smaller portion of the corona was embraced, the bands were brighter, colored, and seen in a different position, viz., as tangents to the limb."

(66.) Captain Haig was stationed at Beejapore. The sky was so heavily laden with clouds that he had given up all hope of witnessing any of the phenomena of totality, when a sudden opening disclosed the eclipse. With the aid of a theodolite, on which he had mounted the prism cap of one of the hand spectrum telescopes, he observed two red flames on the left of the vertex,

"Separated from each other by a small interval, so that their spectra, which were identical, were extended over the dark back ground of the moon's disc, and stood out in most marked contrast with the feeble but continuous spectrum of the corona. In their spectra were two broad bright bands quite sharply defined, one rose madder, and the other light golden. These spectra were soon lost in the spectrum of the moon's edge just before emergence, which had also two well defined bright bands, one green and one indigo, about a quarter of the width of the bands in the spectra of the flames; this spectrum being again soon lost in the bright sun-light."

(67.) Captain Branfill was stationed, with Major Tennant, at Guntoor, and took observations for polarity. He reports as follows:—

"With the finder I directed to the hightest part (the S.E. quarter) of the corona, and examined its light carefully with the Nicoll's prism and crossed quarts, which gave brilliant light dark and coloured bands (Savart's). I noted the position of the maximum white band, and the points of disappearance on each side. It was directly clear to me by several trials that the corona was plentifully polarized in all the planes passing through the sun's centre. The double image prism gave the same results as the plain Nicoll. The polarized light was most where the corona was brightest, least where faintest. Satisfied of this, I turned to examine the light of the horn-like red flame; the corona seemed fainter behind it; but though I contracted my field I could not of course exclude all corona light. I could not detect the presence of polarized light on the red flame. With the double image prism the flame did not seem to vary in tint at all; with the Savart I could not get rid of bands altogether, and I noticed that though extremely faint the bands were continued upon the moon's surface. I was still straining to see and note any differences in brilliancy with the plain Nicol, when a flood of light in the field told me that all was over".

(68.) These observations are pregnant with interest; they lead naturally to the conclusion that the 'corona' is very slightly, if at all, self-luminous, but owes

its brilliance mainly to the light of the sun; while on the contrary the 'red flames' are self-luminous, and composed of intensely heated gaseous matter.

No. XII.—ASTRONOMICAL.

LATITUDE OBSERVATIONS.

(69.) During the preceding year, the astronomical circle employed in these operations had occasioned much embarrassment. It was one of the two sister instruments, with double vertical circles 3 feet in diameter, which were constructed for and materially modified by Colonel Everest, and are described in his account of the great arc. From the year 1839, when it was first employed, until March 1866, its performances had always been highly satisfactory; but after the observations in the field season of 1866-67 had been reduced, it was found that they gave large discrepancies between the latitudes deduced from stars to the north of the zenith, as compared with those deduced from stars south of the zenith. The results from north stars agreed very closely *inter se*, as did those from south stars, but the former exceeded the latter by an amount averaging 6·″2 at the five stations at which the instrument had been set up, and at neither of them less than 5·″3, showing that the instrument had acquired the very disagreeable property of measuring all zenith distances in defect of their true values. This must almost certainly be due to some injury which it must have received on it's return journey to head-quarters after the field season of 1866-67. A most careful examination of every part failed to show the locus of mischief, and consequently the instrument was discarded, and its sister circle (No. 2) was employed instead, in the operations of the present year.

PERSONNEL.

Lieut. W. J. Heaviside, R.E., Assistant Surveyor 1st Grade.
Mr. J. Wood, Sub-Assistant 2nd Grade.
„ G. Belcham, Sub-Assistant 3rd Grade.

(70.) The system of observing to pairs of north and south stars has invariably been adopted in these operations, each of the two components of a pair being as nearly equidistant as possible, compatibly with the selection of the best determined stars in the Greenwich catalogues. Thus the instrumental defect above indicated should be eliminated from the mean latitude deduced from a pair of stars, and the final results ought not to be sensibly affected thereby. It appeared desirable however to establish this point decisively, by taking observations with circle No. 2 at one of the stations where circle No. 1 had been employed. This was done during the present year; the same stars were used as had previously been observed to; no appreciable differences were found between the results from north and south stars, by circle No. 2, and the mean result was found to differ by only 0·″11 from that previously given by circle No. 1. Thus it was clear that the final results of season 1866-67 were thoroughly reliable, and that the observations at other stations need not be repeated. Consequently Lieutenant Heaviside proceeded to determine the latitudes of additional stations of the triangulation on the meridian of 75°.

(71.) The astronomical latitude of Isanpur, the northernmost station of this chain of triangles, is almost identical with, differing by only ·″06 from, the value as computed through the triangulation from Colonel Everest's origin, the station of Kalianpur on the Great Arc, with the elements which have always been employed

hitherto in the calculations of the latitudes and longitudes of the trigonometrical stations, and in which the ellipticity is assumed as $\frac{1}{300{\cdot}80}$. The station at which this close coincidence between the astronomical and geodetic values of latitude occurs, is situated near the northern limits of the great plains of the Punjab, and is rather closer to the Himalayas than the northernmost station Kaliana, of Colonel Everest's arc, which is also situated in an extensive plain; but the astronomical latitude of Kaliana is 5″·2 less than the geodetic value brought up from Kalianpur, suggesting a deflection of the plumb line towards the Himalayas. As the mountain masses are probably quite as great on the meridian of 75° as on that of Kaliana 78°, it would appear that the northerly attraction of the mountains is more fully compensated in the western than in the eastern plains. In order to obtain additional light on this point, Lieutenant Heaviside was directed to observe the latitude of a station of the triangulation on meridian 76°, between Kaliana and Isanpur, the line joining the three stations being nearly parallel to the direction of the mountain ranges:— the value was found to be 3″·9 less than the geodetic latitude, a smaller difference than occurs at Kaliana, but larger than at Isanpur.

(72.) During the field season Lieutenant Heaviside determined the latitudes of four new trigonometrical stations, and re-determined one of the latitudes of last year, as already stated. At each of the new stations 35 pairs of north and south stars, within 30° of the zenith, were selected from the Greenwich 7-year catalogue, and each star was observed on the meridian on six successive nights. The probable errors of the final results in no case exceed ±″·06, a very satisfactory indication of the performances of the observer and the instrument, as well as of the accuracy of the catalogue from which the places of the stars were taken. Observations have now been completed at 7 stations of the triangulation on meridian 75°, over an arc of rather more than 5° of latitude, and the differences between the astronomical and geodetic values are surprisingly small, rather less on an average than 1″, indicating that the extensive plains of the Punjab and Rajpootana, over which the operations have been carried, are admirably adapted for the measurement of a geodetic arc.

No. XIII.—MISCELLANEOUS.

LEVELING OPERATIONS, AND ARRANGEMENTS FOR THE PROTECTION OF THE SURVEY STATIONS.

PERSONNEL.
Mr. C. Lane, Surveyor 2nd Grade.
„ L. H. Clarke, Civil Assistant 3rd Grade.

Native Surveyors.
Nursing Dass, and Sheikh Amjud Ali.

(73.) Mr. Lane was employed in carrying a line of levels from the Trigonometrical Survey Bench-mark at Meerut through Rohilkund, viâ Ghurmuktesar Ghat, Moradabad, and Bareilly, to Pilibhit. These levels were intended for the purpose of checking the trigonometrically determined heights of the survey stations at the northern extremities of the meridional chains of triangles east of the Great Arc, and for connecting the several lines of levels which have been executed in Rohilkund, with a view to furnishing data for the charts of levels of the

North-West Provinces, which are now being prepared in this office.—228 miles of main and branch lines were levelled independently by Messrs. Lane and Clarke, in conformity with the rigorous method of procedure which has been described in former reports, connecting 6 principal trigonometrical stations, and fixing 382 bench-marks, bridges, mile-stones, or other permanent marks in the vicinity of the operations.

(74.) Mr. Lane also deputed a native surveyor to repair all the stations on the southern section of the portion of the Great Arc between Sironj (lat. 24°) and Beder (lat. 18°). Upwards of 30 years had elapsed since these stations had been constructed in the course of the triangulation under Colonel Everest, and meanwhile no special arrangements had been made for their protection from wilful injury or from the action of the weather. They were now ascertained to have fared on the whole far better than could have been expected. Out of 52 stations, 2 were found to have been wholly destroyed, a temple having been erected over the site of one of them; at another station all the mark-stones had been removed but the platform still remained; at 10 stations the upper mark-stone had been removed, but the lower ones were found in good preservation; while at 39 stations the upper mark-stones were uninjured and had evidently not been tampered with.

No. XIV.—GEODETIC.

THE PENDULUM OBSERVATIONS.

PERSONNEL.
Captain J. P. Basevi, R.E., Surveyor 1st Grade.
Mr. W. M. Lemarchand, Sub-Assistant 3rd Grade.
„ J. W. McDougall, Sub-Assistant 3rd Grade.

(75.) These operations have been prosecuted very rigorously during the present year, in conformity with the original programme of observations of vibration in vacuo at certain stations of Colonel Everest's Arc, with the two pendulums which were supplied by the Royal Society, and have been described in previous reports. Proceeding southwards from the Himalayas, Captain Basevi had in the two preceding years completed observations down to the station of Ehmadpur, lat. 23-36. This year the pendulums were swung at no less than 5 stations, Badgaon, Somthana, Damargida observatory, Kota Kodungal, and Namthabad, bringing the operations down to lat. 15° 6′; thus about two thirds of the pendulum observations on the Arc have now been completed.

(76.) At the commencement of the field season, Captain Basevi had to visit the Bombay observatory, in order to test his magnetic instruments by comparing their results with those of the standard magnetometers in that observatory, for reasons which will be explained in the next section. He availed himself of the opportunity to take the pendulums with him, and determine their weights and specific gravities, with the aid of the apparatus which is employed for such purposes in the Bombay Mint. The results thus obtained will probably be of much value in the final reduction of the observations.

(77.) Captain Basevi has continued to devote much attention to all points the investigation of which might tend to improve the accuracy of the results of the operations, by bringing facts to light which have any bearing in the performances of a pendulum. For instance, the accuracy of the temperature corrections depends on the thermometers truly indicating the temperature of the pendulum; it was uncertain whether they actually did so, under the ordinary conditions of observation for several consecutive hours of the day, in a uniformly varying temperature, always hotter at the close than at the commencement of the observations; under such circumstances the temperature of the pendulum *might* lag behind that indicated by the thermometers. To ascertain whether this is actually the case, at Damargida Captain Basevi took complete sets of observations with both his pendulums, lasting over 8 or 9 hours of the night, from about 8 P.M. to 5 A.M., in addition to the ordinary diurnal observations which are of similar duration;—thus the night observations were taken under a falling temperature, and the day ones under a rising temperature. The results seem conclusive as to the fact that lagging exists to an amount which, though very minute, is still sufficiently appreciable to necessitate its recognition in the final reduction of the observations.

(78.) In my last report I described the steps which had been taken for determining the factors of expansion of the two pendulums, and pointed out that they led to the singular and unexpected conclusion that "expansions determined by the vibrations of pendulums under a very low pressure are materially greater than those obtained by vibrations in the air, or by direct measurement." I added that "whether this is due to an actual increase of expansion for a decrease of pressure, or to the action of other phenomena which are at present unknown or only imperfectly known, is a problem for future solution." I have invited the attention of some of the most eminent European savans to this point, but as yet nothing conclusive has been established. The following suggestions have however been received from Professor G. G. Stokes:—

"I can see one cause acting in such a direction as to explain the effect observed, but whether the amount named be sufficient to explain the result, I am not prepared to say. According to Maxwell the viscosity of air increases with the temperature. Now what would be the effect of an increasing viscosity? In a pendulum surrounded by *free* air, doubtless to increase the time and diminish by degrees the arc. But if the pendulum is closely invested by a rigid envelope, the effect is not the same. Evidently when the viscosity is very great, the instantaneous motion of the air tends to depend solely on the instantaneous motion of the pendulum, and consequently the effect of resistance, so far as viscosity is concerned, tends to fall *wholly on the arc*. With a hampered pendulum (I mean one round which the *air* was hampered, the pendulum itself being free) I should expect the effect of increasing viscosity to be, first to increase, and afterwards to diminish the time, the rate of diminution of the arc increasing all along."

Professor Balfour Stewart writes:—

"I feel certain in my own mind that it is not due to an actual increase of expansion for a decrease of pressure. To what it is due is a different question. I hazard the following remark. I fancy it will be shown that the effect of air is of two fluids, one varying with the density, the other independent of the density, but varying with the temperature of the air. I cam imagine that this may, nay that it must make the temperature in air somewhat different to that in vacuo, but whether it will account for such a difference as you have obtained, I am not prepared to say."

No. XV.—MAGNETIC OBSERVATIONS.

PERSONNEL.

Captain J. P. Basevi, R.E.
W. H. Cole, Esq., M.A.

(79.) During the last two years magnetic observations have been taken in connection with the operations of this department, with unifilar magnetometers and declinometers, and dip circles, which were constructed for the Indian Survey under the superintendence of General Sabine and Mr. Balfour Stewart, and were tested at the Kew observatory. But the resulting value of the 'horizontal intensity' at Masoori, differed very materially from what had been obtained at the same station (though not on exactly the same spot) by the Messrs. Schlagentweit in 1855, our value being 7·286, their's 8·125, both expressed in British units. The difference seemed to be very much larger than could be due to any secular variation in the amount of the intensity that could possibly have taken place in the interval of 11 years between the observations. In order to ascertain whether there were any errors in our instruments or our *modus operandi*, Captain Basevi was directed to take an independent set of observations with his instruments at the Bombay magnetic observatory; this was done last November, and the result, horizontal force = 8·068, was absolutely identical with the value simultaneously determined, under Mr. Chamber's directions, with the instruments appertaining to the observatory. Moreover the mean annual value of this element at the Bombay observatory was 7·943 in 1847, and 8·025 in 1857, with which the value now obtained in 1867 is satisfactorily accordant. I have therefore much reason to believe that our results are quite correct.

(80.) Our value of the total intensity at Masoori is 1·06 less that that given by the Messrs. Schlagentweit in the 1st volume of their scientific mission to India and High Asia." But the differences between our values of this element and those given in the Messrs. Schlagentweit's chart of Isodynamic lines are less, and appear to decrease as the latitude decreases; thus at 8 stations between 20° and 30° the average difference is ·45, and at 6 stations between 15° and 20° it is ·21, our values being always smallest.

(81.) The following is a synopsis of the monthly observations which have been taken up to date by Mr. W. H. Cole, M. A., at the head-quarter's office in Dehra Doon.

Station.	Latitude and longitude.	Month and year.	Magnetic Elements.				Remarks.
			Declination.	Horizontal Intensity.	Dip.	Total Intensity.	
	° ′		° ′ ″		° ′		
Dehra	λ 30 20	June 1867,	...	...	41 30·27	...	
	L 78 6	July „	...	7·2785	41 31·18	9·7187	
		August „	...	7·2854	41 26·12	9·7176	
		Sept. „	...	7·2830	41 29· 5	9·7230	
		October „	...	7·2870	41 27·28	9·7227	
		Novr. „	3 3 17·1 E.	7·2954	41 29·68	9·7401	
		Decr. „	...	7·2944	41 28·85	9·7367	
		January 68,	3 2 14·4 E.	7·2944	41 27·38	9·7328	
		February „	...	7·2945	41 27·06	9·7322	
		March „	...	7·2990	41 25·19	9·7336	
		April „	...	7·2811	41 29·98	9·7216	
		May „	...	7·2803	41 33·02	9·7281	
		June „	...	7·2900	41 29·28	9·7317	
		July „	...	7·3053	41 34·04	9·7642	
		August „	...	7·2923	41 28·74	9·7333	
		Sept. „	3 3 4·2 E.	7·2887	41 32·45	9·7379	
		October „	3 2 12·6 E.	7·2762	41 29·96	9·7150	

(82.) The following is a synopsis of Captain Basevi's observations. Each result is usually the mean of two independant determinations, on as many days, the number varying from two to seven at each station :—

Station.	Latitude.	Longitude.	Month and Year.	Magnetic Elements.				Remarks.
				Declination.	Horizontal Intensity.	Dip.	Total Intensity.	
	° ′	° ′		° ′		° ′		
Deyrah,... ...	30 20	78 6	January 1867, ...	E 2 54·2	7·2877	41 27·57	9·7244	The H. I. at Somtana was determined from the mean of 4 observations on the 23d December and 1st January all very accordant. The character of the rock is trap ; a good deal of iron is worked in the neighbourhood, the possible presence of which may account for the discordance in H. I. and Dip.
Meerut,... ...	28 59	77 44	„ „ ...	„ 2 45·6	7·4062	39 7·24	9·5463	
Agra, ...	27 9	78 2	February „ ...	„ 2 46·2	7·5565	36 1·36	9·3430	
Pahargurh, ...	24 56	77 44	March „ ...	„ 2 10·0	7·7070	31 59·31	9·0868	
Kalianpur, ...	24 7	77 42	March & April 1867,	„ 1 49·0	7·8461	30 17·84	9·0872	
Ehmadpur, ...	23 36	77 43	April 1867, ...	„ 2 6·2	7·7607	29 53·79	8·9520	
Chickuldah, ...	21 24	75 56	October „	„ 1 54·0	7·9804	25 42·41	8·8570	
Badgaon, ...	20 44	77 39	November 1867, ...	„ 0 55·1	7·9704	22 40·99	8·6386	
Somtana, ...	19 5	77 42	Dec. 1867 Jan. 1868,	„ 0 28·1	8·3900	23 42·61	9·1635	
Damergidda,...	18 3	77 43	January 1868, ...	„ 1 29·4	7·9955	19 33·04	8·4847	
Secunderabad,	17 27	78 32	February „ ...	„ 1 34·1	8·1239	17 16·99	8·5080	
Kodungul, ...	17 8	77 41	March „ ...	„ 1 28·8	8·0635	16 36·44	8·4145	
Kurnool, ...	15 50	78 6	„ „ ...	„ 1 20·7	8·0726	13 42·79	8·3095	
Namthabad, ...	15 6	77 36	April „ ...	„ 1 10 6	8·1113	11 40·93	8·2829	
Bangalore, ...	12 59	77 39	June and July 1868,	...	...	7 7·44	...	

No. XVI.

THE COMPUTING OFFICE.

(83.) The final reduction of any extensive system of triangulation, in such a manner as to secure entirely consistent and harmonious results, and yet give it's proper weight to every fact of observation, every measured angle and base-line, is a very arduous and difficult undertaking, the more so the greater the extent of the operations, and the number of facts to be recognized. The Indian triangulation is vastly more extensive than that of any European state, but fortunately it has for the most part been executed on a system which considerably facilitates the final reduction of the observations. Chains of triangles are carried along the principal meridians, and the course of the eastern and western frontier, and these are connected together by other chains, the northernmost of which follows the Himalayan frontier line, while the others are carried along certain parallels of latitude, at convenient

Personnel.

J. B. N. Hennessey, Esq., Surveyor 1st Grade.
Lieut. M. W. Rogers, R.E., Assistant Surveyor 2nd Grade.
W. H. Cole, Esq., M.A. Assist. Surveyor 2nd Grade.
Mr. C. Wood, Civil Assistant 4th Grade.
Baboo Gunga Pershad, Computer.
„ Dwarkanath Dutt.
„ Gopal Chunder Sircar.
„ Kally Mohun Ghose, and 8 other computers.

intervals. Colonel Everest's Meridional Arc is naturally, from it's central position and it's intrinsic value, the axis of the system. Base-lines are measured at the extremities of the longitudinal chains, and at the points where the chains cross Colonel Everest's Arc. Thus the triangulation is divisible into large quadrilateral figures, with a base-line at each corner, and somewhat resembling gridirons, with their outer frame-work and intermediate bars; and this arrangement offers certain advantages in the reduction of the observations which are not met with in a net work of triangulation, as the points of junction between the several sections of the operations are reduced to a minimum.

(84.) At each junction there are necessarily two or more values of the lengths, azimuths and co-ordinates of the sides common to two or more chains of triangles, in consequence of the errors generated in the course of the operations. The problem to be solved is to harmonize these values by the application of certain corrections to every measured angle and base line, having due regard to the respective weights of the observations and to certain essential theoretical considerations as well as to the imperative necessity of restricting the calculations within manageable limits. With every assistance that could be derived from the published accounts of the best geodetic operations in Europe, and from Professor Airy, the Astronomer Royal, who has taken much interest in the subject, it has been a matter of no small difficulty to elaborate a system of reduction which would satisfy modern theoretical requirements, and yet be susceptible of practical manipulation, when applied to the very extensive operations of the Indian triangulation. This has at last been accomplished, and the great quadrilateral figure which connects Dehra Doon with Karachi, and comprises 4 base lines, and about 2500 angles appertaining to 8 chains of triangles, is now under treatment; the area covered by the figure is nearly 300,000 square miles.

(85.) A second edition of the tables which are used to facilitate the calculations of the trigonometrical and topographical operations has this year been prepared and printed; it contains a great deal of new matter, of which I may particularize certain tables which have been computed to facilitate the conversion of the spheroidal co-ordinates of latitude and longitude into plane co-ordinates, or *vice versâ* to convert plane into spheroidal co-ordinates, with sufficient accuracy for the practical requirements of surveys of comparatively small areas. These tables should enable Revenue Surveyors to make greater use of the co-ordinates of the stations of this survey than they have done hitherto, and conversely to compute the latitudes and longitudes of a certain number of their points from the plane co-ordinates on which their operations are usually based.

(86.) Of other matters done in connection with the current operations of this office I may notice the magnetic observations the results of which have already been given in para 81, meteorological observations throughout the year at Dehra and during the recess at Masoori, comparisons of standard thermometers and barometers, and the preparation of provisional data of the results of the triangulation for publication, with a view to meet immediate requirements.

No. XVII.

CARTOGRAPHY.

(87.) The map of "Turkestan with the adjacent portions of the British and Rushian Territories" which was stated in my last report to be under compilation, has now been completed and published by the photo-zincographic process. A great deal of valuable information has been incorporated into this map, from the Punjab "Report on the trade and resources of the countries on the North Western Boundary of British India," as to the routes from Afganistan *viâ* Kokan and Kashgar, and *viâ* the Oxus River, the Pamir Steppe and the Sari-kul or Tashkurgan district, to Yarkund;—from Peshawur through Swat, Panjkora and Chitral, to the Pamir Steppe and the sources of the Oxus; and from Leh and Iskardo into Tashkurgan and Yarkund. In the regions beyond the British frontier, which no European could safely enter unless backed by a strong army, there are many hill peaks whose positions and heights have been determined with accuracy by the operations of this survey, in previous years. These points furnish the basis on which the geographical details as obtained from oral information, or traveller's itineraries, or explorations by native surveyors, have been fitted; where they are numerous the map is probably fairly accurate, where they are scanty it is necessarily less reliable. The regions of which least is known are those lying between the Oxus and the southern frontier of Kokan; nothing is known of the configuration of the Pamir Steppe, and very little of the positions of places on it.

PERSONNEL.

W. H. Scott, Esq., Civil Assistant 1st Grade, and Chief Draftsman.
4 Native Draftsmen and 13 Native apprentices.

(88.) The determination of the much questioned positions of the chief towns of Altyshahar, or little Bokhara, is approaching solution. The position of Ilchi, the capital of Khotan, may be considered to have been definitely fixed by Mr. Johnson, while that of Yarkund has probably been very approximately fixed by Captain Montgomerie's explorer, Mohamed-i-Hamid. Adopting these positions, and collecting all the evidence available in this office as to it's distance and bearing from Yarkund and from Ilchi, Kashgar would appear to be in lat. 39° 25′ and long. 75° 25′; this value of the latitude agrees with what has generally been adopted hitherto, but the longitude is 1½° east of the position adopted by Klaproth, Humboldt and Ritter, and no less than 3° 35′ (nearly two hundred miles) east of the value adopted by the Messrs. Schlagentweit. On the other hand a new and entirely independent value of the position of Kashgar has been recently obtained, in the summer of 1867, by the Russian General Poltarasky, in the course of a reconnoisance of the regions to the south of Lake Issik-kul and the Naryn River, down to the border of the plains of Altyshahar; the resulting position of Kashgar was lat. 39° 35′, and long. 76° 22′, or still more to the east than the value adopted in this office. I am indebted to Baron Osten Sacken, Secretary to the Imperial Geographical Society of Russia, who accompanied General Poltarasky's expedition, for the above information, as well as for several of the latest and most correct maps of the regions on the south of the Russian Frontier; they have been of great assistance in compiling the new map of Turkestan.

(89.) Mr. Scott has also been engaged in the very laborious work of compiling Charts of Levels from the combined operations of this survey and of the

Canal, Railway and other Engineering Departments, in which all the levels are referred to the common datum of the mean sea level of Karachi harbour. Some of these charts are already published, as specimens to shew the Officers of the above departments what sort of information is required from them, in order that the charts may be made as perfect as the existing materials will permit of; this I am sorry to say comes in but slowly, and consequently the compilation of the charts is much delayed.

(90.) During the year, 15 topographical and geographical maps have been photo-zincographed, and 20 preliminary charts of triangulation and 10 maps have been zincographed;—7376 copies of these maps and charts, and 10,531 copies of forms for calculations and office work have been printed, the former for issue to the public, the latter for employment in the department.

(91.) An abstract of the out-turn of work executed by the Trigonometrical and Topographical Parties only, during the year under review, is given on the next page.

J. T. WALKER, Lieut.-Colonel, R.E.,
Supdt. Great Trigonometrical Survey,
and Offg. Surveyor General.

Dehra Doon,
1*st December* 1868.

ABSTRACT OF THE OUT-TURN OF WORK EXECUTED BY THE TRIGONOMETRICAL AND TOPOGRAPHICAL PARTIES OF THE G. T. SURVEY, DURING THE OFFICIAL YEAR 1867-68.

Description of Details.	1 Brahmaputra Series. 24-inch Theodolite.	2 Eastern Frontier Series. 24-inch Theodolite.	3 Jubbulpore Meridional Series. 36-inch Theodolite.	4 West Calcutta Longl. Series. 24-inch Theodolite.	5 Bangalore Longl. Series. 24-inch Theodolite.	6 Bangalore Base-line. 24-inch Theodolite.	7 Kumaon and Garhwal Survey. 14-inch Theodolite.	8 Kattywar Survey.	Total Out-turn of Work.
Number of Principal Stations, newly fixed, ...	...	7	19	9	12	16	...	...	63
Number of Principal Triangles completed, ...	...	7	23	8	9	18	...	...	65
Area of Principal Triangulation, in square miles, ...	...	573	5,634	1,326	1,028	...	...	...	8,561
Lengths of Principal Series, in miles, ...	...	38	150	72	33	...	...	...	293
Average Triangular Error, in seconds, ...	...	0·41	0·27	0·28	0·77	0·49	...	...	...
Average Probable Errors of Angles, in seconds ± ...	...	0·19	0·19	0·21	0·19	0·26	...	...	...
Azimuths of Verification, ...	...	...	1	...	...	2	...	...	3
Number of Secondary Stations, whose positions and heights have been fixed, ...	...	6	...	...	14	...	279	81	380
Number of Secondary Stations, whose positions only have been fixed, ...	...	...	...	...	...	...	...	21	21
Number of Secondary Triangles, of which all 3 angles have been observed, ...	...	2	...	...	9	...	175	...	186
Area of Secondary and Minor Triangulation in square miles, ...	...	2,659	...	...	250	...	2,315	1,076	6,300
Number of Points fixed by intersection but not visited,	...	7	...	...	54	...	583	434	1,078
Length of boundary line Surveyed in miles, ...	...	...	...	...	...	...	6	614	620
Length of check lines in miles, ...	...	...	...	...	...	...	...	89	89
Area Topographically Surveyed on scale of 1 inch = 1 mile, in square miles, ...	...	...	...	...	...	...	1,288	260	1,348
Area Topographically Surveyed on scale of 2 inches = 1 mile, in square miles, ...	...	...	...	...	...	...	...	800	800
Area Topographically Surveyed on scale of 12 inches = 1 mile, in Acres, ...	...	...	...	...	...	...	378	...	378
Number of Principal Stations selected in advance, ...	33	22	...	...	5	...	...	...	60
Lengths of Approximate Series, in miles, ...	161	116	...	...	87	...	...	...	364
Number of Towers constructed, ...	10	1	...	6	1	2	...	...	20
Do. Platforms constructed for Principal Stations, ...	...	6	8	...	17	...	...	...	31
Do. Platforms for Secondary Stations, ...	7	...	...	...	...	...	...	...	7
Do. Miles of Rays cleared, ...	578	50	...	272	...	...	...	...	900
Do. Miles of Roads made, ...	...	153	...	...	...	...	...	...	153
Do. Hill tops cleared of forest and jungle, ...	10	20	...	...	...	...	720	...	750
Do. Principal Stations whose elements were computed,	20	19	16	19	28	...	...	...	102
Do. Secondary ditto, ...	90	21	...	...	27	...	336	502	976
Do. Preliminary Charts of Triangulation, ...	...	1	1	...	...	...	...	1	3
Do. Principal Stations placed under official protection,	...	10	26	...	...	...	...	...	...
Do. Tower Stations protected and closed, ...	10	9	...	3	...	...	...	...	...
Do. Platform Ditto, ...	...	...	26	4	...	...	...	...	...

APPENDIX.

EXTRACTS FROM THE NARRATIVE REPORTS

OF THE

EXECUTIVE OFFICERS IN CHARGE

OF THE

TRIGONOMETRICAL SURVEY PARTIES.

EXTRACT FROM THE NARRATIVE REPORT OF LIEUTENANT H. R. THUILLIER, R.E., SURVEYOR 2ND GRADE, IN CHARGE BRAHMAPUTRA SERIES G. T. SURVEY, NO. 93, DATED 18TH AUGUST, 1868.

(2.) The party assembled at Calcutta in the first week of November. Lieutenant Larminie had been lately posted to my party for special work in Assam. As this officer had had a very short opportunity of being trained in the special duties of this Department, and had seen no field work, I thought it prudent, before deputing him to take up the triangulation of the Assam Valley, to give him an opportunity of seeing some practical work of selecting stations and clearing rays.

(3.) It was my intention on arriving at Calcutta to have sent a sub-assistant to Dacca to procure boats for the conveyance of the camp to the field of operations, as they are more easily obtained there, and at cheaper rates than at Calcutta. But in consequence of the damage done to the boating by the cyclone of 2nd November, and the temporary stoppage of the Dacca steamer, I was unable to carry out this arrangement, and had to resort to what was obtainable in Calcutta. The loss and damage caused by the cyclone had been even more severe in the vicinity of Calcutta than at Dacca, so that it was after great delay and trouble that I was able to procure a sufficient number of boats, and these could only be obtained at greatly enhanced rates of hire, on account of their scarcity. I had previously made arrangements to send such a portion of the camp by land as the means of carriage then at my disposal allowed.

(4.) After making the necessary arrangements for taking the field, the main camp started by boats on the 23rd November, proceeding through the Sundarbuns, *vid* Koolna and Kooshtea, to Furreedpore. This was a tedious and circuitous route, the greater portion of it being against stream, but it was the shortest route open at that time of the year. It was in order to avoid this delay that I intended getting boats from Dacca, to meet the camp at Kooshtea, which would have been reached by rail in one day. The numerous wrecks from the cyclone in the neighbourhood of Calcutta were another source of delay on the journey. The channels in many places are so narrow that their navigation was difficult, and the wrecks entirely prevented the boats from proceeding, as usual, by night, and consequently several tides were lost.

(5.) *En route* I detached Messrs. Neuville and Ryall to take up the approximate series in the southern portion of the Furreedpore district, where three stations remained to be selected, and gave them instructions, after completing this object, to work northward, clearing the final rays, Mr. Neuville to work on the left flank, and Mr. Ryall on the right flank of the series.

(6.) My camp reached Furreedpore on the 9th December, the portion which had proceeded by land from Calcutta having arrived there a few days previously. After deputing Mr. Harris to take up the tower building, I started to take up the approximate series from the point where it had been relinquished the previous season. Lieutenant Larminie and Mr. O'Sullivan accompanied me.

(7.) On the 24th December I directed Lieutenant Larminie to proceed with his party to Kooshtea, for the purpose of taking the steamer thence to Gowhatty, in the vicinity of which place his triangulation was to emanate. Mr. O'Sullivan accompanied Lieutenant Larminie, to aid him in selecting stations in the first instance, and afterwards to continue the approximate series, when Lieutenant Larminie returned to commence observations.

(8.) For reasons stated in para. 20 of my last report I determined, with your approval, to confine my operations during the season to the approximate series. I therefore continued selecting stations and clearing trial lines till the 1st April.

(9.) The triangulation follows the course of the Ganges and Jumoona rivers. Owing to the breadth of these rivers, and the shifting nature of their banks, it was not always practicable to select sites sufficiently far removed inland to ensure permanency. But such stations

are few, and these few have been selected with care in such places where the river was not cutting its banks; so that I do not anticipate any immediate loss of stations, and, after allowing a wide margin for the vagaries of the river, by far the greater number will remain for posterity.

(10.) The districts through which the operations were carried are those of Furreedpore, Dacca, Mymensing and Pubnah. In the Furreedpore district, where the series emanates, the country is of a very low level, consisting of immense swamps, intersected by small nullahs and streams. This part of the district is comparatively scantily inhabited, the village sites being raised on artificial mounds. Communication is most difficult, the principal means being by small boats, or canoes hollowed out of trunks of trees. Proceeding northwards the country gradually rises, and becomes densely populated. The villages are of great extent, and surrounded by valuable groves of mangoe, palm and betel-nut trees. Such obstacles considerably impeded our operations. This part of the Furreedpore district is richly cultivated, the principal crops being rice, dhall, sugar-cane, indigo, and tobacco. On the Ganges "chur lands" wheat and gram are also grown. Proceeding to the left bank of the Ganges, in the Dacca district, the country is low and inundated for the greater portion of the year. The surface soil is a mixture of sand and clay. There are no roads, the traffic being entirely carried on by boats. The chief products of this part are rice, safflower, gram, indigo, and jute. In the portions of the Mymensing and Pubnah districts where the operations were carried on, the country is of a similar nature.

(12.) There was a great deal of sickness throughout the whole season in the Furreedpore and Dacca districts, principally from cholera, but I am happy to report that we were comparatively free from sickness. Five men died during the season, one from cholera, and four from ordinary causes.

(13.) On the 4th April the *chota bursat* set in, and heavy rain was experienced, accompanied with severe storms. This weather continued daily for ten days, by which time the country was nearly submerged. As there appeared no prospect of its abating, I closed work, and the camp started *en route* to Calcutta, where it arrived on the 27th April.

(14.) Mr. C. J. Neuville was employed during the whole season on the approximate series. He commenced work on 5th December, and selected two principal stations, clearing 75 miles of trial lines, and 159 miles of final rays. The ground where he commenced work was extremely difficult for the selection of stations, and he was consequently much retarded in his operations at the commencement of the season. As I was unable to examine Mr. Neuville's work, I cannot report on its quality until I go over the ground next season, but considering the difficult nature of the country in which he was employed, I have reason to be satisfied with the quantity.

(15.) Mr. F. W. Ryall was similarly employed on the approximate series, and selected one principal station, clearing 52 miles of trial lines, and 137 miles of final rays. He was working in conjunction with Mr. Neuville, and had the same difficulties to encounter in regard to the physical features of the country. The quality of his work cannot be reported on for the same reason as mentioned in Mr. Neuville's case.

(16.) Mr. G. A. Harris was employed in erecting the towers. As these structures have to be made paka throughout, this part of our operations is by no means of a secondary nature. The difficulties in procuring materials and conveying them to the various sites in a country where communication is so difficult, is a source of much trouble and delay. Mr. Harris has worked well and successfully, and has had a hard field season's work, having had to remain in camp till the middle of June, to complete the towers in hand. The works were greatly delayed on account of the heavy rains in April and May, and the difficulty in procuring labor, the cause of which is mainly due to the railway works of the Goalundo extension, for which all available labor had been taken up. During the season Mr. Harris completed 10 towers, two more being about half built, and the materials for two others prepared and collected. Mr. Harris returned to Calcutta on the 24th June.

(17.) Agreeable to the instructions conveyed in your letter No. $\frac{11}{617}$, dated 23rd October, Lieutenant Larminie was furnished with a sub-assistant and native establishment from the

Brahmaputra Series, to execute the triangulation of the Assam Valley. For this object he left Kooshtea on the 31st December, and arrived at Gowhatty on the 11th January. Not having been provided with elephants, he was totally dependent on the local carriage that could be procured, this consisted merely of coolies; and, although Lieutenant Larminie received every assistance from the local officials, the delays and difficulties he met with on this account hampered him very considerably, and prevented him from accomplishing the amount of work which he could otherwise have performed. Owing to the difficulties experienced in obtaining coolies for carriage of his camp, he was unable to commence work till 25th January. The establishment also with which he was furnished, and which was the largest I could spare him from my party, proved far too small to admit of being broken up into two detached parties, and on this account Lieutenant Larminie was obliged to confine himself to the approximate series, and give up all idea of taking observations till the following season. I have previously addressed you on the subject of these causes of delay, *viz.*, want of carriage, and a larger establishment, the former has already been partially provided for, and next season Lieutenant Larminie will have three elephants, and, with the sanction of the increased establishment which I have recommended, I have every reason to anticipate a large out-turn of work. The actual amount of work accomplished consists of 11 stations selected, 7 platforms built, and 10 hill tops cleared of jungle, the length of the series being 80 miles direct distance. The country over which the triangulation was carried is hilly and wild in the extreme, and but thinly populated, which made the difficulties greater. The following is extracted from Lieutenant Larminie's report :—

ASSAM OPERATIONS.

Lieut. E. M. Larminie, R.E., Assistant Surveyor 2nd Grade.

Mr. W. J. O'Sullivan, Sub-Assistant 3rd Grade.

"It had been my original intention to carry on the approximate series for a short distance, and then return to take the final observations, leaving Mr. O'Sullivan to continue the selections of the stations; but I found it necessary to change this plan, as I had not a sufficient number of men to admit of their being divided into two parties of sufficient strength. The season was also far advanced, and the burning of the immense jungle commencing in February would have caused great delay to the final observations had they been attempted. There is also more fog and mist at this time of the year than earlier in the season. For these reasons I determined to confine myself to the approximate series.

"Commencing to the west of Gowhatty from the old hill stations of Myang and Hatimora of the Assam Longitudinal Series, I carried on a series of quadrilaterals in an easterly direction. All the stations selected, with the exception of one, are situated on hills generally of considerable elevation.

"On the 2nd April, owing to bad weather, and the rapid increase of sickness in the camp, I was reluctantly obliged to close work.

"In all cases roads or paths had to be cut to the tops of the hills, several days often being spent in cutting and burning the jungle before the desired point could be reached.

"I regret much I have not a larger amount of work to show, but I trust that the difficulties I experienced in obtaining carriage, and the difficult nature of the country, will be taken into account. Some idea of the delay occasioned may be formed from the fact that out of this very short field season, 33 days were spent in total inactivity, from the impossibility of obtaining coolies. The time occupied in marching from place to place was much increased by the number of small rivers, &c., to be crossed, and the scarcity of boats.

"Till the end of March the health of the party was very good, but from that time till leaving Assam nearly the whole camp was prostrated with malarious fever, from which two men died. The signal-men I found suffered more than the others during the season, owing, I believe, to their sedentary occupation. The party returned to Gowhatty on 12th April, where we embarked on 23rd April. Proceeding by steamer and rail we arrived at Calcutta on the 28th April."

(18.) Lieutenant Larminie reports very favorably of Mr. O'Sullivan, Sub-Assistant 3rd Grade, for his energy and zeal in carrying out all his instructions. I have always found this officer most diligent and active during the four years that he has been attached to my party. He has been now two and a-half years in his present grade, and I cannot refrain from bringing him to your favorable notice for promotion.

EXTRACT FROM A REPORT OF W. C. ROSSENRODE, ESQ., ASSISTANT SURVEYOR, IN CHARGE EASTERN FRONTIER SERIES G. T. SURVEY, NO. 1, DATED 7TH FEBRUARY, 1868.

I have the honor to inform you that the mean level of the sea by tidal observations at Akyab has been determined. The observations show a difference of 1·94 feet in defect of the computed height determined by triangulation.

(3.) The waters washing the gauge had a direct communication with the sea. The site was sheltered from surf, and the waters deepened rapidly from the bank to the gauge. The gauge was set up in 7 feet of water. It was driven into the bed of the river 6 feet and 9 inches; rocks at the bottom prevented the pile, to which the graduated scale was attached, being driven in deeper. The graduation extended up to 24 feet. The length of the post was 33 feet, and a foot square. The gauge post was isolated. No portion of the outer wood and bamboo work was allowed to come in contact with it. Four outer posts were fixed 12 feet apart, forming a square, with the gauge post in its centre. Between these outer posts four others were driven in. The two corner and centre posts on each side of the square were connected with two beams nailed on diagonally from bottom (low water mark) to top; and four equidistant braces were nailed and lashed on parallel to the surface of the water, and to one another, to secure the stability of the outer wall, composed of coarse strong matting half an inch thick. The mat wall, 12½ × 14 feet, was then fixed to each side, and a floating stage was constructed for the observer.

(4.) I obtained the Government schooner *Dolphin* from the Commissioner, to drive in the piles, and personally superintended the entire construction of the gauge. With all my precaution to ensure firmness and stability I found that the resistance offered by the bamboo matting was so great that the outer portion enclosing the gauge was in a state of vibration during both tides, the vibration ceased only at slack and low water.

(5.) The rains seemed to be over, and experimental observations were commenced on the 19th October; but the water within the enclosure was so agitated that reliable observations could not be taken. I removed the floating stage, which I supposed caused the agitation within; while without the enclosure the water was smooth. Two stages above high and low water were then constructed for the observer, resting on the outer work of the square. I perceived that the removal of the floating stage made no difference whatever. The agitation within the enclosure was still the same, and no satisfactory observations could be obtained. The mat walls were removed, and with it the agitation ceased, and observations commenced on the 24th October.

(6.) On the same dates on which the cyclone caused so much damage in Calcutta, the weather became very boisterous at Akyab. From the 31st October to the morning of the 2nd November it was impossible to take observations, in fact it was dangerous to approach the gauge. No boat could live in the stream, which was like a boiling caldron. The squalls were so severe that the timber was wrenched off from the square surrounding the gauge, and the entire framework leaned over. The whole construction was again righted, and further strengthened with extra cross pieces and braces; and the observations were again resumed. A succession of bad weather followed; during the spring tides rain fell in torrents, squalls were frequent from the 8th to the 15th November, and breaks in the observations occurred. They were resumed for the third time on the 16th November, and I am glad to say a complete lunation was obtained.

(7.) During the stormy weather above alluded to, on the 31st October Mr. Price was employed at the gauge, and suffered very much from exposure. Mr. Connor relieved him; in fact he volunteered to take the remainder of the observations. Mr. Connor commenced on the 5th November, and for some days the weather was propitious, and he obtained good results. Bad weather set in on the 8th, and continued until the 15th November. During these days, unmindful of the heavy rain and squalls, he visited the gauge at the proper times, and tried his utmost to obtain observations. As no umbrella could be held over him owing to the constant squalls, to protect the book, he recorded the readings with a pencil on cloth. He was drenched

to the skin every time he went to the gauge, and remained wet during the whole time of the observations, exposed to the fury of the elements. His praiseworthy efforts to prevent a break in the observations were ineffectual. Two breaks occurred, owing to the boat having drifted away on one occasion, and the boatmen having refused to take him on the other, on account of the frightfully rough state of the river. Mr. Connor commenced a fresh set on the 16th November, and continued observing until the 4th December, when he accompanied me to the field.

(8.) I left Mr. Price to complete the remainder of the observations, which were satisfactorily accomplished on the 16th December, 1867.

Extract from Narrative Report No. 19, *dated* 13*th August*, 1868.

I have the honor to submit the Narrative Report, detailing operations of the preceding recess, and of the field season 1867-68, of the Eastern Frontier Series G. T. Survey of India.

(2.) During the recess of 1867,—

1 Double figure, composed of a hexagon and a pentagon, and six quadrilaterals, completed.
34 Principal triangles completed.
53 Single deductions of latitudes, longitudes and azimuths of principal stations completed.
53 Single heights of principal stations completed.
51 Secondary triangles, 1st class, completed.
12 Do., 2nd class, do.
54 Single deductions of latitudes, longitudes and azimuths of secondary stations completed.
36 Single deductions of heights of secondary stations completed.
72 Weights of angles computed.
1 Preliminary chart, and a copy for the office.

(3.) In compliance with the order conveyed in your letter No. $\frac{13}{603}$, dated 18th October, 1866, tidal observations were taken at Akyab. The preparatory arrangements for erecting the gauge were commenced on the 1st October, and the observations were finally and satisfactorily completed on the 16th December, 1867.

(4.) There being only one figure (a pentagon) prepared for me the previous season, I determined upon detaching Mr. Beverley, Civil Assistant 3rd Grade, on the 1st November, to hasten on the approximate work; a continuance of wet weather prevented my doing so until the breaking up of the rains. From the 16th no more rain fell, and Mr. Beverley took the field on the 21st November. On reaching the scene of his operations he found he could not obtain assistance from the native local authorities, they being themselves powerless, owing to the unwillingness of the inhabitants to do coolie work; he therefore addressed the myouk, the highest native official of Padong; the following is the reply:—"In reply to your letter I beg respectfully to say that I have not entire power on the Thugees and Rajwagoungs to give such order unless I have an order from the Deputy Commissioner to do so. We cannot get any coolies with their consent unless we force them to come. They said that their daily pay is too little for eight annas." Mr. Beverley next addressed Captain Watson, who was then Officiating Deputy Commissioner of Prome, and that officer immediately issued fresh orders, and Mr. Beverley was able to commence work on the 15th December.

(6.) The main party left Akyab on the 4th, and arrived at Thudday, in the Sandoway district, on the 11th December, where the boats were discharged. After arranging for coolies and provisions, I proceeded to my first station, Koguentonggri. On the third day the coolies deserted, leaving me in the jungles. I reported the circumstance to the Deputy Commissioner of Sandoway, who did not punish the men, or assist me. I was obliged to extricate myself the best way I could from this and every difficulty which subsequently occurred. I asked for aid and sought redress, but, receiving none, I made my own arrangements for continuing the operations

without again troubling him. Anticipating difficulty and disaster from my last season's experience of the country, I took the precaution to entertain 35 coolies at Akyab on monthly pay; with these and the native establishment I managed to reach the station, the men going backwards and forwards until all the instruments, baggage, and supplies were conveyed up the hill. The desertion of the coolies at the beginning of the season, and at my very first station, caused me much anxiety. To attempt work without the full complement of men for conveying baggage and supplies in a wilderness was to risk the lives of the whole camp. The coolies who had deserted spread unfavorable reports regarding the treatment they received, *vide* Captain Pemberton's letters; I had therefore to make such arrangements as would enable me to move the whole camp at any time at a moment's notice, in order that there may be no further delay or interruption to the work. The five Government elephants attached to the series had already taken Mr. Beverley, his establishment, and all my signal parties over these uninhabited mountain ranges, and were now employed in conveying supplies to the depôt, which had been established in a centrical position, from whence the party and its detachments could easily be provisioned. This depôt was stored with rice, dhal, and other requisites, to some extent. A further supply was needed to make up the estimated quantity; I could not therefore withdraw all the elephants. After some delay fresh coolies were collected, and brought in by my people. On their arrival I wrote the name of each man, and handed him, through his gong (the sirdar is thus designated in Burma), five rupees, or ten days' hire in advance. Before the time expired fresh advances were made. By keeping them continually advanced, I effectually secured their services, and at the same time satisfied them that the reports against my camp circulated by the deserters were false, for instead of withholding payment, each man was paid in advance. The coolies remained with me until I completed the observations at all my stations on the uninhabited Yoma range of mountains dividing Arracan from British Burma, and when I descended into the valley of the Irrawaddy the men who were inclined to go home were permitted to do so. The provisions lasted until the last signal party left this inhospitable country. All the stations of the Modhitong hexagon were completed by the end of February. There was much sickness in February, mostly among the coolies entertained at Akyab, and as they wished to return to their homes, they were permitted to do so.

(7.) Having completed the above hexagon, and the next figure not being ready, owing to the very difficult nature of the country, I had no other alternative but to close final work and take up the approximate triangulation, which Mr. Beverley reported he was unable to continue single-handed, having rays to trace and clear in the plains covered with dense forest, and to build towers. The base-line was also to be fixed. I reached Timuki village on the 5th of March, where Mr. Beverley joined me the next day. He was in the vicinity of the abovenamed village, employed at this time in exploring the country, and from the information I obtained from him, and after attentive inspection, I selected the base, and left Mr. Connor to clear the line.

(8.) Mr. Beverley was directed to return to the hexagon he had fixed to clear the rays, and to build the tower at Kyangun station, so that the figure may be ready for final observations; but on this duty he, and subsequently Mr. Price, were employed until the end of the season, when the tower was completed.

(9.) I took up the approximate work on the high range of uninhabited hills dividing Prome and Myanoung from Tongoo and Shugeen. The dense haze and smoke from the burning jungle, which during this and the succeeding months is fired by the inhabitants, prevented work being done until the latter part of April. A few showers cleared the atmosphere, and the approximate operations progressed rapidly on the hills, and I returned to the plains to trace and clear the rays, fix stations, and connect the base-line with the hill work. At all times forest rays are tedious and laborious to trace and clear; they become doubly so for want of labor. In Burma there is no laboring class. The inhabitants only cultivate their fields at the proper seasons, and build their huts, and repair them when actually necessary. If coolies are wanted the native local authorities alone can provide them—should they feel disposed to do so—as has hitherto been done on this series during the previous seasons. All coolie work is executed by Shans, Madrassees and Bengalees, who annually come into the country, and are either engaged at high wages by the Public Works Department for roads, or, as a further inducement, and at the same time to expedite public works of utility, a remunerative contract is offered them, which latter

they prefer. On questioning the men employed on the road now being constructed between Prome and Rangoon, I learned that they earned twelve annas to a rupee each daily, working six hours, *viz.*, four hours in the morning, and two in the afternoon.

(10.) There really being no labor in the country, and the native local officials being aware that free trade and free labor prevails throughout the province, never exert themselves to supply the full complement of coolies. A few men are now and then provided, as a matter of policy, to shew that the Deputy Commissioners' perwannahs are attended to. The demand however for coolies was very great when the rays were being traced and cleared, but the supply fell far short of the demand. I therefore offered every inducement to respectable and influential Burmans to act as gongs (sirdars or head-men) of gangs of coolies, and each gong was required to supply twenty coolies. These men, with all their exertions, were unable to procure the above number, each gong however brought in a few men. Very often coolies kept away for days together, in order that the rates may be increased to twelve annas and a rupee. I however remained firm, for had I increased the rates, there would be no limit to their demands. Every inducement and encouragement was held out to the gongs, and, however small the supply daily brought in, the men were retained, and the work gradually progressed.

(11.) The rate of progress this season was most unsatisfactory, from the want of labor. Mr. Connor was engaged for upwards of two months on the base-line, and although he exerted himself to the utmost, and tried his best to procure labor, he could not obtain the aid he so greatly needed. He was only able to clear a narrow gap for the base-line, and undertake two other trial rays. From the same cause, want of labor, one of Mr. Beverley's rays took two and a-half months to clear.

(12.) Mr. Price took the field after the completion of the tidal observations, and after making a survey of the coast on either side of the gauge, he secured eight principal stations by erecting rectangular piers over them, and accomplished the secondary work shewn in the chart. Having fixed the position of Sandoway, and thrown out a few triangles on the Alguada light-house minor series, he crossed the Yoma range, and joined Mr. Beverley, under whom he was employed in clearing rays and building towers, and when that officer proceeded on privilege leave, Mr. Price took over all his duties.

(14.) The ground fixed upon for the base of verification is the very best that could be selected in that part of the country. The east end of the base stands on a swell, and there is a gradual slope from it to the west end, the difference of level being 62·60 feet. The base-line runs through a dense forest, and it will, I believe, take one assistant to prepare it, build the towers at each end and clear the ray, a narrow gap only having been cut by Mr. Connor. The rays to the section stations on either side of the base will also be cleared by him. This work will occupy him a whole season. In other parts of India duffadars are able to clear rays, receiving assistance from the native local authorities, but in Burma no such aid is rendered to them, unless an assistant superintends the work, or is close at hand to provide and send out coolies to his native subordinates.

(15.) Three trial rays were carried on in different parts, in order that the very best ground may be chosen. The site of the base-line above referred to is in every way superior to the others. The soil of the surrounding country is black loam, cotton soil, or, as it is sometimes termed, rotten soil, owing I believe to its instability. Immense cracks and fissures are the distinguishing features of a country where such soil is found. The ground selected is firm, having a large proportion of gravel and sand mixed with clay for the first portion, and the remainder is new virgin soil without cracks or fissures. The base is through a dense forest, which will certainly cost labor and expense, but this is in a great measure counterbalanced by my selecting it nearly in the position you wished it to occupy, it has therefore the advantage of every other site. I doubt, however, whether any other site equally good could be found for miles around. The ground is intersected by two water-courses, which cross and recross the line, but being narrow and shallow, they are of no consequence.

(16.) To select a base-line in a country covered with dense and extensive forests, with partial clearances here and there for village sites and fields, intersected with hill streams, nullahs and ravines, and the paddy fields being fissured and cracked all over, was not an easy

undertaking. The selection caused much labor and anxiety. Owing to the above reasons, and to the country being clothed with dense jungle, a minute inspection could not be made until trial rays were cleared and the ground tested. This anxiety however was nothing compared to that caused by the slow progress of the operations for want of labor, everything was done that could be done to obtain labor for tracing and clearing rays and building towers; and although I continued in the field until driven away by the rains having set in, still only portions of rays were cleared. It will therefore be incumbent on me to employ permanent coolies to some extent, so as not to be entirely dependent on the country.

(17.) If you assist me in obtaining the use of ten elephants from the Commissariat Department in Rangoon, where large numbers are stationed, I should be set up in a great measure. These animals are most useful in forest rays. By crushing and removing bamboos and the numerous creepers which interlace and hold together trees, which cannot be felled before the creepers are removed, they assist the coolies greatly, and do the work of many men. If each ray had the use of three to four elephants the work would progress rapidly. I shall however do my utmost to expedite the operations notwithstanding the difficulties I am beset with.

(20.) The inclination of the series to the west became absolutely and indispensably necessary, to avoid the uninhabited country, which would have added considerably to the expense, and delayed the operations, owing to there being no villages for several stages, and no roads whatever. After much labor and enquiry the most favorable country was selected, and I laid out the approximate triangulation, taking care to have the full use of the much frequented road used by traders and travellers in crossing over the range dividing Myanoung from Tangoo and Shugeen. This road will enable me to establish depôts for supplies, and from it branch roads will be cut to the principal stations, which I shall endeavour to have on either side of it by means of quadrilaterals. I also ascertained that there are villages scattered over this portion of the country from which assistance (however small) can be obtained.

(21.) Mr. H. Beverley, Civil Assistant 3rd Grade, exerted himself, as usual, to advance the approximate work, but, owing to the difficult nature of the country and scarcity of labor, he has not been so successful as heretofore.

(22.) Mr. Price, Sub-Assistant 3rd Grade, accomplished the secondary work allotted to him, and also constructed the rectangular piers, as already enumerated. His work entailed much labor, in visiting the stations requiring to be secured and made over to the local authorities, as well as to attend to his secondary operations. After accomplishing the above he joined Mr. Beverley, and was employed under him. Mr. Price has always worked well and afforded satisfaction.

(23.) Mr. E. J. Connor, Sub-Assistant 3rd Grade, has been very assiduous and attentive to his duties in the office and observatory, and has afforded me much satisfaction. He has had hard work this season, and had he been assisted with coolies, he would have made considerable progress on the rays which he was directed to clear.

(24.) The country traversed during the present season by the main party in the beginning was over the uninhabited chain of mountains dividing Arracan from British Burma, which has been already described in my Report of last season. The intermediate country between the former and the next chain of mountains dividing Prome and Myanoung districts from Tongoo and Shugeen is the valley of the Irrawaddy, the banks of which magnificent river are thickly populated, but as the traveller recedes from it he meets with fewer and fewer villages, until he enters a desolate wilderness. This description may be appropriately applied to the whole country, where the uninhabited preponderates over the inhabited, and where forests are encountered everywhere. Extensive cultivated plains are never met with. Sites of villages, and small portions surrounding them, sufficient to grow grain for consumption, is cleared and cultivated. Where the means of export exist grain is abundantly cultivated, but where these facilities are wanting, sufficient for their wants is alone grown. In consequence of this limited supply, difficulty is always experienced in procuring rice, which is very reluctantly supplied, owing to their having none to spare, and being obliged to replace what they sell by purchasing it elsewhere, and conveying it in their own carts. For this reason the price also varies considerably in short distances, because they add on the cost of carriage to the (selling) price of the rice.

EXTRACT FROM THE NARRATIVE REPORT OF GEO. SHELVERTON, ESQ., ASSISTANT SURVEYOR 1ST GRADE, IN CHARGE JUBBULPORE MERIDIONAL SERIES, NO. 15, DATED 28TH AUGUST, 1868.

(1.) The party of the Jubbulpore Series left Jubbulpore on the 12th of October, 1868, to observe circum-meridian altitudes of pairs of north and south stars for latitude at the principal station Karaondi H. S., where an observatory had been built previous to the setting in of the rainy season. The weather, which had been very unsettled up to this time, permitted observations to be taken uninterruptedly during the nights of the 13th, 14th, 15th, 16th and 17th, after which the sky became clouded, and work was not resumed till the 23rd of October, when the set of observations was completed, giving in all 264 independent deductions of latitude, obtained from 22 stars arranged in pairs north and south of the zenith. A synopsis of the latitudes was supplied to you after the observations had been reduced, and you were pleased to express your approval of the results.

(2.) After returning from Karaondi to Jubbulpore, I employed the party till the 3rd December in computations, &c., as I did not deem it safe to march earlier to my ground through the unhealthy forest tracts between the Nerbudda and Godavery rivers. On the march down the kahars engaged for the 36-inch theodolite deserted in a body at Nagpore, and though the authorities seemed anxious to secure a fresh set of men for me, I was compelled, after losing ten days, to transfer my private establishment of bearers for the carriage of the instrument, and even these men deserted me eventually; but after crossing the Godavery river, and entering the Hydrabad States, I was always supplied by the officials of His Highness the Nizam with as many carriers as I required. I used at first to be anxious about the safety of the great theodolite, as I was obliged to trust to men who were not trained to shoulder it, but I employed such a large number for the purpose that they carried, without any accidents, the large boxes containing the instrument over some of the worst hill roads that I ever had.

(3.) The principal observations were begun on the 21st of January, 1868, at Partabgiri H. S., on the right bank of the Godavery river, near the civil station Seroncha. From Partabgiri we marched through dense forest to Mantani, a settlement of Brahmans, who hold their lands rent-free from the Hydrabad government, and who are reputed to possess great wealth, collected principally during their begging tours; they are said to wander long distances from their homes to fairs and places of pilgrimage, and to return with a good harvest. After leaving Ramgir to visit Yerraballi H. S., we emerged from the forest into open country dotted with palms, well cultivated, and abundantly supplied with water. Some fine tanks are to be seen along our route through this portion of the Ailgandal talook, where there was a good deal of rain during the previous monsoons, while the country farther south suffered severely from drought. The Yerraballi range contains an inexhaustible supply of iron. The hill on which the station of observation is built is called by the Telingis "Inamparwat", and by the Mahommedans of the country "Lohá-ká-pahár", both meaning the hill of iron. The ore is apparently rich in metal. I was told that the hill at times is luminous, and it might become so under certain electric conditions of the atmosphere. I noticed nothing extraordinary while I was encamped near the station. The rocks are of a rusty red color, but when chipped the fracture glistens like iron pyrites; the ore is only worked for local wants. The pillar built at Yerraballi H. S. during the previous field season had been struck by lightning. The stones composing the cairn raised over it had been scattered, and its upper surface had been destroyed. The upper mark-stone was found some distance from the platform. The lamp-man sent to the station reported to me that the inhabitants of the neighbouring villages had begun worshipping the pillar, as he found it decked with garlands of flowers. From Yerraballi H. S. to Katajpur H. S. the country continues open, and though the water supply was good, the cultivation is scanty. The country between Katajpur and the Godavery river is densely wooded. At Incherla, on the route to Yellapuram H. S., there is a noticeable lake about four miles long, dammed by a low sand-stone range, through which it has a small outlet. A good cart track runs through the forest to the works on the Godavery

river. At Mulug there are remains of a fort, and traces of former prosperity. From Yellapuram to Panch Pandol we had to adopt a most circuitous route through a thinly inhabited country entirely destitute of cart tracks. The men of the establishment suffered a good deal from dysentery in this locality. "Brinjarras" graze their cattle in these forest lands as long as water is abundant. Later in the season they migrate with their herds to the banks of the Godavery river. The Gonds who inhabit these forests are very shy of strangers; they deserted their villages when they heard of our approach, but after a little intercourse they became very friendly. From Panch Pandol the party marched to Inkurti, near the foot of Bolikonda H. S., emerging from the forest at Gurur, a large village on the banks of a streamlet whose source is the Pakhal lake, an extensive piece of water. At Bolikonda a fair is held annually on the 1st April, in honor of the god Ramaswami, whose image, carved in relief on stone, is to be seen in a rude enclosure open to the weather. The priests declare that the god will not abide under shelter, and he manifests this by destroying with fire a *thatched* roof that is placed over him during the fair. The miracle is performed without fail, and is a great attraction. The top of the Bolikonda hill is fortified, and the approaches to it are very steep. There are some caves within the walls, and plenty of good water (the accumulation of rainfalls) in a natural cistern.

(4.) The country south of Bolikonda to the banks of the river Kistna was suffering from drought. The numerous tanks upon which the inhabitants principally rely for the irrigation of their crops during the cold months were in nearly all cases perfectly dry. The cultivation was restricted at each village to a field or two, watered from rude gaping wells nearly as wide as they are deep.

(5.) At Anantagiri H. S., a hillock composed entirely of hard sandstone, there is a fort with an inner and outer wall, and water is to be found nearly throughout the year in the clefts and hollows of the rocks. At the foot of the hill there was a well with an inscription in the Telingi character, stating that it was sunk in the year 1540 of the Hindoo era of Salivahana (about 251 years ago) by a "Chetri" raja, and, farther, that the sun was eclipsed that year.

(6.) Between the stations of Anantagiri and Nialamari there is a strip of British territory numbering about 80 villages. A metalled road runs through it from Masulipatam on the sea coast to Hydrabad. There are bungalows for travellers along this road near every encamping ground.

(7.) The forts and fortifications to be met with in the portion of the Hydrabad territories through which I worked are attributed by the inhabitants to the Telingana kings, who ruled the country prior to its conquest by the Mahommedans, and who have left behind them traces of a high state of civilization. The present rulers have done nothing to improve the country. Their chief towns are simply a large collection of rude huts, but the people are apparently quite content. As the Godavery river is now navigable nearly up to Seroncha, I was told that His Highness the Nizam's Government contemplates cutting a road from Hydrabad *vid* Ailgandal to Madhopur, a place of some importance near Seroncha. The old Telingana capital, Warangal, is full of interesting remains. The temples sacred to "Mahadeo," built of massive stone, with exquisitely carved interiors, are common enough in the country. His attendant bulls, some of them of life size, are cut, with all their trappings, out of single blocks of stone. Hanimkonda, a city that has sprung up outside the ruins of Warangal, contains a temple called the "hazar khamb", so named from the thousand pillars that support it; this temple is also dedicated to Mahadeo, who is the principal divinity worshipped.

(8.) The banks of the river Kistna are very little cultivated where the triangulation crossed over; slate crops up through the soil, rendering it unfit for the plough. On the left bank of the river, skirting this tract of slate, there are some remarkable ruins, and cromlechs abound.

(9.) On the 8th of April, 1868, the party entered the Guntur district, in the Madras Presidency, crossing the river Kistna at the Kollur ford, where the bottom is shingly, and the water at this time of the year only knee-deep. At Miadarsal H. S., facing the delta of the Kistna river, I was detained for the first time during the season by bad signals. During my stay here a high wind prevailed from the south-west, so laden with moisture as to make us feel uncomfortably damp by midnight. The northern face of the Miadarsal hill is very precipitous; the

southern face is fortified with a stone wall. From Miadarsal H. S. we marched to Sarangpaili H.S., which is situated on a low plateau skirting the river Kistna, encamping half way at Govindapuram. The inhabitants of our villages near the Hydrabad frontier are, as a rule, very surly, and present a marked contrast to the rest of the people in the Guntur and Kistna districts, who seem attached to the British Government, and who were always willing to help us in every way. I take this opportunity of recording the valuable assistance rendered by the Collector of Guntur to our Survey party during our stay of one month in his district.

(10.) From Sarangpaili we marched to Maniam H. S., one of the stations of our closing side. There is iron ore in the neighbourhood, as they were working it at Gondlapaili, the village nearest the hill. The furnace, which is shaped like a chimney, and perforated at intervals, is charged with alternate layers of wood, charcoal, and ore, till it is very nearly full; the lowermost layer of charcoal is then ignited, and the furnace is closed up for 15 hours; the result is a lump of metal valued at two rupees, and weighing about twenty (20) seers. From Maniam we marched to Kachalboru, the central station of my last figure. Here the natives of the establishment suffered to an alarming extent from an affection of the kidneys, accompanied with severe pains in the small of the back, and temporary stricture of the neck of the bladder, caused apparently by drinking the water of the village well, which must have held some caustic alkali in solution. The panic was indescribable, as hardly a man escaped. I, myself, experienced all the symptoms, but in a mitigated form, as, after the first day, I procured for my own use water from the next village. About four miles south-east of Kachalboru there is a large fort on a hill near the village of Bellamkonta. To the north-east of the station there is a hill near whose summit a great block of quartz is to be seen; it was the more remarkable as it did not harmonize at all with its surroundings, but appeared as if it had been flung there; it was worshipped of course.

(11.) Vorakullu H. S. is built on a steep sandstone hillock overhanging the village of the same name. The country about here is dotted with rocks of this nature, quite isolated from each other, and rising almost perpendicularly from the ground level. To take the instrument up to the station, a strong rope ladder, with stout wooden rungs, was laid in zigzags, and well secured along the face of the hill.

(12.) From Vorakulla we marched to Dhulipala station, where the season's work terminated on the 1st of May, 1868. Both at Dhulipala and Maniam, the stations of the closing side of the Jubbulpore Meridional Series, the upper mark-stones were found in position, and the pillars showed no signs of having been tampered with. It is also necessary to state here that, at the stations where work was resumed at the beginning of every field season, the pillars and marks were invariably found uninjured.

(13.) After closing operations the party marched to recess at Waltair, in the Madras Presidency, reaching it on the 25th May, 1868. The route adopted was by Bezwara (where the Kistna river was crossed by an "anicut"), Ellore, and Rajahmundry. This road was well sheltered nearly throughout by an avenue of grand trees, whose branches united overhead. From Bezwara to Waltair comfortable bungalows 10 to 12 miles apart have been built for travellers.

(14.) Mr. M. C. Hickie was employed by me during the greater part of the field season in building platforms and cutting hill roads, and in revising some of his selections of the previous year. Mr. Hickie's arrangements were all good.

(15.) Mr. F. Bell was ordered to protect, with pillars of packa masonry and earthwork, the principal stations of the Jubbulpore Meridional Series in the districts of Mandla, Jubbulpore and Chanda, but he became so ill shortly after my return from Karaondi H. S. that he could not take the field at all, and was compelled on 1st January, 1868, to apply for three months leave on medical certificate; he was subsequently transferred to the Kumaon and Gurhwal party. Mr. Bell's native establishment provided for the safety of 4 principal stations. Of the 63 stations embraced by the Jubbulpore Meridional Series 40 have been protected, as you desired, and have been formally made over to the care of the civil authorities of the districts in which they are situated; I have also supplied the district officers with descriptive lists of all my stations.

(16.) Mr. E. P. Wrixon was employed in recording my angles, and in assisting me generally. He is diligent, and has improved a great deal since he entered as a probationer. He has been taught the use of the vernier theodolite, and can observe correctly. He has taken a part in all our computations.

(17.) Mr. A. C. Low was kept in camp with me to learn his duties. He was engaged during the field season in making duplicates of the angle books, and sometimes in recording my angles. He has also improved very much. He has learned to observe with a vernier theodolite, and has been practised in all our computations.

(18.) As the triangulation of the Jubbulpore Meridional Series has been brought to a close, I beg here to record the valuable help that has been rendered me throughout by Mr. M. C. Hickie, my head assistant, who laid out the greater portion of my approximate series, and who never failed in anything with which he was entrusted. I think that he is well deserving of promotion to the next higher grade of Civil Assistant.

EXTRACT FROM THE NARRATIVE REPORT OF H. KEELAN, ESQ., SURVEYOR 3RD GRADE, IN CHARGE SAMBALPORE MERIDIONAL SERIES G. T. SURVEY, NO. $\frac{160}{382}$, DATED 16TH JULY, 1868.

(2.) The party left head-quarters on the 3rd, and arrived at Raneegunge on the 7th November, to resume the revision of the operations of the Calcutta Longitudinal Series eastward. On arrival it was found that the heavy rains during the cyclone had flooded the low country eastward of Radamadapur; and in consequence it was deemed advisable to defer marching the camp for a few days, or until such time as the inundation had subsided.

(3.) On the 17th November Mr. Trotter was detached to undertake the building of the new towers, and to repair the old ones. On the 20th the camp broke ground, and proceeded to Radamadapur hill station, this part of the district being high and free from inundation, to take up the rays left uncleared last field season, and also to ascertain if mutual visibility existed to Dubrajpur H. S. The two rays cleared passed through dense forests of sâl, belonging to the Bengal Coal Company. On completing this work the party moved on to Nawagaon T. S., to ascertain if Maluncha H. S. were visible from there, in order that the introduction of Dubrajpur might be dispensed with. The atmosphere being very clear on this occasion, and Maluncha being visible, Dubrajpur was rejected as a superfluous station, which enabled me to complete the double polygonal figure round Beharinath and Radamadapur, closing on the side Karasoli H. S. to Bhalki T. S.

(4.) The party next marched to Bhalki T. S., to see what progress was made with the tower at that station, as well as to detach Mr. Sub-Assistant Peychers to clear the ray Bhalki to Karasoli. Whilst these operations were in progress I proceeded, in company with Mr. Sub-Assistant H. E. T. Keelan, to clear the ray to Madhpur T. S., situated across the Damoodah river, with the view of ascertaining whether this station, as well as Mobarakpur, were suitable for incorporation into the operations, or whether it would necessitate the formation of a double figure to connect the side Karasoli H. S. to Bhalki T. S. This ray was cleared with much trouble in eight days, or about three miles per diem, owing to the heavy cutting in it, the difficulty of procuring laborers, and the opposition of the inhabitants. As soon as the ray was clear, a bamboo scaffolding was erected round the old column at Madhpur, to gain access to its summit; and on the 10th December at 3·30 P.M. the Bhalki heliotrope, at 35 feet high, was visible from the top of the old column at Madhpur, 40 feet high. In order however to obtain mutual visibility at minimum refraction, the tower at Bhalki had to be raised to 40 feet, and the new rectangular tower erected at the station of Madhpur built up to 50 feet, five feet more than was required for Bhalki, on account of the ray to Mobarakpur, which is likewise 22 miles long, and seemingly not so favorable a ray as that between Bhalki and Madhpur. As soon as it was decided that no change was necessary, arrangements were at once made for the preparation of materials for the pucka tower at Madhpur; and Mr. Sub-Assistant Keelan was directed to return to Bhalki, and trace a ray from thence to the point Parhaut, whilst I carried on one to the same place from Madhpur, to form the polygon round it.

(5.) The station of Sonakur was next selected by ray tracings from Madhpur and Parhaut by Mr. H. E. T. Keelan and myself, and connected with Akistapur, to complete the polygon round Madhpur. Although the season was now well advanced, the fields were still wet and miry, and rice cultivation covered the whole country as far as the eye could reach, so the ray tracings across country were rendered very tedious and laborious. Mr. Keelan was next directed to clear all the rays, and at the same time to superintend the preparation of materials for the construction of the towers at the two new stations, for the supply of which arrangements and advances to contractors had been made by myself.

(6.) Whilst these stations were being selected to the north, Mr. Sub-Assistant Peychers was employed on the south flank in clearing the rays Karasoli to Bhalki, and portion of Karasoli to Ganjua. Mr. Sub-Assistant Trotter finished the tower at Bhalki, except the step-ramp, and early in January proceeded to Ganjua telegraph tower station, with instructions to remove four or five feet of the old wall at top, and rebuild it, to support the beams for the pillar for the theodolite and for the balance-crane, with a boarded stage on the top for the observatory tent.

(7.) On completing the ray traces as far down as Akistapur, the main party returned to Madhpur on the 15th of January, and on the following day the old column there, about 40 feet high, was blown up; and at the base, level with the ground, a mark-stone was found, in the normal of which two new ones were carefully inserted. As I intended taking an azimuth here during the season, I selected the point for the referring-mark, and had a small pucka platform, with circle and dot for the referring-mark, built; but as the tower was not ready for the instrument in time for α polaris, and subsequently the weather throughout April and May continued cloudy, no azimuth could be taken.

(10.) The main camp proceeded in February to Ganjua, the telegraph tower station; and the alterations and repairs made to it by Mr. Sub-Assistant Trotter were found satisfactory. I then marched to Bhalki, to expedite the completion of the step-ramp of the tower there; thence I proceeded to Nawagaon, and up to Maluncha, where I began the final observations, and completed them at that station by the end of the month. Mr. Keelan cleared the ray Sonakur to Akistapur, and commenced at the same time the construction of the two towers of Parhaut and Sonakur entrusted to him. Mr. Sub-Assistant Peychers cleared a ray and a-half, and collected materials for the alterations and repairs to the Mobarakpur telegraph tower station; and Mr. Sub-Assistant Trotter was unable to build up the Madhpur tower higher than 30 feet for want of laborers, as he had great difficulty in procuring them in that locality.

(11.) During March final angles were completed at the stations of Nawagaon T. S., Radamadapur H. S., and 2½ zeros at Karasoli H. S. The observations at this last station were retarded, owing to the tower at Madhpur not being ready. Mr. Sub-Assistant Keelan completed both the towers at Parhaut and Sonakur. Mr. Sub-Assistant Peychers completed the alterations and repairs at Mobarakpur, and cleared the remaining half of the ray to Akistapur; and Mr. Sub-Assistant Trotter completed the tower at Madhpur, built 8 feet of the Akistapur tower, and made arrangements for the preparation of building materials for the Aknapur tower.

(12.) In the month of April final observations were completed at the stations of Karasoli H. S., Bhalki T. S., Parhaut T. S., and Ganjua T. S. The balance-crane, of which a drawing, marked B, is herewith submitted, was first used at Parhaut station, and answered very well; but before raising the instrument to the top of the tower, the men of the native establishment were practised in the use of the crane for a whole day in raising and lowering weights corresponding with the body of the instrument, which is 2¾ cwt. The crane weighs 7½ cwt., and was conveyed on the elephants attached to the Series.

(13.) Mr. Sub-Assistant Keelan, after finishing his towers, proceeded to assist Mr. Peychers in removing several high houses in the midway village, standing on high ground in the ray Madhpur to Mobarakpur, as delineated in the chart. These houses, which were more than 20 feet high, and built subsequent to the old work, were a great obstruction. After their removal, the heliotrope at Mobarakpur was seen by refraction over the intervening high ground at 5 o'clock in the afternoon, and for an hour only after sun-rise, when it disappeared; but I found no difficulty subsequently in finishing the horizontal angles with Mobarakpur from Madhpur station. The vertical observations will be taken on resuming operations during the ensuing field season, with the aid of scaffolding. The telegraph tower of Mobarakpur, 75 feet high, stands on the left bank of the Dalkisore, and it is stated that the tides come up the river to within 10 miles of the station. Mr. Peychers who had also cleared the ray from it to Akistapur, states it has all the appearances of a refraction ray, having a village on high ground about midway, the huts in which will likewise require to be removed, and compensation paid to the owners of them.

(14.) Mr. Sub-Assistant Keelan next proceeded to trace the ray Aknapur to Satten, a station of the Calcutta Meridional Series, to connect it, if practicable, and to form the polygon round Aknapur. It was on trial found to have only one obstacle. A high double-storied building, about a quarter of a mile distant from the tower, intercepts the view to Aknapur, to overtop which the tower at Satten, which is only 34 feet high, will have to be raised 10 feet more, but as it is in a very dilapidated condition, and will bear no superstructure, it will be better to raze it, and build a new one over the station 45 feet high, the height at which mutual visibility was obtained by means of a scaffolding raised on the old tower at Satten.

(15.) Final observations were completed at the stations of Madhipur T. S. and Sonakur T. S. by the 23rd of May, when I marched the camp into Burdwan, to secure accommodation for the public instrument, stores, and establishment, as I saw no prospect of extending the work, on account of the continuous wet and cloudy weather. Mr. Sub-Assistant Keelan traced the three rays connecting the new station of Dastanpur, which with the introduction of Satten, forms the single polygon round Aknapur. He then proceeded to the stations of Dilakas, Bola, and Satten, and his memorandum, dated 1st June, on the state of the marks of these stations has been already submitted. Mr. Sub-Assistant Peychers marched to Maluncha, and built up the rectangular pillars of Maluncha, Radamadapur, Susinia, and Karasoli hill stations; closed the arches of the towers at Nawagaon and Bhalki, and joined me at Burdwan. Mr. Sub-Assistant Trotter built upwards of 30 feet of the Aknapur tower, and by the 7th of June completed it, and joined the party at your Head-Quarters on the 15th of the same month.

(16.) Mr. Sub-Assistant Moore assisted me in the observatory in recording angles. His health during the early part of the season was such as to lead me to fear he could not be trusted with the important duty of recording my observations; but fortunately by the time his services were required for this particular duty, he had regained his health, and went through his work very satisfactorily.

(19.) On the approximate operations entering the Hooghly district, I was informed that the owners of trees were dissatisfied with the rates at which compensation was made to them; and they hinted indirectly that the question of compensation would have to be settled by law. In the Birbhoom, Bancoorah, and Burdwan districts the inhabitants generally raised no objection on this score, but several landed proprietors seemed to have an idea that for the removal of their trees we had not the sanction of the local authorities, and, as a matter of course, they refused to receive compensation on several occasions, until they had referred the matter to the collector of the district. What the result of their reference may have been is not known, but as they all subsequently came and received compensation without further demur, I am induced to believe that the collector must have supported the operations of the Department, and that his decision was favorable to the survey, and the recusants must have been satisfied that we had not exceeded our duty.

(20.) Mr. Sub-Assistant Keelan entered the district of Hooghly in the month of April Mr. Sub-Assistant Trotter preceded him by a few days; and they both experienced great difficulty in procuring laborers, owing to the sickness and mortality prevailing in the district, on which the former sub-assistant reported as follows :—

"During the winter months a very peculiar and fatal fever of a typhoid type prevailed throughout the Hooghly district, carrying off numbers of the inhabitants, each village losing a large per centage of its population. In some few cases entire villages were depopulated, these being chiefly situated on the borders of broad and marshy ravines called, locally, 'khâlls', which poisoned the atmosphere with malarious exhalations. Native doctors and compounders were sent by the district officers to alleviate the sufferings of the people, but they do not seem to have done much good, the ravages of the fever having continued unabated till the approach of the hot season, when it seemed to have gradually left the district, receding in a south-westerly direction. The inhabitants of the country round the stations of Aknapur, Bhola, and Satten seemed to have suffered more than those of any other place visited in the district, especially the villages near Aknapur, which, being surrounded by khâlls and marshes, were affected most, the banks of the ravines being converted into veritable golgothas from the remains of the unburied dead. The poorer classes having suffered most, the rites of burial and cremation were, in most cases, unperformed, thereby intensifying the unhealthiness of the season. The survivors, who are now suffering from enlargement of the spleen, the after-effects of the fever, aver with great persistency that the chief cause of their continued illness was the administration of quinine, which they say had killed more patients than the fever itself. Numbers of them come to the camp for medicines to remove the effects of the quinine, which they fully believe has brought on their present illness. The inhabitants of this and the adjacent districts are noted for their disregard of the most ordinary sanitary precautions; their villages being densely packed, and buried in masses of trees, surrounded by numberless tanks choked with noxious weeds; these together with their banks, which are covered with unburied and unburnt bodies, being the chief cause of the fatal epidemic."

(21.) I have already stated that during the early part of the season the district of Burdwan was for the greater portion under water; so much so, that in travelling it was difficult to distinguish jheels from tanks and rice fields, all being submerged. The only dry spots were village sites, with barely ground enough near them to pitch a few tents on; and as there were no facilities of any sort for travelling, the party suffered great hardships in marching across country from one place to another, a detour of miles often being necessary to avoid the jheels which abound in the district.

(22.) Later in the season, when the preparation of bricks was undertaken for the new towers, laborers were not easily procurable. Whole villages were engaged in cutting their rice fields, and on this plea they would not willingly work for us. One of the talookdars, to whom I sent a perwannah in the vernacular to furnish Mr. Sub-Assistant Trotter with laborers, wrote me in reply an English letter, in which he stated that "all the inhabitants about his talook consist entirely of the middle class, and depend solely on the produce of the soil for their food, and are not accustomed to work for money." For ray-clearing burkindazes were sent out the previous evening to collect laborers from the surrounding villages, and with difficulty they have mustered 15 or 20 men by 9 o'clock next morning.

(23.) In the course of the operations resistance was made several times by the inhabitants to the parties employed in clearing rays, and on two occasions they stopped the preparation of bricks for the towers, making the novel and unusual demand of 3 years' revenue for the surface earth used from the adjacent fields. On all occasions of this nature I always referred to the collector, who invariably issued notices to the parties obstructing the work.

(24.) On several occasions the camel-men attached to the camp were severely beaten by the inhabitants whilst foraging for their cattle, and there appeared no means of getting redress for them, without inconvenience and detriment to the work; inasmuch as, if these people complained, they would have to proceed to the magistrate's court at a distance, involving an absence of several days, to the injury of their cattle, and the loss of their services in camp; while there also remained the uncertainty of obtaining justice, the chances being that the matter would be disposed of by their being informed that there was no alternative for them but to purchase their fodder.

(25.) The weather this season was so exceptional as to require cursory notice. During April and May, generally speaking the driest months in the year, it was unsettled. Strong south-westerly winds prevailed every morning after sun-rise, bringing up masses of light clouds, which as the day advanced became denser, and by 2 o'clock in the afternoon, sometimes later, a heavy thunder-storm from the north-west came on, attended with heavy rain, flooding the country all round. This weather I found very unfavorable for the vertical observations, showing, as they do at some of the tower stations, differences between the least and greatest of 20 and 30 seconds, though the signals were heliotropes taken at the same time daily at minimum refraction.

(26.) Considering the nature of the difficulties the party had to contend with, the obstructions caused by the people of the district, and other circumstances, which had a tendency to retard progress, the manner in which the assistants performed their duties is very creditable to all concerned. Throughout they exercised great perseverance and forbearance, without which it would be impossible to conduct the work at all; and in closing this report I beg to bring to your favorable notice the services of Messrs. Keelan, Peychers, and Trotter, who exerted themselves to the best of their ability. I only regret that we could not complete the revision of the Calcutta Longitudinal Series during last season, as you desired; but the work has to be conducted with so much caution, to avoid litigation, that I think we may congratulate ourselves that our efforts have been attended with a fair share of success. During next season every effort will be made to bring the operations connected with the revision of the Calcutta Longitudinal Series to a successful completion.

EXTRACT FROM THE NARRATIVE REPORT OF CAPTAIN B. R. BRANFILL, SURVEYOR 3RD GRADE IN CHARGE MADRAS PARTY, G. T. SURVEY, NO. 84, DATED 24TH JUNE, 1868.

I resumed charge on my return from 20 months' furlough to England on medical certificate, on the 28th January 1868, at Bangalore where I received your No. $\frac{1}{9}$, directing me to do so, and, taking what portion of the party could be spared from the Bangalore base-line, then in course of measurement, to proceed to Cape Comorin to select and prepare a base-line for measurement next season, in accordance with the general instructions issued to this party for the Vizagapatam and Bangalore base-lines. More particularly, the site of the Cape Comorin base was to be "on a level plain," "near the sea," and "far from hills," and "its south end the southernmost point of the great triangulation."

Date of rejoining from furlough.

Ordered to select and prepare Cape Comorin base.

General and detailed instructions.

I was also directed to select a suitable point for tidal observations, and to consult the authorities east and west of the Cape for meteorological data from which to ascertain the most suitable place and time to take them. Finally I was to report upon the most suitable time for the base-line measurement and the best route for the apparatus.

The most suitable place and time for tidal observations to be reported.

(2.) In accordance with these instructions I sent off a party of 15 classees by rail to Caroor (Kárúr) a station on the south of India railway 220 miles north of Cape Comorin (Kanniá Kúmari) directing them to proceed by double marches to Palamcottah (Páliamkóta). The heavy baggage I sent by rail to Beypore on the west coast and thence by steamer to Tuticorin (Túttukúdi) 32 miles east of Palamcottah. I followed on the 13th February by train to Trichinopoly and thence by bullock transit to Pallamcottah, where I arrived on the 20th February, the party of classees on the 22nd, and the baggage on the 23rd. The ground in the vicinity of the Cape was reached by the end of the month, 18 days after the first party of classees left Bangalore.

Party of 15 classees sent by rail and double marches.

Camp equipage sent by rail and steamer,

and executive officer proceeded by rail and dak to Palamcottah where all arrived by 23rd Feby.

Reaching the Cape by 29th.

(3.) Finding the plain between the south end of the great mountain chain of western ghâts and the Cape (Kanniá Kúmari) a distance of about 12 miles covered with palmyra trees and studded with rocky and precipitous hills of various heights up to 1000 feet. I was obliged to seek for suitable ground for the base-line farther east. I therefore examined carefully all the ground from the sea-shore about eight miles inland proceeding eastward visiting Colonel Lambton's old survey stations of "Munpotha," "Punnœ" and "Koodankolam."

Vicinity of Cape Comorin unsuited for a base.

Three stations of Colonel Lambton's survey visited and reported on.

The pillar and side walls of the astronomical station at Punnœ station remain in a fair state of preservation and the local authorities have been requested to ensure their farther protection. A station mark at "Munpotha" still exists on the line rock, and a loose mound of stone and earth alone marks the site of "Koodankolam station." Between Punnœ and Koodankolam the character of the coast ridge changes and the dense palm groves cease for several miles: the break being occupied by low rocky hills covered with dense thorn and cactus jangal.

Country open about Koodankolam.

Character of the coast ridge there.

(4.) On the 21st March I reported a practicable line after several trials, and, after continuing my search and examination of the ground as far as 20 miles eastward along the coast from the cape and to the recommencement of Palm forest, I returned

Practicable line reported 21st March and found to be the best in the neighbourhood.

to it on the 1st April as the best line to be found. The south end is a point about a mile east from Colonel Lambton's "Koodankolam station" and is on the highest point of the rocky part of the coast ridge, having apparently the most suitable ground in the neighbourhood between north west and north east, being near the sea, and as far from the hills as possible without entering the dense palm forest farther east. The north end is about $1\frac{1}{2}$ miles north east by east from the village of Rathapuram on high open ground and bearing north $\frac{1}{2}$ east from the south end, distance $7\frac{1}{2}$ miles.

The south end.

The north end.

(5.) Mr. Norris Sub-Assistant 4th Grade, joined me on the 30th March having left Bangalore on the completion of the base line measurement there on the 16th March.

Joined by Mr. Norris.

(6.) I received your sanction for the line reported on the 21st April, the interval having been spent in endeavouring to find a better line, and failing in success, in clearing and perfecting the line first decided on and in dividing it into sections and laying out the minor triangulation on each flank. By the end of April the foundation of an observatory had been laid at the south end and a lower and upper mark-stone embedded in an isolated pillar. After the middle of April the heat became extremely trying, but beyond a few bad cases of boils and some slight cases of fever and liver complaint the party did not suffer.

Line sanctioned.

Employment during interim.

Pillar, marks and foundations at S end finished.

The heat.

(7.) In consequence of the heavy fall of rain in November and December rendering the country impracticable in those months, I determined to lay the principal mark-stones and foundations at once, before the burst of the south west monsoon, expected about the middle of May, and before quitting the field, in order that they might have time to settle more permanently.

The rains of the N.E. monsoon preventing building in October November and December oblige the foundations and mark-stones to be laid at once.

I was unable to finish more than the two stations defining the ends of the base, and the foundations of the two section stations, in consequence of the carriage for the large mark-stones breaking down and the impossibility of procuring any other without several weeks delay. By the 11th May the upper (ground level) station marks at both ends of the line were engraved, and together with the 8 referring marks by which they were reproduced from the lower mark, covered up and left in charge of the local authorities.

Excepting 2 section station mark-stones all finished and left by middle of May.

(8.) The party then marched northwards reaching Palamcottah on the 13th, Madura on the 20th, Trichinopoly on the 27th, and thence by rail to Bangalore on the 28th May.

The party reaching Bangalore by the end of the month.

(9.) The Cape Comorin base-line is 7,636 miles long (about 640 sets of the compensation bars and microscopes) as deduced by secondary triangulation with a seven inch theodolite from two of Colonel Lambton's stations Manpothi and Pannœ, it has been cleared and in great part prepared for measurement.

Particulars of the base-line.

Its south end is in, lat. 8° $10\frac{1}{2}'$ north, and long. 77° 45′ east as plotted on the Indian atlas sheet No. 63 and it makes an angle of about + 6° with the meridian.

Geographical position of S. end.

Azimuth of line.

A vertical section of the line has been taken by a series of levels shewing an extreme difference of height of 94 feet, and of 8 feet between the two ends, the north being the lower. The steepest gradient in the line is 3·5 in 100.

Gradients.

There is only about	450	feet	over 3 in 100
,, ,,	900	,,	from 2 to 3 in 100
,, ,,	1100	,,	between 1 and 2 in 100
,, ,,	37850	,,	under 1 in 100

It is divided into three sections by two section stations which however will require towers to render them mutually visible, and visible from both ends.

Towers required at section stations.

The selection of the minor triangulation on either side of the base-line was very difficult, but three stations on either side have been selected forming a double hexagon, one of these require a little alteration to bring it within the limits of symmetry laid down in the Department. About 18 miles of ray clearing was required, most of it through cactus hedges and thorn jangal.

Minor triangulation.

Ray clearing.

(10.) The connection with the principal triangulation is proposed to be effected by a pentagon of which the north end of the base line forms the central station, and the south end the most southerly point, and including two of Colonel Lambton's old Survey Stations. With the help of Colonel Lambton's charts four stations in the next figure have been selected. (A rough sketch chart accompanies this report). Two of these Trichendur and Tuticorin, are the points on the coast indicated by you as necessary to be connected. The ray between them 21 miles over sea will require lofty towers to command the distance. At Tuticorin the land is little above the sea level, but at Trichendur there is a sand ridge about 25 feet above the sea, surmounted by high temple visible 15 miles out at sea.

Connection with principal triangulation.

Proposed side Tuticorin to Trichendur will require towers.

Trichendur pagoda.

It happens that the Tuticorin light house is about to be raised or rebuilt from 42 feet to a considerably greater height. I propose by making use of these buildings to obviate the great expense and delay of building the towers that would be required without them.

The new Tuticorin light house proposed to be used.

(11.) Regarding the time for the measurement, from all I can learn I do not think it should commence before the middle of January, and even then I am informed that the tanks are very full and the ground not dried from the effects of the heavy rain 22 inches which nearly all falls in November and December, that is during the height of the north-east monsoon. My informant was an English resident of 26 years residence and observation, the rain fall mentioned being the average of 25 years observation.

End of January, best time to begin measurement.

Heavy rain of N. E. monsoon.

(13.) With respect to the contemplated tidal observations the land-locked harbour of Tuticorin seems the most suitable place along the coast near Cape Comorin whence it lies about 60 miles to the north-east, and the fittest times for observation seem to be about the 1st of April and the 1st of October when the sea is said to be least affected by the monsoons, and when the weather is most moderate.

Tuticorin harbour, the most suitable place for tidal observations.

1st April, and 1st October, the best times.

From the published barometrical observations at Trivandram * (Tiruvandarram) the mean atmospheric pressure at these dates seems nearly coincident with the mean annual pressure.

* More properly (Tiravanandapuram.)

Captain Phipps the master attendant at Tuticorin has kindly undertaken a series of observations of the barometer at that port.

I am glad to have a favourable report to give you of Mr. Norris who worked willingly and well the six weeks during which he was engaged on the Cape Comorin base line selection. I found him zealous and attentive to his duty and apparently desirous of improving his knowledge of departmental matters and acquiring skill in observing.

EXTRACT FROM THE NARRATIVE REPORT OF LIEUTENANT W. M. CAMPBELL, R.E., SURVEYOR 3RD GRADE, IN CHARGE BOMBAY PARTY G. T. SURVEY, NO. $\frac{38}{8}$, DATED 8TH JULY, 1868.

I have the honor to submit herewith, my report for the past year, for the Bombay party, of which I am in charge, and partly also for the Madras party, of which I held charge during a portion of the year, including the recess and the early part of the field season.

Recess work Madras party.

(2.) The assistants of the Madras party during last recess, are named in the margin. These gentlemen were all present at head quarters, and available for the ordinary office duties of the recess season. The computations in hand were lighter than usual because: 1st, owing to the nature of the country in which the operations had been conducted, being unfavorable for the observation of an azimuth there were no star observations to be reduced. 2nd, Very little secondary triangulation had been done, as the selection of the base-line had occupied an assistant, who would otherwise have been employed on work of that nature.

Mr. A. W. Donnelly, Civil Assistant 4th Grade.
„ J. W. Mitchell, Sub-Assistant 2nd Grade.
„ O. V. Norris, Sub-Assistant 4th Grade.
„ C. D. Potter, do. do.

The work was nearly completed by 1st August.

(3.) I obtained privilege leave for August and arranged for the employment of the party during my absence as follows. Mr. Donnelly was instructed to execute some field work on the base-line (rendered necessary by a slight alteration I had made in the site) as the weather would permit, attending office as usual when not so employed.

Officer in charge on leave in August. Duties of assistant during his absence. Mr. Donnelly.

Mr. Mitchell I deputed to close, and transfer to the local officials, the stations of the great arc, at which I had taken final observations during the field season. I chose the month of August for this purpose, because it has the reputation of being the healthiest season of the year in the district of the stations to be visited, most of which are situated in the Ghat country, lying between Mysore, and the Coimbatore and Salem districts. This duty occupied Mr. Mitchell till 25th September when he rejoined me at Bangalore, having closed seven stations. The services of Messrs. Norris and Potter, I placed at the disposal of Lieutenant Trotter, R.E., then in charge of the Bombay party, and also recessing at Bangalore.

Mr. Mitchell.

Messrs. Norris and Potter.

Lieutenant Trotter also kindly took general charge of the Madras party during my temporary absence.

(4.) Lieutenant Trotter had almost more work than he could dispose of with his own strength, for, 1st—He and two of his three assistants suffered during the whole recess, more or less, from sickness contracted during the field season. 2nd—He had some arrears of work in hand, and 3rd—As mentioned by Lieutenant Trotter in his report for last year. Mr. Anding was employed during the whole field season, on minor triangulation, in the Indarpur Taluk, of the Poona district, for the purpose of connecting boundary, and other marks of the Revenue Survey, with the trigonometrical stations in the neighbourhood. The computations, and projection of this work on a chart, took a considerable time.

Recess work of Bombay party.

Lieutenant Trotter was therefore glad of the assistance rendered him by Messrs. Norris and Potter, whose work I believe gave him every satisfaction.

(5.) Shortly after my return from leave at the end of August, Lieutenant Trotter found himself obliged to apply for sick leave to Europe, being totally unfitted for work, by fever which he had contracted during the field season in the jungles of Canara. He obtained leave for twenty months and sailed from Madras on the 26th September. On his departure I assumed temporary charge of the Bombay party, which you afterwards directed me to retain, in addition to that of the Madras party,

Lieutenant Trotter goes on leave.

I take charge of Bombay party.

until relieved of the latter by Captain Branfill, for whom I was acting therein on his return from England, when I should remain in charge of the Bombay party.

Mr. G. A. Anding, Sub-Assistant 2nd Grade.
„ A. Christie, Do. 3rd do.
„ Jas. Bond, Do. 4th do.

(6.) The assistants of the Bombay party are named in the margin, Messrs. Christie and Bond had both suffered considerably from sickness during the recess.

(7.) Office work was continued regularly until the end of October, by which time the computations were very nearly completed.

Work of recess season continued.

The Indarpur work, when computed, was projected on a chart and compared with the chart of the district, furnished by the Revenue Survey Department, the comparison showing a generally satisfactory agreement in the position of those points laid down by both surveys.

(8.) On the 1st November I took the field, and proceeded with the preparation of the base-line for measurement, and the observation of the angles for its connection with the principal triangulation, which latter I hoped to be able to complete by the end of December, when I expected your arrival with the party for the measurement.

Field season commences.

(11.) With a view to providing work for myself after the completion of the base-line, when I hoped to have time enough to execute some principal triangulation, I sent Mr. Mitchell to carry on the approximate work of the longitudinal series, to the west, from the stations Hemagiri, Rangasami, up to which I completed the final observations in the early part of season 1866-67.

Mr. Mitchell Approximate Series of Mangalore Longitudinal Series.

An approximate series was executed some years ago by an assistant of the Bombay party, who selected stations of the Mangalore Meridional Series, down to the latitude of Mangalore, where he converted it into a longitudinal series, and carried his triangles eastwards as far as Bangalore.

This work previously executed.

Unfortunately however, it was found, that the series so selected, did not admit of symmetrical connection with that already finally brought up from Madras, (as far as Hemagiri, Rangasami H. S., or about 40 miles west of Bangalore) without further complicating the compound figure surrounding the base-line, already so extensive as to involve great labor in reduction. I accordingly directed Mr. Mitchell to carry on his approximate work if possible to the western ghats, where the longitudinal is converted into the meridional series, and there to make a simple connection (by one side only) with the approximate meridional series already chosen. Also to build the stations of the first (most eastern) polygon selected.

Mr. Mitchell succeeded in selecting two polygons. The first of these gave a good deal of trouble, owing to the nature of the ground. The second is a large figure covering upwards of 2000 square miles of country. The station platforms &c., of the first figure were also built, and Mr. Mitchell partially selected a third polygon, which will close on the old aproximate meridional series, and complete the gap between the finally finished portions of the Mangalore Longitudinal and Meridional Series. He was unable to fix definitively the two flank stations of the third polygon, as he was obliged to relinquish the work to return to Bangalore, but he saw enough to enable him to report, that no difficulty would be experienced in finding appropriate points.

Execution of works.

He returned to Bangalore by native sailing vessel to Beypore, and thence by rail, arriving on 11th January, just in time to take his place at the commencement of the base-line measurement.

(12.) There remained a few stations of the Longitudinal Series, between Bangalore and Madras to be protected, and regarding the state of others, I was uncertain, because as I mentioned in my last report, Mr. O'Neill, who was sent out on this duty in May 1866, absconded when he had partially performed it, and has not been heard of since.

Mr. Norris.

I instructed Mr. Norris to proceed to visit these stations, to close and transfer those which he found unprotected, and to transfer regularly with the proper documents, those which he should find had been closed by Mr. O'Neill but not transferred. This Mr. Norris carried out satisfactorily and returned to Bangalore on 24th November. After that, he was employed on the work of the base-line generally, and also built platforms over the end marks of Colonel Lambton's old base-line.

Mr. Potter.

(13.) Mr. Potter accompanied me as recorder when I first took the field, but later Mr. Bond relieved him of that duty, and I put him in charge of the work at one end of the line, and the construction of a small tower for one of the minor triangulation stations.

Mr. Anding.

(14.) When I first took the field Mr. Anding was the only assistant of the Bombay party present, and I was therefore obliged to keep him near me, for the office and current duties of the Bombay party.

I accordingly placed him in charge of the work at one end of the line, and I found a good deal of employment for him, in finishing the computations of the party.

The connecting triangulation.

(17.) I did not succeed, as I had hoped, in completing the connecting triangulation during November, and December, but only obtained 14 of the 18 angles required, the remaining four being those at the two stations farthest from Bangalore. Both these stations, I visited, but at both, I failed to get the observations required, owing to unfavorable weather, combined with my inability to remain long absent from the work going on at the base-line, waiting for a change. Throughout these observations I found the signals so bad and uncertain, as to make the work very slow, and its quality inferior. I used the theodolite of the Bombay party (Barrow's 24-inch No. 2) with which I had not previously worked.

Arrival of base-line party.

(18.) Mr. Hennessey arrived at Bangalore with the base-line party on 29th December, from which date the two parties, under my charge, (Madras and Bombay) were placed at his disposal for the measurement.

Captain Branfill takes charge of Madras party.

(19.) On the 28th January I made over charge of the Madras party to Captain Branfill, on that officers return from furlough.

Completion of base-line.

(20.) The base-line measurement was completed on 12th March, and after a few days farther work, in making up the books &c., under Mr. Hennessey, the Bombay party was freed for other duty.

Resumption of ordinary work.

(21.) On 24th March I moved westward, to take up the principal triangulation, commencing at the stations, Hemagiri, Rangasami, and thence to proceed with the final observations, at the stations in advance, prepared for the purpose, by Mr. Mitchell, in November, and December.

I commenced observations at Hemagiri H.S. on 29th March, and experienced a good deal of rain, and much cloudy weather throughout April, by which the progress of the work was somewhat retarded.

Observations completed.

On 3rd May I finished observations at Nughalli H.S., the seventh station visited, which completed one polygon.

I then closed work for the season and marched into Bangalore, where I arrived on 9th May.

Instrument used.

(23.) The instrument used was the theodolite of the Madras party (Troughton and Simms' 24-inch No. 1) that of the Bombay party, being in use by Lieutenant Rogers, on the minor triangulation &c.

(25.) I did as much as I could towards fixing secondary points, chiefly as to their heights, which are more wanted than the geographical positions, the latter being truly enough given in the atlas sheets, for all practical purposes, in the case at least of large villages, Dak Bungalows, &c. The positions of these, as given in the present atlas sheets are as a rule very trustworthy, but natural features such as hills and the small drainage lines are very uncertain.

Secondary triangulations.

(28.) On the return march to Bangalore I had an opportunity for visiting one of the most interesting features of Mysore, *viz.*, the gigantic Jain Statue of "Shravan Bellagula" cut out of the living rock (gneiss) on the summit of a hill, some 800 feet above the surrounding country, from which it is visible for miles in every direction. It is the figure of a man, standing up clear of the summit of the rock, from a little above the middle of his thighs, while from that point downwards, the legs are shewn in strong bas relief, about half their thickness being sculptured on the face of the rock. For a native figure the proportions are not very bad, but all horizontal dimensions are exaggerated, and the legs are dwarfed in height, as compared with the upper part of the body. The arms hang clear of the body, from the shoulder to the wrist. The stone is cut smooth and partially polished, and the color is so white a grey, as to give the appearance of white wash, at a distance of 3 or 4 miles. With a small theodolite I took the following dimensions of the figure, as accurately as the situation admitted:—

Gigantic Statue of Shravan Bellagula.

	ft.	in.
Height of upper part, entire form cut out,	39	0
,, lower part, only half moulded,	21	6
Entire height of figure,	60	6

Width of shoulder 27 feet. Do. of head 10 feet. Do. waist 10′ 4″. Do. between arm pits 14′ 2″.

(38.) I have great pleasure in reporting most favorably on Mr. Mitchells conduct and work during the past year. He was in the field during August and a part of September last, (see para 3) during which time he must have experienced much discomfort if not hardship, as he was working in a difficult country, with a minimum of baggage, and tents, during frequent rain. Again in December, when he was working in the western ghats, he must have had a hard and uncomfortable life. On both these occasions he got through a large quantity of work. Mr. Mitchell always does his work in the field well, and willingly, and he is also a useful assistant in office, regular in his hours, and careful in his work.

Mr. Mitchell.

(39.) Mr. Norris did good work in office during last recess, working hard and regularly. He also did well the duty allotted him in the early part of the field season (para 12). He completed 2 years departmental service in April last, and I should be glad to learn that he had obtained his promotion.

(40) I consider Mr. Potter a very promising assistant, he takes an interest in his work, and evinces zeal in its execution. He has also considerable ingenuity and command of resources in difficulties.

Mr. Potter.

(41.) Mr. Anding has given me general satisfaction since he came under my orders. His duties I have already described, and I need only add, that I consider he worked hard, and made good progress.

Bombay Party Mr. Anding.

(42.) Mr. Christie I have found a willing and intelligent assistant, and consider that he he has worked well. The performance of the last duty on which he was employed was very satisfactory and creditable to him.

Mr. Christie.

(43.) Mr. Bond has proved himself an excellent Recorder, accurate, attentive, and tolerably neat.

Mr. Bond.

He has also shown great inclination to learn, and a considerable amount of quickness in comprehending, and retention in remembering what he is taught.

EXTRACT FROM THE NARRATIVE REPORT OF CAPTAIN T. G. MONTGOMERIE, R.E., SURVEYOR 1ST GRADE, IN CHARGE KUMAON AND GURHWAL SURVEY PARTY, NO. 290, DATED 21ST SEPTEMBER, 1868.

(1.) On the 1st of May 1867, Captain Montgomerie resumed the charge of the Kumaon and Gurhwal Series which had been held during his absence on leave by Lieutenant Carter.

(2.) During the recess, all the computations of the previous season's triangulation were computed out and the points deduced were projected on the ¼-inch chart. Three sheets of the Kumaon and Gurhwal map were completed and printed in the Photozincographic Department. Two sheets of the Mussoorie and Landour maps were finished, and are ready for publication as soon as the boundary line of the settlement has been demarcated.

(3.) The civil authorities having expressed a wish to have the original boundary of Mussoorie and Landour permanently marked on the ground, measures were taken for re-producing the said boundary as closely as the records of the original demarcation would permit.

The original boundary though clearly marked on Major Brown's map of 1840 appears never to have been indicated by permanent pillars of any kind, and the map in fact is the only record remaining, neither field book, notes of bearings, nor any other documents concerning the original survey having been produced.

Fortunately the boundary is given on Brown's map in connection with the natural features of the mountains and in connection with various permanent objects which are still in existence.

(4.) By distances taken from Brown's map between various points still existing and the main points of the boundary, all the salient and reentering points of the original boundary were transferred to the new maps with as much accuracy as Brown's map itself possesses. The boundary transferred in this way to the new maps was examined on the ground, and it was soon apparent from the natural features that the boundary must have originally been very close to the line re-produced as above.

For instance, the line agreed in making the Billaroo-ka-pani ravine and the precipitous cliff along it the boundary, and farther westward a peculiar bend to the north obviously represented a similar shaped cliff which overhangs the low ground above the Aglar and would be a natural limit in that direction. Similarly the agreement of the line with various other natural features north and south made it evident that the line thus reproduced substantially represents the original boundary as far as it has hitherto been examined.

(5.) During the end of the recess, Lieutenant Hill, R.E., and Mr. Ryall were employed on this difficult task. They succeeded in demarcating 5456 and 4303 yards respectively, a total of 9759 yards with the sites for 40 pillars, 36 of which have subsequently been built by the civil authorities. At the same time they finished the sketching on a scale of 12 inches to 1 mile of 378 acres of Mussoorie.

The operation was a most laborious one, great care being requisite in making the transfer from the old map to the new, and the examination of the ground and the searching for the original sites of the main points involved a great deal of hard work. Considerable credit is due to Lieutenant Hill and Mr. Ryall for the judgment and zeal with which they carried out this difficult task.

(6.) Towards the end of the recess the usual preparations were made for taking the field, plane-table sections were projected and fresh instructions were given for extending the triangulation.

Only a small amount of triangulation being ready for topographical work, every endeavour was made to secure a sufficiency to keep the topographical surveyors fully employed during the

current season and at the same time to provide a good surplus for the next field season, a large excess of finished triangulation being essentially necessary to the economical execution of the topographical work.

(8.) The triangulation was pushed to the north of Gurhwal so as to cover the whole of the very elevated basin of the Kali river, one of the main sources of the Ganges. This is the first portion of the highest part of Gurhwal that has been triangulated in detail. Stations were established close up to the highest Peaks of the Himalayas in spite of great cold and a scanty population.

(9.) To the east, the triangulation was extended through a sparsely populated part of Kumaon, more especially to the north and east of Almorah across a high and rugged range covered with forest. Subsequently a farther extension was made on the south, and a series of triangles was carried eastward from the border of Gurhwal to Huldwani south east of Nynee Tal a distance of 50 miles including a tract at the foot of the Himalayas covered with dense jungle which naturally added very much to the difficulties of the surveyors.

(10.) Two thirds of the ground triangulated was of an Alpine nature and the work was executed in the winter, when the surveyors were exposed to constant snow storms, while the remaining third formed a portion of the Terai, subject to heavy fogs which proved even more detrimental to progress than the snow.

(11.) The total outturn of triangulation is 2315 square miles with 583 stations and 279 heights being at an average of 2·5 points and 1·2 heights irrespective of 7·8 heights determined by aneroid barometers in 10 square miles. A large outturn considering the nature of the country and the weather, which at the begining of 1868 was unusually stormy in the mountains.

(12.) Topographical operations were commenced by the sketching of a portion of the valley of the Alakununda above Kurnprag and of the lower portion of the Pindur Valley with ground of every altitude from 2500 to 13000 feet. The higher ground was taken up first, and the lower as the weather became more severe, the work was nevertheless several times interrupted by the snow.

Subsequently the mountains east of Almorah were sketched, portions of them running up to altitudes of 8 to 9000 feet above the sea. The whole of the country up to Almorah was finished, including a very densely populated part of the hills where the villages were so numerous that upwards of 200 were found in 80 square miles, an average of 2½ villages to each square mile, a greater number than is generally found in England. The mountains near the new Sanatarium of Ranikhet have been sketched including all the hills between that station and the plains. The sheet including Ranikhet is urgently required for the new projects for the Sanatarium and the roads to it, and as all the materials are available, measures have been taken to complete the fair sheet for publication as early as possible.

(13.) Towards the end of the field-season further sketching was executed in the valley of the Alakununda between Kurnprag and Rudrprag and in the lower part of the Kali valley, the surveyors advancing from the lower into the higher ground as the weather got warmer.

(14.) The work was interrupted by the snow in the higher ground, and by clouds in the lower, the whole country being hid from view for days at a time. The ground throughout was of an exceedingly precipitous nature and nearly every days work was a matter of climbing from morning till night; notwithstanding these physical difficulties the total area sketched is 1240 square miles. A highly creditable result for 4 surveyors, one of whom was employed for a portion of the season on other duties.

(15.) With a view to the future extension of the triangulation Captain Montgomerie marched from Dehra through Gurhwal and made a reconnoissance of the lower part of Kumaon from the borders of Gurhwal up to the frontier of Nepal on the Gogra river.

(16.) Whilst in Gurhwal he was able to examine a considerable portion of the previous season's sketching and to visit various stations near the line of his route.

(20.) Having reconnoitered the country up to Nepal, Captain Montgomerie commenced the examination of the current topographical work of the season. A portion of the ground of each topographer was examined in detail, the features were checked and the positions of villages &c., tested from various high and low points. Throughout the sketching was found to have been done with great accuracy, none but inappreciable differences having been detected. The ground moreover was in all cases represented both faithfully and artistically the whole of the topographers employed having worked well and zealously. The quality of the sketching was altogether first-rate, and the quantity as much as the accuracy and detail required would admit of the surveyors doing.

(21.) During the field season a number of new points were computed out and projected on fresh plane tables for the use of the topographers after completing the first portion of their work; though involving a great deal of extra labor this was affected without interruption to the current work of the field season.

(22.) In order to examine the topographical work it was necessary for Captain Montgomerie to march right through the Kumaon and Gurhwal mountains, one-half of the topographers being employed in the south and the other half in the north; in this way he was able to see a large part of Kumaon and nearly the whole of Gurhwal as after completing his examination of the current season's work, he marched through that portion which had been sketched when the survey began. Here he found the ground to be well represented though the roads, cultivation &c., did not appear to have been laid down with the same care and attention that has subsequently been attained in the later work yet the work on the whole has been well done, and the improvement in the new work was only such as was to be expected from increased experience.

(23.) During Captain Montgomerie's progress through the mountains, the opportunity was taken to determine the heights of a large number of obligatory points by means of aneroid barometers. In order to get some idea of the amount of reliability of these instruments, three of them were placed side by side in a box well packed with cotton so as to prevent all shaking and all sudden variations in temperature, the box was provided with a lid and hinges so that the aneroids could be read off at once without disturbing them in any way. The box was carried carefully by a man, in addition to readings at the obligatory points required, the aneroids were read at a number of high and low trigonometrical points of which the heights were known; from the readings at the trigonometrical points the value of the scale of the aneroid between any two points was easily ascertained, and with that value the height due to any intermediate reading could be at once obtained by proportion.

From the readings at the various points it was easy to see whether the aneroids retained the same differences at various elevations. Though they were all said to be compensated, the results show that they do vary to an extent which would seriously affect the result if an attempt was made to deduce a height from two readings very far apart.

(24.) The experience with aneroids has hardly been sufficient as yet to lay down any rules, but it is evident that by using them differentially for the heights of points between two known points whose readings have been taken, they may be trusted to give the height of any intermediate point with an error of 4 or 5 per cent. of the difference, the known heights should consequently not differ by more than 1500 feet, and the height of an intermediate point might then be expected to vary 30 to 40 feet on either side of the correct value.

In the present instance the height was always deduced from the trigonometrical station that was nearest in height to the point required. The differences of height between the points determined consisted of thousands of feet where an error of 50 feet was a matter of no very great importance as the object was to give a fair idea of differences of height between the peaks, passes and the valleys below, and this has been substantially secured by the system adopted.

(25.) During the ensuing season farther experiments will be made and some of the detail surveyors will be supplied with aneroids in order to multiply the heights on their sections and to enable them to show the differences in level more correctly than they can at present even with the large number of trigonometrical heights that are supplied to them on this series.

(26.) Reciprocal observations would of course add much to the accuracy of aneroid observations, but that was not possible on the present occasion, nor indeed is it likely to be so at most times, but in more level countries, if reciprocal observations are not to be had, extra precautions must be taken to see that there is as little interval of time between the observations at the known and unknown points as possible, otherwise the hourly and daily variations will affect the result so as sometimes to make the lower point appear the higher, &c. A phenomenon which has already been complained of by those who have used these instruments. A partial remedy for this difficulty would be to take all observations at the same apparent time, if there was no atmospheric disturbance going on at the time, the result should be tolerably correct, but as the variation of the barometer between maximum and minimum on any one day amounts to over 0·05 of an inch in latitude 31° and to over 0·10 in latitude 23°, representing from 50 to 100 feet, it is obvious that there is very little use in attempting to deduce a height from a reading taken at 10 A.M., and another at 4 P.M. when the difference of altitude is small.

(27.) When the known point is close to the unknown point as in the case of a station on the edge of a plateau there ought to be no great difficulty in observing at the known point then at the unknown, and again at the known point so as to get a mean and to see that the instrument returned to its first reading.

(28.) The aneroids appear to be of unequal elasticity, some when taken from one altitude to another and then back to the first returning to their normal state very rapidly and others very slowly while one was observed not to return to anything like its former reading, though the temperature had not varied half a degree; in all cases it was found necessary to let the aneroid rest at the new station for at least a quarter of an hour otherwise they rarely assume the final position due to the altitude they may be at.

(29.) The results of the present experiments have proved that aneroids are at any rate very useful in mountains where the differences of altitude are great. Approximate heights of passes having been determined which could have been got in no other way except at considerable expense.

(30.) The programme proposed for the field season was fully carried out with one small exception, the triangulation has been extended sufficiently to provide work for the full number of topographers during the ensuing field season. With ordinary exertion it will now be possible always to have a proper amount of triangulation in hand.

(31.) Tables showing the amount of triangulation and topography executed during the season are appended to this report.

Captain Pullan.

(32.) Captain Pullan was employed during the whole season in the mountains of Gurhwal chiefly on the Alukununda and its branches. His first section embraced hills of every altitude from 5000 13,000 feet above the sea. During the first and last part of the season he was able to make capital progress, but during February and March he was much delayed by severe weather and on several occasions his camp was completely snowed up. The ground sketched by him was of a very precipitous nature, the only approach to level being some narrow strips along the course of the Alakununda. The execution of the work consequently involved a great deal of hard work.

(33.) A portion of the ground sketched by Captain Pullan was examined in detail and the sites of a large number of villages were tested. The details were found to be accurately fixed and the ground throughout was well and artistically represented. The quality of the work was excellent, the total out-turn being 390 square miles in 6½ months with 990 P. T. fixings.

Lieutenant Hill.

(34.) Lieutenant Hill was employed on the triangulation of the mountains north and east of Almorah including a high and rugged range covered in most parts with a dense forest.

(35.) Being employed on the Mussoorie Settlement boundary up to a late date he did not reach his ground till December. During the first part of the season he was able to make

great progress but in February and March his work was for a time brought to a complete stand still as the clouds regularly settled down on the mountains for days at a time. Snow storms were frequent and the weather generally bad; notwithstanding good progress was made and a very large out-turn of triangulation would have been completed had not Lieutenant Hill unfortunately got a very severe attack of illness as he was bringing the work to a close. This attack prevented him from observing at the few remaining stations he required to complete his work. He was laid up at Almorah for nearly two months.

(36.) The total area triangulated is 765 square mile with 86 heights. The work has been thoroughly done and the points are well distributed. The heights of a number of high and low obligatory points have been determined as well as those of peaks &c. Considering the weather and the short time available Lieutenant Hill's progress was very good. His management of the portion of the native establishment under his orders has been good and his arrangements for supplies and the carrying on the work in a difficult country have proved very efficient.

Mr. Ryall.

(37.) Mr. Ryall starting early took up the trianglation of the very elevated valley of the Kali river, the highest piece of Gurhwal that has as yet been triangulated in detail. The weather being fine he was able notwithstanding the extreme cold to finish the work very rapidly before the heavy falls of snow began. He then descended towards the lower ground and took up fresh work in the south-east part of Kumaon, there the weather though troublesome at times did not altogether stop progress and he was able to push on the work rapidly, carrying his triangulation some 50 miles east.

(38.) The total area triangulated by Mr. Ryall is 1550 square miles with 193 heights.

(39.) Mr. Ryall executed his triangulation in a most efficient and rapid manner. He also arranged and computed out in the field a large portion of his triangles which added very much to his work. His management of the portion of the native establishment under his orders has been good and his arrangements for supplies and the clearing of station sites in the forest clad parts of lower Kumaon were well carried out and enabled him to make an amount of progress that could not have been secured without much care and forethought. His progress has altogether been excellent.

Mr. Peyton.

(40.) Mr. Peyton was employed for some time on the hill shading of one of the sheets of the map of Turkistan and consequently a shorter time than usual was available for field work. At first Mr. Peyton was employed in sketching a section embracing Almorah, a portion of the hills so densely populated that it was hardly possible to introduce the whole of the village sites on the scale of 1 inch to the mile. The amount of detail in such a densely populated country prevented rapid progress. Subsequently Mr. Peyton was employed in sketching a very wooded tract of rough ground between the Kosilla and Ramgunga rivers.

(41.) The whole of Mr. Peyton's work was examined in the field, the ground has been artistically delineated and the detail was found to have been laid down with great accuracy.

Area sketched 240 square miles with 340 plane table points. Progress very good.

Mr. Atkinson.

(42.) Mr. Atkinson during the recess assisted Captain Montgomerie in the translation of the Pundits Trans Himalayan route survey, diary &c. and also in the computations connected with the same. This troblesome work he carried out most satisfactorily and in addition did a large share of ordinary computations.

(43.) During the field season Mr. Atkinson assisted Captain Montgomerie in the computations, recording and general duties connected with the party. Amongst other matters he indexed the whole of the computation sheets, a work that has much facilitated the constant references required for fresh triangulation, topographical work &c. He also took horizontal and vertical observations with an 8 inch theodolite for determining the height of the Putli

Doon. Subsequently he took a large number of observations with aneroids for the heights of various obligatory points that were much required both for the old and new portions of the work. These were done very carefully and will prove a valuable addition to the maps. The amount of computations which Mr. Atkinson carried out while in the field was very large and it was only by his great exertions in this matter that the topographers were kept fully employed.

(44.) Mr. Atkinson's diligence and good business habits were also most usefull in disposing of a large amount of miscellaneous work which naturally arises with a large party, widely scattered over very difficult mountains.

Mr. Braithwaite.

(45.) Mr. Braithwaite starting early sketched the upper feeders of the Ramgunga river and the lower part of the Pindur valley including some very precipitous ground. Subsequently he was employed on the Alakununda and Kali above Rudrprag. From the examination of his work the sketching was evidently very accurately done, and the ground has been well represented, his style of shading showing great improvement on the previous season. Though interrupted by snow and clowds Mr. Braithwaite's progress has been very good. His area is 390 square miles, with 507 plane-table fixings, a very creditable seasons work.

Mr. Pocock.

(46.) Mr. Pocock for some time was employed in learning how to sketch but owing to indifferent health was not at first able to make much progress. Subsequently his health improved and he was employed on the triangulation with Lieutenant Hill, observing from auxiliary stations, taking heights &c. Mr. Pocock observed well and made good progress, with the work assigned to him. With a little more practice he will be able to take up independent triangulation in the hills.

Mr. H. Todd.

(47.) Mr. H. Todd was employed in sketching the lower part of the Kosi valley and the mountainous tract between that river and the Ramgunga, embracing the site of the new sanatarium of Ranikhet. Owing to detention on other duties and subsequently to sickness Mr. Todd had less time for sketching than usual. His work has been very accurately done, all the villages and natural features that were tested having proved to be correct. The ground is well represented and his shading shows steady improvement. His progress for the time available was very good. Area 260 square miles with 600 plane-table fixings.

Mr. Bryson.

(48.) Mr. C. Bryson was directed to carry out a piece of triangulation in continuation of his last year's work but owing to inexperience, inability to control the natives under his orders, and to want of proper arrangements he was unable to do any work. Signals were not erected and Mr. Bryson, instead of proceeding to have them put up under his own directions did nothing, and ultimately lost all the early part of the season.

(49.) Mr. Bryson being evidently unfitted for independent work was placed under the orders of Mr. Ryall for the rest of the season for the purpose of observing at auxiliary stations &c. In this way he did a fair amount of work.

Native Establishment.

(50.) The native establishment was composed as before partly of men from the plains and partly of men from the hills. They have worked well and given satisfaction.

(51.) The small detachment of hill men sent from this party with Lieutenant Carter, to Abyssinia have done good service.

(52.) The health of the natives generally has been good and there has been no severe illness of any kind among them.

(53.) During the season the party has received every assistance from the Civil authorities and the arrangements made by the Commissioner have faciliated progress very much.

With similar hearty cooperation in future seasons, the survey ought to progress satisfactorily, notwithstanding the physical difficulties of the country.

(54.) The country surveyed this season embraces every kind of mountain land from the low hills covered with dense forest up to the bare spurs of the great snowy range, it also embraces a level tract at the foot of the hills for the most part covered with forest. The variety of arrangements necessary in surveying such very different styles of ground and the difficulties as to money, supplies &c., can easily be imagined; but these and the physical difficulties of the country were all successfully met by the zeal and energy of the surveyors employed. Their devotion to the work has throughout been most praiseworthy.

Future operations.

(55.) With reference to future operations the reconnoisance made by Captain Montgomerie, eastward shows that the lower part of the country in that direction is even more difficult than what has already been surveyed. The forests are denser and the inhabitants fewer, indeed population may be said to be wanting except at the two extremities, the breadth of level forest is moreover very much greater extending for nearly 20 miles into the plains, while the forest clad ranges which throughout separate the well populated part of Gurhwal and Kumaon from the plains are to the eastward of much greater breadth than they are in Gurhwal. In the lower ground there will consequently be increased difficulty.

(56.) In Gurhwal the ground remaining to be surveyed is all high. In Kumaon about one-half of the middle ranges have been triangulated, while the higher and most of the lower ground has not as yet been touched.

Future operations.

(57.) Captain Montgomerie intends to have such of the higher part of Gurhwal as was triangulated this season sketched early during the next field season. At the same time a farther portion of higher Gurhwal will be triangulated for future operations. As soon as the fine weather comes to an end, the surveyors will be transferred into Kumaon. There the inner hills and the lower ground will be taken up according to the means available. The lower ground will be done gradually at the best season of the year, as being all very feverish Terai-land, it can only be surveyed during a very short part of the winter.

(58.) A sufficient amount of detail triangulation is ready to keep the topographers fully employed, and further triangulation will be executed so as to have in hand rather more than what is required for the next season's topography.

EXTRACT FROM THE NARRATIVE REPORT OF CAPTAIN C. T. HAIG, R.E., SURVEYOR 2ND GRADE, IN CHARGE KATTYWAR PARTY, NO. S45, DATED 16TH OCTOBER, 1868.

(2.) The party commenced recess duties last year about the 1st May, and concluded on the 15th October.

(3.) Owing to the great amount of triangulation which it was necessary to lay down during the previous season and owing also partly to an unnecessary (as I afterwards learnt from you) amount of labour having been expended in computing the spherical coordinates of every intersected point, the computations were thrown much in arrears and were not completed on our again taking the field, but Mr. D'Souza being incapacitated by a malady, from taking the field I directed him (in accordance with your sanction) to bring up the arrears with the assistance of Mr. J. DaCosta.

(4.) During recess the following computations &c., were completed in duplicate :—

Triangles (3 angles observed)	267
Do. (2 do. do.)	903
Latitude, longitudes and back azimuths of stations	139
Do. do. intersected points	363

There were also prepared description of a few stations for General Report.
Synopsis of latitudes, longitudes of stations as above.
Alphabetical lists of stations as above in duplicate.
Alphabetical lists of intersected points as above.
Do. do. of villages.

(5.) The following maps were also prepared. The 9 plane-tables surveyed during the previous field season were copied on the full scale of two inches to a mile, and reduced to the scale of one inch to a mile. Four plane-tables were further reduced to the scale of $\frac{1}{4}$ inch to a mile (exaggerated.)

(6.) The computers were Lieutenant Dummler, Mr. McGill, Mr. McA'Fee, Wissajee Ragoonath, and Govindjee Mahalay.

The mappers were Mr. D'Souza, Mr. Gwinn, Mr. T. Rendell, and Mr. Wyatt. Mr. McGill also rendered assistance.

(7.) During the recess, for the purpose of training the new native surveyors, I traversed with theodolite and chain the whole of the Poona cantonment boundary. Native surveyors Krishna Govind, Gopal Vishnu, Nurso Dinkar, Krishna Dinkar, Vishnoo Moreshwar and Raoje Narayen, accompanied me on this work, each of them keeping a field book as well as myself. The total distance traversed was 12 miles.

(8.) Of these the first four were also practised in the reduction of a traverse to rectangular coordinates and the other two were practised in drawing, Vishnu Moreshwar shewing considerable aptitude.

(9.) The following is the amount of work done by Messrs. D'Souza and DaCosta in office in Poona during the past field season :—

Descriptions of 159 stations in duplicate.
Abstract of observed angles and approximate azimuths at 171 stations in duplicate.
One copy of synopsis of latitude, longitudes, and azimuths of 267 stations, form G.
One do. alphabetical list of do. do. do. of 675 stations, form I.
Copy of 1160 triangle computations into form H, 2 copies.
Computation of heights of 43 stations, 2 copies.

(10.) Owing to Mr. D'Souza's inability to accompany me and to Lieutenant Dummler being detached for duty in Abyssinia, the party took the field considerably weakened

(11.) On returning to Kattywar I marched the party to Sonpuri the head quarters of the Assistant Political Agent eastern district for the purpose of gathering all possible information regarding the taluka boundaries which were in the course of being settled by committies appointed for the purpose.

(12.) I then intended if possible to put all hands on the boundary survey so as to bring it in advance of the plane-tabling and it was some little time before I found out how utterly impossible it would be to do so in one season.

(13.) From the absence of any reliable map of the country it was impossible to obtain any information as to the approximate sub-division of the district among the numerous petty talukdars.

(14.) Shortly before returning to Kattywar the political agent had appointed boundary committees composed of respectable and well known natives to settle boundary disputes between talukdars, under the political agency, and two such committees were started in the eastern district. These committees of course had no power to deal with disputes in which either of the litigants were subjects of His Highness the Gaikwar or under the jurisdiction of the British Government. Still the report of their work would give much information which could not otherwise be obtained and would shew where Gaikwar or Gogo villages cut in. I therefore requested the Assistant Political Agent to direct the committees to send weekly progress reports to me which he did, but it was not till several weeks had elapsed that I could form any idea of the confusion of sub-division that exists, and of the utter impossibility of getting the boundary survey in advance of the plane-tabling in one season.

(15.) I therefore determined on letting the boundary work and plane-tabling go on independently of each other, except that wherever a boundary was surveyed the interior of which had not been surveyed. I had the boundary plotted on its proper plane table. Subsequently however I abandoned this plan as I found the plotting took up too much time.

(16.) Throughout the season I contrived to keep my camp in the vicinity of the boundary surveyors whom I had to keep following the track of the boundary committees and to whom I could not apportion more than a few days work at a time.

(17.) The following table shews the number of talukas and villages embraced in the area which has been topographically surveyed.

Name of taluka.	*No. of villages.*	*No. of district boundaries.*
Gogo pargana of the Ahmedabad collectorate,	64	6
Monpur, Gaikwar,	6	1
Damnagar, Gaikwar,	5	2
Bhownugger,	2	2
Walā,	32	3
Palitana,	48	1
Lathi,	2	2
Limbra,	4	2
Pachigam,	4	1
Ratanpur,	3	2
Waori Dharwala,	4	3
Gadhali,	3	1
Rasnal,	2	2
Kariana,	4	2
Bhadli,	2	1
Nowanagar,	2	1
Data,	6	2
Waori Wachani,	2	1
Torda,	3	1
Single village talukas,	20	20
Total,	218	56

(18.) Out of these the following have not been surveyed.

Monpur (Gaikwar),	.. 6 ..	1	not settled.
Damnagar, Do.	.. 5 ..	2	Do.
Bhownugger,	.. 1 ..	1	Inaccurately surveyed.
Bhadli,	.. 2 ..	1	not settled.
Data,	.. 6 ..	2	demarcated but not reported to me as such.
Single village (Patna),	.. 1 ..	1	not settled.
Palitana,	.. 48 ..	1	Do.
Waori Wachani,	.. 2 ..	1	Do.
Taoda,	.. 3 ..	1	Do.
Total, ..	74 ..	11	

(19.) Of these the last three are confined to sheets 16 and 17 which I am not sending in this year having only completed a portion of them. No inconvenience therefore will arise from their not having been yet surveyed.

(20.) In addition to the above, a great portion of the boundary of the Dhanduka pargana, Ahmedabad collectorate, that portion which falls within sheet 5 which I intend taking up next season, has also been surveyed. It consists of two isolated villages and a continuous boundary of 60 miles.

(21.) In reckoning the number of distinct boundaries, in paras. 17 and 18, the same boundary is never reckoned twice over, so Bhownugger which is by far the largest taluka has only two "distinct boundaries"; these are two isolated villages entirely surrounded by territory of other talukas, the main Bhownugger boundary being made up by those of the adjoining talukas.

(22.) I append hereto a tabular statement shewing the whole out-turn of the season and the relative value of each surveyor's work.

(24.) As nearly the whole of sheet 6 north of the Kalubha river is a marsh or mud, and very thinly covered with trigonometrical points and as the part to the south of the Kalubha had been previously filled in (in 1863-64) on the 1-inch scale, I resolved to complete the sheet on that scale and I gave it to Mr. T. Rendell.

(25.) During the field season I had the whole of the stations of the old Kattywar triangulation within the area embraced by our minor triangulation covered with masonry pillars as laid down in D. O. No. 1, dated 15th January 1866, and I had similar pillars erected over the sites of all the stations of our minor net work triangulation, but I postponed the covering up with earth until the stations will no longer be required by the plane-table surveyors as the white pillars afford such capital marks.

(26.) The field operations were brought to a close by the 30th April, but shortly before that in compliance with your instructions conveyed in letter No. $\frac{14}{404}$ of 26th August, 1867 I came in advance of the party to Bombay with Mr. Gwinn and with a 14-inch theodolite connected the Bombay triangulation with one of Captain Ducat's stations on the S.E. corner of the new Carnac Bunder, the height of which referred to the Town Hall Datum is 91·17 feet and have since determined therefrom that a correction of + 0·463 feet is necessary to be applied to the heights of the stations of the Bombay triangulation, as reported to you in my letter No. S.39 of 29th ultimo.

(27.) During the past recess, the following maps, computations, &c., have been prepared or will be completed very shortly before taking the field :—

Four Preliminary charts of triangulation, each embracing 1° in latitude and ½° in longitude, containing principal, secondary, and minor triangulation, with intersected points, complete up to date, scale 1 mile to an inch. Sheets Nos. 6, 7, 8, 9 and 15 have been prepared in quarter sheets or sections on the scale of 2 inches to a mile.

Triangles 3 angles observed computed in duplicate, ...	109
Triangles 2 angles observed computed in duplicate, ...	354
Latitudes, longitudes and azimuths of stations, ...	51
Latitudes, longitudes and azimuths of intersected points, ...	224
Heights of stations, ...	90
Heights of intersected points, ...	2

Fair copy of angle books of past season's work.

One general skeleton plan on scale 2 miles = 1 inch for General Report of season 1866-67.

One do. do. for season 1867-68.

Abstract of angles and approximate azimuths for season 1867-68.

Synopsis, in duplicate, of latitudes, longitudes and azimuths of 51 stations of past season's work, arranged in Sheets, viz. 7, 8, 9, 13, 14, 16, 17.

Alphabetical list of latitudes, longitudes and heights of stations, in duplicate, arranged in Sheets, viz. Nos. 7, 8, 9, 13, 14, 16, 17, 18, containing old as well as new points.

Alphabetical list of villages arranged in sheets, viz. Nos. 6, 7, 8, 9, 15.

51 Descriptions of stations.

463 Triangle computations and elements copied into Form H.

Fair copy of the field books of 614 miles of boundary survey into a form adapted for incorporation with the General Report.

(28.) The above completes the whole of the charts, computations and general report forms of the last two season's work, with the exception of the filling in of form O. the Abstract of computations of heights, no supply of that form having yet been received in this office, and includes the computation, in duplicate of 26 heights of stations of the net work triangulation of season 1863-64.

(29.) In addition to the above 22 heights of principal stations of the Sind series, have been computed in duplicate, to comply with the requisition of your No. $\frac{35}{859}$, dated 10th September, 1868 and fair copies are being made of the vertical angle books of the 4 minor meridional series, on Meridians 70°, 70° 30′, 71° 30′, and 72° and of the horizontal angle books of the 72° minor meridional series, and of the north Coast and east Coast Secondary Series, and of the general west Coast Series from Surat to Cambay, and of Sundry Secondary triangulation connected with the 4 minor meridional series in Kattywar and the Kutch Series.

(30.) The following statement shews how each individual has been employed during the recess.

Captain Haig—General superintendence—absent 10 days on expedition to observe the eclipse on 18th August.

Mr. McGill—Making preliminary charts, a very laborious work, and printing names &c. on maps.

Mr. D'Souza—Assisted by Messrs. McA'Fee, Hickie, Fielding and Cusson computing.

Messrs. Gwinn, T. Rendell, Wyatt and J. Rendell mapping.

Native Surveyors—Copying boundary survey field books.

Tabular Statement of out-turn of work during the Field Season 1867-68.

Triangulation.

Officers.	Area.	No. of stations.	No. of intersected points.	Instruments used.	Mean triangular error.	Mean discrepancy per mile derived from comparisons of common sides.				Remarks.
						3 *angles observed.*		2 *angles observed.*		
						No. of comparisons.	Inches.	No. of comparisons.	Inches.	
	Sq. miles.				"					
Captain Haig in Bombay,	35	3	...	14 inch	7·4	...	...	...	...	
in Kattywar,	33	4	11	6½ inch	8·75	3	3·1	10	11·6	
Mr. McGill, ...	1008	98	423	6½ inch	17·3	39	11·2	112	17·3	Also took vertical angles at 10 stations of the Kattywar coast series, the height of which had not previously been determined.

Plane Tabling.

Names.	Plain Tabling.	Stations per square miles.	Remarks.
Mr. Gwinn, ...	44	5·09	Chiefly employed in instructing others, and in plotting boundaries on the plane tables.
„ McA'Fee, ...	215	6·24	
„ T. Rendell, ...	355	3·96	Includes 95 square miles on 2 inch scale, average 6·6 stations per sq. mile, and 260 sq. miles on 1 inch scale, 3 stations per sq. mile.
„ Wyatt, ...	223	4·84	
„ C. Low, ...	40	10·53	Joined 30th March, and left on 12th June 1868.
„ J. G. Rendell, ...	40	4·78	Joined 29th February, closed work on 10th April, on account of a fall from his horse.
Wissaji Raghunath, ...	10	9·10	Exclusive of trial work—Employed also in computing, and other miscellaneous duties.
Gobindji Mahalay, ...	73	5·69	Ditto ditto.
Vishnu Morishwar, ...	60	5·48	Ditto ditto.

Traversing.

Names.	Order of merit.	Linear miles of boundary.	Linear miles Check lines.	Remarks.
Gopal Vishnu, ...	1	79·12	60·04	
Narsu Dinkar, ...	2	118·58		
Bholuji Bhosekar, ...	3	159·72		
Krishna Govind, ...	4	125·37		
Ganesh Bapuji, ...	5	31·38		Sick for 3 months, subsequently discharged. Learnt plane tabling at beginning of season.
Krishna Dinkar, ...	6	40·78	28·48	Learnt plane tabling early in the season.
Raoji Narrayen, ...	7	29·76		Sick for 3½ months—subsequently dismissed for fudging—Learnt plane tabling early in season.
Captain Haig, ...	...	6·78		Instructing Bholuji Bhosekar.
Mr. McA'Fee, ...	...	7·19		
„ T. Rendell, ...	...	8·56		
„ Wyatt, ...	...	6·87		
		614·11	88·52	

C. T. HAIG, *Captain, R.E.*

EXTRACT FROM A REPORT BY LIEUTENANT T. T. CARTER, R.E., ON THE SURVEY OPERATIONS IN CONNECTION WITH THE ABYSSINIAN EXPEDITION.

The Survey party to accompany the Abyssinian field force was organized at the desire of His Excellency Sir Bobert Napier, Commander-in-Chief, and was composed as follows:—Officer in charge, Lieutenant T. T. Carter, R.E., Surveyor G. T. Survey of India, Assistants, Lieutenant A. E. Dummler, R.E., Assistant Surveyor G. T. Survey of India, and Lieutenant T. H. Holdich, Assistant Surveyor Topographical Survey of India with a Native establishment of 40 (forty) classies.

The first intimation of the survey party being required, and my having been selected to the charge of the same was made to me about the middle of the month of October. Lieutenant Holdich and myself were at the Head-Quarters of the G. T. Survey at Dehra Doon. Lieutenant Dummler at Poonah with the Bombay Party under Captain Haig, of the Royal Engineers; no time was lost in making the necessary arrangments, and it having been intimated that the party need not be at Bombay till the 1st of December 1867, up to the 11th of November I was employed with Lieutenant Holdich under instructions from Lieut.-Colonel Walker, R.E., in taking astronomical observations and practising with the view of accustoming ourselves to the astronomical work which would form part of our Survey operations.

On the 11th of November 1867, I left Dehra, accompanied by Lieutenant Holdich and taking with me 10 (ten) classies, natives of the hills, and accustomed to the Survey work in the Himalayas, Captain T. G. Montgomerie, R.E., the officer in charge of the Kumaon and Gurhwal Series, having kindly permitted me to take such men of his party who were willing to accompany me; the services of these men I subsequently found most useful.

I proceeded by rail from Meerut to Jubbulpore, marched across to Nagpore and thence by rail to Bombay, arriving there on the 30th of November. At Bombay I was joined by Lieutenant Dummler and the rest of the classies; these latter were with few exceptions men new to to the work and entertained at Poonah.

It was the 13th of December before the party embarked, so that ample time was afforded for such equipment as I thought necessary to take with me, and providing the classies with warm clothing &c.

The instrumental equipment consisted of—

A portable transit instrument.

Two 6″ Thedolites fitted with micrometers in the eye piece, with the view to using them for traversing in hilly country and 2 prismatic compasses with the same micrometer arrangement; 3 plane-tables and stands and a battery of 4 chronometers as well as aneroid barometers and boiling point thermometers for determining the altitudes of different places.

The chronometers were rated at the Bombay observatory before starting.

The party arrived in Annesley Bay on the 4th of January and disembarked on the 8th; it was the 15th before any carriage could be furnished, all available carriage at the time being required for the conveyance of provisions to the front. In the mean time having reconnoitered the country at the foot of the hills, I determined to measure a base-line near Koomaylee, the first march towards Senafe; the ground here was level, but free from heavy jungle, though much cut up with ravines, but by means of the subtense instruments, a base-line of 5146·9 yards was measured, and from the extremities of this base two points on the lower spurs of the hills were fixed, 8 miles apart, and on this side, the triangulation was extended fixing several commanding peaks at distances from 10 to 20 miles off. Observations were taken at one extremity of the base-line to determine its latitude, and also the azimuths of the other extremity. These observations having been worked out, I was enabled to project a plane table and to lay down on it

the points I had fixed by triangulation, and I directed Lieutenant Holdich to take up the plane tabling of the country from Zoola to Senafe, and to sketch in as much of the same on either side of the line as circumstances permitted. I also requested him to take a Theodolite and when visiting those peaks already fixed, to extend the triangulation; by this means I hoped to connect this portion of the triangulation with the new base I intended measuring near Senafe; but to make certain of having a connection between these two base-lines I directed Lietenant Dummler to carry a traverse from one end of the Koomaylee base and to join on with the Senafe base. By the 1st of February Lieutenant Holdich had left me on independent work and I proceeded to Senafe, arriving there on the 5th of February, measured the new base-line and fixed several points in advance, projected a plane-table and took up the sketching of this portion of the country. On the 10th of February Lieutenant Dummler connected the base-line at Senafe with the Koomaylee one by the traverse. Some delay was occasioned here, on account of working out the traverse, Lieutenant Holdich having written to me for the same, and reporting that the weather was so unfavourable, cloudy and rainy; he had ascended a few of the higher peaks on either side of the line of march but always to find himself surrounded with clouds; he had tried remaining on the peaks all night, but with no success, the clouds always rising with the sun and shutting out every thing from his view. His Excellency the Commander-in-Chief had written to me for a sketch of this portion of the country, being most anxious to find a route from the High land to the coast, by which to turn the difficult defile of the Looroo Pass. Lieutenant Holdich suggested leaving this portion of the country to be done later, but for the reason above mentioned, and also because I thought it unadvisable to leave any gap in the work, depending for its completion on such opportunities for survey work as the return march would allow of, (no such opportunities were afforded, on the return of the army) I directed him to remain and complete the sketching of this part of the country as the weather permitted, and I am happy to say that by the 12th of March he had completed the survey of—square miles of very difficult country up to Senafe, and had been instrumental in finding a road by which the Looroo defile was turned; by this time I had completed the survey of about——square miles beyond Senafe, and I now requested Lieutenant Holdich to continue sketching from the point I left off, towards Adegerat, while I proceeded to Antalo to measure a third base. Lieutenant Dummler had in the meanwhile continued the traverse to Antalo and I now intended him to plane-table back to meet Lieutenant Holdich; this was ultimately done, and a continuous survey of the line of march shewing the topography of the country on either side for a distance of from 10 to 15 miles, was finished by the 6th of April, completing the survey to Antalo. The march of the army was so rapid and it being impossible to carry more than a few days supplies on account of scarcity of carriage, prevented a continuous series of triangles being carried on; the system I then adopted was measuring base-lines at distances of about 40 mile from each other, building one or two figures on these bases and fixing points, and connecting the bases by traverse. I hoped in this way to have plane-tabled a large portion of the country on either side of the line of march but the nature of the country beyond Antalo prevented ourgoing off the line; plane-tabling was carried on to a point 20 miles beyond Lake Ashangi, though the amount of the country sketched in on either side was considerably less than what was able to be done up to Antalo, on account of the plane-table having to accompany the traverse.

On arriving at Antalo on the 19th of March, I found His Excellency the Commander-in-Chief advancing so rapidly on Magdala, that I proceeded at once to Lake Ashangi leaving a gap of 50 miles to be filled in subsequently by Lieutenants Dummler and Holdich. At Ashangi I measured a 4th base and having fixed a sufficiency of points proceeded to sketch in the country in advance; at Ashangi, the continuous hard work without the amount of stimulant and food to which one was accustomed, began to tell, and I found I could not do the same amount of walking &c., as I had hitherto done; and after plane-tabling as far as Murawur, the 3rd march from Ashangi in advance, I was obliged to abandon the plane-table, and carry on the traverse alone. The Commander-in-Chief was now close on Magdala and I had neither time nor was I able single-handed to do more than traverse. I succeeded in carrying on the traverse as far as Magdala, arriving there on the morning of the 13th, the day of the assault. After the taking of Magdala and up to the 20th, I was employed at Sir Robert Napier's desire, in making a plan of the position and neighbouring country on the scale of ½ a mile to the inch, (this plan was completed and made over to Sir Robert Napier on his arrival in England).

Virtually the expedition was now at an end, and the Medical Officers being of opinion that I should for the present give myself a rest, I proceeded on the return march to the coast, a few day in advance of the main column. At Ashangi, I met Lieutenants Dummler and Holdich who had completed a route survey between Antalo and Ashangi. I made over the charge of the party here to Lieutenant Dummler, requesting him to extend the work if possible on the return march; but no opportunities were afforded of doing anything more, and the survey party arrived at Zoola on 30th of May. Lieutenant Dummler endeavoured to connect the end of the base-line at Koomaylee with the harbour at Zoola, by traverse, and when doing so received a sun-stroke which disabled him from doing any further work.

No observation for determining a longitude had yet been taken, and this piece of the work devolved on Lieut. Holdich who was kindly assisted by Captain Darrah, R.E., (an officer who was employed on the British Columbian boundary commission). A Longitude of Zoola was determined by the method of moon culminating stars with results as stated in the margin, and I dare say the result will agree more closely when corrected for increase of moon's right ascension determined by actual observation at Greenwich observatory, where it is proposed to send the computations for final correction.

Zoola East of Greenwich

	h.	m.	s.	
June, 1st	2	38	50·41	Observed before full-moon.
„ 2nd	2	38	45·97	
„ 3rd	2	38	52·47	
„ 4th	2	38	58·66	
„ 5th	2	39	15·73	Observed after full-moon.

Several observations of moon's zenith distance were also taken for Longitude, but these have not yet been worked out. On the 30th of May at the recommendation of a Medical Board I left for England; on the 5th of June, Lieutenant Dummler also left, and we were followed on the 12th by Lieutenant Holdich, with the records &c. the Government of India having sanctioned our all proceeding to England for six months with the view to the completion of the work, and Her Majesty's Government having approved of the same.

The native establishment, with the instrumental equipment, were sent to Bombay in charge of Captain Pottinger, R.A., of the Quater Master General's Department; the instruments were consigned to care of Captain Ducat, R.E., Executive Engineer Bombay

The hurried nature of the expedition, the difficulty of moving off the line of march, and the weather were all unfavorable for survey work, and it was only by very great exertion that the party was able to complete the survey of as much of the country as it did.

In conclusion I would beg to bring to the notice of the Heads of their different Departments the services of both Lieutenants Dummler and Holdich.

Out-turn of Work.	No.
Longitudes measured by moon culminating stars, ...	1
Longitudes measured by moon zenith distances', ...	1
Base-lines measured, ...	5
Triangles observed all three angles measured, ...	8
No. of Intersected points fixed, ...	50
No. of heights observed with Theodolite, ...	30
No. of heights determined by Boiling Thermometer, ..	50
Latitudes determined by Circum-Meridian altitude, ..	8
Latitudes by observation to the Pole Star, ...	6
Azimuths observed, ...	5
Miles of traversing with subtense Instrument, ...	400
No. of square miles surveyed on ¼ inch scale, ...	7000
Plan of Magdala position on ½ mile to inch, ...	70 square miles.

Connected with the Astronomical Latitude, Longitude, and Azimuths were some 50 time observations.

The party are at present doing office duty at the Topographical Department of the War Office London, but results of their operations will be compiled in one Report on the completion of the work.

EXTRACTS FROM THE REPORTS ON THE TOTAL ECLIPSE OF 18TH AUGUST 1868.

Lieutenant Herschel's Report.

(3.) It is perhaps necessary in the first place to explain the circumstances under which I became connected with these observations as an employé of the Royal Society of London. Attention was drawn to this eclipse as important to science by Major Tenant, R.E., early in 1867. I was at that time in England on sick leave, and in May of that year, a proposal was made to me, on the part of the Royal Society to undertake certain observations of a definite character (the nature of which I shall have occasion to describe presently) should my return to India and other considerations make it possible. As you are aware I accepted the proposal subject to your approval, and accordingly the Royal Society decided to purchase instruments suitable to the occasion, while I turned my attention to the branch of science involved—that of "spectral analysis".—and addressed you with a view to ascertaining how far I was justified in accepting the position.

(4.) It thus came about that on the expiration of my leave I returned to India in charge of certain instruments entrusted to me by the Royal Society; and with a paper of instructions, indicating the character of the desired observations, in my pocket. I landed at Madras on the 8th December and the eclipse was to take place on the 18th August. The intervening time was in great measure devoted to my professional duties as a member of the Survey department—first in assisting at the measurement of the base-line at Bangalore, and afterwards in the computations arising out of it but the whole of my leisure was spent in practising with the instruments and in preparations and arrangements. As these were necessary rather than interesting I need not enter into details about them, further than to show the precautions requisite to ensure, if not actual success, at least a reasonable probability of it.

(5.) It is necessary however, before proceeding further that I should sketch the nature of the observations proposed. That light may be separated into its constituents and those constituents *sorted* and arranged according to their colours, in passing through a wedge or triangular prism of glass, has long been known; also that solar light so distributed produced a "Spectrum" of a definite character was also known, and its peculiarities had been closely observed; but it was only within the last 8 or 9 years that a theory was propounded, which has since been very generally accepted, that these peculiarities viz:—Fraunhofer's lines—were due to a solar atmosphere, which, according to the theory, absorbs a portion of the light emitted by the body of the Sun. This theory was based mainly on the observed identity of position in the spectrum, of these lines with those of light known to be emitted by certain definite elementary substances when intensely heated; the only difference being that the latter were *bright* lines while the former were dark. And the explanation of this difference was that they were dark by comparison only. So that if the sun were supposed to be enveloped in vapours of the elementary substances—intensely heated indeed, and luminous perhaps, but *less so* than the central body—certain portions of the light from the latter would be absorbed, in favour of light of precisely the same kind, only less luminous, and therefore by comparison with the unobstructed light, dark.

(6.) The use of the prism in analyzing light is of very much larger application than any thing I have sketched here, and it would be quite out of place to attempt to explain the tests which it applies. Suffice it to say that the appearance of the spectrum may or may not indicate the source of the light as well as the chemical and physical constitution of that source.

(7.) The appearances presented during an eclipse, as seen through telescopes, had suggested all manner of theories as to the constitution and nature, both of the corona and red prominences. At the last great eclipse—that of 1860—spectroscopes were unknown. It was not till two years later that sufficient advance had been made in this direction to enable Mr.

Huggins, whose name is so well known in connection with this most interesting branch of physical discovery, and Padre Secchi of Rome, to commence the spectroscopic examination of celestial objects. To their discoveries I need not refer further except to point out how they naturally excited a lively interest and a strong desire to apply the new implement to the solar appendages during a total eclipse, when the comparatively blinding light of the sun's body should be obscured.

To make more clear the special questions which a spectroscopical examination of the corona &c., was expected to aid in solving, I should add that a "spectrum" has of necessity one of two characters. It is either *continuous* or *discontinuous, i. e.* the series of colours is either unbroken, or is only a series by courtesy, one or more representative colours only occupying their proper places, the rest being absent. These characters indicate whether the light emanates from a luminous solid or liquid, or from a luminous gas or vapour, and in the latter case may, and some day no doubt will indicate certainly from *what* gas or vapour.

On the supposition that the "corona" was a solar atmosphere, the questions arose, is that atmosphere a self luminous vapour or mixture of vapours? and in that case of what vapours does it consist? or is it a non-luminous vapour rendered visible by the reflection of the solar light from its material particles? or, again does it consist of strata shewing both these characters? and others of a like kind.

Again, there was a still greater curiosity, if possible, to learn something about those strange appearances called, for want of any knowledge of their real nature, "protuberances" "prominences" "flames" and the like. Were they really flames? and if so flames of what? On all these points the spectroscope, if it spoke at all would certainly speak the truth; and science seemed fairly able to interpret the oracle by the help of late discoveries in terrestrial physics.

The event, which so far as I was concerned in it, I now proceed to relate, has in great measure answered these questions, thereby, as in all cases of scientific search, limiting speculation and pointing the way to fresh questions, to be answered, it is hoped, on some future occasion.

The instruments placed in my hands for these observations—as well as for another kind which I shall advert to presently—were

1st. A fine equatorially mounted telescope of 62 inches focal length and 5 inches aperture, with clock-work driving machinery to ensure an automatic maintenance of direction upon a moving object: and in connection with it, though an independent instrument.

2nd. A spectroscope containing a single flint glass prism for the separation or analysis of whatever light might be collected and thrown upon it by the above telescope.

The latter of these two I should observe, acts the part of a large, and in some respects inconvenient, *eye-piece* to the former, with this difference as compared with an ordinary eye-piece, that whereas the latter presents to the eye a magnified image of the object towards which the telescope is directed, the former offers no such advantage, but only receives and *sorts* the light and presents the resulting arrangement for inspection, quite devoid of any *form* corresponding to that of the real object. It will therefore be understood that I had to make up my mind to see nothing of the eclipse *as a spectacle*, with the fine telescope at my command. Nor did I: were it otherwise I should confine myself in this report to a description of a more generally interesting character than I am now enabled to offer.

Having now given an outline of the proposed objects, and sufficiently indicated the nature of the instruments, I need not dwell on the preliminary arrangements—among which however I should mention the construction of a portable wooden observatory (which I contemplated making use of afterwards for survey purposes) and the choice of a station of observation. With regard to the last, I may take this opportunity to offer my grateful acknowledgment of your energetic assistance in procuring through the local Governments the necessary information as to climate and weather at numerous stations along the line of eclipse; and of your warm

support, and concurrence, in all my endeavours to obtain for the Royal Society the best chances of success; more especially in procuring the sanction of Government for the necessary expenditure; and in giving me the assistance of Lieutenant W. Maxwell Campbell, R.E.

The station selected, with your approval, was Jamkandi—a small town notorious on the Bombay side for the small rainfall which characterizes the district in which it is situated. It is the residence of an independent native chief well known in those parts for the enlightened taste which he displays in surrounding himself with the products of European skill and refinement, as well as for other reasons. I was, perhaps unduly, biassed in this choice by the spontaneous offers of assistance made through his secretary, when the question of a suitable position was first mooted. I wish I could add that I had reason to congratulate myself on my choice. In point of fact, it was by no means an easy thing to decide. There seemed a strong probability of cloudy weather, wherever we went, at that season; and access was not equally practicable to all places. The main road through Dharwar and Belgaum might reasonably be expected to be passable even in August, and Jamkandi was distant from it only 80 miles. Nevertheless I was unwilling to risk sending my camp such a distance except in charge of an assistant. I had received your permission to avail myself, to the full extent of my requirements, of the services of Lieutenant Campbell's assistants at Bangalore. I proposed to enlist one of these gentlemen as a recorder and observatory assistant, and a second was required to take a series of independent observations of the intensity of the chemical action of sun-light during the progress of the eclipse. I believe Lieutenant Campbell was a little doubtful whether the nature of the observations with which he was entrusted would be such as to require an assistant, but other considerations—arising out of his professional work, and requiring the detachment of an assistant in that direction—which will no doubt find a place in his regular report, induced me to consent to this further increase to the strength of the party.

Mr. G. Anding accordingly went as Lieutenant Campbell's personal assistant, and as the senior, in charge of the party. To Mr. A. Christie I entrusted the photo-chemical apparatus, and instructed him in the use of it: while Mr. J. Bond accompanied the party to act eventually as my assistant.

The party left Bangalore on the 7th July and reached Jamkandi on the 9th August, having made a very creditable march of 392 miles over very bad roads, in 34 days, including halts.

Lieutenant Campbell and myself followed later arriving at Jamkandi on the 14th. On the evening of the same day, the observatory was up and the instrument in position, but unadjusted.

Before proceeding further I will endeavour to describe the nature and object of the special observations which Lieutenant Campbell was about to secure. I have said that some of the questions which it was desirable to have answered if possible, had reference to some remaining uncertainty as to whether the corona was or was not a solar atmosphere, or whether it was not possibly of the nature of a terrestrial atmospheric halo. This question appeared to be susceptible of solution by the help of the "polariscope".—An instrument for indicating the *plane of polarization* of light. Light being always more or less polarized by reflection it was surmised that if the corona was *reflected* solar light, it should show some traces of this peculiarity when viewed with the polariscope, which instrument would at the same time indicate the plane of polarization and therefore the probable position of the reflecting surface, with regard to the source of light. It is hardly necessary to add that the polariscope is merely an adaptation to a telescope, of one or other of certain peculiar combinations of crystalline plates. This instrument does not, as in the case of the spectroscope, materially affect the form or appearance of the object. In one case it presents two distinct fields of view, identical in every respect except that they are differently tinted when polarized light is present: in the other, one view only is presented crossed by more or less faintly shaded and coloured parallel bands, the direction and arrangement of which give the required information as to polarity. So much of explanation seems necessary in connection with Lieutenant Campbell's report, copy of which I enclose.

I should also state that the Royal Society furnished me with 4 small instruments called "hand-spectroscopes" for distribution according to circumstances. I was at some pains to give

these instruments a fair chance but up to the present time I have received no reports from which any thing material can be gathered.

Two other instruments which I brought out myself—of a like nature—and which I lent to Mr. C. S. Chambers, Government Astronomer at Bombay, were rendered useless in his hands by cloudy weather. On the whole these instruments have fared so badly that there seems no occasion to describe them here.

I may now return to the principal subject of this report, to which the greater part of the foregoing remarks must be considered as necessary an introduction, as the actual preliminaries were to the event. The interval from the 14th to the 18th August was occupied, as may be supposed, in anxious preparation and uncertainty. The weather was far from promising, being persistently cloudy; but we entertained hopes each day that it would be the last of an unusually protracted interval of such weather in that country. The uncertainty as to the phenomena to be witnessed combined with the uncertainty as to the space of time which the clouds might allow for observing them, rendered it almost impossible to lay down a definite course of action, and greatly heightened the nervous apprehension otherwise so natural to the occasion. To this cause I must attribute the almost complete abstraction whose result is so evident both in my own personal recollections of that morning and in the absence of any observations of a generally interesting character which one might fairly be supposed to have made. I was closely imprisoned from 10 minutes before to nearly the same time after the total phase, and was sensible to *nothing* external but the hum of voices around me.

About 10 minutes before totality commenced I took up my position at the telescope and occupied the interval in final measures of the solar lines—to which any subsequent measurements might be referred. As I was thus engaged the spectrum of what remained of the sun grew rapidly narrower, and I was watching eagerly—and it may be guessed how intently! for the final disappearance which was to reveal, in place of the solar spectrum, that of the corona—when the latter faded prematurely through the intervention of a cloud, and the precious moment was lost.

I went to the finder, removed the dark glass, and waited how long I cannot say, perhaps half a minute. Soon the cloud hurried over, following the moon's direction, and therefore revealing, first, the upper limb with its scintillating corona, and then the lower. Instantly I marked a prominence near the needle point, an object so conspicuous that I felt there was no need to take any precautions to secure identification. It was a long finger like projection from the lower left hand portion of the circumference. A rapid turn of the declination screw covered it with the needle point and in another instant I was at the spectroscope. A single glance and the problem was solved. THREE VIVID LINES, RED, ORANGE, BLUE; NO OTHERS, AND NO TRACE OF A CONTINUOUS SPECTRUM.

From that time until the end of the 5 minutes I was endeavouring to seize the fitful glimpses of these lines for purposes of measurement. I succeeded with the orange and blue, but there was not sufficient time for the 3rd. The field became suddenly re-illuminated and the total eclipse was over. Nothing more could be done except to check the measurements against those of the solar spectrum.

Of the result of this comparison I will say as little as possible, for obvious reasons. My impression is that the flame I was looking at consisted principally of sodium, and *possibly* hydrogen, in an intensely heated condition; but it would plainly be premature to indulge in speculations, when a little patience will supply other and independent data.

The absence of any spectrum of the corona is simply negative evidence, and nothing more can be based on it than the presumption that it was faint and probably "continuous;" which would imply reflection of solar light rather than intrinsic luminosity. On this point also reserve is better than hasty speculation, although the conclusion to be derived from Lieutenant Campbell's observations of polarity—that the corona is not self-luminous but only a reflecting agent—is irresistable.

Lieutenant Campbell's Report.

I was deputed to accompany Lieutenant Herschel, on his expedition to observe the phenomena of the total eclipse, and to use the instruments supplied by the Royal Society, for the observation of Polarized light in the corona and red flames.

The instruments in question were as follows :—

A telescope of 3 inch aperture, mounted on a rough double axis, admitting of motion in azimuth and altitude by hand only, unaided by any appliances for clamping and slow motion. The telescope was provided with three eye pieces of magnifying powers of 27, 41, and 98, and with it were furnished two Analyzers, for polarized light—viz., a double image prism and a "Savart's polariscope."

The first gives two images of the object viewed, which when polarized light is present, become strongly colored with complementary tints, by whose changes, according to the position in azimuth of the analyzer, the plane of polarization may be found.

The second shows the presence of polarized light by the formation, across the image of the object viewed, of colored bands, which alter in arrangement, and intensity according to the position of the polariscope with reference to the plane of polarization, and hence afford a means of arriving at a knowledge of the latter.

With the former, slight polarization would probably be more readily recognised at a glance, while with the latter, the plane of polarization could be more easily and accurately determined.

To carry these Analyzers, I had a pair of jointed arms constructed, so attached by a collar and screw to the eye tube of the telescope, as to admit of the eye piece being changed.

Each arm carried one of the Analyzers in a Cell, in which a rotatory motion could be given for analyzing purposes.

Either analyzer could in this way be brought instantly into position before the eye piece of the telescope, or both could be turned aside and the telescope used by itself, at pleasure.

Immediately behind this apparatus, a circular piece of card-board of about 12 inches diameter, and neatly graduated, was firmly attached to the eye tube, and to each analyzer was affixed a long pointer, by which its azimuth could be referred to the graduations on the card circle, should measures of position, or change of azimuth appear desirable. I was also furnished with a hand spectroscope for direct vision.

The point chosen for my station was on the northern slope of a low range of hills, about 1½ miles W. by S. of Jamkhandi.

The flatness of the hills on top offered no point, from which an uninterrupted view could be obtained in all directions, and from my station I only obtained a view of the northern half of the distant horizon, over the plains extending in that direction for many miles, above the general level of which I was raised about 200 feet.

Early on the morning of the 18th, I proceeded to the spot, having previously sent up the instruments, and a tent for shelter in case of necessity.

At sun rise the sky was beautifully clear, except in the northern horizon, where there were low clouds lying over the river Kistna. There was a gentle breeze from W. by S.W.

A little later, light flocculent clouds began to rise, and form in an arch overhead from west to East, continuing to increase, as the morning wore on; then a light scud set in and turned gradually into broken masses of thick dark clouds.

Before the commencement of the eclipse I took observations for time with a small theodolite, from which I computed the error of my chronometer (a mean time chronometer by McCabe) to be 1*h*. 14*m*. 55·2*s*. *fast* on local apparent time, and by that quantity I have accordingly corrected all observed chronometer times, in the statements of time which follow.

I observed the first contact, which took place at 7*h*. 45*m*. 13*s*. (local apparent time) about 15° from the vertex, after which I watched the progress of the eclipse, and noted the time of occultation of three spots which were visible on the sun.

During the progress of the eclipse, I observed no unevenness in the moon's limb, nor any want of sharpness in the cusps—using magnifying power 27.

The following notes were taken on the spot. At first contact, Sun very slightly obscured by flying clouds. At 8*h*. 0*m*., clouds thick and gathering, rising from S.W. and W.

Wind higher and gusty.

h.	*m*.	
8.	10.	Clouds overhead, increasing and thickening, and rising steadily from west.
8.	20.	Sky nearly entirely overcast, clouds thickest in neighbourhood of sun.
8.	25.	A clear break.
8.	30.	I thought I could discern very faintly the dark limb of the moon, beyond that of the sun, and at this time, making allowance for the general cloudiness, I did not perceive any decrease of light on the landscape.
8.	40.	But 10 minutes later the darkening was decided.
8.	45.	Thick clouds well broken up, still gathered most closely in the region of the sun. Light becoming lurid, and increase of darkness very apparent.
8.	52.	Cusps perfect (magnifying power 27).

Closely before totality, a bright line of light appeared to shoot out at a tangent to the moon's limb at its vertex, as if running across the bright crescent of the sun, (though of course not visible against the superior light) and extended beyond each cusp to a distance of nearly or quite 15 minutes. The corona became visible immediately after, betwen the dark limb of the moon and the bright line. The corona did not appear so bright as the line, the brilliance and whiteness of the light of which was most striking. This was seen through a lightly smoked glass. At this period, probably not more than 3 to 5 seconds before totality ensued, a thick cloud shut out everything, and the rest of the phenomenon was only seen fitfully through openings in the clouds—for an aggregate period, which I estimate at somewhat less than half that of totality.

This alternate appearance and disappearance troubled me greatly, and gave rise to nervousness and excitement, for owing to the imperfect mounting of my telescope, I was apt to lose my place whenever the light was cut off by clouds, and waste the precious moments of clearness in finding it again. On the first opportunity after the commencement of totality I turned on the double image prism, with the eye-piece of 27 magnifying power, as recommended in the "instructions," which gave a field of about 45′ diameter. A most decided difference of color was at once apparent between the two images of the corona, but I could not make certain of any such difference in the case of a remarkable horn-like protuberance, of a bright red color, situate about 210° from the vertex reckoned (as I have done in all cases) with reference to the actual, not the inverted image, and with direct motion. I then removed the double image prism and applied the Savart's polariscope, which gave bands at right angles to a tangent to the limb, distinct but not bright, and with little if any appearance of color. On turning the polariscope in its cell, the bands instead of appearing to revolve on their own centre, passing through various phases of brightness, and arrangement &c. travelled bodily along the limb, always at right angles thereto and without much change in intensity, or any at all in arrangement.

The point at which they seemed strongest, was about 140° from vertex, and I recorded them as black centred.

Believing that with a higher power, and smaller field, I should find it easier to fix my attention on one point of the corna, and observe the phases of the bands at that point, I changed eye pieces, applying that of 41 power.

With this eye-piece, the first clear instant showed the bands, much brighter than before, colored, and as tangents to the limb, at a point about 200° from the vertex, but before I could determine anything further, a cloud shut out the view, and a few seconds later, a sudden rush of

light told, that the totality was over, though it was difficult to believe, that 5 minutes had flown by since its commencement.

I experienced a strong feeling of disappointment, and want of success, the only points on which I can speak with certainty being as follows. 1st,—when using the double image prism, the strong difference in color of the two images of the corona, and the absence of such difference in the case of the most prominent red flame. 2nd,—with the " Savart's polariscope." The bands from the corona were decided. With a low power, they were wanting in intensity and color, (excepting alternate black and white) making it difficult to specify the nature of the centre, and their position was at right angles to the limb, extending over a space of about 30° of the circumference. When the polariscope was turned, the bands travelled bodily round the limb, without other change in position or arrangement, as if indeed they were revolving round the centre of the sun as an axis. With a higher power when a smaller portion of the corona was embraced, the bands were brighter, colored, and seen in a different position, viz., as tangents to the limb.

The appearance observed with the low power seems exactly what might be expected, supposing the bands to be brightest at every point, when at right angles to the limb, in which case, the bands growing into brightness at each succeeding point of the limb, would distract attention from those fading away at the points passed over, as the Analyzer revolved.

After totality was over, the clouds cleared somewhat, and I watched the eclipse till its conclusion, noting the times of emersion of the spots, last contact &c.

A light shower fell at 9·30.

During totality several stars and planets were seen by those who were with me, and a fowl, which I had placed near me out of curiosity, was observed to compose itself to sleep. It was at no time so dark as I had expected; after the commencement of the total phase, I read the chronometer, and wrote notes in pencil without difficulty, and the light of a bull's eye lantern, when thrown on my paper, appeared somewhat dull.

The brilliance of the light of the corona, when it burst out through the openings in the clouds astonished me. Also the very gradual decrease of light before totality, and the wonderfull flood which followed the instant of the sun's limb's re-appearance (though behind a cloud) was very striking.

I was too much occupied in watching the position of the sun, so as not to lose an instant of the precious intervals of clearness, to see much of the general effect. I had no opportunity of using the hand spectroscope. There was no one in my neighbourhood (except those of my own party, who had been warned to keep silence,) but when totality commenced a wailing shout was heard in the distance, apparently rising all round us, which was succeeded by silence after a few seconds. The distant features of the landscape disappeared, and I noticed one light, apparently a village fire, some miles distant.

I give below the different times I observed, as of possible interest.

Local apparent time is used.

		h.	*m.*	*s.*		*h.*	*m.*	*s.*
Sun and moon,	1st contact,	7	45	13	last contact,	10	21	59
Spot No. 1,	1st ,,	7	57	39				
	entire disappearance,	7	59	5	entire re-appearance,	9	7	5
Spot No. 2,	1st contact,	8	40	28	ditto,	9	54	39
,, No. 3,	1st ,,	8	46	58	ditto,	10	3	25

Latitude of station 16° 30′ 10″ long. 75° 20′ 0″.

I cannot state, with any approach to accuracy, either the instant of the commencement or termination of totality.

Captain Haig's Report.

I may state at once that I observed the spectra of two red flames close to each other and in their spectra two broad bright bands quite sharply defined, one rose madder and the other light golden. These spectra were soon lost in the spectrum of the moon's edge just before emergence, which had also two well defined bright bands, one green and one indigo, about a quarter the width of the bands in the spectra of the flames, this spectrum being again soon lost in the bright sun-light.

I will now proceed to give a detailed account of the observations in which Captain Tanner (Bombay Staff Corps of the Nimar survey, who at my earnest solicitation accompanied me), and Mr. Kero Luximon, Professor of Mathematics at the Deccan College took part, and during which Mr. Hunter, Bombay Civil Service, and Dr. Kielhorn, Professor of Sanscrit in the Deccan College were present as non-professional observers.

Our instrumental equipment consisted as follows :—Mr. Kero Luximon brought an ordinary pedestal telescope of $2\frac{1}{4}$ inches aperture and 36 inches focal length by Horne and Thornthwait which he temporarily mounted on a stand equatorially and had a scale fitted in the 60-power eye-piece, which however, he was unfortunately not able to use on account of a fall which his instrument sustained from being blown down by the high wind, he therefore, had to use another eye-piece of power 70 not furnished with a scale; he also had a pocket chronometer beating 5 times to 2 seconds, by Arnold and Dent. Captain Tanner had an Everest theodolite by Troughton and Simms having a remarkably good telescope of $1\frac{7}{8}$ inches aperture, and 18 inches focal length, and eye-piece of power 46. I had one of the Royal Society's small hand spectroscopes and a small 6-inch transit theodolite by Troughton and Simms, the cap of the object glass of which I had cut so as to receive the prism cap of the spectroscope and had fitted one to the other, so that I could *at once* shift the prism cap from its own telescope to that of the theodolite and *vice versa*.

The sky in the early morning of the 18th was very very cloudy, so that our hopes of success were very low, but as it afterwards brightened up for a while rather suddenly we were somewhat encouraged to hope for a similar brightening during part of the eclipse; soon however, at about 7 o'clock, it darkened again and remained so till after the total phase was over; occasional openings in the nimbi giving us glimpses of the sun through the cirro-cumuli which were floating very high up. At 7 o'clock we had reached our station of observation, which was on a large solid tower called the Upari Burj, 67 feet high and 60 feet diameter at top, a most favourable position from which to observe the phenomena of the eclipse and the general aspect of the surrounding country. On account of the prevailing high wind we planted our instruments on and near the top of the external stone staircase, so as just to be protected by the tower from the wind. Mr. Kero Luximon first set up his telescope on top of the tower, but it was blown down as I have previously mentioned. This accident much interfered with the carrying out of our preconcerted plan of observations, which was as follows :—Mr. Kero Luximon and Captain Tanner were to take the times of first and last contact, the latter by observing the actual occurrences, the former by measuring several lengths of the common chord soon after first and before last contact, with the aid of the scale in his 60 power eye-piece, and noting the times. Captain Tanner (an expert delineator) was during totality to take command of Mr. Kero Luximon's telescope measuring the heights of the flames at times which would be recorded by Mr. Kero Luximon, whose whole attention during totality was to be given to recording the times of occurrence of any phenomena that he or either of us might observe. Captain Tanner was also to make rapid sketches of all he saw, and I was to confine myself to spectrum observations. Unfortunately contact was not observed until about 50 seconds after the commencement when Captain Tanner at once made a sketch of the obscuration, Mr. Kero Luximon recording the time. The sketch made the common chord = 3′ at $7h.\ 51m.\ 17s.$ local time, giving $7h.\ 50m.\ 17s.$ as the time of first contact. Captain Tanner also afterwards tested that sketch by noting the time before last contact when the chord appeared of a similar length, which gave an interval of 45 seconds, so that taking the

mean between the original estimate and its verification, we have 7*h*. 50*m*. 25*s*. as the time of first contact. While the obscuration was increasing Captain Tanner, during the few peeps we got at the eclipse, made drawings of the sun's spots and sketched the mountains on the moon's edge, of which there were two plainly visible even with my small theodolite. The darkness increased very slowly till just before totality, when the increase was very rapid and sudden and a general spontaneous exclamation "oh", from all of us, gave Mr. Kero Luximon the time of beginning of totality, which he recorded as 9*h*. 1*m*. 49*s*. The eclipse was at that time completely shut out from our view by the clouds—nimbi low down being rapidly carried past by the high wind—we, therefore, felt at leisure to make our remarks on the degree of the darkness which we were surprised to find so far from total; we could easily write and read our writing and read the seconds of our watches without the aid of artificial light. We were all lamenting our misfortune in not being able to observe the eclipse and had given up all hope of witnessing the phenomena we had come so far to see, and Captain Tanner had just noticed the faint re-appearance of light in the west, when contrary to all expectation and to our intense satisfaction, a sudden opening in the nimbi shewed us the eclipse, through the cirro-cumuli. We were each at our telescopes in an instant. I immediately saw through the naked telescope of the small theodolite that red flames were visible and at once pointed the spectroscope, using the theodolite telescope as a rest; I very fortunately directed the spectroscope with its "refracting edge" tangent to the moon, where two red flames were protruding separated from each other by a small interval, so that their spectra which were identical were extended over the dark back ground of the moon's disc and stood out in most marked and brilliant contrast with the feeble but continuous spectrum of the corona, and in their spectra there were the two broad bright bands I have described above. Most fortunately also these red flames were on that part of the sun which *first* re-appeared, so that just before or just *at* emergence, there appeared at the very part I was intently observing, one brilliant wide spectrum with the green and indigo bands before described, remaining visible for an interval just long enough to enable me to make *quite sure* of the position of the bands which were then obliterated by the bright light of the sun. Of course observing with the spectroscope alone, it would have been impossible to say whether the spectrum with the green and indigo bands appeared just before or just after emergence; but I think it must have been just before, because Captain Tanner called out when totality was over, and I immediately remarked that I thought he was rather late, but he was quite confident about the accuracy of his observation. What struck me as being very remarkable was the circumstance that though the light of the red flames was to the naked eye so feeble as to be out-shone to extinction by that of the corona, nevertheless when viewed with the spectroscope, the spectrum of the corona was very weak and that of the flames remarkably brilliant. On the first glimpse of the eclipse, before looking through the telescope, the corona appeared so bright that it gave me the momentary impression (as it did to Captain Tanner) of its being an annular eclipse. We are divided in our estimate of the length of the interval during which we observed the totality. It appeared to me very short, so much so that when it was over I was quite taken by surprise to hear that both Captain Tanner and Mr. Kero Luximon had taken sketches of the flames, and their sketches both as to position and structure were with one slight exception remarkably coincident. From the time of my first pointing the spectroscope, to the bursting out of the sun's light, I never once withdrew my eye, though it was my intention to have shifted the prism cap to the telescope of the thedolite as soon as I should have carefully noted the spectrum of the flames, but while I was intently gazing on the two bright bands, to impress their color well on my memory, the new spectrum of the moon's edge appeared, so that I was under the impression that the length of the time of observation was very short. On the other hand Captain Tanner judging from the amount of work he did in the time, estimated it at a minute. Mr. Kero Luximon estimated it at 40 or 45 seconds. Immediately after totality, we all three made rough notes of our observations, and Captain Tanner and Mr. Kero Luximon's notes agree together wonderfully in their description of the structure of the flames.

"The following is an extract from Captain Tanner's notes made almost immediately after the eclipse:"—

"I at first saw three prominences, one long curved pointed tongue, and two close together, straight but flat topped, about two-thirds the height of the former. They were of a rose madder color, and were decidedly more like flames than anything else, not only in their general appearance and color but by their being composed of smaller tongues of flames parallel (or nearly so)

to the general axis of the flame, so that they had a streaky appearance and a ragged edge. At first glance when the sun was somewhat obscured by clouds I thought that they were homogeneous and had hard edges, but this idea was at once dispelled when the clouds cleared off. The two protuberances which were close together were not as far as I could see joined by any smaller shots of flame. I afterwards observed one small protuberance and marked the position of it in my sketch. I did not observe that it was streaky as the others were, perhaps on account of its being so small and perhaps because I had not sufficient time to examine it properly. As regards the corona, when we just began to see the eclipse through the clouds I was under the impression that the eclipse instead of being total was only annular; so bright was the corona near the moon's limbs. I could not detect any irregularities in the structure of the corona, but the light appeared to be gradually shaded off all round."

Captain Branfill's demi-official Report.

We had a beautifully fine morning, but sometime before totality a film of cirro-stratus spread overhead, and cumuli appeared in several quarters, enough to increase our anxiety and nervousness to a terrible pitch. Tennant had not slept for many nights except in fitful snatches. However watching the progress of the earlier phases exercised a calming influence. Everything was ready on our part to do our best. I had no recorder, and think I must have lost at least a minute in recording my observations by lamp light. I had noticed and recorded the very serrated edge of the moon and also the occasional blunting and cutting off of the cusps, both new facts to me, and at first sight rather unaccountable. I had also noticed a very peculiar but distinct line of light, apparently upon the moon's surface, as if in continuation of the cusps—perhaps it was caused by the telescope.

I had watched for the first appearance of the moon's limb against a lighter back ground outside the sun, but only caught sight of it a few minutes before totality. I was watching the formation of bright beads and bugles at the S. cusp of the de-crescent sun, when suddenly, some seconds (15 or more I should think) before totality, I saw plainly a group of red flames—a gorgeous spectacle, and also a wonderful hornlike prominence. Hearing the general shout of the town's folk and fancying totality must be on the point of commencing, I removed the pale dark glass I was using, but too soon, for I could not bear to look on the last of the disappearing sun. It was only for a second, for on taking a second glance I found no sun left: only a splendid group of rose coloured flames and that horn, backed by a bright field of light of various intensity. I took one look and received an indelible impression of the scene, and then set to work in earnest. With the finder I directed to the brightest part of the corona (the S.E. quarter) and examined its light carefully with the Nicoll's prism and crossed quarts, which gave brilliant light, dark, and coloured bands, (Savart's). I noted the position of the maximum white band, and the points of disappearance on each side. It was directly clear to me by several trials that the corona was plentifully polarized in all the planes passing through the sun's centre. The double image prism gave the same results as the plain Nicoll. The polarized light was most where the corona was brightest, least where faintest. Satisfied of this, I turned to examine the light of the hornlike red flame; the corona seemed fainter behind it; but though I contracted my field I of course could not quite exclude all corona light. I could not detect the presence of polarized light on the red flames. With the double image prism, the flame did not seem to vary in tint at all, although with the Savart I could not get rid of bands altogether, and I noticed that though extremely faint the bands were continued upon the moon's surface. I was still straining to see and note any difference in brilliancy with the plain Nicoll, when a flood of light in the field told me that all was over, to my intense disgust and disappointment. I was in despair at first, thinking I had done little or nothing, and that perhaps useless; still unheeding every thing else, I went on writing down what I had seen, and it gradually came over me that I had seen and noted all that the prisms showed, as well as I could, and could only do the same again.

EXTRACTS FROM A NARRATIVE REPORT DATED 6ST AUGUST 1868, BY LIEUTENANT HEAVISIDE, ON HIS ASTRONOMICAL OBSERVATIONS.

(1.) In my report of the operations for the field season of 1866-67, I pointed out, that, throughout the observations, the latitude obtained from stars north of the Zenith, was greater than that found from stars south of the Zenith. The differences, denominated N — S, averages + 6″·18 for the four stations observed at during that season. After a close examination of the records of the observations, it become evident, that the cause of this large value of N — S, was not due to the method of reducing the observations, and would be found, either in the instrument or in the method of observing.

(2.) You therefore ordered the instrument, Astronomical Circle No. 1, to be brought up to Masoorie, and between the middle of September, and the end of October 1867, a variety of methods were adopted for determining the cause of the error. It appears unnecessary to give details, here, of what was done, as the methods employed were carried out either with your own hands, or under your direct superintendence: moreover a full report on the subject, was submitted towards the end of October. It may, then, suffice to say, that the error appeared to be due to flexure in the telescope of the instrument. As, at this time, the field season was far advanced, you considered it undesirable that the investigations should be carried further, and by your orders Astronomical Circle No. 1, was returned into store, and I proceeded into the field with Astronomical Circle No. 2, the instrument which had been used by Mr. Taylor throughout the previous field season.

(3.) Before leaving, however, observations were taken by me on 4 nights, with Astronomical Circle No. 2, for the determination of the latitude of the Masoorie observatory. The resulting latitude differed from that obtained in 1866, with Astronomical Circle No. 1, by 0″·2, and the value of N—S, in 1867 was about +2″, whereas in the previous year it had been +6″·26. There was, therefore, much reason to hope, that whatever may have been the defects in Astronomical Circle No. 1, which caused the large difference between north and south stars, with mean result obtained by pairing north and south stars of equal zenith distances, would be uninfluenced thereby.

(4.) That there might be no doubt on the subject, you directed me to visit one of the stations of 1866-67, and take a fresh set of observations, with the new instrument, to the same stars which I originally observed at that station. Sungutpur T. S. was considered the most convenient station to test.

(5.) In your letter No. $\frac{4}{624}$, dated 29th October 1867, you assigned certain limits within which the new and old value of the latitude of Sungutpur might differ. If, however, the difference should exceed that laid down by you, the whole of the observations taken in 1866-67. were to be rejected.

(6.) Owing to the above circumstances, the party did not leave Dehra until the 2nd of November. Mr. 2nd Class Sub-Assistant J. Wood, had, however, started about a fortnight previously, to build an observatory at Isanpur T. S. of the Rahun Series. The camp arrived at Isanpur on the 17th of November, and observations were commenced on the 19th. After finishing work at Isanpur the camp marched through the Kupurthalla territory to Sungutpur T. S.

(7.) The weather at Sungutpur, was very unfavourable for observing, constant clouds and rain, with heavy fogs in the early morning greatly retarded the observations. This, however, was of advantage in other ways: for, Mr. Wood being laid up with rheumatism, it enabled Mr. Belcham and myself to finish off the calculations, as the observing proceeded. On the night of the 15th January, the observations on one zero were completed, and on the 16th the mean resulting latitude was found to be 31° 17′ 35″·24; the mean from both zeros in the previous year being 31° 17′ 35″·35.

(8.) This was well within the limits assigned in your letter No. $\frac{4}{624}$, and indeed, the two results do not differ from each other by more than half the sum of their probable errors. It was, therefore, unnecessary to take any more observations for verification, and I was at liberty to proceed southwards.

(9.) Ram Thull S. about 150 miles distant, was the next station at which observations were to be taken. As Mr. Wood, was still unwell, I left the camp under Mr. Belcham's charge, to follow me at the ordinary rate, while I went on by double marches. By these means I reached Ram Thull about 8 days before the camp, and as I had previously sent on a chuprassie to collect materials, I was enabled to get the observatory nearly finished in that time.

(11.) Observations were finished at Ram Thull on the 4th of March, and I then proceeded with the camp to Garinda S. in the Shekawattee states.

(12.) The towns of Cheroo and Ramgurh, south of Ram Thull, are full of large well built houses, serais and temples, and standing, as they do, surrounded by a barren waste of constantly shifting sandhills, strike one at first, with wonder. Their existence, is partly accounted for by the block kunkur which underlies the sand, and is dug out in large quantities, in the valleys, throughout the part of the Beekanir country, which I passed through. This kunkur furnishes a good building stone and an admirable lime.

(13.) After finishing observations at Garinda, I went to Rewat, H.S. in the Jodhpur states. These stations had been selected by me, in the latter part of the previous field season, as suitable for observing at, and a description of the country was given in the 2nd part of the narrative report for that season.

(14.) Observations were finished at Rewat on the 25th April. After making arrangements for protecting the mark-stone the camp marched into Ajmere, arriving there on the 1st May.

(15.) Messrs. Wood and Belcham and myself left Ajmere on the 4th May, proceeding by dâk and rail to head-quarters.

(16.) The health of the native establishment was very good throughout the season. At Ram Thull the water was very brackish and bad, but by employing the baggage camels a supply of good water sufficient for the whole camp was brought daily from a distance of about 6 miles.

(17.) I am much indebted to Major W. H. Beynon, Political Agent at Jeypur, and to Captain E. C. Impey, Political Agent at Jodhpur, for the assistance afforded me during the time the party was working in the States under their charge. Owing to their admirable arrangements, I had no difficulty in obtaining labor and supplies, and was able to prosecute my work without let or hindrance.

(18.) The natives in these States, though naturally, somewhat more independent than those in British territory, were always very civil and obliging, and I found this more especially the case with the authorities at Futtehpur, Seekur, and Koochaun.

(19.) Observations have been taken this season at four stations, in addition to those taken at Sungutpur, the station of verification. At each of these four stations 35 pairs of stars have been observed without changing zero. These stars generally extended over 12 to 14 hours, and I usually finished the first half, which came nearer and nearer sunset each day, before commencing the second half. This is, I think, a better arrangement, than taking 16 or 24 pairs and changing zero. In the first place it is generally easier to obtain from the Greenwich 7-year catalogue, 32 pairs extending over 12 hours, than 24 pairs extending over 8 hours and if the 24 pairs are observed on the same night as would be the case, 32 pairs observed on two nights give less, and perhaps enough observing for each night. In the next place, no change of zero is required, and the flying microscopes can be placed opposite the fixed microscopes, at 0° 0′, where they can be read with comfort. This position for the flying microscopes has been adopted at the four new stations; but at Sungutpur, these microscopes were placed at 60° of altitude, as had been the case in the previous year, at all stations where the stars were observed on two zeros.

(21.) Table of results.

Names of Stations.	Series.	No. of pairs of stars observed.	No. of zeros.	N − S	Probable errors.	$\lambda_o - \lambda_c$	Remarks.
				"	"	"	
Isanpur T. S. ...	Rahun,	34	1	+ 0·38	0·06	− 3·93	λ_o indicates the observed latitude of a station; λ_c the value obtained by calculation through the triangulation from Kalianpur station of the Great Arc.
Sungutpur T. S. ...	Gurhagarh,	21	1	+ 0·67	0·10	+ 0·49	
Ram Thul, S. ...	"	35	1	− 1·09	0·06	− 0·72	
Garinda, S.	"	35	1	− 1·54	0·05	− 0·77	
Rewat, H. S. ...	"	35	1	− 0·34	0·05	+ 0·58	
				"			
			Mean	− 0·38			

(22.) It will be seen from the above table that the local attraction at each of the three last stations is apparently less than 1".

I have three stations selected for next season's work. Zethgarh, H. S.: Khamor, H. S.: Arumlia, S. The two former are about 35 miles apart and have been prepared for observations by having a collimator pillar, &c. built. Arumlia is about 80 miles from Khamor, and no preparations have been made there.

(23.) During the field season five stations were protected and handed over to native officials.

(24.) Mr. 2nd Class Sub-Assistant J. Wood was employed during the field season in building observatories at Isanpur, Garinda and Rewat. He also made surveys with the theodolite of the hills on which Ram Thull, Garinda and Rewat stand. Whilst I was observing at Rewat, he went on to Jethgarh and Khamor. He prepared these stations for next season's observations and made surveys of the hills around them. Mr. Wood was laid up with rheumatism for about a month, when the camp was at Sungutpur, but otherwise he has had good health. I am glad to be able to repeat the good opinion I expressed of his work last year. After leaving Ram Thull in February he did not meet me again until the camp reached Ajmere in May, and it is much to his credit that he not only did his work well, but had no difficulties with the inhabitants of the wild country through which he passed.

(25.) Mr. 2nd Class Sub-Assistant G. Belcham acted as my recorder throughout the season, which work he performs with great care. He is a neat, quick and accurate computer and has done more than his share of the season's computations. I have every reason to be satisfied with the work he has performed.

EXTRACT FROM THE NARRATIVE REPORT OF C. LANE, ESQ., SURVEYOR 2ND GRADE, IN CHARGE NO. 3 EXTRA PARTY G. T. SURVEY, NO. 304, DATED 20TH JULY 1868.

The party marched from Deyrah Dhoon on the 11th November en-route to Meerut *vid* Roorkee. On arrival at Meerut, the levelling operations were commenced by myself and Mr. Clarke, assisted by native recorders, on the 25th November 1867, from the cross mark cut by Captain Branfill on the surface of the stone slab opposite the north pillar of the central west doorway of the station church, towards Moradabad. On the way a branch line was taken to Sirsa tower station of the Budhon meridional series. At Moradabad the station church and several paka points, including bench-marks of the cantonment levels were connected, and after that a branch line was carried to Bhataoli tower station of the Budhon meridional series. At this stage to follow the straight course, it became necessary to carry the line of levels direct to Pilibhit; the attempt was made, but found impracticable, owing to the extreme unsteadiness of the moist ground across country arising from frequent and heavy falls of rain throughout the cold weather, and overflowings of numerous gools or water courses of the adjacent rice producing district of Pilibhit. In consequence, the detour along the G. T. road *vid* Bareilly was adopted. At Bareilly the station church was connected, after which line of levels to Pilibhit was continued from M. S. Bareilly 3, Moradabad 54. Numerous bench-marks of the Rohilcund contour survey were thus met with and determined, as also the tower stations of Kalianpur and Umrao on the southern flank of the north-east longitudinal series between the Rangir and the Amua meridional series. After Kalianpur on the southern flank it was intended to connect Kham Kera tower station on the northern, but the men deputed to examine the condition of that station, as well as of the next, if required, Donao tower station, found no upper mark-stone at either, which necessitated connection with Umrao tower station on the same southern flank. The towers of Kalianpur, Kham Kera and Donao were being repaired under the orders of the civil authorities. Umrao T. S. which had been built by myself about the season 1844-45 was found in excellent preservation; the central pillar being perfectly sound; its surface as level as the day it was completed, and the mortar as hard as stone. At Pilibhit the Jamay Masjid, a large and remarkably durable building, and other paka points were determined. From here the line of levels might have been carried across country *vid* Mahomdy to Lucknow, or by the road *vid* Shajehanpur, but from information derived from Mr. Florien, Assistant Engineer Oude Canals, either line would have entailed great delay owing to frequent falls &c., whilst that from Bareilly to Shajehanpur by the G. T. road would not only save some 25 miles of levelling, but would afford a number of check points for a new canal under contemplation; the party therefore marched back to Bareilly, and from thence resumed continuation of the first main line from the station church towards Shajehanpur. It was now becoming late in the season, in consequence of which it was intended to close field work on Kasrak station of the Rangir meridional series, about 25½ miles in advance of Bareilly, but on excavation of the large mud pile, which is all there is to indicate the station, the mark-stone was found entombed in a horizontal position. In consequence of this disappointment the work was closed at Fatehganj on the roadside at 0·94 chain east of the mile-stone 51 Futtehgurh, 26 Shajehanpur, 24 Bareilly, on a bench mark consisting of the mark-stone of Kasrak, which was lying useless there and no other suitable stone being available for the purpose. This mark-stone is a cut stone about 36 × 6 × 6 inches. Being slender, a slab of a chaki or native grinding stone, of about 18 inches in diameter, was placed underneath it and the additional precaution was also taken of having under the slab a kankar foundation, well watered and rammed, in order to prevent any future sinking. After about some 10 or 12 hours over the fixing of the bench-mark, which has $\frac{\text{G. T. S.}}{\text{B. M.}}$ engraved on its head, it was connected with the aforementioned mile-stone, and after another similar interval the observations were repeated to test its stability: this condition being satisfied, a suitable space of ground containing both the bench-mark and a brick masonry pillar, constructed to indicate its position, was surrounded by a wooden fence as a protection against carts, and the District Superintendent of Police was also addressed to issue the necessary orders to the Police Officers located within a few yards, right opposite, for their protection and preservation.

(4.) Native Surveyor Nursing Dass reports having, in conformity with Departmental Order No. 1, dated 15th January 1866, repaired 43 platforms, constructed 42 rectangular masonry pillars, and transferred to the charge of the Local Authorities 52 hill stations of the Great Arc Series. Of these the upper mark-stones of the following stations had been removed by the natives and new ones were fixed instead, viz :—

(1.)	Gargaja	66·5	inches	above the lower mark.
	Ehmudpur,	64·6	ditto	ditto.
	Audar,	26·5	ditto	ditto.
	Ladi,	32·5	ditto	ditto.
(5.)	Samasgarh,	21·0	ditto	above the middle mark.
	Ikjera,	53·6	ditto	above the lower mark.
	Yenagapali,	39·5	ditto	ditto.
	Bachapali,	16·5	ditto	ditto.
	Sukli,	40·0	ditto	ditto.
(10.)	Ashti,	14	feet	ditto.

Of the following hill stations the upper mark-stones were found intact viz :—

(11.) Surantal, H.S. Pardho, H.S. Handiaparo, H.S. Bhaorasa, H.S. N.E. End Sironj base-line, S.W. End Sironj base-line, Kalianpur, H.S. Khamkhera, H.S. Gidgarh, H.S. Ranipur, H.S. Ner, H.S. Badali, H.S. Wirur, H.S. Mahur, H.S. Betergaon H.S. Bhesa, H.S. Dudala, H.S. Malgi, H.S. E. end of Beder base-line, W. end of Beder base-line, Damargida, H.S. Muganal, H.S. Burgapali, H.S. Baktapur, H.S. Shevalingapa, H.S. Somtana, H.S. Terban, H.S. Sakri, H.S. Kopdi, H.S. Pilkher, H.S. Badgaon, H.S. and Bhunbet H.S.

Of the hill stations of Bam and Shevni the upper and lower mark-stones were not found, and the former station was transferred to the charge of the village official after merely repairing the platform.

Of the hill stationof Yemsha no vestige of the platform or pillar remains these having been demolished and a temple built over the site about 15 years ago, by the late Raja Ragpat Raddi, of the village of Saranpali in the territory of His Highness the Maha Raja of Indore, who died about 5 years ago.

The rectangular masonry pillars of the following hill stations having been previously constructed by Mr. J. Mulheran, Surveyor 2nd Grade in charge No. 2 or Central Provinces Topographical Survey Party were simply transferred viz :—

Tek, H.S. Morpani, H.S. Narwargarh, H.S. Dhabadao, H.S. Jagdhar, H.S. Alampur, H.S. Salbaldi, H.S. Dhar, H.S. and Nilgarh, H.S.

Supplement to Mr. Lane's Narrative Report for 1866-67.

Mr. Civil Assistant L. H. Clarke, reports having in conformity with Departmental Orders No. 1, dated 15th January 1868, repaired 25 platforms of the Great Arc Series, transferring them after having repaired the platforms and erected rectangular masonry pillars over Circular Pillars.

Of these all the lower mark-stones were found intact, but the upper mark-stones of the following stations had been removed by the natives and new ones were fixed instead, viz :—

Ladpur	upper markstone removed	and platform replaced.
Alipur,	ditto,	ditto.
Dimdimma,	ditto,	ditto.
Dholpur,	ditto,	ditto.
Pagara,	ditto,	ditto.
Raipur,	ditto,	ditto.
Dobi,	ditto,	ditto.
Shergarh,	ditto,	ditto.
Gurjapahar,	ditto,	ditto.
Machi,	ditto,	ditto.
Nuidhar,	ditto,	ditto.
Juktipura,	ditto,	ditto.
Mao,	ditto,	ditto.
Nimdant,	ditto,	ditto.
Hatiapahar,	ditto,	ditto.
Diadbei,	ditto,	ditto.
Berkbei,	ditto,	ditto.
Gugabara,	ditto,	ditto.
Mimoni,	ditto,	ditto.
Kasri,	ditto,	ditto.
Chilwani,	ditto,	ditto.
Den,	ditto,	ditto.

Of the following hill stations the upper markstones were found intact viz :—

Madhoni (mark-stone *in situ*).
Usira.
Pahargarh.

EXTRACT FROM THE NARRATIVE REPORT OF CAPTAIN J. P. BASEVI, R.E., SURVEYOR 1ST GRADE, IN CHARGE NO. 4 EXTRA PARTY, NO. 58, DATED 10TH AUGUST 1868.

(2.) During August and September 1867 I made some experiments at Chiculdah on the correction due to the readings of a thermometer on account of the diminution of the pressure on its bulb when placed in an exhausted receiver. For the purpose of determining this correction I had been supplied with a thermometer hermetically enclosed in a glass tube whose readings would of course be unaffected by change of pressure. This is placed in a receiver alongside of the thermometers to be experimented on, and the difference of its readings before and after the exhaustion indicates the true change in the temperature of the receiver; so that the difference between the above differences and those shewn by the other thermometers is the effect of the diminution of pressure on them.

Experiments at Chiculdah on the correction to a thermometer on account of reduction of atmospheric pressure.

(3.) When at Mussoorie in the year 1865 I took some observations for this same purpose, using a small airpump and receiver borrowed from the Roorkee C. E. College, but obtained very unsatisfactory results, owing, partly perhaps to the smallness of the receiver, but chiefly to my not allowing a sufficient interval of time to elapse after pumping out the air. For the process of exhausting *lowers* the temperature, and on the contrary when the air is re-admitted the temperature of the receiver is *raised* by an amount equal to that by which it had been previously lowered. The ordinary thermometers rapidly assume the temperature of the receiver, but the* hermetically sealed one requires very much more time, so that unless a considerable time is allowed to elapse, the effect of diminution of pressure on the bulb of the thermometer is mixed up with the effects due to the exhaustion of the air.

Reason of similar Mussoorie observations failing.

(4.) In my observations at Chiculdah I used the large receiver in which the pendulums are swung, and after exhausting always allowed a long time generally as much as 24 hours to elapse before reading the thermometers. The results are as follows :—

Results at Chiculda.

No. of observations.	Pressure in Inches.	Corrections.			Remarks.
		No. 714.	No. 715.	Mean.	
		°	°	°	
3	1·8	+ 0·31	+ 0·27	+ 0·29	Average atmospheric pressure at Chiculdah 26·2 inches.
6	4·4	·24	·25	·25	
7	7·8	·20	·21	·21	
6	12·8	·11	·12	·12	

This correction most probably depends on the form of the bulb.†

(5.) The party consisting of Mr. W. M. Lemarchand and Mr. J. W. Macdougall both Sub-Assistants 3rd Grade took the field on the 11th October, leaving Chiculdah on that date and Ellichpore on the 16th of October.

Arrangements for Field Season 1867-68.

(6.) From Budnaira I detached both my Assistants, Mr. Lemarchand marching ahead to prepare the observatory at Somtana H.S. near Nandair in Hyderabad territory, and Mr.

* When testing the freezing points the hermetically sealed one requires at least one hour's immersion in the ice, whilst the others fall to 32° in a quarter of the time.

† Note.—General Sabine (Phil. Trans. 1829) obtained a correction of 0·7 of a degree for one thermometer, and as much as 1° for another which had a bulb of unusually large diameter. In the preliminary Pendulum Observations at Kew the correction to thermometers No. 712 and 714 was found to be + 0°·43 from one experiment only.

Macdougall went by rail *vid* Sholapore to Damargida near Beder to get that observatory ready, he was directed to await there further orders from me, my intention being to recall him to the main party or send him further ahead according to the progress made by Mr. Lemarchand. I myself marched to Badgaon, 16 miles from Budnaira, where the observatory had been built last season. During Mr. Macdougall's absence my wife recorded for me, but all computations made in the books have been of course since examined.

Delayed at Badgaon H.S. clock out of order.

(7.) I experienced much delay at Badgaon in consequence of the bad going of the clock shelton, and had to reject several days observations and replace them by others, so that although I commenced work on the 25th October, the observations were not completed until the 16th of November.

Magentic observations at Bombay on H.I.

(8.) I now, in accordance with your instructions, went down to Bombay for the purpose of taking Magnetic observations at the Government Observatory and so comparing my results with theirs. I reached Bombay on the 19th November and took observations for horizontal intensity on the 22nd and 23rd, my result are

22nd	November	8·0768
22nd	,,	8·0618
23rd	,,	8·0649
Mean		8·0678

The mean of two observations taken at the Observatory on the 20th November (provisionally reduced) was

8·068

which almost exactly agrees with my own determination.

Determination of specific gravities of Pendulums at Bombay mint.

(9.) I also when in Bombay took my two Pendulums to the mint for the purpose of determining their specific gravities. A tin trough was made up for me, capable of receiving the pendulum, which was placed above one scale pan of the balance, being supported independently from the ground on boxes; each pendulum was suspended by wire inside the trough and weighed water was then poured into the trough until the pendulum was completely immersed and its weight again taken. I noted the length of the wire not immersed and measured and weighed the wire. The water used was Vehar water taken from a large reservoir in the mint. A short time before weighing I weighed by means of a specific gravity bottle equal volumes of the Vehar water and distilled water, noting the temperatures. In all these measurements one of the officers of the mint most kindly assisted me. The results are

No. 4 *Pendulum*

Results. Weight in air 95,536·4 grains specific gravity 8·023

No. 1821 *Pendulum*

Weight in air 91,723·4 grains specific gravity 7·929 at temperature 81° F. compared with distilled water at 39·°2 F.

Remarks on the smallness of the results.

(10.) These specific gravities are both, I believe, unusually small for brass, and I intend, if opportunity offers, to repeat the determination; at the same time I have no other reason for suspecting their accuracy, and the only omission that I can think of was the neglecting to note the temperature of the water at the time of weighing. As however the water was taken from a *large* reservoir and its temperature was observed a short time before, there cannot be an uncertainty about the temperature sufficient to produce any very appreciable effect on the specific gravities.

Thermometers tested in ice.

(11.) I also in Bombay procured some ice and tested the freezing points of my thermometers. I left Bombay on the 23rd of November and reached Budnaira on the 24th and at once marched for Somtana.

(12.) Observations were commenced at Somtana on the 20th December and completed on the 4th January. The going of the clock here was excellent and I am disposed to attribute its bad behaviour at Badgaon to the presence of a small brass clamping nut which I had attached to the adjusting screw of the pendulum in order to preserve an invariable length. I had never used this nut prior to Badgaon and I removed it before commencing operations at Somtana. It is difficult to conceive how it affected the regularity of the clock's rate but I can see no other explanation.

Somtana.

Explanation of the bad going of the clock at Badgaon.

(13.) I marched from Somtana to Damargida and commenced observations there on the 22nd January. At this station in compliance with a suggestion made by yourself I took a "set" with each pendulum in a *falling* temperature, the "set" commencing at about 8 o'clock P. M. and lasting until about 5 o'clock A. M. The object of these observations was to ascertain whether the temperature of the pendulum *lagged* behind the temperature of the air to any appreciable extent. The thermometers on the dummy pendulum are not in contact with it, and so only record the temperature of the *air* inside the vacuum cylinder. If therefore any lagging exists, in a rising temperature the pendulum will be always behind the temperature shewn by the thermometers, consequently too high a temperature will be imputed to it and the number of vibrations will be *apparently* in excess. In a *falling* temperature the converse will hold, the temperature of the pendulum will be *above* the thermometer readings and the vibrations will be *apparently* in defect. The results obtained are as follows :—

Damargida.

Observations to determine the amount of "lagging."

			Vibrations.		
	Rising temperature		86,036·902	Range	70° to 76°
Pendulum No. 4.	Falling	„	36·437	„	76 „ 70
		Mean	86,036·670		

Results. In a {Rising / Falling} temperature, vibrations are 0·232 {in excess / in defect.

Dividing by 0·486 the temperature co-efficient the amount of lagging = 0°·48 F.

			Vibrations.		
	Rising temperature		85,935·474	Range	69° to 74°
Pendulum No. 1821.	Falling	„	35·127	„	74 „ 69
		Mean	85,935·300		

In a {Rising / Falling} temperature, vibrations are 0·174 {in excess / in defect.

Dividing by 0·470 the temperature co-efficient the amount of lagging is found to be = 0°·37 F.

(14.) These observations, though of course too few to be conclusive as to the *amount* of the lagging, still I think establish the existence of it, and shew the necessity of taking it into account. For since the duration of each "set" is constant, it is obvious that the amount of the lagging must vary with the range of temperature, and consequently observations at different stations are not strictly comparable unless the range is the same. It would have been undoubtedly better to have so observed that the effect of lagging should cancel at each station, but now the only thing to be done is to take special observations in order to correct for it, for it would necessitate the adoption of a new system of observation which would be on many grounds objectionable.

Observations not sufficient to be conclusive but shew the necessity of further examination.

(15.) Observations were completed at Damargida on the 1st of February, and, having spare time the Kota Kodungul observatory being only just completed, I marched first to Secunderabad where I took a set of magnetic observations and also again tested my thermometers in ice not having been quite satisfied with my Bombay results. I reached Kodungul on the 23rd February where I was joined by Mr. Macdougall.

Kota Kodungul. Magnetic observations taken at *Secunderabad.*

(16.) I finished off at Kodungul on the 10th March and marched *viâ* Kurnool, where I took magnetic observations, to Namthabad station close to Gootty and one of Colonel Lambton's latitude stations. Observations were completed here on the 15th April when I proceeded by dâk and rail in advance of my camp to Bangalore, leaving it to follow in charge of Mr. Macdougall by the regular marches. It arrived on the 30th April.

Magnetic observations taken at *Kurnool Namthabad.*

Return to quarters.

(17.) The field season's work comprises pendulum and magnetic observations at five stations *viz.*, Badgaon, Somtana, Damargida, Kota Kodungul, Namthabad, and magnetic observations at these and four other places *viz.*, Chiculdah, Bombay, Secunderabad, Kurnool.

Out-turn of work.

(18.) I have now to report on my assistants Mr. W. M. Lemarchand prepared the observatories of Somtana, Kota Kodungul and Namthabad and made a rough survey of the Somtana hill. On the completion of the last station, having been offered the appointment of Local Fund Engineer at Ellichpore, he resigned his appointment in the survey, and was allowed to proceed to take up his new one in anticipation of the sanction of Government. He is a great loss to my party in which he had done very good work.

Mr. W. M. Lemarchand.

(19.) Mr. J. W. Macdougall, as already stated, prepared the Damargida observatory for me, and afterwards partly assisted Mr. Lemarchand in building the one at Kodungul; he recorded for me at Kodungul and Namthabad, and brought up all the arrears of computations which had accumulated during his absence from the main party. I have no reason to alter the favorable opinion I expressed last year of Mr. Macdougall, he is a valuable assistant and well up in all the computations.

Mr. J. W. Macdougall.

(21.) In appendix III. is given a table of the probable errors of the various kinds which are susceptible of calculation for each station from the commencement. The *mean* results from 15 stations are

Probable errors given in Appendix III.

Transit observations.

Probable errors of star's transit over one wire,	= ± 0^s·092	Extremes ± ·141 and ± ·061	
Probable error of mean of 5 wires,	= ± 0·041	,,	± ·063 and ± ·027
Probable error of clock rate deduced from 6 stars,	= ± 0·031	,,	± ·051 and ± ·016

Pendulum observations.

	No. 4.	No. 1821.
Probable error of observation of one coincidence,	= ± 0^s·472	± 0^s·472
Deduced probable error of vibrations per diem,	= ± 0^v·026	± 0^v·029

Computed from results.

	No. 4.	No. 1821.
Probable error of one "set" at a station,	= ± 0^v·167	± 0^v·149
Probable error of result at a station,	= ± 0^v·058	± 0^v·054

(23.) During the last two seasons I have kept a register of the readings of an aneroid barometer at all places that I have visited. Appendix VIII, gives the results of these observations from Meerut to Bangalore. They are computed by table XVIII, of Boileau's tables, the observed heights being the difference of the tabular numbers due to 30·00 inches and to the observed barometer reading. A mean correction is obtained from the difference between the thus computed and the trigonometrical or spirit leveling heights of two stations including the other stations. For instance the correction for stations between

Barometric heights of stations en-route between Meerut and Bangalore.

Somtana and Damargida is obtained from the mean difference between the computed and trigonometrical values of these two stations.

(24.) I have already alluded to the necessity of taking observations to determine the effect of "lagging"; there is another subject of equal importance to which my attention was also directed by yourself. It has been shewn that the temperature of the pendulum lags behind the readings of the thermometer; but besides this effect and after making due allowance for it, it is probable that the thermometers will still not give the true *mean* temperature of the pendulum; for the thermometers have been placed on the dummy pendulum at two points equidistant from the ends of the bar and from each other, so as to give the temperature of the bar, but not the mean temperature of the whole pendulum. Were the pendulum *at rest* its mean temperature would be found by the formula

On the mean temperature of a pendulum.

$$T = \frac{m_1 t_1 + m_2 t_2 + m_3 t_3}{m_1 + m_2 + m_3}$$

where m_1 m_2 m_3 denote the masses of the bar, bob and tailpiece, and t_1 t_2 t_3 are their respective temperatures. When however the pendulum is in motion, its *mean* temperature is that which, if common to the whole pendulum, would cause its vibrations to be performed in the same time.

Supposing the pendulum homogeneous it can be shown that the true mean temperature which may be called "mean *vibrating* temperature" is given by the formula

Mean "vibrating" temperature defined and formula.

$$T = \frac{2 \cdot \Sigma [m k^2 T]}{\Sigma [m k^2]} - \frac{\Sigma [m a T]}{\Sigma [m a]}$$

where $m k^2$ denotes the moment of inertia of one of the masses (m) of which the pendulum is composed, T the temperature of k its radius of gyration, and a the distance of its centre of gravity from the axis. Applying this formula to the pendulums in use whose dimensions are very nearly the same, I find

Application to Indian pendulums.

$$T = 0{\cdot}91\, t_1 + 0{\cdot}08\, t_2 + 0{\cdot}01\, t_3$$

where t_1, t_2, t_3 are the temperatures of the bar, bob and tailpiece respectively, so that the thermometers are in a very favorable position for determining the true mean vibrating temperature, unless the differences of temperature between the bob and upper bar are large which is not likely to be the case in practice. The proof of the preceding formula is given in Appendix IX. it is, I believe, a new way, but at the same time the most theoretically correct way of determining the mean temperature of a pendulum.

Result. That the thermometers as placed give the mean vibrating temperature with sufficient approximation.

Abstract of heights of places visited during seasons 1866-67 *and* 1867-68, *computed from the readings of an aneroid Barometer.*

	Stations.	Computed heights in feet.	Heights by spirit leveling or trigonometrical operations.	District.
Road Meerut to Agra,	Kharkaoda encamping ground, ...	739	714	Meerut.
	Hauper „	649	693	„
	Galaoti „	667	681	Bolandshahur.
	Bolundshahur „	649	667	„
	Khoorjah „	693	655	„
	Somna „	636	622	„
	Allyghur „	604	606	Allyghur.
	Sasnee „	591	589	„
	Hattras „	622	...	„
	Saidabad „	684	...	Agra.
Agra and Indore road,	Thehara „	616	...	Dholepore.
	Munia „	643	...	„
	Dholepore „	687	...	„
	Noorabad „	696	588	Gwalior.
	Gwalior near old Residency, ...	670	680	„
	Paniar encamping ground, ...	884	948	„
	Raint „	1119	...	„
	Mohona „	1101	1020	„
	Choorpoora „	1292	...	„
	Satambara „	1374	1338	„
	Seepree south of cantonment, ...	1484	...	„
	Do. traveller's bungalow, ...	...	1516	„
	Kolaras encamping ground, ...	1374	...	„
	Lakwasa south of village, ...	1420	1461	„
	Badurwas encamping ground, ...	1447	1492	„
	Pahargarh H.S., ...	...	1641	„
	Kala Bagh village, ...	1508	...	„
	Goonah cantonment, ...	1555	...	„
	Araon large village on road to Seronj, ...	1731	...	„
	Kalianpore observatory, ...	...	1765	Tonk.
	Ehmadpore H.S., ...	...	1681	Gwalior.
Bhilsa to Ellichpur,	Bhilsa south of town, ...	1431	...	Bhopal.
	Raiseen „	1506	...	„
	Bunchor village, ...	1533	...	„
	Chukloud „	1579	...	„
	Kalliakheri „	1561	...	„
	Chouki encamping ground, ...	1491	...	„
	Jerrapur on N. bank of Nurbudda, ...	1084	...	„
	Hosungabad cantonment, ...	1120	...	Nurbudda.
	Itarsee near traveller's bungalow, ...	1175	...	„
	Kaisla village	1284	...	„
	Dhar „	1395	...	„
	Nimpanee „	1990	...	„
Road Badnur to Ellichpur,	Badnur civil station of Baitool, ...	2198	...	„
	Kairree village N. of Taptee, ...	2122	...	„
	Jhular „ S. „	2389	...	„
	Dawa „	1746	...	Berar.
	Ellichpur cantonment, ...	1440	...	„

Abstract of Heights Continued.

	Stations.	Computed heights in feet.	Heights by spirit leveling or trigonometrical operation.	District.
	Chickuldah, Colonel Prescott's house, ...	3721	3730	Berar.
	Badgaon H.S., ...	...	1120	,,
Ellichpur to Nandair and Hyderabad.	Karinja traveller's bungalow, ...	1293	...	,,
	Mungrool, ...	1383	...	,,
	Bassim close to cutcherry, ...	1692	1758*	,,
	Kinergaon S. bank of Paeen Ganga, ...	1518	...	,,
	Kondallah, ...	1673	...	,,
	Hingollee cantonment, ...	1473	1495*	Hyderabad.
	Nandapur S. bank of Khair Nuddee, ...	1383	...	,,
	Sindaghee, ...	1437	...	,,
	Korundah, ...	1293	...	,,
	Mullaigaum, ...	1238	...	,,
	Nandair N. bank of Godavery, ...	1203	1276*	,,
	Moodkhaid, ...	1221	...	,,
	Sindee, ...	1265	...	,,
	Somtana H.S., ...	...	1711	,,
Nandair and Hyderabad road,	Kapsi, ...	1210	...	,,
	Manjeeram, ...	1318	...	,,
	Salgera, ...	1210	...	,,
	Yeklar, ...	1201	...	,,
	Bichkoonda large place, ...	1236	...	,,
	Burra koorupokul, ...	1516	...	,,
	Kullair, ...	1435	...	,,
	Nizampett large place, ...	1489	...	,,
	Narainkhaid ,, ...	1699	..	,,
	Damergida observatory, ...	...	1934	,,
Nandair and Hyderabad road,	Sunkerrumpettah, ...	1536	...	,,
	Jogiepettah, ...	1709	...	,,
	Nawabpettah, ...	1609	...	,,
	Bagumpettah, ...	1627	...	,,
	Ramachandrum, ...	1709	...	,,
	Cokutapilli, ...	1792	...	,,
	Secunderabad cant. near traveller's bungalow,	1728	1800*	,,
	Boorhan sahib's doorgah near Hyderabad city,	1590	...	,,
	Shumshabad traveller's banglow Kurnool road,	1847	...	,,
	Conatoor cross road to Koasghi and Narrainpett,	2125	...	,,
	Moojanthpoor, ,, ,,	2041	...	,,
	Dhadapur, ,, ,,	1884	...	,,
	Hossanabad, ...	1856	...	,,
	Kota Kodungul H.S., ...	...	1972	,,
	Doulatabad, ...	1836	...	,,
	Kaungoortee on road Beder to Narrainpett, ...	1938	...	,,
	Narrainpett large place, ...	1389	...	,,
	Palmamodi, ...	1335	...	,,
	Nirwah, ...	1262	...	,,
	Ammurchinta, ...	1181	...	,,

Note.—The heights marked with an asterisk are taken off the Quarter Master General's Map of the Madras Presidency (1863).

Abstract of Heights Continued.

	STATIONS.	Computed heights in feet.	Heights by spirit levelling or trigonometrical operations.	DISTRICT.
	Venkatapuram on Hyderabad and Kurnool road,	1074	...	Hyderabad.
	Pangtoor south bank of Kistna, ...	976	...	„
Kurnool to Gootty.	Kurnool cantonment traveller's bungalow, ...	993	900*	Kurnool.
	Chinna Taykoor „ ...	1057	...	„
	Eldoortee „ ...	1163	...	„
	Dhone „ ...	1416	+2148*	† Probably Hill Stn.
	Piapullee „ ...	1708	...	„
	Namthabad Station, ...	...	1219	Bellary.
Road Gootty to Bangalore.	Paumree traveller's bungalow, ...	1129	...	„
	Garraldinny „	1175	...	„
	Hundy Anantapoor „	1193	...	„
	Dadaloor „	1346	...	„
	Cottoor „	1601	...	„
	Palsamoodrum „	2314	...	„
	Baugapilli „	2389	...	Mysore.
	Wooralconda „	2741	...	„
	Wonaikul „	3039	...	„
	Cheddulpur „	3010	...	„
	Dawundhully „	2991	...	„
	Yellawunkah „	2991	...	„
	Bangalore, ...	...	3000*	

NOTE.—The heights marked with an asterisk are taken off the Quarter Master General's Map of the Madras Presidency (1863).

On the mean Vibrating Temperature of a Pendulum.

Suppose the pendulum to be homogeneous and to consist of the several masses $m_1\ m_2 \ldots m_u$ whose centres of gravity are distant $a_1\ a_2 \ldots a_u$ from the axis of suspension, their mean temperatures $t_1\ t_2 \ldots t_u$ and moments of inertia at the zero from which the above temperatures are measured $m_1 k_1^2,\ m_2 k_2^2 \ldots m_u k_u^2$.

Then the length of the corresponding simple pendulum at that temperature.

$$l = \frac{\Sigma[m k^2]}{\Sigma[m a]}$$

Let $T_1\ T_2 \ldots T_u$ be the temperatures of $k_1\ k_2 \ldots k_u$ which may be supposed to hold also for $a_1\ a_2 \ldots a_u$ then the length of the simple pendulum will be.

$$l' = \frac{\Sigma[m k^2 (1 + 2 f T)]}{\Sigma[m a (1 + f T)]} = \frac{\Sigma[m k^2] + 2 f \Sigma[m k^2 T]}{\Sigma[m a] + f \Sigma[m a T]}$$

where f is the factor of expansion of the metal of which the pendulum is composed, the second powers of which are neglected.

Again if $\mathbf{T}$ = mean vibrating temperature we must have

$$l' = \frac{\Sigma[m k^2](1 + 2 f T)}{\Sigma[m a](1 + f T)} = \frac{\Sigma[m k^2] + 2 f T \Sigma[m k^2]}{\Sigma[m a] + f T \Sigma[m a]}$$

whence

$$\Sigma[m a]\Sigma[m k^2] + 2 f \Sigma[m a]\Sigma[m k^2 T] + f T \Sigma[m a]\Sigma[m k^2] = \Sigma[m a]\Sigma[m k^2] + f \Sigma[m k^2]\Sigma[m a T] + 2 f T \Sigma[m a]\Sigma[m k^2]$$

or

$$\mathbf{T} = 2 \frac{\Sigma[m k^2 T]}{\Sigma[m k^2]} - \frac{\Sigma[m a T]}{\Sigma[m a]}$$

Applying this result to the pendulums whose dimensions are so nearly the same that the values of $\mathbf{T}$ obtained for one will hold good for the other

Bar	$m_1 k_1^2$	=	3,880	$m_1 a_1$	=	154	k_1	=	18·8	a_1	= 14·0
Bob	$m_2 k_2^2$	=	54,635	$m_2 a_2$	=	1,352	k_2	=	40·4	a_2	= 40·3
Tailpiece	$m_3 k_3^2$	=	2,990	$m_3 a_3$	=	61	k_3	=	49·4	a_3	= 49·0
	$\Sigma[m k^2]$	=	61,505	$\Sigma[m a]$	=	1,567					

whence we get

$$\mathbf{T} = \cdot 03\ T_1 + \cdot 91\ T_2 + \cdot 06\ T_3$$

But assuming the temperatures $t_1\ t_2\ t_3$ of the bar, bob, and tailpiece to hold good for their respective lengths we find

$$T_1 = t_1;\quad T_2 = \frac{37}{40} t_1 + \frac{3}{40} t_2;\quad T_3 = \frac{37}{49} t_1 + \frac{6}{49} t_2 + \frac{6}{49} t_3$$

whence finally

$$\mathbf{T} = 0{\cdot}91\ t_1 + 0{\cdot}08\ t_2 + 0{\cdot}01\ t_3$$

EXTRACT FROM THE NARRATIVE REPORT OF J. B. N. HENNESSEY, ESQ., SURVEYOR 1ST GRADE G. T. SURVEY, IN CHARGE COMPUTING OFFICE, DATED 1ST MAY 1868.

(4.) The ordinary work of the twelvemonth is set forth in the following tables :—

Progress.

Subject.	Quantity.
Examined indexing,	298 volumes of angle books.
Numbered pages of and indexed,	118 do.
Micrometer readings, copied,	69½ openings of an angle book.
Do. compared,	52½ do.
Mean readings, computed,	22½ do.
Do. examined or compared,	491 do.
Angles, computed,	46½ do.
Do. examined or compared,	637 do.
General means and level corrections, (of vertical angle book) computed,	19½ do.
Do. do. examined or compared,	158 do.
Abstracted observed angles,	927 angles.
Abstract of angles, copied,	279 do.
Do. compared,	126 do.
Weights of observed angles, computed,	597 do.
Spherical excesses, computed,	78 triangles.
Principal triangles, computed,	44 do.
Computation of principal triangles, extended to 8th place of logs,	642 do.
Principal latitudes, longitudes and azimuths, computed,	29½ single deductions.
Computed corrections to figures, by the method of least squares,	1 quadrilateral. 5 simple figures. 14 compound figures.
Made consistent to within 5 in the eighth place of logs, figures already reduced,	8 quadrilaterals. 18 simple figures. 4 compound figures.
Computed weights of sides of continuation,	27 quadrilaterals. 1 simple figure. 8 compound figures.
Computed azimuths observed at	12 stations.
Computed latitudes observed at	2 do.
Compared proofs of,	473 pages.
Letters written and copied during the year,	199.

(5.) *Auxiliary Tables.*—I have also to notice the revision and extension of the old "Tables to facilitate the computation of a Trigonometrical Survey," published under the title of "Auxiliary Tables." The amount of addition to the old tables may be estimated from the circumstance, that while they were included in 43 pages of type, the auxiliary tables extend over 83 pages of a larger size.

(6.) *Miscellaneous Duties.*—Prominent notice is due to a large amount of calculations made, in connection with the reduction of triangulation executed on the Gridiron system, and more especially with the view of making consistent the triangulation understood by the N.W. Quadrilateral. I am obliged to content myself with this brief and general allusion to these processes, on which the most earnest efforts of the Computing Office have been expended, because a more detailed notice would involve the introduction of technicalities that could not be made generally intelligible except by a lengthy explanation. It may be sufficient therefore to state, that the subject of such reduction having undergone an exhaustive discussion under your directions, a definite process of working this geodesical problem stands established in almost every detail.

(7.) Comparison of instruments and meteorological observations.—Forty-five thermometers were rigorously compared with the standard 4,246 at every 2° fahrenheit, and tables of corrections prepared for all the thermometers at each degree of temperature. The Dehra meteorological observatory was organized and set working. A complete set of observations is taken there, twice a day, on every day of the year, and the results supplied to the Reporter on Meteorology, N. W. Provinces. Nearly similar observations were taken at Mussoorie for a portion of the year. Barometer tubes have been filled, and the index errors of the instruments determined when required.

(8.) *Magnetic Observations.*—These observations have been taken in compliance with your wishes by Mr. W. H. Cole, M. A., they consist of measures of the following elements :—

Dip.—Observed monthly, 24 readings, at least, of each of numbers 1 and 2 needles taken on each occasion.

Vibration.—Observed monthly. Two sets of observations taken on each occasion.

Deflection.—Observed monthly. One set of observations taken on each occasion.

Declination.—Observed occasionally.

(9.) *Photozincographic Branch.*—The work performed by this office is set forth in the following table :—

Maps Photo-zincographed.	No. of parts.	No. of copies.
Path of Eclipse for pamphlet, ...	1	27
Kashmir Survey, section 11, ...	1	106
,, section 12, ...	1	106
,, section 13, ...	1	106
,, section 17, ...	1	106
Kumaon and Gurhwal, No. 1, ...	1	150
,, No. 6, ...	1	150
,, No. 7, ...	1	150
Leveling operations, Sheet No. 1, ...	1	150
Bench marks, ...	1	150
Leveling operations, Sheet No. 3, ...	1	150
Bench marks, ...	1	150
Turkestan, Sheet No. 1, ...	1	300
,, Sheet No. 2, ...	1	450
Dehra Dhoon, ...	1	200
Totals, ..	15	2,451

Maps Zincographed.	No. of parts.	No. of copies.
Sketch of Goojrat, ...	1	24
Map of the world, ...	1	1,000
Map of Syr Daria, ...	1	100
Canal charts for Captain Jeffreys, ... No. 1, ...	2	30
No. 2, ...	1	30
No. 3, ...	1	30
No. 6, ...	1	30
Rails and telegraphs of India, ...	1	1,050
Pundit's Route, ...	2	250
Path of Eclipse of August 1868, ...	1	235
Total, ..	..	2,779

Charts Zincographed.	No. of parts.	No. of copies.
Eastern Frontier Series, 1862-63, ...	1	50
,, 1863-64, ...	1	50
,, 1866-67, ...	2	50
Madras Meridional Series, No. 9, ...	1	50
,, No. 10, ...	1	50
Revised Calcutta Longitudinal Series, No. 3, ...	1	50
,, ,, No. 4, ...	2	50
Coast Series, No. 1, ...	1	50
,, No. 2, ...	1	50
,, No. 3, ...	1	50
,, No. 4, ...	1	50
,, No. 5, ...	1	50
,, No. 6, ...	1	50
,, No. 7, ...	1	50
,, No. 8, ...	1	50
Preliminary Chart, Minor coast series, ...	1	50
,, Cherrapoonjee and Sylhet 1859 to 1861, ..	4	50
,, ,, ,, 1861-62, ..	1	50
East Calcutta Longitudinal Series, ...	1	50
Jubbulpore Meridional Series, ...	1	50
Total, ..	..	1,000

Forms Zincographed.	No. of subjects.	No. of copies.
Office, ...	33	6,079
Professional, ...	23	4,204
Professional for Abyssinian expedition, ...	4	248
Total, ..	60	10,531
Diagrams of various kinds, ...		1,148

Comparing the work of 1866-67 against that of 1867-68, it appears that,—

Subjects.	1866-67 No. of prints.	1867-68 No. of prints.	Increase of work No. of prints.
Maps, Charts and Diagrams, ...	7,118	7,376	260
Forms, " Professional" " Office" &c., ...	5,152	10,531	5,379

10. In point of quantity, the work performed is quite as good as that of the preceding year, while this process of map printing is yearly acquiring a larger range of utility. I believe however that the definition of the prints can be further improved, and it is highly desirable that the process of transferring a subject should be performed with greater certainty. Every effort is being made in these directions, and I trust hereafter to be able to report, that the improvement in the quality of the work keeps pace with the quantity required to be discharged. It will be observed that the annual demand for forms by the G. T. Survey department has in 1867-68, for the first time, been met entirely by the two presses at the head quarters of the Superintendent. This advantage will be the more apparent, if it be remembered, that the larger number of forms involve the tabulation of mathematical formulæ, and that, unless such forms can be passed through the press under qualified supervision, they are likely to contain errors which would detract seriously from their usefulness.

(11.) *Printing Branch.*—This office composed 641 pages (foolscap size), and printed 126,296 impressions of them. Compared with the work of 1866-67, there were 145 pages fewer composed and 32,885 pages more printed. The duties of this branch have been discharged with greater efficiency than during the preceding year, and its utility in printing professional papers, proved, by the publication of several pamphlets.

(12.) I gladly avail myself of this opportunity to acknowledge the cordial assistance I have always received from Lieutenant M. W. Rogers, R.E., and Mr. W. H. Cole, M.A.

(13.) I would also express my thanks to Mr. C. Wood for his willing and very useful aid, and to Baboo Gunga Pershad for the help he has afforded. Baboo Gopal Chunder Sircar continues painstaking and anxious to prove efficient. Baboo Kally Mohun Ghose is gradually becoming a leading computer.

Bangalore base-line.

(14.) I now turn to the measurement of the Bangalore base-line, which you directed me to superintend.

(15.) Lieutenant M. W. Rogers, R.E., took charge of the standard and compensated bars, thermometers and such other components of the measuring apparatus as were deposited at your head quarters at Dehra; and proceeded with them to Calcutta; where I joined the party.

(16.) The heavy portion of the apparatus had already been forwarded to Lieutenant W. M. Campbell, R.E., so that it awaited our arrival at Bangalore.

(18.) At Bangalore, I met Lieutenant J. Herschel, R.E., and Lieutenant W. M. Campbell, R.E., with the assistants and native establishment appointed by you to take part in the measurement.

(20.) Captain B. R. Branfill, returned from leave to England and resumed charge of the Madras party during the measurement of the 1st section. Being under orders to proceed to Cape Comorin and select a base-line there, he took no part in the measurement; but he was good enough to leave the 4 assistants of his party, as well as the greater portion of his native establishment at my disposal; taking with him to the Cape, only a sufficient number of natives to aid him in the required selection.

(21.) The Bangalore base-line had been selected under Lieutenant Campbell's directions by Mr. Donnelly. The stations of the minor triangulation, as well as the section stations of the base had also been chosen by Lieutenant Campbell. He had further generally prepared the ground for measuring over, and had also made the requisite arrangement for building the observatories at either end of the base-line as well as for the construction of the section stations and those of the verificatory triangulation. Thus on my arrival at Bangalore, I found that the preparatory arrangements had all been effected with every desirable efficiency, and it only remained to instruct the sub-assistants in the use of the base-line microscopes, before commencing work. With the exception of Mr. Mitchell, none of these assistants had been present at previous base-lines,—they however shortly acquired the necessary knowledge under instruction from Lieutenants Herschel, Campbell and Rogers.

(22.) The base-line in question runs over the undulating ground which lies, generally, north of the large military station of Bangalore. It trends N.E. and S.W. being about 6·84 miles in length, and its S.W. end is under 2 miles from the cantonment. The sum of the rises and falls in this line, is much greater than in any of the preceding 8 Indian base-lines; but considering the height above sea level at which the line stands (about 3,000 feet) and the nature of the surrounding country, I am of opinion that the selection made is as good as could be expected. I may here allude to Colonel Lambton's base-line which lies some 7 miles, generally S.E. of that measured under your orders, and to your wish that the Bangalore line should correspond with the one chosen by the Colonel. This condition could not be secured as the railway now runs across the desired line.

(23) After due consideration, I decided on commencing to measure at the S.W. end. The comparing microscopes were set up there for bar comparisons on the 3rd January and the entire process of measurement and comparison, including the packing of the apparatus, was concluded on 12th March 1868.

(24.) The line, as measured, was nearly 573 sets of bars and microscopes in length, or about 6·84 miles. This distance was divided into 3 sections. The bars were compared before and after the measurement, and also about the middle of that process.

(25.) The Boning Instrument and the two end microscopes were manipulated by Lieutenant Herschel, Lieutenant Campbell, and myself. We exchanged places at the commencement of each section, so that each observer occupied the three most important positions in the measurement successively, and thus acquired a practical knowledge of every detail. Lieutenant Rogers had charge of the microscope in the middle of the set of bars for about a quarter of the measurement, when he was temporarily incapacitated for further work by an attack of illness. On his recovery, he was deputed to proceed with the minor and connecting triangulations, as will be mentioned hereafter. The other intermediate microscopes were manipulated chiefly by Messrs. Donnelly, Anding, Christie, Bond and Norris, the trestles being laid for by far the greater portion of the line by Mr. Mitchell. Mr. Potter's state of health excluded him from nearly all the duties of the measurement. When able to resume work, he was employed chiefly on the construction of the observatories and the building of platforms.

(26.) It has been the practice at previous base-lines to fix the section stations at an integral number of sets of bars and microscopes (nearly) from the origin. This necessitated an approximate determination of the required points, and it was unavoidable to fix the blocks of stone for carrying the marks only a few days before the measurement reached them. With your permission this source of instability was avoided at the Bangalore base, by fixing the section points in direction, *i. e.* in the line, but without regard to their occupying assigned positions in length. The blocks of stone for the dots were thus fixed in line by Lieutenant Campbell before the measurement was commenced, and the distances of these points, from an end of the nearest bar when laid down, was taken off with the aid of a beam compass. The height of register above the dot on the tongue, was determined, at your suggestion, by marking the nozzle at the height of the dot, and measuring from the top of the register to this mark.

(27.) In compliance with your wishes, the S.W. end of the line was connected by spirit leveling with the railway bench-mark at Bangalore railway station. This bench-mark had been referred to "Colonel D'Haveland's mark near Fort St. George" by the railway engineers, and I was informed by the Deputy Chief Engineer that the *bench-mark* in question was 3,033·97 feet above the mean sea level at Madras. Mr. Donnelly performed the required spirit leveling, and as a precaution against mistakes, I directed him to determine the difference of level by two independent routes. The resulting circuit agreed satisfactorily.

(28.) The verificatory minor triangulation of the base-line, the triangulation connecting Colonel Lambton's base with our main series, the measurement of the angles to Colonel Lambton's station of Dodagunta, and of the angles at Tirtapali and Ossur Principal stations, besides the determination of the azimuth at the extremities of the base-line by observations to stars about their maximum elongations; these duties were all executed by Lieutenant M. W. Rogers, R.E., with Barrow's 24 inch theodolite No. 2. He thus set up his instrument at 16 stations, three of these being unavoidably visited twice over, and measured 45 angles, besides the determination of the two azimuths already mentioned. His average triangular error is 0″·49 and his mean $p.\ e. = 0{\cdot}26$. Lieutenant Rogers' report is appended to this paper.

(29.) The base-line apparatus, together with the books of the measurement and the records of Lieutenant Rogers' observations were all handed over to Lieutenant Herschel, R.E., in accordance with your directions. The closing of the marks on the base-line was entrusted to Lieutenant Campbell, R.E.

Conclusion.

(30.) I cannot conclude this report without expressing my acknowledgments to Lieutenant John Herschel, R.E., Lieutenant W. M. Campbell, R.E., and Lieutenant M. W. Rogers, R.E., for their cordial co-operation in the work we performed. And I would further thank Lieutenant Campbell, for the very considerable and hearty assistance, which his knowledge of the country and his never tiring energy, enabled him to render.

(31.) I am also much obliged to the sub-assistants who shared in the duties of the measurement.

Mussoorie, 23rd June 1868.

To

J. B. N. HENNESSEY, Esq.

Sir,—In accordance with your instructions I left the camp of the base-line parties on the 11th February and proceeded to the S. West end of the base in order to commence the minor triangulation of the base-line. My party consisting of detachments from the Bombay and Madras parties and my instrument being the one belonging to the Bombay party. Barrow's 24-inch theodolite No. 2.

After observing at two stations of the minor triangulation I proceeded to the old base-line measured by Colonel Lambton in 1804, which was to be connected to the new triangulation. This is effected by a quadrilateral on a side (Túrakungúta, S.W. end of new base) of the Base-Line figure.

The old Base runs nearly north and south. The ground on which it lies being very level for that part of the country. The old mark-stones which were discovered by Captain Branfill have been protected by kacha masonry platforms with mark-stones imbedded in isolated pillars. The villages mentioned by Colonel Lambton in his description of the Base-Line still remain.

In accordance with your further instructions I next proceeded to Tirtapalli and Ossur two stations of the Base-Line figure the angles at which were required in order to complete the polygon connecting the Base-Line with the Main series.

On the completion of these stations I returned to the S.W. end of the Bangalore Base-Line, where under your direction I observed the azimuth of the N.E. end of the Base: using for that purpose the stars 51 Cephei and λ Ursee Minoris.

I then proceeded to complete the minor triangulation which was finished on the 5th April and being then at the N.E. end of the Base I observed the azimuth of the S.W. end. This being the periodic time of polaris I arranged to use that star, but the weather proved unfavorable, the clouds seldom or ever settling down and leaving the pole clear until nearly midnight. After several days delay I had recourse to the same stars with which I had observed the azimuth at the S.W. end. These, elongating one after another, about midnight I was able to get my observations generally without hindrance from clouds. The weather during the last month of my observations was cloudy with frequent storms of thunder, lightning and rain, and I was very rarely able to use heleotropes. Whilst employed in observing the azimuth I received instructions from Colonel Walker to find and connect the old station of Dodagúnta at which observations for latitude had been taken by Colonel Lambton &c., which had been used by Captain Clarke in his determination of the figure of the earth. Having no data except the latitude to guide me as to its whereabouts. I had to apply to Colonel Walker and Captain Branfill for information, and pending their replies, I made enquiries in the neighbourhood of Lambton's old Base and sent men to the villages near. By this plan I was fortunate enough to obtain a clue to its whereabouts, and after some digging and searching I found the station beneath the surface of the ground in a field about 1½ miles north of Bangalore and about ¼ mile distant from station δ of the minor triangulation.

The platform when exposed was circular and about 10 feet in diameter, built of brick and stone, one side had been destroyed, evidently by some one cutting into it to see if anything valuable was contained inside. There was no sign of there having been an upper mark-stone, and the one found was firmly imbedded in the masonry (which itself was very hard and compact from age) and was evidently undisturbed. The station was marked by a deeply cut dot without a ring. On leaving I requested Mr. Sub-Assistant Mitchell, who was in charge of the Base-Line stations and marks to have the platform repaired and raised above the present level of the ground, and to have the temporary isolated pillar which I had constructed for my instrument replaced by a permanent one with an upper mark-stone.

The station was connected to the first section of the new Base by a single triangle with the three angles observed.

This work was finished on the 20th April and having placed my theodolite in the godowns of the Bombay party and handed over my men to Mr. Sub-Assistant Mitchell, I proceeded to join head-quarters at Mussoorie.

ANNUAL RETURN OF AMOUNT OF WORK EXECUTED IN THE DRAWING BRANCH OF THE OFFICE OF SUPERINTENDENT G. T. SURVEY FROM 1ST MAY 1867, TO 30TH APRIL 1868.

DESCRIPTION OF WORK.	REMARKS.
Map of Dehra Doon with Mussoorie and Landour—(Compilation,)	For Photozincography.
Sketch of the Province of Goojerat on Transfer Paper, ...	For Zincography.
No. 1 Preliminary Chart of the Coast Series ditto, ...	ditto.
No. 2 Ditto ditto ditto, ...	ditto.
No. 3 Ditto ditto ditto, ...	ditto.
No. 4 Ditto ditto ditto, ...	ditto.
No. 5 Ditto ditto ditto, ...	ditto.
No. 6 Ditto ditto ditto, ...	ditto.
No. 7 Ditto ditto ditto, ...	ditto.
No. 8 Ditto ditto ditto, ...	ditto.
Preliminary Chart of the Coast Line Minor Series, 1861-62, on Transfer Paper, ...	ditto.
Ditto, Eastern Frontier Series 1861-62 ditto, ...	ditto.
Ditto, ditto 1863-64 ditto, ...	ditto.
Ditto, Madras Meridional Series 1863-64 ditto, ...	ditto.
Ditto, Cherrapoonjee Sylhet and Cachar Series, 1861-62, ditto, ...	ditto.
Ditto, Cherrapoonjee and Sylhet Series, 1859-60-61, ditto, in 4 sheets,	ditto.
Ditto, East Calcutta Longitudinal Series 1866-67 ditto, ...	ditto.
Ditto, Jubbulpore Meridional Series 1866-67, ditto, ...	ditto.
No. 3 Ditto, Revised Calcutta Longitudinal Series, ditto, ...	ditto.
No. 4 Ditto, ditto ditto, ditto, in 2 sheets,	ditto.
Map of Syr-Daria (Jaxartes), ditto, ditto, ...	ditto.
Sketch Map of India to illustrate Railway and Telegraph Lines, ditto, ...	ditto.
Sheet No. 6 Kumaon and British Gurhwal—(Compilation), ...	For Photozincography.
Skeleton No. 6 Ditto ditto ditto, ...	For Zincography.
Sheet No. 14 Mussoorie and Landour, ditto	For Photozincography.
Skeleton No. 14 ditto ditto ditto, ...	For Zincography.
Completed Sections Nos. 12, 13, 16 and 17 Kashmir Survey (Originals)	For Surveyor General's Office.
Ditto 12, 13, 16 and 17 ditto. (Duplicates)	For Photozincography.
Sections Nos. 11 and 15 Kashmir Survey Scale 8 miles=1 inch	ditto.
Index to the Kashmir Survey Sections, ...	For Surveyor General's Office.
Ditto ditto, ...	For Office use.
Ditto ditto, on linen, ...	For Colonel Walker, R.E.
Route Survey from British India into Great Tibet through the Lhassa Territories on transfer paper, ...	For Zincography.
Path of the Total Phase of the Solar Eclipse on transfer paper, ...	ditto.
Sheet No. 1 Spirit Levels and Trigonometrical heights of the G. T. Survey of India &c., (Compilation)	For Photozincography.
Ditto No. 3 Ditto ditto ditto, ...	ditto.
Sheet No. 1 Map of Turkestan (Compilation), ...	ditto.
Sheet No. 2 Ditto ditto.	ditto.
A tracing from the N. W. Himalaya Survey Containing Dalhousie and Chamba &c., ...	For Mr. Davies.
Ditto ditto, of the country between the Parallels of 30° 56′ and 31° 19 and the meridians of 76° 59′ and 77° 23′,... ...	For Colonel Dickens.
A tracing from the N. W. Himalaya Survey of the country between the Parallels of 32° 13′, and 32° 50′ and the meridians of 75° 50′ and 76° 30′,	For Surveyor General's Office.
Corrected 100 Copies of Skeleton Sheet No. 7 Mussoorie and Landour, ...	For Photographic Office.
Colored 125 „ Sheet No. 1 Map of Turkestan, ...	ditto.
Do. 130 „ Sheet No. 2 ditto, ...	ditto.
Do. 36 „ Dehra Doon with Mussoorie and Landour, ...	ditto.
Do. 45 „ Plan of Dehra, ...	ditto.
Do. 250 „ Route Survey from British India into Great Tibet through the Lhassa Territories, ...	ditto.
Do. 35 „ Sheet No. 6 part of British Gurhwal, ...	ditto.
Do. 12 „ do. „ 1 ditto, ...	ditto.
Do. 75 „ do. „ 7 ditto, ...	ditto.
Do. 42 „ do. „ 1 Spirit Levels and Trigonometrical heights &c., ...	ditto.
Do. 35 „ do. „ 3 ditto ditto, ...	ditto.
Do. 21 „ Sketch of the Province of Goojerat, ...	ditto.
Do. 20 „ Map of Syr-Daria (Jaxartes), ...	ditto.
Do. 20 „ Map of Central Asia, ...	ditto.
Do. 25 „ Section No. 11 Kashmir Survey, ...	ditto.
Do. 25 „ do. „ 12 ditto, ...	ditto.
Do. 25 „ do. „ 13 ditto, ...	ditto.
Do. 25 „ do. „ 15 ditto, ...	ditto.
Do. 25 „ do. „ 16 ditto, ...	ditto.
Do. 2 „ Sketch Map of India in 12 Sheets	For Colonel Walker, R.E.
Protraction of Routes for Level Sheets Nos. 3 & 5 and copies of Bench Mark Drawings &c.,	...
Sheet No. 3 Map of Turkestan for Photozincography—(Compilation)	Very nearly finished.
Do. „ 4 Ditto ditto ditto, ...	Half of the Printing and out-lining finished.
Do. „ 5 Spirit Levels and Trigonometrical heights of the G. T. Survey of India &c., For Photozincography—(Compilation), ...	Nearly finished.
Do. „ 15 Kumaon and British Gurhwal For Photozincography—(Compilation), ...	About ⅔ of the out-lining finished.
Printed Parchments, Forms, Labels &c., ...	For Photographic and Computing Offices.
Examination of Preliminary Charts &c., ...	

REPORT

ON

THE TRANS-HIMALAYAN EXPLORATIONS

IN CONNECTION WITH THE

GREAT TRIGONOMETRICAL SURVEY OF INDIA

DURING 1867.

DRAWN UP BY

CAPTAIN T. G. MONTGOMERIE, R.E.

IN CHARGE TRANS-HIMALAYAN EXPLORING PARTIES.

NARRATIVE REPORT OF THE TRANS-HIMALAYAN EXPLORATIONS MADE DURING 1867, DRAWN UP BY CAPTAIN T. G. MONTGOMERIE, R.E., OF THE G. T. SURVEY, FROM THE ORIGINAL JOURNALS &c., OF THE TRANS-HIMALAYAN EXPLORING PARTIES.

The Trans-Himalayan explorations made during 1865-66 from the Mansarowar lake to Lhasa supplied various pieces of information as to routes and places in Tibet of which the names were unknown in India. Tibetans had been heard to talk of their gold mines and salt mines, and the position of some of the latter was indicated roughly on European maps but our knowledge of all such places was vague in the extreme though the Tibetans certainly do bring both gold and salt. The 1st Pundit heard of these places whilst in Lhasa and the 2nd Pundit when at the Gartok fair heard various particulars from which he gathered that the route to those gold fields east of Gartok was likely to be feasible.

It will be remembered that the 2nd Pundit made his way to Gartok in 1865 by one route and returned by another thus connecting that place with points in British territory on the south that had been fixed by regular survey. There however still remained a large gap between Gartok and the Ladak territory which latter had also been surveyed. It appeared to me very desirable that this gap should be filled up, the more especially as it embraced a portion of what was said to be the course of the great river Indus, a portion moreover that had never been traversed by any European.

The information I received, during the prosecution of the survey of Ladak, as to the Indus lead me to think that there was a large eastern branch of that river and I was confirmed in that opinion by the reports of the Surveyors who sketched the extreme south-east of Ladak.

Owing to the great jealousy of the Tibetans the Surveyors could not make their way very far beyond the frontier, the fact of their being engaged on the survey of Ladak arousing the suspicions of the Tartars so much that a regular watch was established the moment a Surveyor approached the frontier. Nevertheless the ground was sketched to same distance beyond, and peaks were fixed at a still farther distance by the theodolite.

The natives pointed out the position where the eastern branch came in, and a gap seen in the mountains in that direction made its existence highly probable. Having this information it seemed to me very desirable that the question as to the existence or non-existence of this branch should be settled. I consequently determined that the 2nd expedition of the Pundits should be in that direction, the first object being to settle various doubtful points as to the position of the Upper basin of the Sutlej,—the 2nd object, the question of the eastern branch of the Indus,—the 3rd, the connection of Gartok with the regular survey in Ladak, and the 4th to explore up to the gold and salt mines east of Gartok and as far beyond as the Pundits could get in an easterly direction. The latter being with a view to gain some knowledge of the vast terra incognita lying between the desert of Gobi and Lhasa.

Preparations for the expedition were made during the spring of 1867, a third Pundit was entertained and trained to supplement the place of the 2nd Pundit who had proved to be somewhat wanting in nerve. Starting from Mussoorie on the 2nd of May the party under the first Pundit reached Badrinath on the 24th of May and Mana on the 3rd June. The Mana pass to the north had not been declared open and the party had consequently to wait at Mana. Whilst there several heavy falls of snow occurred on the neighbouring mountains.

The Pundit found that before his party could cross into Tibet it was necessary that the opening of the pass should be formally notified by the Tibetan officials and before this is done the Jongpon (or Zungpung) of Chaprang makes inquiry every year as to the political and sanatory condition of Hindustan. The inquiry seems to be carried out with all that assumption of lofty superiority for which Chinese officials are famous. Looking down from their elevated plateaux they decide as to whether Hindustan is a fit country to have intercourse with. The

decision come to appears not to be at all a dead letter, for as will be seen hearafter it ultimatcly affected the Pundits movements not a little. The especial enquiries are made as to whether there is war, epidemic, famine &c., such as are in any way likely to affect Tibet.

During his stay at Mana the Pundit made complete arrangements for their journey and he gave the 3rd Pundit some farther practice in route surveying. Whilst there he was also fortunate enough to secure the services of three men, *viz.*, of a Bisáhiri trader, a resident of Badrinath and a Ladaki trader from Zaskar. All these men knew the routes to the gold and salt mines east of Gartok. They proved moreover exceedingly useful in collecting provisions, servants and asses, the latter for the carriage of the small parcels of merchandize which formed the ostensible object of their journey. On the whole the halt at Mana was a decided gain to the party.

At length on the 9th of July three men sent by the Jongpon of Chuprang arrived and having made all their inquiries declared the Mana pass open to traders from Gurhwal; the party accordingly was able to commence its march on the 26th July. It consisted of 11 men, 12 asses and one poney, the men being all armed with weapons they had borrowed at Badrinath, as they were told that arms would be required to keep off robbers. On the 28th they crossed the Himalayas by the Mana pass (18,570 feet) and on the 29th July reached Lumarti Camp. Here they were told to halt until more traders joined them, so that the Tibetan officials might be saved trouble by examining and taxing a number at the same time. The 2nd Pundit however was sent on ahead to intercede with the Chuprang Jongpon and he succeeded in getting authority for the party to advance alone. Churkong is the place where traders are generally taxed but in this instance the examination was made at Barku. The Abtuk of Chuprang searched the baggage fortunately without discovering the instruments and being satisfied that the party was a trading one he levied the taxes at the usual rates.

On the 6th August the party reached Totling, passing the small town of Chuprang on their left (north).

At Totling they put up in the monastery, the Monks (Gelongs or Dabas) allowing all travellers to do so. The monastery with its numerous dykes of stones is about one mile in circumference it has 50 to 60 Monks attached to it, the head one bearing the title of Ling-Khambo.

Between Mana and Totling there is no cultivation of any kind but at Totling itself a grain called nai (barley) is sown in April and reaped in September.

From Totling the party advanced direct towards Gartok crossing the Sutlej by a remarkable iron suspension bridge 76 feet span, 7 feet wide and about 40 feet above the water. The chains are formed by links of iron of the shape of the figure 8 each about one foot in length, the iron being over one inch square. The bridge is said to have been built by Gyalpo Kesar or Sekundar Badshah (Alexander the Great)! The iron is in capital preservation owing to the very small rainfall, and to the care with which it is annually lubricated with butter (ghee.)

After crossing the Sutlej the Pundit and his party all assumed the costume worn by Bisáhiri traders.

On the 9th August they crossed the watershed between the Sutlej and the Indus by the Bogola pass 19,220 feet above the sea and reached Gugti camp close to Gartok on the 11th instant avoiding the latter place, lest its officials should in any way interfere with their onward progress. Continuing their journey they ascended the mountains east of Gartok and after crossing the Gugtila pass 19,500 feet above the sea they found themselves on the 14th August in a vast desolate plateau, the lowest points of which they ascertained to be 15,280 feet above the sea.

This plateau is called Chojothol or Antelope plain, from the great number of those animals seen on it.

On the 16th they reached a small lake covered with ducks and other wild fowl. On a head no signs of a path or of either houses or tents were to be seen and the party became

anxious as to fresh water which was said to be very scarce. It was not till the evening of the 2nd day that they came upon fresh water.

Several very brackish lakes were passed so intensely salt, that even the wild fowl avoided them. No potable water could be got till they found a glacier and melted its ice.

On the 10th they crossed the Pabha-la 17,650 feet above the sea and descended to the Giachuruff camp on the banks of the Singh-gi-chu or Indus river 15,730 feet. After the desolate and arid table-land they had crossed, the sight of the river and its fresh water, and of the large camp beyond was at first very pleasant to the Pundit's party; their pleasure was however soon damped as they found the inhabitants of the camp very suspicious as to the object of their journey. Their progress being for the first time impeded by the officials. Gopa Tajam the head man questioned them as to the objects of their journey and as to who and what they were &c. When told that they were Bisáhiris who had come there solely to sell coral and purchase shawl wool (pushm) in exchange, he told them flatly that he did not believe their story. With great correctness he then proceeded to point out the proper country of each individual and said that if they had been really all Bisáhiris and had been lately in Bisáhir, they would never have dared to enter Nari Khorsum that year, as an order had been promulgated at the time of opening the passes, forbidding Bisáhiris to enter the country on any account, as they had in the previous year introduced small pox, which proved fatal to many of the inhabitants. The head man moreover hinted that the party had introduced Europeans into the country.

These suspicions being so strongly expressed, alarmed the Pundits, more especially as they never thought that the disguise of a Bisáhiri, which had served them so well on the route to Lhasa, would prove a hindrance on this occasion.

The Pundit thought these suspicions were due to the jealousy of an acquaintance of his who lived near Badrinath. However by repeated protestations he managed to bring the head man round to a partial belief in their story, so that he at last consented to allow a portion of the party to proceed onwards provided the remaining portion was left as a hostage for their good faith.

As the 2nd Pundit's nerves were again considerably shaken by the dreary mountains they had crossed and by the check they had received, the 1st Pundit decided to leave him at Giachuruff whilst he and the 3rd Pundit pushed on ahead on the pretence of selling their coral.

Whilst preparations for this purpose were being made the head man's suspicions began to gather again and it was only after farther entreaties accompained by presents, that they were allowed to advance. The Pundit left the Giachuruff camp on the 22nd August with the 3rd Pundit; but the latter was very soon after starting detached with one servant to carry a route-survey up the river Indus as far as he could get.

The Pundit himself made a very long march, so as to get well clear of the Giachuruff people and by night was far away to the east resting near the bed of a small dry stream. On the 23rd August he hoped to have been able to cross the Chomorang range, but owing to a very heavy fall of snow, he was obliged to halt at a camping place below it. Snow continued to fall on the 24th and 25th and he was not able to continue his march till the 26th August, when he crossed the Chomorang-la pass 18,760 feet above the sea and after a very long march crossing a good deal of snow he reached the large camp of Thok-Jalung * the chief gold field of that part of the country.

As the Pundit descended the Chomorang-la pass, the Thok-Jalung camp came in sight, he found it pitched in a large desolate plain of which the prevailing color was reddish brown. As far as he could see, it at first appeared to be like other Tibetan standing camps, except that it was very much larger. As he got closer he made out the noise of a great number of voices singing together, and on his arrival found that this came from the gold diggers and their families whilst the men were at work.

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* Thok-Jalung Latitude N. 32° 24′ 26·5, Longitude 81° 37′ 36″.

The Pundit had armed himself with a letter from the Giachuruff Chief and this he presented the next day to the Thok-Jalung Chief with a small present of the best Indian tobacco, which he had somehow discovered to be a particular weakness of that individual.

The Chief received the Pundit in his large tent, he was much gratified by the present, but in spite of that and the letter it was evident from his manner that he did not think that matters were quite right. He cross questioned the Pundit and then advised him to do what he had to do in Thok-Jalung quickly and to return to Giachuruff by the same road as he came. The Chief said that it was out of his power to allow the Pundit to stay long and that properly he ought to have sent him back at once as there was an order in force forbidding all Bisáhiris to enter the country that year.

Hearing that the Pundit had coral for sale he asked to see it. As soon it was displayed the Chief's Wife who was present, took such a liking to it that she persuaded the Chief to offer gold in exchange, the Pundit thought his only chance was to acquiesce and he did so, making as he afterwards found out, a very bad bargain. Having given up his coral, the Pundit was allowed to retire.

The Chief was an inhabitant of Lhasa called Yoodak Mingmár, about 45 years of age. He had been master of the Thok-Jalung gold field* for some time. The Pundit saw him several times afterwards and always found him very civil. His usual dress was a red robe of Lhasa or Shigatze manufacture, his head was covered with a brown felt hat of Chinese fashion with a broad rim turned up all round. He told the Pundit that he and every one else wore furs in the winter, and that they could not live at that season without them which is no doubt correct as the Pundit's observations make the gold field to be at the great altitude of 16,330 feet above the sea. His tent was a large circular one about 25 feet in diameter with two poles, it was pitched in a wide pit some 7 or 8 feet below the surface of the ground and the descent to it was by means of steps. Outside, the Pundit noticed one of the gigantic black dogs of Lhasa, this beast was tied unpleasantly near the door and was so savage that there was great difficulty in preventing him from flying on strangers. The Pundit had seen many of these dogs in Lhasa and he at once recognized it by its great size, deep jowls, and the white mark on its chest. The Lhasa people call them Gya-ki or royal dogs.

The tent was made of black Yaks hair, it contained bales of shawl wool (pushm), leather packages of tea, strings of dried beef from the Yak and a few other Tibetan luxuries such as dried apricots, currants &c., the poles were garnished with several match-locks and a sword. The Chief's seat was beside a small box in which there was a drawer containing paper, pen, ink and couple of cups or bowls, one for drinking tea and the other for Chung or Whiskey. The Chief's tent seems to have also been the shrine of the camp as behind his seat there were piled up the usual images, small brass bells, tiny vases, books, pictures†, lights &c., that are carried about by wandering Budhist Lamas. Whether the Chief was also a Lama was not ascertained but his red dress and the ritualistic instruments point to that conclusion.

The Chief was constantly smoking a silver-mounted Nepalese hookah. Tea was forthcoming at all hours. He had about ten personal servants who lived in small tents round about his own. The Chief was a very intelligent man and all things considered the Pundit thought him well informed. His shrewdness there was no mistaking as instanced in the matter of the coral. He noticed the Pundit's box, examined it carefully and then asked him how he came to have such a good box. The Pundit was fortunately ready with his answer and said he bought it at one of the 'Saheb logues' auctions to carry his coral in. The fame of these auctions had reached even this Tibetan Chief and he expressed himself as quite satisfied, allowing the box to be removed without discovering the large sextant which was stowed away in a secret compartment. The chief took a great liking to the Pundit and used to send for him every now and then in order to discuss over tea and tobacco the great country down below.

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* From previous information it appears that gold was first discovered to be abundant at Thok-Jalung about 8 or 9 years ago.

† Quaintly painted on cloth, many of that kind can be seen in Ladak at the Hemis and other monasteries.

The Pundit found the part of the gold field that was being worked to be a great excavation from 10 to 200 paces in width and some 25 feet in depth, access to the bottom being by means of steps and slopes, the earth as dug out being thrown upon either side. The excavation at the time of the Pundit's visit was about a mile in length.

The digging is carried on with a long handled kind of spade and occasionally with an iron hoe, the iron for these implements is brought from Bisáhir, Ladak &c. The camp had a blacksmith who could repair these tools.

A very small stream runs through the gold field and the bottom of the excavation is consequently rather a quagmire during the day time; but the stream is put to good use for washing the gold out of the soil. The diggers dam up the water and leave a sloping channel for it to escape by. A cloth is spread at the bottom of the channel and kept down by a number of stones so as to make the bottom uneven. One man brings earth from the excavation and sprinkles it over the channel, whilst another man drives water down the channel by means of a leather bag. The water carries the lighter soil right away, but the pieces of gold fall into the uneven places and are easily collected in the cloth by lifting up the stones. The yield of gold seems to be large and the finds occasionally very heavy—the Pundit saw one nugget of about 2 lbs. weight (75 tolahs). The diggers say they can recognize the soil that contains gold at once but judging from the large number of gold fields that have been used at one time around Thok-Jalung and are now more or less abandoned, the Tibetan gold diggers seem to be quite as capricious as those of Australia or California and the probability is that whenever they are a long time without getting good finds they strike their Camp and move off to what they think a more tempting field.

From what the Pundit heard during this last expedition and the previous one to Lhasa, there is a whole string of gold fields extending all the way from Lhasa to Rudok along the route which must run close to the northern water-shed of the Brahmaputra, probably in the depression to the north of it.

The gold fields are carefully watched by the Lhasa Authorities, a gold commissioner, called Sarpon,* superintends the whole of them and each field has a separate master. Any individual is allowed to dig provided he pays the annual tax of one sarshoo weight of gold which is about ½ a tolah or $\frac{2}{5}$ths of an ounce. The greater part of the diggers come from the Chung province around Shigatze. The gold commissioner makes an annual tour through the gold district, visiting each field and collecting the taxes.

The Pundit says that in all his travels he never experienced such intense cold as he did at Thok-Jalung, owing as he thought to the high cold wind that was always blowing, more than to the great elevation *viz.*, 16,330 feet above the sea.

The tents of the diggers are always pitched in pits some 7 or 8 feet below the surface of the ground so as to keep out the wind. Spite of the cold the diggers prefer working in the winter and the number of their tents which in summer amounts to 300, rises to nearly 600 in winter. They prefer the winter as the frozen soil then stands well and is not likely to trouble them much by falling in.

The water near Thok-Jalung is so brackish that the diggers cannot drink it till it has been frozen and then re-melted. Considering these difficulties about water, the great elevation the total absence of wood, and the general severity of the climate, gold digging at Thok-Jalung is carried on under very much greater difficulties than in any other part of the world. Nevertheless the diggers appeared to be cheerful and were constantly singing, their families joining in a sort of chorus, which could be heard at a great distance.

Argols of dried dung from the yaks, ponies and sheep, &c. form the only fuel. The Tibetans cook and eat three times a day, their food consisting chiefly of boiled meat, barley cakes, butter-milk and tea stewed with butter.

The Pundit said the Tibetans all preferred China tea and did not approve of Himalayan tea spite of its price, they vowed the latter was too heating for them and that only very poor folks take it.

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* Sar is the Tibetan name for gold.

There was no attempt at masonry in the whole camp, the only apology for it being a square churtan of dry stone plastered with white earth and surmounted with a pole and flag.

At the foot of the mountains round about, the diggers had collected 7 or 8 piles of white stones (probably quartz) and on the bare slopes they had also picked out with white stones the letters of the sacred sentence "om mani padmi hom," on such a gigantic scale that it could be read at a great distance. The sentence was repeated in this way over and over again.

The diggers all eat yaks' flesh and they are said to get over their Tibetan scruples by strangling their tame yaks, but they nevertheless do not object to wild animals, yaks, asses &c. that have been shot.

The Tibetans say that eating roasted meat impedes their breathing and that fresh milk has the same effect, they consequently forbid both and invariably eat boiled meat, throwing away the water in which it is boiled and drinking butter-milk. They extract their butter (ghee) from the milk of yaks, goats and sheep. Their tea is invariably stewed with butter. The meal they use is generally barley meal.

The position in which Tibetans sleep is a most extraordinary one, they invariably draw their knees close up to their heads and rest on their knees and elbows, huddling every scrap of clothing they can muster on to their backs. Those who are better off rest in this manner on a sort of mattrass that rises towards the head and the poorer people in standing camps generally manage to get a suitable slope on the mountain side, or to arrange stones and earth so as to rise in the same way; but rich and poor adopt the same position for sleeping. The Tibetans employed in Ladak by the Survey, though provided with tents (shouldaries) invariably slept in the way described above, arranging themselves in a circle round the tent. This position is most probably adopted in order to secure as much warmth as possible for the stomach, the thighs pressing against it and thoroughly excluding the external air. The gold diggers smoke a great deal, using brass, zinc or iron pipes the latter being most common.

The Pundit mixed freely with the gold diggers and observed all their ways and habits, but his time was limited. The Chief spite of his friendly conduct insisting that he could not let him stay beyond the 31st of August.

He ascertained that the price of the gold at Thok-Jalung was only Rs. 5½ to Rs. 6 in silver per saishoo, (which weighs about a half tolah and 8 ruttees), or rather less than Rs. 30 per ounce. There were two tents belonging to goldsmiths in the camp, they came from the Chung or Shigatze province.

Seeing no chance of extending his journey to the east of Thok-Jalung the Pundit retraced his route to Giachuruff, there he found the 3rd Pundit who had made his way for a considerable distance up the river Indus to a place called Jiachan.

Though the 3rd Pundit had heard that a large band of mounted robbers were wandering about the upper Indus, he was in no way hindered by them till he reached Jiachan.

There however, whilst he was down at the river, a couple of armed robbers fell upon his servant an oldish man, and knocked him over seizing a thermometer and the cocoanut containing the supply of quick silver. Fortunately the Pundit was not for away and hearing the cries he rushed to the rescue, seizing one of the robbers by his pig tail he swung him round and took back the stolen things. This 3rd Pundit being a tall, powerful man completely turned the tables and the robbers pretended that they had only been joking with the old man and did not really mean to take anything. The robbers made off as soon as they could, and the 3rd Pundit thinking they might bring down more of their brethren on him, decided to retrace his steps. He was very reluctant to do this as from all he could hear, 3 or 4 marches more at the outside would have taken him to the source of the Indus, which at the farthest point he visited was still a good sized stream. He was however certain that from the peculiar head dress of the robbers that they belonged to the armed band he had been warned against—the head dress being one peculiar to the nomadic inhabitants of the Shellifuk and Majin districts who are noted as professional robbers.

The whole of the Pundits party having been recollected at Giachuruff he decided to trace the Indus down to its junction with the river upon which Gartok stands. Starting on the 4th September they marched steadily down stream passing numerous camps with their flocks, and herds, but seeing no cultivation or villages till the 7th, when they came to a small village with the first patch of cultivation. All along the banks there was a low bushy jungle. The grass appears to have been abundant and near one camp there was a herd of 5 or 600 horses or large ponies running almost wild, mostly of a white or a greyish color. On the 12th September they reached the junction of the Indus and Gartok rivers and crossing the latter encamped near the Lujan-Chumik spring.

From Lujan-Chumik the Pundit sent the 3rd Pundit to trace the river down into the Ladak territory, whilst he traced it up to Gartok. On the 14th September he reached Gar-Gunsa, the winter residence of the Gartok Authorities. He found only 3 large and 8 small houses in it and was informed that the rest of the inhabitants lived in tents. All along the banks of the river he found the grass tall and luxuriant. The valley all the way up was flat and wide.

On the 16th September the Pundit reached Gartok * where he found a camp of about 200 tents mostly belonging to traders. On his arrival he was alarmed to find that some one had been spreading reports as to his being in British employment and he found it advisable to hasten his return. Choosing a new route he got separated from his baggage and the greater part of his party and had he not fallen in with traders from Shipki, he would have been put to very great hardships. He crossed by the Laochia pass and marching by Shiang and Dunkhar reached Totling on the 26th of September. Here they waited for the 3rd Pundit who joined them on the 29th of September, after having traced the Indus down to Demchok in Ladak. From Demchok he crossed from the basin of the Indus to that of the Sutlej by a very high pass and carried a route-survey down to Totling. †

From Totling the 2nd and 3rd Pundits were sent down the Sutlej to Shipki tracing the river as closely as they could. From Shipki they carried a route-survey in a southerly direction crossing the Himalayas by a high pass and descending to Nilung on the upper course of the Ganges.

The Pundit himself returned from Totling to Badrinath by nearly the same route as he advanced by, only making one small variation.

Ultimately the 2nd and 3rd Pundits rejoined the 1st and they all made their way down into British territory by the beginning of November.

The geographical results of the exploration can be seen at a glance from the accompanying map. They account for the geography of about 18,000 square miles, founded on 850 miles of route-survey with 80 heights. The routes are checked by 190 latitude observations taken at 75 different points.

The course of the Sutlej river has been roughly traced from Totling down to Shipki on the border of British territory. Hitherto there has been no survey of any kind of this portion, and the route though only actually touching the river for a short distance was carried near enough to it to enable the Pundits to lay down its probable course very closely.

The position of Gartok as determined by the two routes of the last expedition has been confirmed by a third route carried up from Badrinath. The mean of three gives a very good

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* Gártok is said to be a corruption of Gúrtod, tod meaning upper, it is also called Gár Yár-Yársá, Yársú meaning summer abode, from Yársá summer and sá abode. The winter quarters are called Gár-Gunsá from Gungá winter and sá abode.

† The portion between Medokding and Totling was previously traversed by Captain Henry Strachey.

longitude of Gartok * as has been proved by the farther route-survey carried from Gartok to Demchok, which latter had been previously fixed by the regular survey operations in Ladak. The longitude by the route-survey only differing from that of the regular survey by 2½ minutes, a very satisfactory result from a route-survey† traversing 160 miles direct over such a very rough tract of mountains.

The routes have also defined the courses of both the upper branches of the river Indus from near their sources to their junction and the conjoint stream from that point into Ladak. Neither of these branches had been previously surveyed in any way, except a small portion of the Gartok branch above Gartok which had been roughly laid down by Moorcroft.

The existence of the eastern branch was doubted by many Geographers‡ as no Europeans had ever seen it: The Pundits route has now proved that this eastern branch is the main stream known to the natives as Singh-gi-Chu or Singh-gi-Khamba (Lion's mouth), the river Indus itself whilst the other branch hitherto generally supposed to have been the main stream is much smaller than the eastern one and invariably called the Garjung-Chu.

The routes extended beyond the eastern watershed of the Indus as far as the great Thok-Jalung or Thok-Samba gold field. Thok-Jalung was moreover roughly connected with various other gold fields and salt mines by means of information derived from travellers and the general correctness of this information was roughly established by a route to Rudok, derived from similar information which made out the position of that place tolerably close to that determined by the regular survey.

A number of lofty snowy peaks were determined from various stations of the route-survey, the most remarkable being the Aling-Gangri group north of the Indus, which, judging from the great mass of snow seen on the southern face during August, September must be upwards of 23,000 feet above the sea, possibly as much as 24,000 feet.

The line of perpetual snow on the southern slopes of the Ladak mountains approximates to 20,000 feet in the same latitude and it would require several thousand feet of snow above that line in order to be very imposing at 80 miles, at which distance the Pundit first saw it. The Aling-Gangri group had never as far as I am aware been heard of before. They appear to be a continuation of the range between the Indus and the Pangkong lake. The Pundit could see no farther continuation of the range to the east of Thok-Jalung.

Another high group was seen to the east of the Medok-la, on the watershed between the Sutlej and Indus.

Altogether the Pundit and his brethren have as I predicted improved very much in the art of fixing distant peaks, satisfactory proof of this has been forthcoming from their back bearings to well known peaks, such as Leo-Porgyal, Kamet &c. which gave very accurate positions to those peaks, forming at the same time a valuable check on the route-surveys and proving that there has been no large accumulation of error.

The numerous heights determined by the boiling point give a good idea of the great elevation of the country traversed and the consequently enormous difficulties under which the route-surveys were made. From them it will be seen that the Pundits were for more than three months at an elevation of over 13,000 feet.

They crossed the great range between the Sutlej and the Indus three times, that between

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* Gartok Longitude E. 80° 23′ 33″, Latitude N. 31° 44′ 4″, and height 14,250 feet above sea.—T. G. M.

† The values of the pace as tested by the differences of latitude were very accordant thus:—

	Difference latitude.			Deduced length of pace in feet,	Remarks.
	°	′	″		
From Badrinath to Gartok, ...	0	59	36	2·495	By 1st Pundit.
„ Gartok to Thok-Jalung, ...	0	40	23	2·512	„ 1st Pundit.
„ Gartok to Demchok, ...	0	57	17	2·634	„ 1st and 3rd Pundits.
„ Demchok to Totling, ...	1	13	24	2·495	„ 3rd Pundit.

T. G. M.

‡ It was indicated from Native information by H. Strachey, on his Map of Ladak and Gnair-Khorsum.

Gartok and Chajothol once, between Chajothol and Giachuruff once, the Chomorang range twice, and the Himalaya range three times, each of the crossings involving a pass of over 17,000 feet, two of them being over 19,000 feet.

The height of Gartok by the above is only 14,250 feet instead of 15,000 as had previously been assigned to it. At the several points Totling &c. where Henry Strachey's heights were taken the Pundit's heights are generally lower. A difference in the same direction was noted in the results of the previous expedition at a point near the Mansarowar lake and judging from the following comparisons, it appears to arise from a constant difference, probably due to the thermometer employed :—

	By the G. T. Survey.	*By H. Strachey.*
Hanle, ...	14,276 feet	14,500
Pangkong, ...	13,936 „	14,300
Tankse, ...	12,791 „	13,000
Diskit, ...	9,950 „	10,400

The above shows that Captain H. Strachey's were generally higher than the G. T. S. values, by about 300 feet on the average, and the Pundit's values differing from Captain Strachey's by about the same amount, it may be concluded that they are tolerably near the mark, and at any rate not in excess.

The Pundit's heights agree with those of Badrinath as determined by another observer.

During their journey from Mana to Thok-Jalung a total distance of 207 miles, they only met with cultivation once, *viz.*, near Totling on the Sutlej, every where else the mountains were too high to allow grain to grow. The mountains however produce plenty of coarse grass, sufficient to support large flocks and herds, the Pundit's coming across camps nearly every day.

The weather until they reached the Chomorang range was good, there however the fall of snow was very heavy, though it did not extend in any great quantity on the Thok-Jalung side. At Thok-Jalung itself, only a little rain fell, though it was often cloudy.

During the whole of the time* the Pundit was on the Upper Indus there was a dense bank of clouds in the direction of the Kailas peak and consequently neither he, nor the 3rd Pundit could ever get a bearing to that peak though they were on the look out to do so.

In spite of the desolate aspect of the mountains traversed, the number of wild animals was remarkable, quantities of Tibetan antelopes, wild asses (kiangs), yaks, grey wolves, hares and marmots. Wild fowl swarmed on some of the small lakes and ravens used to visit the camp in pairs.

The actual source of the eastern branch or main stream of the Indus was not reached, but the people between Giachuruff and Jiachan said it rose at a place called Gangri-Goorgiap which may perhaps refer to the Gangri or Kailas peak; but the direction of the course of the Indus as seen from near Jiachan pointed rather to the east of that mountain. The whole district along the upper course of the Indus is called Bongthol which is divided into the small districts (puttees) of the Singhtod and Singhmet. "Tod" signifying upper and "Met" lower.

At the highest point visited the Indus was still a considerable stream. At Giachuruff the ford was always a difficult one and for 8 days after the fall of snow the Pundit experienced, the river was not fordable in any way. Whilst it was snowing on the Chomorang range, heavy rain fell at Giachuruff and the river consequently rose very much. The stream was generally very clear and full of fish† of all sizes, up to about 18 inches in length.

The 3rd Pundit though a very tall powerful man, had great difficulty in crossing when the river was falling, he crossed over to catch their baggage animals which were out grazing, but being delayed till dark he was unable to venture back and was consequently kept out all night with hardly a scrap of clothing, he and his companions huddling together in order to keep themselves warm.

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* The rains were in full progress at this time on the outer Himalayan ranges.

† The Dokpa people eat these fish but those Tibetans who have read Budhist books do not do so.

From Jiachan to Giachuruff the Indus flows through a rather broad, flat valley and from Giachuruff to its junction with the Garjung-Chu it flows through a similar valley, the banks being lined in many places with long patches of low jungle.

The Indus above the junction was from 100 to 200 paces in breadth with a depth of 6 to 4 feet; while the Garjung-Chu was in places as much as 250 paces in width but with a depth of only 1 to 2 feet.

The Garjung-Chu between Gartok and the junction flows through a particularly broad and flat valley.

The Indus below the junction flows through a wide valley to a considerable distance below Demchok.

When at Thok-Jalung the Pundit made diligent enquiry as to the adjacent countries, he was informed that a large district called Majin extended for nine days journey to the east, and that a smaller district called Shellifuk lay to the south-east. The Majin country was said to be a difficult one to travel in as no rivers ran through it. The Shellifuk district boasted of some streams, but they all run into a large inland lake.

Immediately to the north of the gold fields there is no regularly inhabited country, as far as the Thok-Jalung people are aware. They say there are some wandering thieves Champas or Khampas who live entirely on meat and have had so little acquaintance with grain in any shape that, they get sick when they take it from their more southerly brethren. The Pundit however seemed to have very little faith in this part of the story. He heard that at a considerable distance to the north-east there was a tract called the Whor country inhabited by Shakpo people the same style of people as those who come from Jilung.* Tartary is said to be to the north-east of Whor. To the north-west of Thok-Jalung lies Rudok, the route to which has been roughly indicated on the accompanying Map. Ting-Chu and Rawung are the intermediate districts; the first is a very cold place and has very little sweet water, though plenty of brackish water. Rawung has much the same climate as Rudok, only slightly colder, it has however plenty of fresh water.

There is said to be a direct route from Thok-Jalung, south-east to Tadam monastery on the great Gartok and Lhasa road. This route crosses some comparatively low ranges but is said generally to run over great plains.

Such inhabitants as there may be on the north, east and south are all nomadic, living in standing camps, shifting every now and then according to the state of the pasture, time of the year &c. They are almost all addicted to highway robbery.

I have already pointed out how well the Pundits have succeeded in the difficult art of intersecting and fixing distant peaks. The way in which the Chief Pundit quartered his ground and divided it, so as to account for the geography of the whole, with a few routes, is another great improvement, their work covering a much greater breadth and leaving very little doubt as to the position of the intermediate ranges.

As before, the Chief Pundit showed great tact in making his way among strangers and his conduct of the whole expedition is highly creditable and the way in which he has carried out my instructions is deserving of all praise.

The 2nd Pundit proved useful in various ways. The 3rd Pundit in his route-survey from Lujan-Chumik to Demchok and thence to Totling proved that he was thoroughly up to his work and likely to prove a very valuable addition to the party.

It is a matter of regret that the Pundits were not able to fix the heights of the peaks they intersected, more especially of Aling-Gangri, but as they have now succeeded so well in fixing the positions, it only remains for them to learn to take altitudes to them, in order to determine their heights.

They have already been trained to do this and I have no doubt but that their next expedition will prove fruitful in this respect.

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* Jilung, about one month, north of Lhasa.

Route-Survey—Badrinath to Totling.

Name and number of station.	Bearings of forward station.	Distances in paces to forward station.	Remarks.
	° ′		
Badrinath, ...	9 45	3,400	Latitude observations taken at Badrinath near Temple.
2	338 0	1,200	
3	313 0	700	
4	3 30	3,300	
5	351 30	6,100	
6	330 0	4,000	
7	344 0	10,000	
8	315 30	12,700	
9	24 30	11,700	Cross Himalayas by Chirbittia-la.
10	22 45	11,800	
11	67 0	11,700	
12	358 0	4,700	Observations for latitude taken at Lumarti 2,760 paces from station 12 on route to station 13.
13	28 0	6,000	
14	6 30	6,800	Observations for latitude taken at station 14 (Chirkong.)
15	25 0	12,400	
16	27 0	12,000	
17	37 0	5,500	Observations for latitude taken at station 17 (Barku.)
18	76 45	10,000	
Totling, 19	...	...	Observations for latitude taken at Totling.

Route-Survey—Totling to Thok-Jalung.

	° ′		
Totling, ...	52 0	38,200	Observation for latitude taken at Nairding-Sumdo 12,300 paces from Totling on route to station 20.
20	68 0	50,600	Observations for latitude taken at Khangiah camp 32,300 paces from station 20. Observations for latitude taken at Gugti camp 50,340 paces from station 20.
21	47 0	13,700	
22	85 0	5,300	Observations for latitude taken at Dumlung-Sumdo, station 22.
23	62 0	4,500	
24	44 30	11,300	
25	88 15	4,100	Observations for latitude taken at Chojo-Gugti 2,000 paces and with a bearing of 250° from station 25.
26	98 30	8,000	

Route-Survey—Totling to Thok-Jalung.—(Continued).

Name and number of station.	Bearings of forward station.	Distances in paces to forward station.	Remarks.
	° ′		
27	68 0	9,300	
28	20 45	13,300	
29	48 0	56,000	Observations for latitude taken at Giamchicho 15,300 paces from station 29 on route to station 30.
30	20 0	3,700	Observations for latitude taken at Kiangmachumik 35,500 paces from Giamchicho on route to station 30.
31	44 30	30,600	
32	70 0	19,900	Observations for latitude taken at Giachuruff 5,000 paces from station 31 on station 32.
33	94 0	6,000	Observations for latitude taken at Thok-Jalung, 4,000 paces from station 33 on route to end of bazar.
End of Thok-Jalung Bazar, ...			

Route-Survey—Giachuruff to Gartok by Lujan-Chumik and Gar-Gunsa.

	° ′		
Giachuruff, ...	316 30	22,700	
2	300 0	19,100	Latitude observations taken at Shildung camp, station 2.
3	290 0	4,100	
4	246 0	5,700	Latitude observations taken at Giamchung-phu 2,000 paces from station 4 on route to station 5.
5	291 0	9,400	
6	323 0	4,400	
7	289 0	17,100	Latitude observations taken at Thankar village 8,000 paces from station 7 on route to station 8.
8	272 0	9,800	
9	225 0	3,500	
10	276 0	6,300	Latitude observations taken at Pika village, station 10.
11	308 0	2,300	
12	242 30	2,000	
13	290 0	3,300	
14	258 0	3,000	
15	265 30	16,500	Latitude observations taken at Burkung, 900 paces from station 15 on route to station 16.
16	258 0	11,100	
17	287 0	10,000	Latitude observations taken at Marku camp, station 17.

Route-Survey—Giachuruff to Gartok by Lujan-Chumik and Gar-Gunsa.—(Continued).

Name and number of station.	Bearings of forward station.	Distances in paces to forward station.	Remarks.
	° ′		
18	209 0	6,700	
19	255 0	7,800	
20	226 15	5,900	Latitude observations taken at Dak-Maru, or station 20.
21	260 30	29,000	Latitude observations taken at Ralajung 19,900 paces from station 21 on route to station 22.
22	227 45	9,500	
23	143 0	19,500	Latitude observations taken at Lujan-Chumik, or station 23.
24	130 0	24,800	Latitude observations taken at Ju camp, or station 24.
25	150 0	47,200	Latitude observations taken at Gar-Gunsa, or station 25.
26	129 0	26,700	Latitude observations taken at Loa-Gong camp 30,400 paces from Gar-Gunsa on route to station 26.
Gartok.			Latitude observations taken at Gartok.

Route-Survey—Lujan-Chumik to Demchok.

	° ′		
Lujan-Chumik.	319 15	16,700	
2	314 30	6,300	Latitude observations taken at Tashikang, or station 2.
3	309 30	18,400	
4	326 42	3,500	Latitude observations taken at Damakolok same as station 4.
5	311 0	6,700	
6	312 30	1,700	
Demchok.			Latitude observations taken at Demchok.

Route-Survey—Demchok to Totling.

	° ′		
Demchok.	312 30	1,000	
7	224 30	3,900	
8	194 30	8,800	Latitude observations taken at Demchok-Phu 5,390 paces from station 8 on route to station 9.
9	186 30	6,900	
10	169 30	2,100	
11	178 0	5,500	
12	158 30	21,900	Latitude observations taken at Deboche 4,000 paces from station 12 on route to station 13.

Route-Survey—Demchok to Totling.—(Continued).

Name and number of station.	Bearings of forward station.	Distances in paces to forward station.	Remarks.
	° ′		
13	150 30	12,300	
14	197 30	5,300	Latitude observations taken at Medokding village, station 14.
15	117 0	7,200	
16	160 30	8,800	Latitude observations taken at Dilchachini-Sumdo 3,500 paces from station 16 on route to station 17.
17	150 30	20,500	
18	153 0	7,500	Latitude observations taken at bank of Lamoche stream 6,200 paces from station 18 on route to station 19.
19	167 30	2,500	
20	134 0	2,600	Latitude observations taken at Jia-Sumdo, or station 20.
21	206 0	12,300	
22	223 0	4,100	Latitude observations taken at Chokche village, 800 paces from station 23 on route to station 24.
23 (same as station 1 below,) ...	317 0	2,700	
24	308 0	5,600	Latitude observations taken at Rabgialing 5,600 paces from station 24.
1 (same as station 23 above, ...	143 0	1,800	
2	139 0	1,500	
3	141 30	16,200	Latitude observations taken at Shangche village, 7,600 paces from station 3 on route to station 4.
4	142 0	3,600	
5	160 0	4,100	
6	114 30	4,000	
7	131 0	10,200	Latitude observations taken at Tibuphu 4,900 paces from station 7 on route to station 8.
8	102 0	4,000	
9	69 30	1,700	
10	104 0	4,100	
11	187 30	4,800	Latitude observations taken at Dunkhar village 600 paces from station 11 on route to station 12.
12	181 0	24,300	
Totling, ...			Latitude observations taken at Totling.

Route-Survey—Barku to Shipki.

	° ′		
Barku, ...	229 0	10,400	
2	224 30	9,500	

Route-Survey—Barku to Shipki.—(Continued).

Name and number of station.	Bearings of forward station.	Distances in paces to forward station.	Remarks.
	° ′		
3	244 0	9,500	
4	287 0	2,000	
5	305 0	1,700	
6	290 30	1,700	
7	234 0	2,700	
8	284 30	2,000	
9	340 0	3,300	Latitude observations taken at Puling-Gongma, or station 9.
10	294 30	3,000	
11	289 0	7,900	
12	292 0	2,500	
13	325 0	4,500	
14	305 0	2,900	
15	323 0	1,900	
16	323 0	13,200	
17	345 0	3,300	
18	322 0	4,500	Latitude observations taken at Rildighang, or station 18.
19	325 0	2,200	
20	301 0	3,300	
21	298 0	9,500	
22	308 0	7,200	Latitude observations taken at Ri village, or station 22.
23	355 0	19,300	Latitude observations taken at Lanjan-Samba (bridge over Sutlej) 8,500 paces from station 23 on route to station 24.
24	324 30	4,600	
25	278 30	8,800	Latitude observations taken at Dongkhang 3,100 paces from station 25 on route to station 26.
26	282 0	11,500	Latitude observations taken at Miang village 2,400 paces from station 26 on route to station 27.
27	216 0	4,000	
28	302 0	2,900	Latitude observations taken at Tiak village 500 paces from station 28 on route to station 29.
29	315 0	3,300	
30	264 0	13,900	Latitude observations taken at Kuak village 8,550 paces from station 30 on route to Shipki.
Shipki, ...			Latitude observations taken at Shipki.

Route-Survey—Shipki to Nilung and Mukpa.

Name and number of station.	Bearings of forward station.	Distances in paces to forward station.	Remarks.
	° ′		
Shipki, ...	84 0	13,900	
2	135 0	3,300	
3	122 0	2,900	
4	302 0	500	
5	167 30	6,600	Latitude observations taken at Tiak village, or station 5.
6	172 30	4,500	Latitude observations taken at Kuang 2,800 paces from station 6 on route to station 7.
7	222 30	3,800	
8	205 0	1,600	
9	170 30	12,300	Latitude observations taken at Sang 4,000 paces from station 9 on route to station 10.
10	160 0	2,000	
11	90 0	8,600	Latitude observations taken at Sumna 5,000 paces from station 11 on route to station 12.
12	133 0	3,200	
13	106 0	3,200	
14	36 0	2,200	
15	53 30	1,300	
16	101 30	6,200	Latitude observations taken at Biar 4,700 paces from station 16 on route to station 17.
17	157 30	2,700	
18	126 30	4,500	
19	129 0	2,800	Latitude observations taken at Sarang village 800 paces from station 19 on route to station 20.
20	152 45	3,700	
21	139 0	1,700	
22	127 30	2,000	
23	130 0	2,300	
24	141 0	1,300	
25	205 0	2,300	
26	156 0	10,000	
27	177 0	6,900	
28	167 0	10,700	
29	202 30	1,900	
30	193 30	3,000	

Route-Survey—Shipki to Nilung and Mukpa.—(Continued).

Name and number of station.	Bearings of forward station.	Distances in paces to forward station.	Remarks.
	° ′		
31	235 0	1,900	
32	188 0	1,900	Latitude observations taken at Changjum-Sumdo 1,280 paces from station 32 on route to station 33.
33	231 0	1,100	
34	176 0	1,000	
35	203 0	2,200	
36	196 0	1,200	
37	153 0	4,300	
38	212 30	1,800	
39	160 0	1,200	
40	192 0	4,400	Latitude observations taken at Nonam 1,600 paces from station 40 on route to station 41.
41	196 30	3,800	
42	158 0	1,400	
43	211 0	2,800	
44	251 30	2,700	
45	263 30	4,300	
46	217 0	1,100	
47	255 30	5,600	Latitude observations taken at Nilung village, or station 47.
48	182 0	2,500	
49	213 0	5,700	
50	220 0	3,700	
51	259 0	5,300	
52	225 0	2,000	
53	257 0	2,000	
54	288 0	5,700	
55	266 0	4,900	
56	259 0	3,200	
Mukpa, ...			Latitude observations taken at Mukpa.

Route-Survey—Gartok to Dunkhar.

	° ′		
Gartok, ...	281 0	9,900	Latitude observations taken at Gartok.
2	259 0	7,500	
3	213 30	5,800	

Route-Survey—Gartok to Dunkhar.—(Continued).

Name and number of station.	Bearings of forward station.	Distances in paces to forward station.	Remarks.
	° ′		
4	259 0	8,000	
5	327 0	5,200	
6	292 30	5,200	
7	315 0	8,000	
8	285 0	4,400	
9	315 0	3,200	
10	270 0	2,800	
11	309 0	10,500	
12	230 0	3,500	
13	306 30	3,100	
14	270 0	13,500	
15	146 0	17,300	
16	169 0	16,000	
17	95 0	4,000	
Dunkhar, ...			Latitude observations taken at Dunkhar.

Route-Survey—Dunkhar to Totling.

	° ′		
Dunkhar, ...	185 1	5,200	
19	179 0	23,700	
Totling, ...			Latitude observations taken at Totling.

Route-Survey—Totling to Chirkong.

	° ′		
Totling, ...	123 30	9,100	
2	200 0	17,300	
3	252 30	6,000	Latitude observations taken at Mangnang village, or station 3.
4	225 0	9,000	
5	242 0	7,700	
6	230 0	7,500	
Chirkong, ...			Latitude observations taken at Chirkong.

Route-Survey—Giachuruff to Jiachan up the river Indus.

	° ′		
Giachuruff, ...	155 0	7,900	Latitude observations taken at Giachuruff.
2	90 0	2,600	
3	170 0	5,200	
4	208 0	2,400	

Route-Survey—Giachuruff to Jiachan up the river Indus.—(Continued).

Name and number of station.	Bearings of forward station.	Distances in paces to forward station.	Remarks.
	° ′		
5	198 0	5,600	
6	135 0	9,600	
7	124 0	10,200	Latitude observations taken at Lapta-Rebo, station 7.
8	193 0	10,000	Latitude observations taken at Nagpo-Shamdo, 7,000 paces from station 8 on route to station 9.
9	245 0	8,900	
10	216 0	11,600	
11	190 0	18,900	
Jiachan, ...			Latitude observations taken at Jiachan.

Route-Survey—Milam to Gartok.

	° ′		
Milam, ...	33 0	6,400	
2	5 0	9,000	
3	22 30	2,800	
4	333 10	8,200	
5	30 0	5,000	
6	26 20	6,100	
7	52 0	21,500	
8	48 40	3,600	
9	90 0	1,400	
10	71 40	2,900	
11	38 30	2,500	
12	52 30	12,500	
13	46 0	15,400	
14	26 0	15,400	
15	350 20	11,800	
16	358 10	7,600	
17	26 0	6,700	
18	28 20	2,100	
19	72 20	6,000	
20	32 20	6,800	
21	318 20	22,600	
22	322 10	10,500	

Route-Survey—Milam to Gartok.—(Continued).

Name and number of station.	Bearings of forward station.	Distances in paces to forward station.	Remarks.
	° ′		
23	315 40	10,800	
24	335 0	22,900	
25	319 0	20,200	
Gartok, ...			Latitude observations taken at Gartok.

Route-Survey—Gartok to Milam.

	° ′		
Gartok, ...	170 20	10,300	Latitude observations taken at Gartok.
27	141 20	8,800	
28	155 30	4,200	Namochi, same as station 29.
29	155 30	10,500	
30	196 10	12,100	
31	235 0	2,200	
32	235 20	21,300	
33	231 30	6,000	
34	171 0	3,500	
35	202 0	2,500	
36	203 10	3,500	
37	191 40	10,500	
38	170 50	3,600	
39	200 0	11,000	Dongpu village, same as station 40.
40	196 0	3,000	Nagbo village, same as station 41.
41	197 30	7,300	
42	194 30	9,700	
43	177 30	13,800	
44	176 0	13,000	
45	176 0	5,700	
46	130 30	16,100	
47	172 0	12,400	
48	166 0	7,900	
5	153 10	8,200	No. 5, 4, 3, 2 correspond with same numbers in route Milam to Gartok.
4	202 30	2,800	
3	185 0	9,000	
2	213 0	6,400	
Milam.			

Observations for Latitude taken in Great Tibet with Elliott's 6-inch Radius Sextants, No. 44 and No. 45.

No. of Observations.	Astronomical Date.		Watch Time.	Station.	Object on Meridian.	Upper or Lower Transit.	Double Altitude.	Single.	Index Error.	Deduced Latitudes.	Mean Latitudes.	Remarks.
	1867.		*h m*				° ′ ″			° ′ ″	° ′ ″	
1	May	29	6 30 P.M.	Badrinath Temple (near.)	Polaris.	Lower	58 40 0		+ 3′	30 44 29·4	...	Sextant No. 45.
3	,,	31	6 30 ,,	Do. foot of steps.	...	...	58 41 10		...	30 45 4·7	...	Do.—See observation No. 84.
4	June	7	11 30 ,,	Mana village, Ghonoli house.	Autares.	Upper	66 12 10		+ 3′ 10″	30 45 20·6	...	Do.
5	,,	27	10 0 ,,	Do.	...	...	66 12 40		+ 2′ 50″	30 45 15·0	30 45 17·8 ...	Do.
6	July	27	3 30 ,,	Rában-Thok, camp Lumarti.	Polaris.	...	65 10 50		+ 2′ 30″	31 11 29·6	...	Do. took observations for time 6*h*. 49*m*. 42*s*.
7	,,	27	4 30 ,,	Do. Lumarti.	...	...	65 18 20		− 7′ 10″	31 10 24·6	31 12 9·7	Do. No. 44.
8	,,	30	3 15 ,,	Do. do.	(*Fomalhaut*)	...	57 4 0		...	31 13 22·3	...	Do.
11	August	1	4 15 ,,	Chirkong or Shibuk.	Pollars.	...	65 23 10		− 7′ 10″	31 12 52·0	31 12 52·0	No. 44.
13	,,	3	4 15 ,,	East of Chaprang village at Thalthousa.	...	...	65 43 0		+ 2′ 30″	31 27 35·6	31 27 35·6	Do. No. 45.
15	,,	5	4 30 ,,	Totling village.	...	...	65 43 30		...	31 27 48·9	31 27 48·9	
16	,,	7	11 0 ,,	Nairding-Sumdo camp.	Altair.	...	134 5 30		− 7′ 10″	31 32 36·7	31 32 36·7	No. 44.
17	,,	10	2 30 A.M.	Khangiah.	(*Fomalhaut*)	...	56 5 0		− 7′ 0″	31 42 52·7	31 42 52·7	Do. near a Ravine of the same name.
18	,,	11	5 40 ,,	Dukti camp.	Polaris.	...	66 25 10		− 7′ 0″	31 44 0·3	...	Sextan No. 44.
19	,,	11	5 40 ,,	Do.	...	...	66 17 0		+ 3′ 0″	31 44 55·3	31 44 47·0	Do. No. 45.

Observations for Latitude taken in Great Tibet, &c.—(Continued.)

No. of Observations.	Astronomical Date.		Watch Time.	Station.	Object on Meridian.	Upper or Lower Transit.	Double Altitude.	Single.	Index Error	Deduced Latitudes.	Mean Latitudes.	Remarks.
			h m				° ′ ″			° ′ ″	° ′ ″	
20	August	11	5 40 A.M.	Dukte camp.	Polaris.	Upper	66 16 0		+ 5′ 0″	31 45 25·3	...	Pocket Sextant No. 12.
21	,,	12	...	Fort of Gugti-la.	...	...	66 23 30		+ 3′ 0″	31 48 18·7	...	Junction of two streams Dung-lung-Sumdo.
22	,,	12	...	Do.	...	...	66 30 30		− 7′ 0″	31 46 48·7	31 47 33·7	Sextant No. 44.
23	,,	13	...	Gugti camp.	...	...	66 39 20		...	31 51 13·1	...	Chojothal District.
24	,,	13	...	Do.	(*Fomalhaut*)	...	55 25 30		+ 3′ 0″	31 57 21·9	31 54 17·5	Watch stopped.
26	,,	16	...	Nabipa-cho.	Polaris.	...	67 0 40		− 7′ 0″	32 1 54·1	32 1 54·1	Do.
27	,,	19	4 0 A.M.	Kiangmachumik.	...	...	67 9 30		+ 3′ 0″	32 11 20·0	32 11 20·0	
28	,,	20	...	Giachuruff camp.	...	...	67 16 0		...	32 14 34·5	32 14 34·5	District Singmiath, bank of Singi-Chu stream also called Thok-Somba. Sextant No. 45.
29	,,	26	2 42 ,,	Thok-Jalung, near gold mine.	...	...	67 37 0		...	32 25 5·6		
30	,,	27	9 30 P.M.	Do.	Altair.	...	132 13 0		...	32 13 46·5		
33	,,	30	9 5 ,,	Do.	...	...	132 13 10		...	32 23 41·8	32 24 26·5	
34	,,	30	12 15 A.M.	Do.	(*Fomalhaut*)	...	54 33 30		...	32 23 36·9		
35	,,	30	2 30 ,,	Thok-Jalung.	Polaris.	...	67 37 20		...	32 25 16·8		Sextant No. 45.
36	Septr.	2	12 5 noon.	Singmiath-Puttee.	Sun.	...	132 14 30		...	32 12 38·4	Deduced thermometer 50°.	One and half mile south of Giachuruff Camp.

37	,,	,,	11 40 P.M.	Do.	Jupiter.	...	91 15 10	...	32 11 57·8	Barometer 16·4 in.	Do.	
38	,,	,,	...	Do.	Do.	...	91 16 0	+ 5′ 0″	32 10 32·8	32 9 23·6	Pocket Sextant No. 12.	
40	,,	3	12 18 A.M.	Do.	(*Fomalhaut*)	...	55 2 0	+ 3′ 0″	32 9 16·7		Wind was high, not confident in the observation.	
41	,,	,,	1 0 ,,	Do.	Polaris.	...	67 2 0	...	32 7 40·8		Do.	Do.
43	,,	4	8 40 P.M.	Shildung camp.	Altair.	...	132 27 10	...	32 16 42·9	32 19 27·0	Near Mane, not taken on Meridian.	
44	,,	,,	2 0 A.M.	Do.	Polaris.		67 31 10	...	32 22 11·0			
45	,,	5	2 0 ,,	Giamchung-phu camp.	...	...	67 40 40	...	32 26 57·5	32 26 57·5		
46	,,	6	8 40 P.M.	Thanker (one house only.)	Altair.	...	132 0 40	...	32 29 57·6	32 30 47·6		
47	,,	,,	2 0 A.M.	Do.	Polaris.	...	67 50 0	...	32 31 37·6			
49	,,	7	8 30 P.M.	Pika village.	Altair.	...	131 58 0	...	32 31 18·2	32 31 43·1		
50	,,	,,	11 30 ,,	Do.	(*Fomalhaut*)	...	54 18 50	...	32 30 59·0			
51	,,	,,	1 30 A.M.	Do.	Polaris.	...	67 51 20	...	32 32 17·5			
52	,,	8	8 20 P.M.	Burkung village, (in ruins.)	Altair.	...	131 55 10	...	32 32 43·3	32 32 53·1		
53	,,	,,	1 36 A.M.	Do.	Polaris.	...	67 52 50	...	32 33 2·8			
54	,,	9	8 15 P.M.	Marku camp.	Altair.	...	131 58 30	...	32 31 3·6	32 31 3·6	Near Singi-Chu stream.	
55	,,	10	8 18 ,,	Dak-Maru.	Altair.	...	132 0 30	+ 2′ 30″	32 30 18·8	32 30 3·0		
56	,,	,,	11 48 ,,	Do.	Polaris.	...	67 46 50	...	32 29 47·2		(Near Gamuk village) on bank of Singi-Chu stream.	
57	,,	11	8 15 ,,	Ralajung.	Altair.	...	132 5 0	...	32 28 4·4	32 27 52·6		
58	,,	,,	1 30 A.M.	Do.	Polaris.	...	67 42 40	...	32 27 40·7		On bank of Singi-Chu stream.	
59	,,	12	8 15 P.M.	Lujan-Chumik camp.	Altair.	...	132 11 40	...	32 24 44·5	32 24 35·1		
60	,,	,,	1 25 A.M.	Do.	Polaris.	...	67 36 10	...	32 24 25·6			

Observations for Latitude taken in Great Tibet, &c.—(Continued.)

No. of Observations.	Astronomical Date.		Watch Time.	Station.	Object on Meridian.	Upper or Lower Transit.	Double Altitude.	Single.	Index Error.	Deduced Latitudes.	Mean Latitudes.	Remarks.
			h m				° ′ ″			° ′ ″	° ′ ″	
61	Sept.	13	8 0 P.M.	Name unknown.	Altair.	Upper	132 30 50		− 7′ 0″	32 17 54·6	32 18 22·8	
62	,,	13	1 30 A.M.	Do.	Polaris.	...	67 30 30		...	32 18 50·9		
63	,,	14	7 55 P.M.	Gargunsa village.	Altair.	...	132 50 0		...	32 10 19·0	32 8 45·6	
64	,,	14	1 25 A.M.	Do.	Polaris.	...	67 11 10		...	32 7 12·1		
65	,,	15	7 50 P.M.	Loa-Gong camp.	Altair.	...	133 10 30		...	32 0 3·6	31 57 45·9	
66	,,	15	1 40 A.M.	Do.	Polaris.	...	66 47 40		...	31 55 28·1		
67	,,	16	1 30 ,,	Garyarsa, large village.	...	...	66 22 30		...	31 42 50·6	31 43 54·0	
68	,,	16	7 30 P.M.	Do.	Altair.	...	133 40 30		...	31 45 4·2		
69	,,	18	...	Do.	...	...	133 40 40		...	31 44 59·3		
70	,,	19	1 0 A.M.	Do.	Polaris.	...	66 22 10		...	31 42 41·6		
71	,,	24	7 15 P.M.	Dunkhar village.	Altair.	...	133 47 30		...	31 41 34·1	31 41 26·9	
73	,,	24	5 0 A.M.	Do.	Orionis. (*Rigel*)	...	100 3 0		...	31 41 7·7		
74	,,	25	noon.	Do.	Sun.	...	115 54 30		...	31 41 38·9		
76	,,	28	7 35 P.M.	Totling monastery.	Altair.	...	134 9 40		...	31 30 30·3	31 30 4·7	
77	,,	28	10 45 ,,	Do.	(*Fomalhaut*)	...	56 31 0		...	31 29 56·2		
79	,,	29	5 51 A.M.	Do.	Orionis. (*Rigel*)	...	100 26 0		...	31 29 39·8		Date mistaken.

80	„	30	noon.	Totling monastery.	Sun.	...	112 23 10	− 7′ 0″	31 30 22·5	31 30 4·7		
81	Octr.	2	5 40 A.M.	Do.	Orionis. (*Rigel*)	...	100 25 30	...	31 29 54·6			
82	„	4	7 0 P.M.	Mangnang village.	Altair.	...	134 27 0	...	31 21 50·1	31 21 47·2		
83	„	„	5 30 A.M.	Do.	Orionis. (*Rigel*)	...	100 41 50	...	31 21 44·2			
84	Novr.	14		Badrinath Temple.	Do.	...	101 56 50	...	30 44 9·9			Watch not going. See observations 1 and 3, preceding.
1	Sept.	13		Tashikang village.	Altair.	...	132 2 0	+ 3′ ″0	32 29 19·4	32 30 13·1		Observations taken near monastery.
2	„	„		Do.	Polaris.	...	67 49 0	...	32 31 6·7			Deduced thermometer 55°, Barometer 18·2 inches.
3	„	14		Domakolok camp.	Altair.	...	131 46 0	...	32 37 18·6	32 38 9·7		Do.
4	„	„		Do.	Polaris.	...	68 4 40	...	32 39 0·8			
5	„	15		Demchok village.	Altair.	...	131 40 0	...	32 40 18·6	32 41 38·5		Thermometer 55° Barometer 18·2 inches.
6	„	„		Do.	(*Fomalhaut*)	...	53 58 0	...	32 41 22·9			
7	„	15		Do.	Polaris.	...	68 11 30	...	32 42 26·2			
8	„	16		Demchok-phu camp.	Altair.	...	131 45 20	...	32 37 38·1	32 38 30·7		Deduced thermometer 55°, Barometer 17·5 inches.
9	„	„		Do.	Polaris.	...	68 5 20	...	32 39 23·3			
10	„	17		Deboche.	(*Fomalhaut*)	...	54 22 30	...	32 29 2·3	32 29 8·7		Thermometer 51° Barometer 16·8 inches.
11	„	„		Do.	Polaris.	...	67 45 0	...	32 29 15·1			
12	„	18		Madok Sing.	Altair.	...	132 22 0	...	32 19 17·5	32 20 14·0		Do.
13	„	„		Do.	Polaris.	...	67 28 50	...	32 21 10·5			
14	„	19		Dilchachinisumdo.	Altair.	...	132 36 30	...	32 12 3·1	32 13 3·7		Junction of two streams (Sumdo) thermometer 52° Barometer 17·2 inches.

Observations for Latitude taken in Great Tibet, &c.—(Continued.)

No. of Observations.	Astronomical Date.		Watch Time.	Station.	Object on Meridian.	Upper or Lower Transit.	Double Altitude.	Single.	Index Error.	Deduced Latitudes.	Mean Latitudes.	Remarks.
							° ′ ″			° ′ ″	° ′ ″	
15	Sept.	19		Dilchachini-Sumdo.	Polaris.	Upper	67 14 40		+ 3′ 0″	32 14 4·3	32 13 3·7	Junction of two streams (Sumdo), thermometer 52° barometer 17·2 inches.
16	,,	20		Right bank of Lamoche stream.	Altair.	...	132 58 30		...	32 1 2·9	32 0 47·8	Thermometer 53°, Barometer 17·4 inches.
17	,,	,,		Do.	(*Fomalhaut*)	...	55 19 30		...	32 0 32·6		
18	,,	21		Near Jia-sumdo.	Altair.	...	133 1 10		...	31 59 43·0	31 59 43·0	Do.
19	,,	22		Rabgialing (near monastery.)	...	...	133 10 20		...	31 55 8·0	31 53 37·0	Thermometer 53°, Barometer 17·5 inches.
20	,,	,,		Do.	(*Fomalhaut*)	...	55 30 30		...	31 55 2·4		
21	,,	,,		Do.	Polaris.	...	66 30 50		...	31 52 8·8		
22	,,	23		Chokche village.	Altair.	...	133 14 40		...	31 52 58·2	31 52 58·2	Thermometer 54°, Barometer 17·8 inches.
23	,,	,,		Do.	(*Fomalhaut*)	...	55 34 40		...	31 52 58·1		
24	,,	24		Shangche village (near.)	Altair.	...	133 21 40		...	31 49 28·3	31 49 16·0	Thermometer 54°, Barometer 18·0 inches.
25	,,	,,		Do.	(*Fomalhaut*)	...	55 42 30		...	31 49 3·6		
26	,,	25		Tibu phu.	Altair.	...	133 36 0		...	31 42 18·4	31 42 0·7	Thermometer 55°, Barometer 18·2 inches.
27	,,	,,		Do.	(*Fomalhaut*)	...	55 58 0		...	31 41 18·7		
28	,,	,,		Do.	Polaris.	...	66 11 0		...	31 42 12·8		

29	„	26		Dunkhar village.	Altair.	...	133 42 20	...	31 39 9·1	31 39 34·1		600 paces S.W. of village.
30	„	„		Do.	(*Fomalhaut*)	...	56 0 10	...	31 40 16·8			
31	„	„		Do.	Polaris.	...	66 5 30	...	31 39 25·2			
1	„	30	7 25 P.M.	Barku village.	Altair.	...	134 10 0	+ 2′ 0″	31 25 50·4	31 25 52·0		
2	„	„	10 30 „	Do.	(*Fomalhaut*)	...	56 30 0	...	31 25 55·9			
3	„	„	5 0 A.M.	Do.	Orionis. (*Rigel*)	...	100 24 40	...	31 25 49·7			
4	Oct.	2	7 30 P.M.	Puling-gongma.	Altair.	...	134 20 50	...	31 20 24·7	31 20 20·2		Camp.
5	„	„	10 16 „	Do.	(*Fomalhaut*)	...	56 41 0	...	31 20 22·7			
6	„	„	4 30 A.M.	Do.	Orionis. (*Rigel*)	...	100 35 50	...	31 20 13·3			
7	„	4	7 30 P.M.	Rildighang village.	Altair.	...	134 0 0	...	31 30 50·3	31 31 9·9		
8	„	„	10 10 „	Do.	(*Fomalhaut*)	...	56 17 0	...	31 32 25·0			
10	„	„	4 40 A.M.	Do.	Orionis. (*Rigel*)	...	100 13 40	...	31 31 19·5			
11	„	„	5 40 „	Do.	(*Sirius*)	...	83 55 0	...	31 30 4·7			
12	„	5	7 30 P.M.	Ri village.	Altair.	...	133 48 10	...	31 36 45·1	31 36 58·5		
13	„	„	10 55 „	Do.	(*Fomalhaut*)	...	56 8 20	...	31 36 43·9			
14	„	„	4 56 A.M.	Do.	α Orionis.	...	131 30 0	...	31 37 0·7			
15	„	„	5 42 „	Do.	(*Sirius*)	...	83 42 0	...	31 36 34·1			
17	„	6	12 15 „	Do.	Polaris.	...	66 2 0	...	31 37 11·0			
18	„	7	7 20 P.M.	Lanjan Samba.	Altair.	...	133 39 30	...	31 41 7·0	31 41 8·0		Near bridge over Sutlej river.
19	„	„	5 33 A.M.	Do.	*Sirius.*	...	83 33 0	...	31 41 9·0			

Observations for Latitude taken in Great Tibet, &c.—(Continued.)

No. of Observations.	Astronomical Date.		Watch Time.	Station.	Object on Meridian.	Upper or Lower Transit.	Double Altitude.	Single.	Index Error.	Deduced Latitudes.	Mean Latitudes.	Remarks.
			h m				° ′ ″			° ′ ″	° ′ ″	
20	Oct.	8	9 42 P.M.	Dongkhang.	(*Fomalhaut*)	Upper	55 51 0		+ 2′ 0″	31 45 24·6	31 45 49·7	
21	,,	,,	5 30 A.M.	Do.	(*Sirius*)	...	83 22 40		...	31 46 14·7		
22	,,	9	12 o'clock.	Miang village.	Polaris.	...	66 23 0		...	31 47 38·0	31 47 16·3	(Midnight.)
23	,,	,,	3 53 A.M.	Do.	Orionis. (*Rigel*)	...	99 42 0		...	31 47 11·5		
24	,,	,,	5 21 ,,	Do.	(*Sirius*)	...	83 22 0		...	31 46 37·7		
25	,,	10	9 30 P.M.	Tiak village.	(*Fomalhaut*)	...	55 48 10		...	31 46 58·8	31 46 59·5	
26	,,	,,	5 15 A.M.	Do.	(*Sirius*)	...	83 21 20		...	31 47 0·2		
27	,,	11	6 20 P.M.	Shipki village.	Altair.	...	133 24 50		...	31 48 27·5	31 48 25·6	
28	,,	,,	9 23 ,,	Do.	(*Fomalhaut*)	...	55 44 50		...	31 48 37·4		
29	,,	,,	3 40 A.M.	Do.	Orionis. (*Rigel*)	...	99 39 40		...	31 48 22·8		
30	,,	,,	5 10 ,,	Do.	(*Sirius*)	...	83 18 50		...	31 48 14·5		
31	,,	12	6 12 P.M.	Kuak village.	Altair.	...	133 27 20		...	31 47 12·3	31 47 49·6	
32	,,	,,	11 48 ,,	Do.	Polaris.	...	66 24 40		...	31 48 26·8		
33	,,	14	9 6 ,,	Kuang village.	(*Fomalhaut*)	...	55 53 50		...	31 44 0·5	31 43 52·6	
34	,	,,	3 22 A.M.	Do.	Orionis. (*Rigel*)	...	99 48 50		...	31 43 44·7		
37	,,	16	8 55 P.M.	Sumna village.	(*Fomalhaut*)	...	56 8 20		...	31 36 43·2	31 36 43·2	

38	„	17	8 50 P.M.	Beghar or Bikar village.	(*Fomalhaut*)	...	56 6 50	+ 2′ 0″	31 37 32·1	31 37 32·1		
39	„	18	8 45 „	Sarang village.	...	...	56 13 40	...	31 34 5·3			
40	„	„	10 55 „	Do.	Polaris.	...	65 56 0	...	31 34 12·6			
41	„	„	3 4 A.M.	Do.	Orionis. (*Rigel*)	...	100 8 30	...	31 33 54·6	31 34 11·3		
42	„	„	3 32 „	Do.	(*Sirius*)	...	83 46 50	...	31 34 10·3			
43	„	20	11 30 „	Do.	Sun.	...	96 58 40	...	31 34 29·8			On meridian.
44	„	23	8 20 P.M.	Changjum Sumdo.	(*Fomalhaut*)	...	56 47 10	...	31 17 18·6	31 17 18·6		
45	„	24	8 15 „	Nonam.	...	...	57 0 40	...	31 10 33·4	31 10 33·4		
46	„	25	8 10 „	Chongsa or Nilung village.	...	...	57 7 30	...	31 7 10·3			
47	„	26	noon.	Do.	Sun.	...	93 41 40	...	31 6 16·5			
48	„	„	8 5 P.M.	Do.	(*Fomalhaut*)	...	57 9 50	...	31 6 0·2			
49	„	29	7 50 „	Do.	...	...	57 10 0	...	31 5 54·8			
50	„	„		Do.	Orionis. (*Rigel*)	...	101 4 30	...	31 5 54·0	31 6 17·9		Watch ceased going.
51	„	„		Do.	(*Sirius*)	...	84 43 0	...	31 6 4·5			Do.
52	„	„		Do.	*Procyon.*	...	128 55 50	...	31 5 4·6			Do.
53	„	30	noon.	Do.	Sun.	...	90 56 40	...	31 7 58·2			
55	Novr.	6	...	Mukpa village.	...		86 42 20	...	31 2 25·6			
56	„	„	7 55 P.M.	Do.	(*Fomalhaut*)		57 18 30	...	31 1 44·3			
57	„	7	noon.	Do.	Sun.		86 5 40	...	31 2 47·2	31 2 10·8		
58	„	8	7 55 P.M.	Do.	(*Fomalhaut*)		57 18 20	...	31 1 49·1			
59	„	„		Do.	(*Sirius*)		84 51 20	...	31 1 56·4			

Observations for Latitude taken in Great Tibet, &c.—(Continued.)

No. of Observations.	Astronomical Date.		Watch Time.	Station.	Object on Meridian.	Upper or Lower Transit.	Double Altitude.	Single.	Index Error.	Deduced. Latitudes.	Mean Latitudes.	Remarks.
							° ′ ″			° ′ ″	° ′ ″	
61	Novr.	9	noon.	Mukpa village.	Sun.		84 56 20		+ 2′ 0″	31 2 21·9	31 2 10·8	
1	August.	26		Lapta rebo camp.	Polaris.		66 58 10		− 7′ 0″	32 0 23·0	32 0 23·0	
2	,,	29		Jiachin camp.	(*Fomalhaut*)	Upper	55 20 30		...	32 5 27·3	32 5 27·3	A little after transit.
3	,,	30		Nagpo Shamdo camp.	Polaris.		66 44 0		...	31 53 19·2	31 53 19·2	

Observations of the Boiling Point taken in Great Tibet.

No. of Station.	Astronomical Date.		Watch Time.	Station.	Thermometer.		Thermometer.		Deduced height above Sea.	Remarks.
					No.	Boiling Point.	No.	In Air.		
	1867.		*h m*							
1	June	28	5 42 P.M.	Badrinath, ...	22	195·40	30	60· 0	10,284	On first step of temple.
2	July	4	8 30 A.M.	Mana village 1¼ mile N. of Badrinath,	„	195·10	„	64· 0	10,510	
3	„	5	4 30 P.M.	Do.	„	195·00	„	66· 0		
4	„	26	7 0 A.M.	Ghastoli (halting place), ...	„	190·40	38	51· 0	13,251	
5	„	26	7 0 „	Do.	30	191.00	„	50· 0		
6	„	27	3 0 P.M.	Tare (foot of hill), ...	„	185.50	„	50· 0	16,587	
7	„	28	9 0 A.M.	Hutoli (pile of stones), ...	„	182· 0	„	37· 0	18,576	On crest of pass, also called Chirbitiala and Doongri-la.
8	„	30	noon.	Lumarti-Sumdo camp, ...	„	185·50	„	57· 5	16,660	
9	„	30	...	Do.	22	185·40	„	57· 5	16,317	
10	Augt.	1	5 47 A.M.	Do.	30	185·50	„	30· 0	16,396	
11	„	2	7 40 „	Chirkong, ...	„	187· 0	„	53· 5	15,708	
12	„	4	6 8 „	Barku village, ...	„	191·50	„	55· 5	13,005	
13	„	5	4 0 P.M.	Totling monastery, ...	„	192·75	„	69· 0	12,295	On house top about 15 feet above ground, and 60 feet above river.
14	„	7	7 0 „	Be-Songbo-ka-Sumdo, ...	„	191·50	„	64· 0	13,050	Junction of streams.
15	„	8	6 8 „	(Larcha) Bogola foot of mountain,	„	187·50	„	49· 0	15,364	
16	„	9	9 0 A.M.	Bogola, ...	„	181·00	„	40· 0	19,220	On crest of pass.

Observations of the Boiling Point taken in Great Tibet.—(Continued.)

No. of Station.	Astronomical Date.		Watch Time.	Station.	Thermometer. No.	Thermometer. Boiling Point.	Thermometer. No.	Thermometer. In Air.	Deduced height above Sea.	Remarks.
	1867.		*h m*							
17	August	9	6 30 P.M.	On other side of Bogola, ...	30	186·50	38	45· 5	15,935	Foot of mountain.
18	„	10	6 30 „	Khangiah camp, ...	„	188·00	„	58·25	15,129	
19	„	11	5 10 „	Gugti camp, ...	„	188·00	„	67·50	15,205	On bank of Gugti stream.
20	„	12	4 25 „	Gugti-Sumdo, ...	„	184·50	„	62·50	17,324	Junction of streams.
21	„	13	9 0 A.M.	Gugti-la, ...	„	180·50	„	37·00	19,490	On crest of pass.
22	„	13	5 45 P.M.	(Chojothôl) Gugti camp, ...	„	185· 0	„	58·25	16,968	On the other side of Gugti-la.
23	„	14	5 5 „	Lojang camp, ...	„	186· 0	„	58·25	16,353	On bank of Lang-Chu stream.
24	„	15	6 0 „	Chojo-Gunsa, ...	„	187· 0	„	53·00	15,700	Do.
25	„	16	6 36 „	Name not known, ...	„	187·75	„	58·25	15,289	
26	„	19	4 23 „	Kiangma Chumik, ...	„	185·50	„	59·00	16,669	Halting place where water is procurable.
27	„	20	9 0 A.M.	Paba-la, ...	„	183·75	„	49·25	17,649	On crest of pass.
28	„	20	5 30 P.M.	(In Puttie Singmiath) Giachuruff,	„	187·00	„	57·00	15,732	Camp on bank of Singi-Chu stream.
29	„	22	3 53 „	Chomorang-la, ...	„	185·00	30	56·00	16,949	Foot of mountain.
30	„	23	6 0 „	Chomorang camp, ...	„	184·50	„	45·00	17,151	
31	„	27	7 0 A.M.	Thok-Jalung (near gold mine), ...	„	185·75	„	41·00	16,346	} 16,337.
32	„	29	2 50 P.M.	Do.	„	186·00	„	55·00	16,327	
33	„	31	3 0 „	Chomorang-la, ...	„	182·00	„	53·00	18,765	On top of mountain.

34	Septr.	4	6 15 „	Shildung camp, ...	„	188·75	38	55·00	14,652	Near stream.
35	„	5	4 23 „	Giamchung (Gopha), ...	„	188·50	„	62·50	14,861	
36	„	6	5 30 „	Thanker village, ...	„	188·75	„	59·75	14,688	On bank of Singi-Chu about 12 feet over the water.
37	„	7	5 52 „	Pika village, ...	„	188·80	„	56·75	14,637	
38	„	8	6 30 A.M.	Do.	„	189·00	„	40· 0	14,388	
39	„	„	3 36 P.M.	Burkung village, (in ruins), ...	„	189·40	„	64· 0	14,324	On bank of Singi-Chu stream.
40	„	9	4 15 P.M.	Marku camp, ...	„	189·75	„	57· 5	14,071	Do.
41	„	10	5 12 „	Dak Maru, (red hill), ...	„	190·00	„	58·25	13,920	On top of hill.
42	„	11	6 2 A.M.	Do.	„	190·50	„	23·00	13,393	
43	„	„	5 35 P.M.	Ralajung, (on bank of Singi-chu),	„	191·50	„	58·50	13,022	
44	„	12	5 55 „	Lujan-Chumik, ...	„	191·50	„	54·50	12,999	On bank of Garjung-Chu stream.
45	„	13	5 0 „	On bank of Garjung-Chu stream,	„	191·00	„	53·00	13,287	
46	„	14	5 30 „	Gargunsa village, near stream, ...	„	189·50	„	47·00	14,147	
47	„	15	5 30 „	Loagong, (Rebo) camp, ...	38	188·75	„	49·00	14,381	
48	„	17	5 30 A.M.	Garyarsa monastery, ...	„	188·75	„	30·00	14,241	
49	„	25	9 0 „	Dunkhar village, ...	„	190·00	„	51·50	13,652	
50	„	30	6 55 „	Totling (monastery), ...	„	192·50	„	42·00	12,101	
51	October.	5	8 0 „	Mangnang village, ...	22	190·80	„	supposed 30	12,867	
1	August.	25	5 30 P.M.	Gobarteja-rebo, ...	38	187·00	„	56·00	15,495	In puttee Singmiath.
2	„	28	6 30 A.M.	Chakrang camp, ...	„	186·50	„	40·00	15,659	
3	„	29	7 0 „	Niarcher camp, ...	„	186·50	„	44·30	15,709	
4	„	„	5 30 P.M.	Jiachan Gûnsa, (house), ...	„	186·25	„	47·25	15,878	
5	Septr.	23	6 30 A.M.	Tashikong village, ...	30	191·50	„	60·25	13,027	Near Monastery.

Observations of the Boiling Point taken in Great Tibet.—(Continued.)

No. of Station.	Astronomical Date.		Watch Time.	Station.	Thermometer.		Thermometer.		Deduced height above Sea.	Remarks.
					No.	Boiling Point.	No.	In Air.		
	1867.		h m							
1	October	1	6 30 A.M.	Barku village, ...	38	191·75	38	34· 0	12,503	
2	„	2	6 12 „	Sharbarak-chu, ...	„	190·00	„	36·25	13,545	
3	„	3	6 6 „	Puling-Gongma camp, ...	„	189·50	„	29·50	13,801	
4	„	5	5 50 „	Rildighang camp, ...	„	189·50	„	17·00	13,709	
5	„	6	5 15 „	Ri village, ...	„	189·75	„	26·50	13,634	
6	„	8	5 59 „	Lanjam-Samba, (near), ...	„	196·00	„	39·75	10,039	On bank of Sutlej river.
7	„	„	4 38 P.M.	Sirang-la, ...	„	185·00	„	32·00	16,491	On top of mountain.
8	„	9	6 0 A.M.	Dongkhang, (one house), ...	„	189·50	„			The Mercury sunk so low that the Thermometer could not be read.
9	„	10	5 51 „	Miang village, ...	„	193·50	„	30· 0	11,458	
10	„	11	6 37 P.M.	Tiak village, ...	„	196·75	„	36·50	9,592	
11	„	12	6 25 A.M.	Shipki village, ...	„	196·00	„	35·00	10,027	On top of a house.
12	„	13	5 28 „	Kuak village, ...	„	196·00	„	37·50	10,030	
13	„	15	7 32 „	Kuang village, ...	„	191·50	„	27·00	12,610	
14	„	„	12 24 P.M.	Pungrang-che-la, ...	„	185·75	„	34·00	16,057	On crest of pass.
15	„	16	7 7 A.M.	Sang village, ...	„	189·50	„	18·00	13,715	
16	„	„	12 42 P.M.	Pimikche-la, ...	„	183·50	„	33·00	17,403	Do.

										13,201	
										11,201	
										11,783	
	„				„		„			16,810	On crest of pass.
21	„	24	7 32 A.M.	Sumdo Changjum camp, ...	„	190·75	„	16·00		12,984	
22	„	25	7 22 „	Nonam village, ...	„	191·50	„	22·00		12,583	
23	„	27	6 30 P.M.	Nilung or Chorsa village, ...	„	194·00	„	32·00		11,181	
24	„	30	1 8 „	Do.	„	193·75	„	51·00		11,407	
25	Novr.	7	4 45 „	Mukpa village, ...	„	199·25	„	48·00		8,172	Alongside Dharamsala.
26	„	11	6 42 A.M.	Do.	„	199·50	„	34·00		8,012	