GENERAL REPORT

ON THE OPERATIONS

OF THE

GREAT TRIGONOMETRICAL SURVEY OF INDIA,

DURING

1868-69,

Prepared for submission to the Government of India.

BY

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

SUPERINTENDENT G. T. SURVEY.

Dehra Doon:

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

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THE OPERATIONS OF THE

GREAT TRIGONOMETRICAL SURVEY OF INDIA.

IN 1868-69.

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, Burmah.

III. *Trigonometrical;* the Beder Longitudinal Series, parallel 18°.

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

V. *Trigonometrical;* the Bangalore Meridional Series.

VI. *Trigonometrical;* the measurement of a base-line of verification in the neighbourhood of Cape Comorin.

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

VIII. *Topographical;* the Survey of Kattywar.

IX. *Topographical;* the Survey of Guzerat in the Bombay Presidency.

X. *Geographical;* Explorations of Trans-Himalayan Regions.

XI. *Astronomical;* latitude observations at certain stations of the triangulation on the meridian of 75°.

XII. *Leveling;* execution of certain lines of spirit levels.

XIII. *Geodetic;* pendulum observations at certain stations of Colonel Everest's Arc.

XIV. *Magnetic;* determinations of Dip, Declination and Total Force.

XV. *Computations;* the final examination and reduction of the observations.

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

(2.) The out-turn of work executed by the Trigonometrical and Topographical parties I to IX may be briefly summarized as follows. The measurement of a base-line in the neighbourhood of Cape Comorin. The measurement of 7 azimuths of verification. Principal triangulation* with the Great Theodolites; 72 triangles, the average errors of which, as well as the average probable errors of the angles, are shewn in the margin; they cover an area of 6,508 square miles, and would, if united, form a chain of triangles 320 miles in length. Secondary triangulation, with theodolites of various sizes; 6,615 square miles, defining the positions of 1,939 points, of 632 of which the heights were also determined. Topographical surveying, on the scale of 12 inches to the mile, 13,173 acres; on that of 2 inches to the mile, 2,334 square miles; and on that of 1 inch to the mile, 1,338 square miles. Boundary surveys and check lines, 914 linear miles.

Series.	Probable Errors of Observed Angles.		Errors of Triangles.	
	Number.	Amount.	Number.	Amount.
I ...	45	±0″·20	15	0″·58
II ...	36	·38	12	·59
III ...	48	·20	16	·35
IV ...	39	·22	13	·32
V ...	15	·13	5	·27
VI ...	33	·21	11	·64
Averages, ...		± 0·23	...	0·47

(3.) During the field season I went down from my head-quarters at Dehra Doon to inspect the operations which were in progress in the Madras Presidency. I availed myself of the opportunity to comply with a request which was made by the Secretary of State for India, at the suggestion of Professor Airy, Astronomer Royal, that I should draw up a document providing for the future administrative arrangements of the Madras Observatory, by prescribing certain definite duties for its future performance. This document was submitted for the orders of the Secretary of State, on my return from the Madras Presidency.

(4.) I had hoped to have been able to employ a second Astronomical Party this year in determining the latitudes of some of the principal stations of this survey; but unfortunately no instrument was available for the purpose. Of the two Astronomical Circles which were brought out to India by Colonel Everest, one has become unserviceable; but I expected to have received one of the two Zenith Sectors, which, with the other instruments for the determination of differences of longitude

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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.

with the aid of the electric telegraph, had been sanctioned by the Secretary of State no less than seven years ago. But not one of these instruments had been received, and I was consequently obliged to employ the second Astronomical Party in other operations. I can only hope that when the instruments arrive eventually, their qualifications will be found to bear some proportion to the time that has been expended on their construction, for in this case they will certainly be very exquisite and efficient.

(5.) Captain Clarke has remarked, in the chapters on the figure of the earth, at the end of his account of the Principal Triangulation of Great Britain, (*London* 1858), that if there had been a larger number of astronomical points on Colonel Everest's Arc, they would have added very greatly to the weight of the determination of the earth's figure. Several such points have since then been added to the Northern Section of this arc, as I have previously reported, and other's will be determined on the Southern Section as soon as a suitable instrument is received for the purpose. But the triangulation of India, when completed, with its astronomical observations of latitude and longitude, will furnish not only several meridional arcs, such as have until very lately been solely relied on by Geodesists for determining the figure of the earth, but it will also furnish several arcs of parallel, such as are now being completed in Europe. These therefore should greatly enhance the weight of all future determinations of the figure of the earth.

(6.) Already the operations, so far as they have been completed, shew that there is a considerable probability that they will materially modify the latest and best determinations which have been published hitherto. One of the stations of the Indian Arc is Dodagoontah, near Bangalore, the astronomical latitude of which, as given by Bessel, in Numbers 334,335 of the *Astronomische Nachrichten*—from calculations based on Colonel Lambton's observations—is 12° 59′ 52″·2. This station has been recently connected by triangulation with the Madras Observatory, and its latitude, as referred to the astronomical latitude of that observatory, is found to be 13° 0′ 0″·6, or 8″·4 in excess of the value determined by the astronomical observations on the spot. The error generated in the triangulation from Madras cannot possibly exceed $\pm$ 0″·2; consequently, if, as may be expected, the errors in the adopted elements of the stars which were observed at both places are immaterial, the difference between the two results must be almost wholly due to a local deflection of the plumb line, either at Dodagoontah or at Madras, or at both; such a deflection would however most probably be met with at Dodagoontah, which is situated on a table land elevated about 3,000 feet above the sea, and was rejected by Colonel Lambton, as unsuitable for observations of this nature; whereas Madras stands on an extensive level plain raised very slightly above the level of the sea, and is at a considerable distance from any mountains, or *apparent* irregularities in the disposition of the earth's crust, which might tend to cause a meridional displacement of the plumb line. If the position of Dodagoontah is at fault, all determinations based thereon must necessarily be materially modified. In any case, the advantages of multiplying the astronomical stations, and adding to the number of geodetic facts of observation, must be very considerable.

(7.) At the suggestion of the Government of Bombay and the Superintendent of the Geological Survey of India, measures were sanctioned the year before last for determining the mean sea level at various points on the coasts of the Peninsula—and more particularly on the coasts of Kattywar and the gulf of Cutch—with the

intention that the observations should be repeated a few years hence, in order to show whether any progressive change in the relative level of land and sea is going on, such as has long been supposed to be the case at the head of the gulf of Cutch. As the secular changes of level which have been hitherto ascertained are believed to indicate a very slow rate of change, "not more than a foot or two in a century," it is necessary that the tidal observations should be made with very great accuracy, in order that reliable results may be obtained in the course of a few years. For this purpose self-registering tide gauges of an improved design are being constructed; and, as the tidal ranges at different points of the coasts are very variable, at some places not more than two or three feet, at others as much as fifty feet, the guages are made of different scales—natural, half, and other scales—in order that the tidal curve at each station may be exhibited on the largest scale which can be conveniently employed. Some of these instruments are now completed, and the remainder are nearly ready; the observations may therefore be commenced next year.

(8.) In order to combine the results of the pendulum observations which are being carried on in India by Captain Basevi, with those taken in other parts of the globe, with other pendula, it is necessary that the several pendula should be compared, by being observed at the same spot. The most important observations now in progress out of India are, I believe, those in Russia; as the pendula employed in the Russian operations are much smaller and lighter than those which were supplied by the Royal Society for the operations in India, I applied to Mons. Otto Struve, Director of the Poulkova Observatory, for the loan of one of the Russian pendula, partly with the object of comparing it with those of the Royal Society, and partly with a view to its being employed by Captain Basevi, in taking observations on the elevated table lands north of the Himalaya mountains, to which the heavier and more cumbersome apparatus at present in use could not be transported without much difficulty and expense. At M. Struve's recommendation, the Russian Imperial Academy of Science has been so obliging as to lend me an apparatus which was employed, during the summer of 1868, by Professor Sawitsch, on the southern section of the Russo-Scandinavian arc of meridian. The following resolution on this subject was passed by the Academy, at a meeting in December 1868:

"Considering that to combine the results of pendulum observations made on the Russian and "the Indian arcs it would be most advantageous if one and the same apparatus was used at least on a "couple of stations of *both* arcs, and as far as possible under similar conditions, the Academy resolves

"1*st*. To lend Colonel Walker, in agreement with a desire expressed by him to Mr. O. Struve, "the whole apparatus used by Professor Sawitsch on the Russian arc, for a period of 3 years, beginning "next summer.

"2*ndly*. To charge Mr. O. Struve with the necessary transactions on that subject with Colonel "Walker."

The apparatus has been duly despatched from St. Petersburg, and may be expected to reach Calcutta in January 1870.

(9.) I have much gratification in reporting that the results of the Trans-Himalayan Explorations, which have been carried on of late years under the superintendence of Major Montgomerie, in connection with the operations of this Department, have been very favorably received by some of the most eminent Geographers in Europe. The Russian Geographical Society has been particularly struck

with our method of equipping the Pundits, who are deputed into regions inhabited by a Buddhist population, with 'prayer wheels', containing the instruments which have to be most frequently used in the course of the route-surveys. In the expectation that such an arrangement will be found of use in explorations from the Russian Territories into southern Mongolia, the Society has applied to me for a prayer wheel, which I have had much pleasure in supplying; and I may well hope that it will be found as serviceable to Russian as it has been to British Geographers.

(10.) The operations of this Department were long restricted to geodetic investigations, and to the execution of triangulation as a basis for the Topographical Surveys which are executed under the orders of the Surveyor General, and the several Superintendents of Revenue—or Fiscal—Surveys in the three Presidencies. But the Topography of the Himalayas has, from the time when these mountains were first fairly accessible to Europeans, been allotted to the Trigonometrical Survey, and of late years other topographical labors have been undertaken by this Department, as it's ordinary operations are rapidly approaching completion. Of these surveys the most important hitherto has been the one of Kashmir, Ladak and Tibet, executed under the superintendence of Captain—now Major—Montgomerie. The interest which was felt in those regions on the annexation of the Punjab, led, —though they belong to a Native Prince, who is a feudatory of the British Government—to their Survey being completed, before other portions of the Himalayas, which had long been subject to the British Government, were undertaken. On the completion of that Survey, Major Montgomerie's party was transferred to the British states of Kumaon and Gurhwal, in which it has now been operating for about four years, executing a topographical survey on the scale of 1 inch to the mile, or four times that of the survey of Kashmir and Ladak. These circumstances are all well known to the Government of India; but I have considered it desirable to state them here in order to explain why certain Topographical Surveys are being executed by this Department, while others are done by purely Topographical Departments; for this often perplexes persons who are imperfectly familiar with the operations of various branches of the Survey of India. The topography of the Himalayas was doubtless at first allotted to this Department because it commanded the services of assistants who could be trained to delineate the features of the mountains, accurately and artistically, more readily than the assistants in the other branches of the Survey; and though this is no longer the case, it is now necessary to transfer a gradually increasing number of the assistants from the original work of this department to topographical duties, in order that they may be adequately employed in the still vast portions of the empire, which have not hitherto been regularly surveyed in detail.

(11.) I will now proceed as usual to report on the general operations of the respective Survey Parties and Offices. Further details will be found in the Appendices, which contain selections from the annual Narrative Reports of the Executive Officers, a Report by Major Montgomerie on the Trans-Himalayan Explorations, and Notes on the Tinnevelly District by Captain Branfill, with a paper on the climate of south Tinnevelly, which the Revd. Dr. Caldwell obligingly prepared for Captain Branfill, as an addition to his Notes.

No. 1.—TRIGONOMETRICAL.

THE BRAHMAPUTRA SERIES, MERIDIAN 90°.

(12.) This chain of triangles emanates from the Longitudinal Series east of Calcutta, which was completed in 1866-67; it trends northwards, along the meridian of 90°, through the District of Furreedpore, crossing the Ganges a little below its junction with the Jamoona Branch of the Brahmaputra, and then advancing along both banks of the Jamoona through the Districts of Dacca and Pubna. The stations are generally built at as great a distance from the river as possible, in order that they may not be liable to be swept away during the annual floods.

PERSONNEL.

Captain H. R. Thuillier, R.E., Dy. Supdt. 2nd Grade.
Lieut. Larminie, R.E., Assistant Supdt. 2nd Grade.
Mr. C. J. Neuville, Surveyor 3rd Grade.
„ F. W. Ryall, Assistant Surveyor 1st Grade.
„ G. A. Harris, Assistant Surveyor 2nd Grade.
„ W. J. O'Sullivan, Assistant Surveyor 2nd Grade.

(13.) Captain Thuillier, reports that

"This tract of country is perfectly flat and uninteresting, there being scarcely any undulation to break the monotony of its even surface. The southern portion of the Furreedpore district consists of immense morasses, covered with long reed grass and other aquatic plants, extending for miles without a spot of dry ground, excepting the small mounds artificially raised by the inhabitants for their huts. These great swamps cover a large portion of the district, the only really dry land being on the banks of the rivers and streams. Communication, as may be imagined, is very difficult, but our chief difficulties were in finding solid ground for our tower sites, and in carrying rays of 9 to 11 miles in length across such a country. Proceeding northwards the country gradually rises, but the slope is very slight. Even at the point where I closed work, about 60 miles north, the ground is of such a low level that it is inundated during the rains. The open ground in these parts (Dacca District) is principally used for rice crops and becomes submerged after a heavy fall of rain."

(14.) The operations were commenced last year; but the preliminary measures of selecting and building the stations—invariably masonry towers of a height of 30 to 40 feet—and cutting the lines between them, were found to be so laborious that it was necessary to concentrate the entire exertions of the party on this portion of the operations only. The measurement of the principal angles, with one of Messrs. Troughton and Simm's 24 inch theodolites, was postponed to the present year, when they were commenced by Captain Thuillier who reports that

"During the early portion of the season, great delay was experienced in the observations, owing to the heavy fog and mist which invariably rose after sunset and continued till some time after sunrise. This fog entirely precluded any work being obtained from lamps, and I may say that up to the end of January I obtained no lamp observations whatever, so that the horizontal observations were restricted to heliotropes for about two hours daily. In February these fogs diminished, but I was still greatly harassed in my night work up to the end of the season. As the water in the "Jheels" and low lands gradually decrease, the reeds and jungle dry, the inhabitants then fire them in all directions, to prepare the ground for their crops, and the smoke arising from these fires added considerably to my difficulties. In February and March also the atmosphere was unusually hazy and for many days the heliotropes were invisible. It was not till the 9th of April that we were relieved by clear weather, caused by north-westerly storms which generally come in March."

(15.) The positions of 15 new principal stations were fixed, forming 3 hexagonal figures which cover an area of 778 square miles and extend over a direct distance of 56 miles; an azimuth of verification was observed; 13 towers were built and 373 miles of lines were cleared of trees and jungle; stations were also selected in advance over a distance of 56 miles, for the triangulation of next season.

(16.) In connection with these operations, a chain of first class secondary triangulation, with a 14-inch theodolite, is being carried, by Leiutenent Larminie,

through the valley of Assam, towards it's upper extremity, where Revenue Survey operations are now in progress. This triangulation has not advanced as rapidly as I had hoped; the out-turn of work merely consists of 2 quadrilaterals and a polygon extending over a direct distance of 56 miles and covering an area of 480 square miles. In most other parts of India Lieutenant Larminie would probably have done very much more; but Assam is a proverbially difficult country to do anything in; the amount of forest and jungle, the absence of roads, the numerous rivers and few ferries, the scanty population, and the very limited resources of the district, render the more moving about from place to place a very slow and troublesome matter. The atmosphere moreover is generally most unfavorable for trigonometrical observations; throughout the entire field season the snow peaks on the by no means distant ranges to the north of the valley were only seen once, and that very imperfectly; a thick haze hung over the ground for months in succession, which there was no rainfall, to dispel, such as usually happens about Christmas. In the dry but healthy months of the cold weather, the stations were seen with difficulty from each other, though at comparatively short distances apart, and in March, when the early rains commence, the country becomes too unhealthy to permit of further operations in the field. I can only hope that next season the atmosphere will be more favorable, and the progress of the operations more rapid.

No. II.—TRIGONOMETRICAL.

THE EASTERN FRONTIER SERIES, BURMAH.

(17.) This chain of triangles was commenced in the year 1861-62, near the western extremity of the Assam valley, and was carried through the Kossia and Tipperah Hills, and the districts on the east coast of the Bay of Bengal, as far south as Sandoway; then, following the line of frontier as closely as possible, it was directed into the northern portion of British Burmah. Last year it was carried across the range of mountains between Burmah and the Bay of Bengal, the operations of the season closing in the vicinity of the town of Prome.

PERSONNEL.

W. C. Rossenrode, Esq., Depy. Supdt. 3rd Grade.
Mr. H. Beverley, Surveyor 2nd Grade.
„ W. C. Price, Assistant Surveyor 3rd Grade.
„ E. J. Connor, Do. do.
„ R. Gibson, Probationary Asst. Surveyor 4th Grade.

(18.) In my last report I shewed that, as compared with what had been accomplished in preceding years, there had been a marked falling off in the out-turn of work, whether measured by the progress in direct distance, or by the area brought under triangulation. I attributed this to the difficulty in obtaining the number of workmen that were required for the necessary operations of building the stations of observation and cutting down the forest and jungle on the lines between them. I anticipated that when the operations advanced into British Burmah, the difficulties of this nature would be lessened, but that as that Province is thinly inhabited and more or less covered with dense forest and jungle, the future progress of the operations would necessarily be slow, as compared with what can be accomplished in other parts of India.

(19.) This year presents a marked improvement over the last, as regards the amount of work completed, but it has been achieved by excessive exertions on

the part of Mr. Rossenrode and his assistants, which, in other districts, would have been rewarded with a far greater out-turn of work. Leaving his recess station, Moulmein, in October, Mr. Rossenrode arrived in the Myanoung district early in November, and was told by the local authorities that he had come too soon, that the country was not dry and the roads were not open, that to march at that time was impossible, and the danger of venturing out so early was very great, as the whole camp would probably be prostrated with fever. He decided however on breaking ground at once, rather than losing two months of fine weather by remaining at Myanoung for the country to dry and the roads to become passable. After surmounting various difficulties, he reached his stations in succession, and carried on his observations until the latter end of February; at this time it is customary for the villagers to set fire to the jungles, and then the atmosphere becomes so laden with smoke and the haze of the previous months of dry weather, that observations to distant stations become impossible. These operations were resumed in April after the first fall of rain, and they were continued until the first week in June, when nothing further could be done, as the rainy season had fairly set in.

(20.) In all, 10 new principal stations were fixed, forming two hexagonal figures in continuation of the preceding triangulation; they cover an area of 1491 square miles, and extend over a direct distance of 58 miles, lying wholly in the districts of Prome and Myanoung. Nine platform stations were constructed on hills, and 5 tower stations on plains, including a tower at one of the extremities of a base-line which will be eventually measured in the Monyo Teik. 150 miles of final lines, 120 of trial lines and 140 of pathway were cleared through dense forest.

(21.) Mr. Rossenrode observes that "it is very disheartening indeed, after resuming operations so early as October and closing in June, to show so small a quantity of work"; but I am of opinion that, under the circumstances, more has been done than could almost have been expected. The system of free labor appears to be carried out in this Province as fully as if the inhabitants had from time immemorial been free and independent Britons, whereas but lately they were in a state of servitude to Native Rulers, and were bound to do everything required of them, often with little, or without any, remuneration for their labor. The change to a state of perfect freedom will doubtless be beneficial eventually, but at present it is attended with great inconvenience to the public service. As laborers, the people of the country receive far higher wages than obtain in most other parts of India—8 annas, or a shilling a day. Mr. Rossenrode says that "they eat three times a day, and smoke cigars which they make up on the spot, and chew beetle-nut all day; from two to two and a half hours are taken up in eating and in making up cigars, and in smoking and chewing. They come to their work at 7 o'clock in the morning and will on no account remain after 5 o'clock in the evening. It will therefore be seen that out of ten hours they actually work for only seven and a half or eight hours daily". If any pressure is put on them to do a fair day's work they immediately run away. Frequently villages are met with where there are numbers of men unemployed, but several days have to be spent in talking before the people can be induced to do any work; and these delays are particularly embarrassing to our officers, as they practically reduce—and that very materially—the length of the season of field operations, which at best is but little more than half the year in this climate. Again, the survey parties are often in danger of famishing in the midst of plenty, unless they are prepared to pay twice or three times as much as the local prices for

whatever they may require, as the natives seem to make a point of over charging all strangers and more particularly Europeans and their followers.

No. III.—TRIGONOMETRICAL.

THE BEDER LONGITUDINAL SERIES, PARALLEL 18°.

PERSONNEL.

Geo. Shelverton, Esq., Depy. Supdt. 3rd Grade.
Mr. M. C. Hickie, Surveyor 3rd Grade.
„ F. Bell, Surveyor 4th Grade.
„ A. Wrixon, Proby. Assist. Surveyor 4th Grade.

(22.) This chain of triangles is a portion of the longitudinal chain which, when completed, will extend from Vizagapatam, on the east coast of the Peninsula, to Bombay, on the west coast. The portion west of the Great Arc (meridian 78°) has long since been completed. During the field season now under review, Mr. Shelverton finished the portion between the triangles of the Arc—in the vicinity of the Beder Base-line—and the Jubbulpore Series, meridian 82°; he measured 16 principal triangles, fixing the positions of 8 new stations, covering an area of 2,653 square miles, and extending over a direct distance of about 100 miles.

(23.) The district lies wholly in the territories of the Nizam of Hyderabad, who obligingly deputed an influential official to accompany Mr. Shelverton and render him all the assistance he needed. Mr. Shelverton expresses himself as much indebted to the Nizam's Government for the valuable help which was given him on all occasions. The country consists of a succession of granite ridges and valleys, the hills being for the most part covered with a dense forest, containing no valuable timber trees, but swarming with tigers. Seventy-two hill tops had to be cleared of forest and jungle in the preliminary operations. Several hill forts were met with, which Mr. Shelverton considers very formidable; they are usually situated on isolated granite hillocks, scarped all round excepting at the main entrances, which however are strengthened by massive defences; in each fort there is said to be an ample supply of water. The Surveyors were only allowed to enter the forts on the condition that they should not build stations or set up any kind of signals on them, but the restriction was of no importance, as in all cases better positions were found on the surrounding hills.

(24.) Two azimuths of verification were observed, at stations especially selected for their freedom from any *apparent* influences which might tend to deflect the plumb-line, in order that latitude observations also might be taken at them hereafter. Stations were also selected in advance, over a distance of 100 miles, for the operations of next season. The positions of upwards of 150 secondary points were fixed, and route-surveys were carried to connect 37 villages with the immediately adjacent principal stations, in order to facilitate the identification of the latter whenever they may be required at any future time.

No. IV.—TRIGONOMETRICAL.

THE LONGITUDINAL SERIES WEST OF CALCUTTA.

(25.) The whole of the triangulation between the meridian of Colonel Everest's Arc (78°) and that of Calcutta (88½°), from the Himalayas southwards down to the Beder Longitudinal Series, is dependent on the Calcutta Longitudinal Series, for its initial elements. In my report for 1864-65 I pointed out that the triangulation on the parallel of Calcutta had been executed by a few surveyors, during Colonel Everest's absence from India (1825-30), with inferior instruments, and under manifold difficulties, and that it most inadequately served the purpose of a basis for several meridional series of triangles, for which it was originally intended. Of far less accuracy than any portion of the triangulation of subsequent years, it has long been the *bête noire* of this survey, and has quite prevented the possibility of bringing the several chains which are dependent on it, into harmony and consistence, in a satisfactory manner. For, the circuits formed by successive pairs of the meridional chains and the connecting portions of the longitudinal or frontier chains at their extremities, have been generally found to be liable to greater inaccuracies, in the small portions into which the triangles of the Calcutta Longitudinal Series enter—which rarely comprise more than a twentieth part of any circuit—than in all the other parts of the circuits. The final reduction of the triangulation was therefore necessarily postponed, until the angles of this Series could be re-measured with a first class instrument.

PERSONNEL.

H. Keelan, Esq., Deputy Superintendent 3rd Grade.
Mr. H. E. Keelan, Surveyor 4th Grade.
„ H. Peychers, Assistant Surveyor 2nd Grade.
„ J. F. Trotter, Assistant Surveyor 2nd Grade.
„ A. Moore, Assistant Surveyor 4th Grade.

(26.) This important and indispensable operation was commenced, in the field season of 1863-64, by Mr. Shelverton, who re-observed the angles between the Great Arc and Jubbulpore, as a preliminary to his triangulation southwards from Jubbulpore towards Madras. Since then it has been carried eastwards by Mr. Keelan, and the last links of the chain which was required to connect the Seronj base-line, at it's western extremity, with the Calcutta base, at it's eastern extremity, were completed by that Officer, in the field season now under review. The revision has clearly established the unsatisfactory nature of the original triangulation, indicating errors of nearly as much as a foot per mile on certain of the sides, and errors in the elements of Calcutta of no less than 4″ in latitude and 1″ in longitude. The value of the computed length of the Calcutta base-line, as deduced from the revised triangulation, differs from the measured length by less than half an inch per mile, whereas the original difference was more than 20 times as great. The values of height determined from the measurement of the vertical angles in the course of the new operations differ by only 2 feet from those determined by the spirit leveling operations, whereas formerly the difference was about 111 feet. The data now obtained will amply suffice for the reduction of the whole of the triangulation dependent on this chain, which will therefore be taken in hand without further delay.

(27.) In a revisionary operation of this nature, it is very necessary, at all the sides of junction with preceding triangulation, to make a connection with the identical points at which the former observations were made. In the present instance, the original points were identified in almost every case; but at a station

near Hazaribagh, on the side of origin of the Chendwar Meridional Series, the markstone had been removed. Consequently Mr. Keelan was directed, after completing the junction at Calcutta, to proceed to Chendwar, and connect the new station with those of the Meridional Series, a measure which protracted his operations into the middle of the unusually intense heat of the summer of 1869.

(28.) While Mr. Keelan was engaged in the above operations, one of his assistants was employed in selecting stations and making other preparations, for the triangulation southwards on the meridian of 84°, through Belaspur and Raipur, which will be commenced next field season, at the requisition of the Surveyor General, to afford a basis for the Topographical and Revenue Surveys of those districts.

(29.) The entire operations of this Party during the present year are briefly as follows; observations of principal angles at 14 stations, completing 13 triangles which cover an area of 1,403 square miles, and extend over a direct distance of 83 miles; azimuths of verification were measured at two stations; 2 new towers and 14 platform stations were built, and 4 of the old telegraph towers, on the line between Calcutta and the Upper Provinces, were converted into trigonometrical stations; 172 miles of lines were cleared between the stations in the vicinity of Calcutta; 13 stations, extending over a direct distance of 100 miles, were selected in readiness for the triangulation of next season on the meridian of 84°.

(30.) In previous reports I have described the difficulties which are met with now-a-days by our Officers in carrying on their operations in the vicinity of the Presidency towns, because of the opposition which is often raised by Zemindars, or other owners of property, to the steps which have to be taken for clearing the lines, and thus securing the mutual visibility of the stations which is essentially necessary as a preliminary to the measurement of the angles. Upwards of 40 years had elapsed since the stations near Calcutta were first constructed, and meanwhile all the lines had become more or less obstructed by the growth of trees which had to be removed before observations could be commenced. I am gratified to be able to report that Mr. Keelan and his assistants succeeded in conciliating all persons interested, and doing whatever was required for the furtherance of the operations, without being involved in any disputes with the inhabitants of the district.

No. V.—TRIGONOMETRICAL.

THE BANGALORE MERIDIONAL SERIES (78°.)

(31.) The well known Meridional Arc which was measured by Colonels Lambton and Everest, was done in parts at different times. The southern portion, from Punnæ near Cape Comorin, in latitude 8° 10′, to Damargida, in latitude 18° 23′, was measured by Colonel Lambton and his native assistants, prior to the year 1818, at intervals during the progress of the triangulation of the Peninsula. Proceeding

northwards, the section between Damargida and Takalkhera, latitude 21° 6′, was measured by Colonels Lambton and Everest conjointly, and the section between Takalkhera and Kalianpur, latitude 24° 7′, by Colonel Everest solely. Up to Kalianpur the triangulation had been executed with instruments which, though the best that were then procurable, were very inferior to those which were subsequently obtained by Colonel Everest, in the interval between 1825 and 1830, when he went to England to recruit his health and obtain new instruments.

(32.) On returning to India he carried the operations northwards with his new instrumental equipment, measuring the section of the arc between Kalianpur and Kaliana, latitude 29° 31′. Subsequently he re-measured the section between 18° 3′, and 24° 7′, with the new instruments, for the following reasons, which I quote from pages XXXV and XXXVI of the introduction to his account of the Indian Arc which was published in 1847.

"The triangulation was executed with very inferior instruments to those now at my disposal, for the portion between Beder and Pilkher was performed with an 18-inch instrument, engine divided and of no great accuracy, whilst in the remaining portion between Pilkher and Seronj the old large theodolite which had been seriously injured was employed, whence in looking over the data the following facts will be noted as also a sufficient clue afforded to guide us to their origin :—

1*st*. The divers observations from which the general means are drawn exhibit discordancies *inter se* seldom less than 20″, and in one case to so large an amount as 36″·5.

2*nd*. The errors in the triangles in the former portion frequently amount to 4″ and 5″, and in one case there is an error of upwards of 8″, whilst in another, there is an error exceeding 11″, also in the latter portion, though the similar errors are generally much smaller, yet there are three instances wherein they amount to upwards of 6″.

3*rd*. There is a discrepancy between the base measured at Beder and that brought down from computation in terms of the Takalkhera Base of upwards of $6\frac{3}{4}$ feet, whilst the comparison between the bases of Takalkhera and Seronj instituted in like manner shows little more than 3 inches.

4*th*. There is an uncertainty about the azimuths in the whole extent between Beder, and Seronj, the observations not having been sufficiently numerous, and adequate care not having been bestowed on the subject."

(33.) But the southern portion of the arc, or that comprised between the the parallels of 8° 10′, and 18° 3′, cannot be considered to be materially superior to the triangulation which Colonel Everest condemned and re-measured. At the request of the President and Council of the Royal Society, a committee, composed of Professor Airy (Astronomer Royal), Doctor Miller and Professor Stokes, reported, in 1861 on Colonel Lambton's Surveys; and their report concludes with the following suggestions :—

"The Committee think it right, however, to call the attention of the President and Council to the general quality of Colonel Lambton's surveys, which, though executed with the greatest care and ability, were carried on under serious difficulties, and at a time when instrumental appliances were far less complete than at present. There is no doubt that at the present time, the surveys admit of being improved in every part. The standards of length are better ascertained than formerly, and all uncertainty on the unit of measure can be removed. The base measuring apparatus can be improved. The instruments for horizontal angles used by Colonel Lambton were inferior to those now in use, and one of them was most severely injured by an accidental blow, the result of which was more distinctly injurious because the circle was read by only two microscopes. Allusion has already been made to the circumstances of observation affecting the altitude of stations. Though the astronomical observations were probably good for their age, yet new observations, conducted with such instruments and on such principles as those adopted by Sir George Everest, would undoubtedly be better. The Committee therefore expresses their strong hope that the whole of Colonel Lambton's Survey may be repeated with the best modern appliances. No arc of meridian yet measured has such claims on the attention of the patrons of science as the Indian Arc, from its proximately equatorial position, and from its anorpalies and the reference of them to the attraction of the Himalaya mountains."

(34.) The time has now arrived when so much of Colonel Lambton's triangulation as appertains to the Arc of the meridian, may be repeated with the best modern instruments, without interfering with the operations for completing the triangulation of British India. In fact a portion of the Arc was revised in 1866-67, on the completion of the longitudinal chain of triangles from Madras as far as Bangalore, by the Madras Party, when the operations were directed southwards along the Arc, revising about 60 miles towards Cape Comorin. Last year the party was employed in the measurement of a base-line at Bangalore, and this year it was similarly employed in the neighborhood of Cape Comorin. But on the completion of the latter operation, Captain Branfill—the officer in charge of the party—was directed to occupy himself for the remainder of the field season in re-measuring the angles of the southern extremity of Colonel Lambton's Arc, and connecting the stations with the new base-line. Though the time available for these operations was but short, Captain Branfill was able to finish observations at six stations, carrying the triangulation over a direct distance of 23 miles. He also observed an azimuth of verification at one of the extremities of the Cape Base-line, Lieutenant Rogers observing the azimuth at the other extremity.

No. VI.—TRIGONOMETRICAL.

THE MEASUREMENT OF THE CAPE COMORIN BASE-LINE.

(35.) In the course of the early operations of this Survey, several base-lines were measured with chains, by Colonel Lambton and other Officers; but there is some uncertainty about their units of length, and their intrinsic value is much inferior to that of the base-lines measured since 1830, with the Colby apparatus of compensated bar and microscopes which was constructed for this Survey under Colonel Everest's superintendence. They have served the purposes for which they were originally required, but are useless as a check on the triangulation which has been executed since 1830.

PERSONNEL.

Captain J. P. Basevi, R.E., In charge.
Lieutenant J. Herschel, R.E.
Captain B. R. Branfill.
Lieutenant M. W. Rogers, R.E.
Mr. J. W. Mitchell.
„ G. Anding.
„ G. Belcham.
„ A. Christie.
„ O. V. Norris.
„ C. D. Potter.
„ J. Bond.
„ J. McDougall.
„ C. Torrens.

(36.) On the Arc, Colonel Everest employed the Colby apparatus in re-measuring the old chain-base at Seronj (latitude 24° 6′), and in measuring a base at Dehra Doon (latitude 30° 18′) and a new base, instead of the chain-base, at Beder (latitude 17° 55′). The apparatus has also been used in measuring bases at the corners of the quadrilateral figures which are formed by certain obligatory meridional and longitudinal chains of triangles, as at Calcutta, Karachi, Attock, Vizagapatam &c. But until lately no opportunity has been presented of measuring new base lines, in place of the chain-bases on the southern section of Colonel Lambton's Arc. Last year however a base was measured near Bangalore with the Colby apparatus, as has already been reported; and this year I decided on measuring a base-line in the vicinity of

Cape Comorin, as I could secure the services of almost all the Officers and Assistants who had been employed on the Bangalore base, and had thus become familiarized with the use of the apparatus.

(37.) The Cape Base-line is, I consider, the last that needs to be measured for the verification of the triangulation within the limits of India proper, though others may have to be measured in Burmah and Tenasserim. It is the tenth base-line which has been measured with the same apparatus, and I intended, on it's completion, to prepare a detailed report of it and the preceding bases, for publication. No such report however would now-a-days be considered of much scientific value unless it furnished complete details for estimating the probable errors of the measurements. To a certain extent such details have already been furnished by the system—which has almost invariably been followed hitherto—of dividing each base into sections connected by triangulatiou, and comparing the measured lengths of the several sections with the values obtained from the triangulation. But only in a single instance has there been an independent determination of probable error by an actual re-measurement. Colonel Everest measured the base in Dehra Doon twice, and has given the discrepancies between the results of the two measurements at page XXV of his work of 1847. There is however reason to suspect that, in consequence of an oversight which was made at the commencement of the operations—the compensated bars having been compared with the standard in a building at Dehra, and not, as they should have been in tents, under circumstances precisely similar to those of the measurement—the discrepancies there recorded do not fairly represent, but rather exaggerate the probable errors of the measurement. I therefore determined to re-investigate this point at the Cape Comorin Base.

(38.) Deeming that a single re-measurement would not throw sufficient light on the subject, while several measures of a line of the usual length—about 7 miles—would be very laborious, I divided the line into three sections, of which the middle section was 1·68 miles in length; and I gave instructions that the middle section should be measured four times, and that the lengths of the two end sections should be determined from the central one by triangulation on both flanks of the line, whereby the entire length would be determined with as great accuracy as if it had been once measured throughout, in the usual manner.

(39.) The superintendence of the operations was entrusted to Captain Basevi, who was transferred for a short time from his Pendulum operations for the purpose; and I have every reason to be well satisfied with the manner in which he has carried out the investigations that were required; also with Captain Branfill's selection and preparation of the line, and with the manner in which Lieutenant Herschel has conducted the reductions of the field measurements, with which he was entrusted, pending the arrival of instruments from England for his astronomical determinations of latitude; the triangulation for determining the entire length of the base, from the measured central section, has been very satisfactorily completed by Lieutenant Rogers.

(40.) Full details of the results have not yet reached me, nor indeed has the time arrived when the results can be *exactly* ascertained. I had previously been led to believe that the value of the factor of expansion of the Standard Bar, which was determined for Colonel Everest in the Calcutta Mint in 1832, was six or seven per cent too great, for I had ascertained that it exceeded by that amount the factors of similar bars whose expansions have been determined subsequently, in

England by Captain Clarke, and in Russia by M. F. G. W. Struve; I had also found that a corresponding correction would *invariably* improve the results of the comparisons between the compensated bars and the standard, under different temperatures, at all the Base-lines hitherto measured in India, and that it would almost always diminish the discrepancies between the measured values of bases of verification and the values computed through the triangulation carried up to them from the base of origin. The Cape Base-line also tells the same tale, as do certain preliminary differential determinations which have been subsequently completed, and will be described in Section XV. Thus it has become necessary to re-determine the factor of expansion of the standard, and this is now being done, but until the observations are completed, none of the base-line measurements can be finally reduced.

(41.) So far as the Cape Base has yet been reduced, with an approximately corrected value of the factor, the results indicate a very high order of accuracy in the performances of the apparatus at this base; the maximum difference between any two of the four measurements of the central section—the length of which is 8,915 feet—being ·077 of an inch, or 0·72 millionth's of the length, and the theoretical probable error of a *single* measurement being ± 0·20 millionth.

No. VII.—TOPOGRAPHICAL.

HIMALAYAN SURVEYS, IN KUMAON AND BRITISH GURHWAL.

(42.) These operations are proceeding very satisfactorily. As regards the triangulation of the present year, which has been executed to furnish a basis for future topographical operations, Major Montgomerie reports as follows:—

PERSONNEL.

Major T. G. Montgomerie, R.E., Dy. Supdt. 1st Grade.
Captain A. Pullan, Assistant Superintendent.
Lieutenant McCullagh, R.E., Asst. Superintendent.
Mr. W. G. Beverley, Surveyor.
„ E. C. Ryall, Surveyor.
„ J. Peyton, Surveyor.
„ J. Low, Assistant Surveyor.
„ G. W. Atkinson, Assistant Surveyor.
„ C. Braithwaite, Assistant Surveyor.
„ L. Pocock, Assistant Surveyor.
„ H. Todd, Assistant Surveyor.
„ C. Bryson, Assistant Surveyor.
„ T. Kinney, Assistant Surveyor.

"The greater part of the Pindur valley of Gurhwal was triangulated. In Kumaon the triangulation was extended to the east of Almorah, up to the Goree River, and further south as far as the Surdah River, crossing some very rugged hills in parts covered with heavy forest.

"In the Terai a good many new points were fixed to the south and south-west of Nynee Tal. The ground triangulated was, as in the previous season, generally very elevated, and though the work was carried on in the lower ground during the worst weather, it was several times interrupted by snow and clouds.

"The total out-turn of triangulation is 1,650 square miles with 661 points and 354 heights, being an average of 4 points and over 2 heights in each 10 square miles."

(43.) As regards the operations for filling in the details of the ground which had been triangulated in previous years, Major Montgomerie reports that

"Topographical operations were commenced very early in the higher part of Gurhwal; the sur-
"veyors starting at the end of the rains were able to commence work as soon as the clouds cleared off,
"and before the first heavy falls of snow in December were able to commence the sketching of the two
"main branches of the Mandagui or Kali Gunga river, which drain the southern face of the Kidarnath

"and Badrinath snowy peaks. The sketching included mountain ground of every altitude from 7,000 "to nearly 23,000 feet above the sea, involving a great deal of hard work and exposure. The heavy "falls of snow in December prevented any further extension in Gurhwal.

"In Kumaon topographical work was carried on in the mountains around Almorah and through "the low Terai land east of the Ram Gunga river and of the Kotirao; in the former portion the work "was extended about 30 miles to the east of the new hill station of Ranikhet, and in the latter through "about 40 miles of the lower hills and Terai.

"The higher ground, though in many parts very rugged, was in others so thickly studded with "villages that there was considerable difficulty in showing the whole of them on the scale used. In "portions the heavy forest was a great hindrance, and in the Terai land there were the usual difficulties "arising from the dense jungle and heavy fogs.

"The Surveyors were as before removed from the higher ground to the lower and *vice versâ* accord- "ing to the season, with a view to secure the largest out-turn of work possible.

"The area sketched in Gurhwal amounts to 392 square miles, and in Kumaon to 946 square miles being a total of sketching, for the field season, of 1,338 square miles on the scale of one inch to the mile.

"The greater part of the work was amongst rugged mountains running up to considerable alti- tudes, in many parts covered with forest. The remaining portion embraced a considerable tract of Terai land presenting almost as great difficulties though of a different kind. Throughout the field season the Surveyors worked zealously and their exertions are deserving of all praise."

(44.) Major Montgomerie examined a portion of the ground allotted to each of the detail Surveyors—with a single exception—and found that it was well delineated, giving an excellent and accurate representation of the country, none but small differences having been detected in the positions of the villages, mountain peaks and spurs, water courses, &c., which were tested. Both in quantity and quality the out-turn of work is all that can be desired, considering the difficult nature of the ground.

(45.) With the aid of the process of photozincography the maps of the several survey parties are published now-a-days in a few hours after they are completed and sent to press, whereas of old, years might, and very frequently did, elapse between their completion and publication. Among other advantages of the saving of time which is effected by the present method of publication is this, that the surveyors have frequently to pass through tracts of country which have already been surveyed, in their progress to the more distant tracts awaiting survey, and they can readily ascertain on the spot to what extent the published maps succeed in representing the configuration of the ground, and whether they are as complete as they should be. This is more particularly the case with reference to the relative relief given to the features of the mountain ranges, as a very short examination from commanding points is sufficient to decide whether it has been adequately represented; corrections may be made, and additional heights determined barometrically, if they are considered necessary for a correct understanding of the map. Moreover opportunities are afforded of introducing the details of new roads, and showing any alterations which have taken place since the ground was surveyed. Major Montgomerie takes notes on all these objects, with a view to the preparation of 2nd editions of the maps, with all the latest corrections and improvements.

(46.) In addition to the 354 Trigonometrical determinations of heights of obligatory points, 260 differential determinations, with aneroid barometers, were made at junctions of rivers and other points in the valleys, and on mountain passes and other points which could not be reached conveniently by triangulation; these

barometric determinations, though far less accurate than the trigonometrical, are sufficiently exact for the purpose of indicating the relative levels of ground of every altitude from 2,500 to over 20,000 feet.

(47.) I have already reported that the Survey of the Sanitaria of Masoori and Landour is taken up by Major Montgomerie at intervals during each year's recess, when the weather will permit and the Surveyors can be conveniently spared from their ordinary duties. As under these circumstances the progress of the Survey was not very rapid, it was considered desirable to employ some of the Surveyors on it during the last field season, instead of sending them into Gurhwal. The result is that the survey of both sanitaria is now nearly completed, upwards of 13,000 acres having been triangulated (95 points and 63 heights) and topographically surveyed on the scale of 12 inches to the mile, during the season; 4,700 yards of boundary line were first approximately demarcated for the civil authorities, and subsequently laid down finally, after various conflicting claims as to rights of property had been judicially decided on.

(48.) I may here observe that the reduction of the astronomical observations and route-surveys of the Trans-Himalayan explorers, throws a great deal of additional work on Major Montgomerie and his assistants. The natives who are employed in these explorations are purposely trained to observe only, and not to perform any of the reductions, in order that they may not find out how to fabricate observations, or learn how to apply arbitrary corrections to harmonize the results of erroneous observations. The reductions are invariably carried on under Major Montgomerie's superintendence, and this year they entailed the calculation of 190 astronomical latitudes—from sextant observations, of 77 deductions of height—from boiling point observations, and of 850 miles of route-survey.

No. VIII.—TOPOGRAPHICAL.

THE SURVEY OF KATTYWAR.

(49.) The circumstances which gave rise to the survey of this Province, and the special objects which it is intended to provide for, have already been so fully explained in section VIII of my Administration Report for the year 1866-67, that I need only now observe that the survey differs from all other Topographical operations in progress throughout India in that the plane table or field sections are drawn on an enlarged scale, *viz.*, that of 2 inches to the mile instead of 1 inch as usual, and that special operations are carried on, *pari passu* with the topography, for the purpose of laying down the boundaries of all the Talookas, or chief sub-divisions, of the British and Native States in the Province.

PERSONNEL.

Captain C. T. Haig, R.E., Depy. Supdt. 2nd Grade.
Lieutenant Baird, R.E., Assistant Superintendent.
Mr. J. McGill, Surveyor.
" W. Todd, Surveyor.
" A. D'Souza, Surveyor.
" N. Gwinn, Assistant Surveyor.
" C. McA'Fee, Assistant Surveyor.
" T. Rendell, Assistant Surveyor.
" E. N. Wyatt, Assistant Surveyor.

(GUZERAT PARTY.)

Mr. J. G. Rendell.
" J. Hickie.
" W. Fielding.
" G. Cusson.
" C. Goslin.

Native Surveyors.

Vissajee Ragonath, and others.

(50.) During the present year the operations have proceeded very satisfactorily, but with the serious drawback that Captain Haig—the Officer in charge—has suffered severely, his health breaking down so suddenly towards the end of the recess that he was unable to draw up as complete a report of the year's operations, as would otherwise have been desirable; he was obliged to give up the charge abruptly, and proceed to Europe on furlough for the benefit of his health, without loss of time. This was the more unfortunate as I was thus deprived of his assistance when I recently went down to Poona to inspect the operations of the party, and Lieutenant Trotter, who had been summoned from Bangalore to relieve Captain Haig, had taken charge only a few days before my arrival. But I had full reason to be satisfied with the results of my examinations, and I came to the conclusion that the operations of the party must on the whole be considered to be very satisfactory, and creditable to Captain Haig and his senior asssistants.

(51.) The last field season's operations comprise the following amount of work. *Triangulation ;* an area of 1,836 square miles, in which the positions of 953 points and the altitudes of 267 of these points, were determined by observations at 208 stations. *Topography ;* 2,334 square miles on the scale of 2 inches to the mile, chiefly in the Dandooka Pergunnah of the Ahmedabad Collectorate, in Bhaonuggur and Wardwan, and in the Limree, Choora, Pallyall and Moolee Talooks of Gohelwar. *Boundary surveys and check lines ;* 725 linear miles of the former, and 186 of the latter. Five assistants were trained for the survey of Guzerat which is shortly to be taken up.

(52.) The mapping has also proceeded very satisfactorily. The maps are published on the three scales of 2 inches, 1 inch and ½ inch to the mile, in the following manner. First a fair copy of the field surveys is drawn on the same scale (2 inches = 1 mile) and a few copies are printed to full scale, by the photozincographic process, for the use of the District Officers ; the original is however drawn in such a manner as to be suitable for reduction to the ordinary 1 inch scale by photography ; the reduction is transferred to a zinc plate and printed, in black ink, for general issue as a topographical map. A few impressions are also printed in pale blue ink, and returned to the Surveyors, by whom as much of the details as is desirable to be shown on a further reduction to the quarter inch, or geographical, scale is drawn boldly over the blue grounding with black ink, and the names of the towns and villages are printed on the map, also in black ink, and sufficiently large to be clearly legible when reduced in size to one-fourth. The maps thus prepared are called the 'exaggerated maps', and when they are reduced by photography and printed on zinc, the minor details of the blue grounding, which have not been blackened, disappear, and the result is a clear and sharp geographical map, giving all the necessary details and no more, and obtained with vastly less labor than if it had been drawn originally on the quarter inch scale by hand. In this Party, the printing of names, heights &c., is invariably done by type, with the aid of small stamping machines which all the assistants are expert in using.

No. IX.—TOPOGRAPHICAL.

THE SURVEY OF GUZERAT.

(53.) This survey has been purposely postponed until Lieutenant-Colonel Nasmyth's return from furlough to direct the operations. As his leave of absence did not expire until after the termination of the field season of 1868-69, nothing has yet been done in Guzerat; meanwhile the assistants who will be employed in these operations were employed elsewhere, chiefly in the Survey of Kattywar.

No. X.—GEOGRAPHICAL.

TRANS-HIMALAYAN EXPLORATIONS.

(54.) These explorations have, under Major Montgomerie's directions, been extended during the present year somewhat further into the vast *terra-incognita* which lies beyond the eastern watershed of the upper Indus. One of the Pundits has carried a route-survey from Dunkhar, in British Spiti, across the upper part of Chumurti, to the south-east corner of Ladak, and thence by a new route to Rudok—the capital of the north-west part of Tibet—which had never before been seen by a Surveyor. He found the town to be about nine miles from the Pangong lake, a small portion of which was actually visible from it.

(55.) From Rudok the Pundit advanced nearly due east, over an elevated plateau averaging more than 15,000 feet above the sea. From commanding points this plateau appeared to be of a dazzling white, extending as far as the Pundit could see, and confirming what he heard as to it's great extent. The whiteness appeared to be due to some salt mixed with the soil. The plateau lies to the north of the great Aling-Kangri group of snowy peaks which was discovered during 1867; from all accounts it must extend very far to the east, either joining or running parallel with the great desert of Gobi; it's general position is indicated under the name of the "Aksai-Chin or white desert", in my map of Turkestan. The routes in this portion are 630 miles in length, of which 500 miles passes over entirely new ground, the only point on it which had previously been visited being Thok-Jalang. The remaining portion of the route is also in a great measure new, but, it had been touched upon previously in several places. The greater portion of the country thus traversed lies beyond the watershed of the Indus, and drains entirely to the eastward into inland lakes. These new routes will roughly account for the geography of an area of about 16,000 square miles; they are checked by latitude observations taken at 37 different places. The general height of the country is very great and has been determined by boiling-point observations at 49 different places.

(56.) From the accompanying report by Major Montgomerie, it will be seen that the above explorations fully confirm the oral information collected during the previous expeditions; the route between Thok-Jalung and Rudok agrees very

fairly with that first given; the number of gold, salt and borax fields, seen and heard of, is quite as great as was anticipated, and the amount of mineral wealth seems to be very great. The sources of the eastern or main branch of the Indus have been satisfactorily traced to the back of the Kailas Parbut, and a very high range to the north-east of that peak. The routes were continued to the east, not going over much new ground, but giving bearings to some high peaks, north and south of the great road to Lhasa; these will prove useful additions to the geography of the country in that direction.

(57.) Another explorer was employed to the eastward, who has made a route survey 1,190 miles in length, with 29 latitudes and 12 determinations of heights,—fewer than usual of the latter, owing to breakage of thermometers. Of this work a small portion is entirely new, going behind or north of Mont Everest. Further advance in that direction was unfortunately prevented by the jealousy of the Tibetan Officials, but the route, as far as it goes, is valuable, insomuch as it gives us a little additional information as to the Himalayan watershed, which has invariably been found to lie at a very considerable distance to the north of the great Himalayan peaks which, from the side of Hindustan, seem to form the watershed. This peculiarity has been further confirmed by the routes of a Zaskari who accompanied the third Pundit for some distance, but made his way back by a different route, having been turned out of Tibet by the Lhasa authorities, as a suspicious character. This man crossed from the Tadum monastery over the Himalayas to Muktinath.

(58.) The greater part of the 1,190 miles of routes will be valuable in still further elucidating the geography of the eastern Himalayas, when combined with the information collected during previous explorations. In many parts the routes traverse country that is almost new, though some places in it have been indicated on maps from information of all kinds but without any regular connection; the results will be published with my next report.

(59.) To the north-west of India, a Mahomedan gentleman has been employed in exploring the countries north of the Hindoo Koosh, and of the Mustagh and Karakoram ranges; he has however only just returned, and as yet his work has not been thoroughly examined. He succeeded in making his way from Cabul into Badakshan, and thence ascending through the upper valley of the Oxus he reached the Sirikul (or Victoria) lake of Lieutenant Wood; skirting the southern end of the Pamir Step he passed from the Sirikul lake down to Tash Kurgan, and thence over the mountains by a nearly direct route to Kashgar the capital of eastern Turkistan (or little Bokhara). From Kashgar his route was carried on to Yarkand and thence to the vicinity of the Karakoram Pass. The most interesting part of the route will no doubt be that between the Sirikul lake and Kashgar; Major Montgomerie will report on it as soon as the field work has been examined, and prepared for publication.

(60.) With reference to Trans-Himalayan explorations I still hope that some further extensions may be made into Tibet, though the jealousy of the Lhasa officials is very much against any thing of the kind. Every effort is also being made to add to our knowledge of the countries beyond the Hindoo Koosh, comprising the upper branches of the Oxus, the Pamir Steppe &c., and I hope that the absolutely unknown ground in that direction will, at no very distant time, be reduced to a small quantity.

No. XI.—ASTRONOMICAL.

LATITUDE OBSERVATIONS ON MERIDIAN OF 75°.

(61.) The chain of triangles on this meridian, which is now very nearly completed, will extend from the southern slopes of the Himalayas, in latitude 33°, to the vicinity of Mangalore, latitude 13°. In this and previous years, latitude observations have been taken at 11 stations, at about 1° apart meridionally, completing the observations of this nature over the northern half of the chain of triangles. So far, the ground passed over has been for the most part a very level plain, with few hills or other local irregularities of the earth's surface, and these of but small magnitude; judging from outward appearances only, there is no such favorable belt of country in all India for astronomical observations, in its freedom from any influences which might tend to deflect the plumb-line; for, though great deflections have been found on level plains, as at Moscow, such ground must on the whole be considered more favorable than a hill region.

PERSONNEL.

Lieutenant W. J. Heaviside, R.E., Asst. Supdt.
Mr. J. Wood, Assistant Surveyor.

(62.) The southern half of this chain of triangles does not offer the same advantages; it crosses several ranges of mountains, and the deep sunk valleys of the Nerbudda and Taptee Rivers. In such regions the value of astronomical observations may be questioned; if however they are avoided the triangulation which has been necessarily carried over them will be of no use to geodesy. On the whole however it appears desirable not to ignore them, but to carry the latitude observations over them; and it may be observed that they are not less favorable for such observations than the tracts of country over which a considerable portion of Colonel Everest's arc, and some of the European arcs, have been carried. I have therefore directed Lieutenant Heaviside to continue the latitude observations southwards, but enjoined particular care in the selection of the stations. He now makes a flying reconnoisance of the ground, determines differences of level barometrically, and draws sections through the meridians of the stations, and finally determines which positions appear to be most suitable for the observations, in being situated where the influences of the surrounding hills and hollows on the plumb-line may be fairly expected to cancel each other.

(63.) These operations necessarily take up a considerable portion of the field season; but Lieutenant Heaviside was nevertheless able to take complete sets of observations to 36 pairs of north and south stars,—of the Greenwich seven year catalogue—each star being observed on the meridian on six nights, with astronomical circle No. 2. The observations are excellent, giving probable errors which average less than $\pm$ ″·05, when computed on the assumption that there are no constant errors in the Greenwich catalogue.

No. XII.—LEVELING.

DETERMINATIONS OF ALTITUDE BY THE SPIRIT LEVEL.

(64.) Since the completion of the main line of Spirit Levels which was carried, from the datum of the mean sea level of Karachi harbour, through Sind, the Punjab, the North-West Provinces and Bengal, down to Calcutta, branch lines of level have been carried from the main line for the purpose of connecting the various detached groups of levels which have been executed for Irrigation and other public

PERSONNEL.

C. Lane, Esq., Deputy Superintendent.
Mr. A. W. Donnelly, Surveyor.

Native Assistants.

Nursing Dass.
Amjad Alli.

works, and reducing them to a common datum; also for the purpose of correcting the trigonometrical determinations of the heights of some of the stations of this Survey, which had been made under very unfavorable circumstances, and were not as reliable as is to be desired.

(65.) During the present year Mr. Lane has carried a line of levels from the vicinity of Bareilly through Shahjehanpore, Seetapore and Lucknow, to Cawnpore, and from Lucknow eastward beyond Fyzabad. These operations are a continuation of the line which was commenced last year at a bench-mark of the main line at Meerut, and carried through Moradabad to Bareilly, and which has now been connected with the main line at Cawnpore. The height, above mean sea level, of the bench-mark at Cawnpore, as brought down directly from Meerut by the main line, is 407·75 feet; as deduced by the circuitous branch line it is 407·11 feet. Thus the two determinations differ by 0·64 feet, but this cannot be considered a material discrepancy, for the two lines are of the respective lengths of 290 and 330 miles, and thus form a circuit of 620 miles.

(66.) During the present year, 353 miles of line were leveled independently by Messrs. Lane and Donnelly, in conformity with the rigorous method of procedure which has been described in former reports; in the course of these operations, the heights of 9 Trigonometrical Stations, on the Amua, Karara and Gurwani meridional chains of triangles, were determined, as well as of 411 bench-marks, bridges, milestones and other permanent marks in the vicinity of the line.

No. XIII.—GEODETIC.

THE PENDULUM OBSERVATIONS.

PERSONNEL.
Captain J. P. Basevi, R.E., Depy. Superintendent.
Mr. J. W. McDougall, Assistant Surveyor.
„ C. P. Torrens, Do.

(67.) Although Captain Basevi was employed during a considerable portion of the field season in supervising the measurement of the Base-line at Cape Comorin, he was nevertheless able to complete the pendulum observations—in conformity with the system of operation which has already been described in previous reports—at no less than 6 stations, viz., at the two extremities of the Bangalore Base-line, at Pachapolliam, Mallapatti, Kudankolam, and Punnæ, all stations on the southern section of Colonel Everest's arc.

(68.) The whole of the pendulum observations on the Arc have now been completed, but before the apparatus is returned to the Royal Society, it is desirable that observations should be taken on the highest accessible table lands of the Himalayas, as well as at various points on the coast line, and at the Calcutta and Madras observatories.

(69.) I have already reported that the results of the first season's operations tended to confirm the hypotheses of Mr. Airy and Archdeacon Pratt that the density of the strata of the earth's crust under the Himalayan mountains is less than under the plains at a distance from those mountains. Thus it may be expected that, on the other hand, the density of the strata under the bed of the ocean must be greater than under continents, and Archdeacon Pratt has suggested that "below sea beds the crust of the earth is as much denser, through a certain depth,

as will equal the deficiency of matter caused by the ocean hollow, and beneath mountains the density is as much less, through a certain depth, as will account for the excess of mass in the mountains." It is impossible to take observations on the bed of the ocean, but should the hypothesis be correct, there is a considerable probability that as the pendulum stations advance from the interior of the main land towards the coasts, the observations will indicate an increase in the force of gravity, just as when they advance towards the Himalayas they indicate a decrease of force. Captain Basevi will therefore take observations at a few points on the coasts, and also on the low island of Minikoy, which is in the same latitude as his southernmost station of Punnæ, and stands on a coral reef in the ocean at a distance of upwards of 250 miles from the main land. When these observations are completed, he will proceed to the Himalayas to take the necessary observations at the highest attainable altitudes.

No. XIV.

MAGNETIC OBSERVATIONS.

(70.) These operations having been sufficiently described in former reports, it is only necessary for me to give, in the present place, the results of the several determinations of magnetic elements which have been made since my last report was submitted. The measures of intensity are all expressed in British units.

Synopsis of Magnetic Observations.

Station.	Latitude.	Longitude.	Month and Year.	Magnetic Elements.				Remarks.
				Declination.	Horizontal Intensity.	Dip.	Total Intensity.	
	° ″	° ′				° ′		
Dehra Doon, ...	30 20	78 6	November 1868, ...		7·2939	N 41 30·87	9·7409	Observed at head-quarters by Mr. W. H. Cole M. A.
			December „ ...		7·2903	„ 35·02	9·7466	
			January 1869, ...		7·2963	„ 32·20	9·7475	
			February „ ...		7·2947	„ 31·29	9·7431	
			March „ ...		7·2915	„ 28·10	9·7307	
				° ′				
			September „ ...	E 3 5·17	7·2578	„ 35·43	9·7041	
			November „ ...	„ 3 6·73	7·2965	„ 32·12	9·7475	
Bagesir, ...	29 50	79 48	March 1869, ...		7·3472	N 40 52·50	9·7167	Observed at stations in Kumaon and British Gurhwal by Major T. G. Montgomerie, R.E.
Ramnugger, ...	29 24	79 10	February „ ...		7·3443	„ 40 6·07	9·6015	
Nyneo Tal, ...	29 23	79 30	March „ ...		7·3586	„ 39 50·22	9·5832	
Bheem Tal.	29 21	79 35	„ „ ...			„ 40 8·24		
Bangaloro (N.E. end,	13 5	77 42	October 1868, ...	E 1 5·8	8·1059	N 7 23·51	8·1738	Observed at stations on the Great Arc by Captain J. P. Basevi, R.E.
Base (S.W. end,	13 1	77 37	Septr. & Octr. 1868,	„ 0 50·4	8·1009	„ 7 10·58	8·1649	
Pachapolliam, ...	11 0	77 41	November 1868, ...	„ 1 4·4	8·0427	„ 2 48·44	8·0524	
Mallapatti, ...	9 29	78 4	December „ ...	„ 0 51·5	8·0268	S 0 36·91	8·0273	
Kudankolam, ...	8 11	77 45	April 1869, ...	„ 0 44·5	8·0618	„ 3 33·99	8·0774	
Punnæ, ...	8 10	77 41	March „ ...	„ 0 45·0	8·0562	„ 3 21·21	8·0700	

No. XV.

THE COMPUTING OFFICE.

(71.) The principal triangulation which is completed on each of the several meridional and longitudinal chains during each field season, is provisionally reduced, during the following recess, by the officers by whom the respective operations have been conducted. The most probable corrections to the observed angles, which are required to satisfy the geometrical equations of condition of the several polygonal figures forming the successive links of the chains of triangles, are computed in the first instance, and then the linear values and azimuths of the sides, and the latitudes and longitudes of the stations are calculated. Preliminary Charts are then prepared and published, on which the triangulation and numerical details are exhibited, and these are placed in the hands of the Topographical Surveyors and Geographers by whom they may be required.

PERSONNEL.

J. B. N. Hennessey, Esq., Depy. Supdt. 1st Grade.
W. H. Cole, Esq., M.A. Assistant Superintendent.
Lieut. McCullugh, R.E., Assistant Superintendent.

Computing Office.

Mr. C. Wood, Surveyor.
Baboo Gunga Pershad, Computer.
„ Gopal Chunder Sircar.
„ Kully Mohan Ghose, and 8 other native, computers.

Printing Office.

Mr. M. J. O'Connor.

(72.) The information given in these charts is of a high order of accuracy, and quite sufficient for all immediate purposes; but it cannot be considered final, because final results cannot be determined until the several chains of triangles are completed, when further reductions become necessary to harmonize the results of the operations. For example, a chain of triangles may start from and close on measured base-lines; certain corrections are then necessary to make the results of the triangulation, as computed from the base at one extremity, coincide with the given length of the base at the other extremity. Again, calculations may be carried from any adopted side of origin through a circuit formed by a pair of meridional and a pair of longitudinal chains of triangles; certain corrections are then necessary to satisfy the condition that the values of the length and azimuth of the side of origin, and of the coordinates of it's extremities, as obtained from the calculations, shall agree with the initial values. In this survey similar conditions have to be satisfied, not merely for single chains of triangles between a pair of base-lines, or for single circuits, but for several such chains and several circuits, which are mutually connected together. These reductions are performed in the computing office under Mr. Hennessey's superintendence.

(73.) Theoretically, the final reductions should be postponed until the triangulation of all India is completed, the whole of which should then be treated simultaneously; but the practical solution of such a problem, would be quite unmanageable, as it would entail an immense amount of inter-dependent calculations, which would be liable to be visited by a single error. Thus it is necessary to divide the triangulation into sections, and reduce each section *per se*, and the subsequent sections in such a manner as not to disturb the results which have been obtained for those previously reduced. The primary sections are those which are formed by the triangulation between the great quadrilateral figures at each corner of which there is a measured base-line; two of these figures have been very recently completed in all their details, so their final reduction may now be commenced.

(74.) As a tentative measure, a portion of one of these figures, comprising 3 meridional and 2 longitudinal chains of triangles, was taken in hand in the first instance, by Mr. Hennessey, during the present year. It comprised about a third of the entire figure, but presented 380 unknown quantities subject to 11 geometrical equations of condition, for solution. Numerous difficulties were met with and overcome in the course of the computations, such as the devising of checks at every successive stage, ascertaining the degree of arithmetical precision which was required to satisfy the conditions of the problem, and preparing forms for the computations which would reduce the labor to a minimum and serve as a guide to the computers. But the problem was satisfactorily solved, and after the application of the angular corrections—the magnitude of which in no case exceeds 0″·4, and averages 0″·15—the geometrical equations of condition were found to have been adequately satisfied, the maximum linear discrepancy at either of the 5 closing sides being only 1·7 in the seventh decimal place of the logarithm of the length, and the maximum angular discrepancy in either of the 6 circuits of latitude, longitude, and azimuth being only 0″·005. Thus the problem may be considered to have been successfully grappled with, and the experience which has now been gained will be of much value in future applications of the methods employed to problems of still greater magnitude. I am very greatly indebted to Mr. Hennessey for the care and attention which he has devoted to this subject in every stage, from the primary theoretical investigations to their practical application; I have also to acknowledge the valuable assistance which has been rendered, both to Mr. Hennessey and myself, by Mr. Cole, not only in the details of the operations, but by his translations from various German authors who have written on similar subjects.

(75.) I have already, in para. 40, alluded to the uncertainty which exists about the factor of expansion of the standard bar. When the bar was brought back to Dehra, after the completion of the measurement of the Cape Comorin Base-line, I made some observations, with Mr. Hennessey's assistance, to determine the value of the factor differentially, by comparing the bar, under different temperatures, with the new steel standard which was lately constructed in England for this survey, for the reasons which have been stated in Sec. XIV of my Administration Report for 1866-67. The factor of the steel standard has been very accurately determined by Captain Clarke, whose observations are given in detail in his volume entitled "Comparisons of the standards of length of England, France &c." The observations indicate a value of factor about 4 per cent less than the one which has hitherto been adopted; but they were not as satisfactory as is to be desired, for they were taken under rapidly changing natural temperatures, and there is reason to believe that the temperatures indicated by the thermometers were not identical with those of the bars, but had a tendency to lag behind them, being too low under a rising and too high under a falling temperature. This had been previously anticipated, and guarded against as far as practicable by observing only at the maximum and minimum temperatures, but these precautions were to some extent nugatory, for the steel bar is much more massive than the standard and consequently is less affected by the diurnal ranges of temperature, and it's times of maximum and minimum heat do not coinside with those of the standard. The results show that satisfactory comparisons can only be taken when the temperatures of both bars are thoroughly controlled by artificial means; the necessary apparatus for this purpose has been very recently constructed, and the question will be immediately investigated with the aid of this apparatus.

No. XVI.

CARTOGRAPHY.

(76.) The Drawing Office has been chiefly employed in the compilation of the Charts of Levels which are alluded to in para. 80 of my last report. Of these no less than 14, embracing 1° in longitude and ½° in latitude, on the scale of 2 miles to the inch, have been completed, as far as the requisite materials for them have been supplied by the Department of Public Works; 6 of these, as well as 2nd editions of the 2 charts first published, are now nearly ready for the press. I am much indebted to Mr. Scott for the constant attention he has devoted to the preparation of these laborious compilations. The series when completed will form a most valuable record of the Levels of this Survey and other Departments, in the Doab between the Jumna and the Ganges.

PERSONNEL.

Drawing Office.

W. H. Scott, Esq., Surveyor and Chief Draftsman.
5 Native Draftsmen, and 9 Apprentices.

Photozincographic Office.

Mr. C. G. Ollenbach.

(77.) In addition to the above, a new map of the whole of the surveys which have been executed by this Department in the Himalayas, is under preparation, for publication on a smaller scale, and in a more convenient and portable form, than the maps hitherto published. 18 skeleton charts of triangulation, and as many topographical and geographical maps have been prepared; 5,538 copies of these maps and charts have been printed, of which 2,297 have been colored by hand, for issue to Government Officials and sale to the public, and 10,800 copies of forms for calculations and office work have been printed for the use of the Department.

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(78) An abstract of the out-turn of work executed by the trigonometrical and topogrphical parties I to VIII during the present year, is given on the next page.

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

DEHRA DOON,
2nd December 1869.

ABSTRACT OF THE OUT-TURN OF WORK EXECUTED BY THE TRIGONOMETRICAL AND TOPOGRAPHICAL PARTIES OF THE G. T. SURVEY, DURING THE OFFICIAL YEAR 1868-69.

Description of Details.	1 Brahmaputra Series. 24-inch Theodolite.	2 Eastern Frontier Series. 24-inch Theodolite.	3 Bedar Longl. Series. 36-inch Theodolite.	4 West Calcutta Longl. Series. 24-inch Theodolite.	5 Madras Party. 24-inch Theodolite.	6 Bombay Party. 24-inch Theodolite.	7 Kumaon and Gurhwal Survey. (Topographical.)	8 Kattywar Survey. (Topographical.)	Total Out-turn of Work.
Number of Principal Stations, newly fixed, ...	15	11	8	14	6	11	...	...	65
Number of Principal Triangles completed, ...	15	12	16	13	5	11	...	...	72
Area of Principal Triangulation, in square miles, ...	778	1,491	2,653	1,303	283	...	...	...	6,508
Lengths of Principal Series, in miles, ...	56	58	100	83	23	...	...	...	320
Average Triangular error, in seconds	0·58	0·59	0·35	0·32	0·27	0·64	...	...	...
Average Probable errors of Angles, in seconds ±	0·20	0·38	0·20	0·22	0·13	0·21	...	...	...
Azimuths of verification, ...	1	...	2	2	1	1	...	...	7
Number of Secondary Stations, whose positions and heights have been fixed, ...	11	1	6	...	9	...	417	267	711
Number of Secondary Stations, whose positions only have been fixed, ...	...	...	52	...	...	...	...	20	72
Number of Secondary Triangles, of which all 3 angles have been observed, ...	14	1	90	...	...	...	192	380	677
Area of Secondary and Minor Triangulation in square miles, ...	480	1,822	720	...	107	...	1,650	1,836	6,615
Number of Points fixed by intersection, but not visited,	9	21	100	...	21	...	339	745	1,235
Length of boundary line Surveyed in miles, ...	...	...	...	...	...	...	3	725	728
Length of check lines in miles,...	...	...	...	...	...	...	...	186	186
Area Topographically Surveyed on scale of 1 inch = 1 mile, in square miles, ...	...	...	...	...	...	...	1,338	...	1,338
Area Topographically Surveyed on scale of 2 inches = 1 mile in square miles, ...	...	...	...	...	...	...	...	2,334	2,334
Area Topographically Surveyed on scale of 12 inches = 1 mile, in Acres, ...	...	...	...	...	...	...	13,173	...	13,173
Number of Revenue Survey Stations fixed, ...	2	...	...	...	...	...	...	...	...
Number of Principal Stations selected in advance, ...	22	...	...	13	6	6	...	...	47
Lengths of Approximate Series, Principal in miles, ...	56	46	100	100	37	...	...	...	339
Lengths of Approximate Series, 1st class secondary, in miles, ...	64	...	...	...	...	...	...	...	64
Number of Towers, constructed,...	13	5	...	2	7	1	...	...	28
Do. Platforms constructed for Principal Stations, ...	...	9	8	14	6	5	...	...	42
Do. Platforms constructed for Secondary Stations, ...	7	...	66	...	...	...	...	...	73
Do. Miles of Rays cleared, ...	373	150	...	172	...	15	...	...	710
Do. Miles of path-way made, ...	42	140	15	...	...	...	...	...	197
Do. Hill tops cleared of forest and jungle, ...	7	4	72	4	...	...	...	...	87
Do. Principal Stations whose elements were computed,	...	7	19	7	7	...	...	...	40
Do. Secondary ditto, ...	...	19	...	...	10	...	583	263	875
Do. Preliminary Charts of Triangulation, ...	1	1	1	1	2	1	1	...	8
Do. Principal Stations placed under official protection,	15	3	...	17	...	9	...	...	44
Do. Tower Stations protected and closed, ...	15	...	...	13	...	9	...	...	37
Do. Platform Ditto, ...	...	...	...	4	...	...	...	...	4

APPENDIX.

EXTRACTS FROM THE NARRATIVE REPORTS

OF THE

EXECUTIVE OFFICERS IN CHARGE

OF THE

SURVEY PARTIES AND OPERATIONS

TABLE OF CONTENTS.

EXTRACT FROM THE NARRATIVE REPORT OF CAPTAIN H. R. THUILLIER, R.E., DEPUTY SUPERINTENDENT, IN CHARGE BRAHMAPUTRA SERIES, NO. 93, DATED 20TH SEPTEMBER, 1869.

(2.) First, I will proceed to detail the work of the Brahmaputra Series and then report on the Assam triangulation which is being carried on by Lieutenant E. M. Larminie in connection with my party though completely detached, there being a distance of 350 miles between our work.

(3.) The Brahmaputra Series Party assembled at Calcutta from Head Quarters on 1st November and after making the necessary preparations for taking the field, I started the larger portion of my camp on 15th November to march *vid* Baraset and Jessore to Dowlatpur, a station of the E. Calcutta Longitudinal Series whence the Brahmaputra Series emanates and where I had to commence observations. I followed on 17th idem by boat accompanied by Mr. Ryall, having previously instructed Messrs. Neuville and Harris to proceed *vid* Kushtia, to the point where we had closed the previous season; the former to continue the Approximate Series northwards and the latter to proceed with the building of the towers.

(4.) I arrived simultaneously with my party at Dowlatpur on the 24th November and on the following day, detached Mr. Ryall to renew the platforms of the towers in advance which had been built the previous season.

(5.) I was delayed a few days at Dowlatpur erecting a new platform, as the old one had disappeared, three years having elapsed since the station was last visited. On the 2nd December, I put up the Theodolite and commenced observations. In accordance with your instructions, I determined to take a set of azimuth observations at this station, it being more favorably situated than the other stations of the E. Calcutta Longitudinal Series which I had to visit. For this purpose I selected two stars viz., 51 Hev. Cephei and λ Ursæ Minoris at opposite elongations and completed the observations on 7th December. The result shows a discrepancy of + 6·73 seconds with the computed value as brought up from the Calcutta Base.

(13.) The triangulation follows the course of the Ganges and Jamuna rivers. The changes in the courses of these streams, which run through a sandy soil, are very great. Islands or "Churs" are annually thrown up in one place and washed away in another and the banks undergo considerable change every monsoon. In some places, the great breadth of these rivers prevented my selecting sites for the towers sufficiently inland to secure permanency, but such sites have been selected with care, in places where the action of the stream is slight and I am in hopes they may last for years; by far the greater portion however are well inland.

(14.) In Furreedpore and Dacca there are numerous Indigo factories, scattered over the portions of the districts through which the triangulation was carried, but by far the greater number of them I found deserted and in ruins. Communication in these parts, is very difficult in the dry months owing to the want of roads: in the rainy season the traffic is entirely carried on by boats.

(15.) In these districts fever is very prevalent in the commencement of the cold season, which is the reason of the Party not taking the field earlier. Again when the southern monsoon sets in, generally in March, fevers commence and that is the period in which the establishment suffers most. One of the principal causes of sickness at this time of the year is bad water. As the hot season approaches the lands become thoroughly dry; water in the small streams stagnates and good fresh water is very difficult to procure. During the months of March and April, I found it necessary to dig wells at all my stations; the water in the pools and small streams being so foul and bad that it was unfit even for bathing purposes. Cholera also invariably appears at this season of the year and in some parts of the Dacca district the mortality was great this year, but not so severe in the vicinity of my operations as during the preceding spring, when whole hamlets were almost denuded of their male inhabitants. The health of the Establishment was on the whole, good; there were however six casualties, 4 from cholera and dysentery and 2 from an accidental cause, by drowning.

(16.) On the 10th January the whole of Bengal was visited by a very severe earthquake. I was observing at the time at Saidpur T.S. (about 15 miles south west of Furreedpore) on the top of a 40 feet tower where the motion was rather alarming. There were three distinct shocks, which I timed to occupy 45 seconds, the first happening at 4·53 P.M. The wave appeared to pass from S.W. to N.E. When the shocks were apparently over, I watched the level of the Theodolite and at the end of 20 minutes the bubble was still oscillating. The tower luckily did not undergo any damage.

(17.) As the survey progresses northwards the country gets higher and more favorable for our operations and is not so unhealthy, so that I trust to take the field earlier in future than I have been able to do in the low and marshy districts, in which this Party has been employed for the last seven years.

(18.) After completing observations at Paipara T.S., the end of the third hexagon, I closed work on 19th April.

(19.) Mr. Neuville commenced work on the 26th November and proceeded with the Approximate Series, on which undertaking he was occupied during the whole season. By the 30th March he had selected 15 stations, arranged in hexagons, covering a direct distance of 56 miles. This operation involved the clearance of 344 miles of trial rays. I then sent him instructions to turn back from the point he had reached, clearing the final rays on his way. On closing work on the 14th April, he had added 160 miles of final rays to his out-turn. This amount of work I consider very creditable to Mr. Neuville.

(20.) Mr. Ryall was employed during the early part of the season in renewing the platforms at the towers which had been erected during the previous season, and also in re-clearing the rays. The growth of vegetation in these parts is so rapid, especially bamboos, that in six months time a ray becomes entirely choked up. After he had completed this duty, he was engaged in clearing the final rays between the stations selected last field season and at the close of his work, had completed the clearance of 213 miles of fresh final rays. I have every reason to be satisfied with Mr. Ryall's progress.

(21.) Mr. Harris took the field on the 17th November, and was employed during the whole season in building the towers. At the commencement of the season he heard of the fall of a portion of the Harina tower, which he had built the previous season: this appears to have occurred from the sinking of the foundation. The site was a well raised mound which had originally been occupied by a hut. The country, in parts is so low and swampy, that these artificial mounds are the only sites on which towers can be built and I consequently found it difficult to procure good and permanent sites. Mr. Harris speedily made arrangements to rebuild this tower and succeeded in getting it completed before I required it for my final observations, so that I was not delayed thereby. During the season Mr. Harris completed seven rectangular towers, 17 × 13 feet at base, and six perforated pillars, varying in height from 35 to 40 feet. Materials also for three other pillars were prepared and collected. These structures are paka throughout; the materials have to be prepared and lime, &c., brought from a distance and conveyed, with much trouble and delay, to the various tower sites. Mr. Harris' arrangements were very good and his progress satisfactory. He returned to Calcutta on 28th May.

ASSAM OPERATIONS.

Lieut. E. M. Larminie, R.E., Asst. Surveyor 2nd Grade.
Mr. W. J. O'Sullivan, Sub-Assistant 2nd Grade.

(22.) The Assam triangulation, which had been commenced last field season by Lieutenant Larminie R.E., was continued by the same Officer. Owing to the difficulties he met with in that season, he was obliged to confine himself to the Approximate Series, so that this was the first year in which observations were taken. His equipment this season was more favorable than during the last; the establishment No. 7 Extra Party, had been, ad interim, much increased and he had been provided with three Elephants. This amount of carriage however proved inadequate to his requirements and he was much delayed on this account; coolies, which are the only local resort for carriage in Assam, being most difficult to procure. The season also seems to have been very exceptional: the observations were considerably delayed by the haziness of the atmosphere, which Lieutenant Larminie attributes to the failure of the rain which usually falls about Xmas time. The instrument used was a 14 Inch Theodolite by Troughton and Simms and the

out-turn of work consists of observations taken at 11 stations, covering an area of 480 square miles, in a direct distance of 56 miles. The Approximate Series was advanced 64 miles in direct length, by the selection of seven stations arranged in polygons: 42 miles of roads were constructed up to stations and seven platforms built. The following is extracted from Lieutenant Larminie's report. "Up to the end of January I was able to get very fair observations, though great delay was occasioned by the time occupied in marching from one station to another, owing to rivers having to be crossed, where ferries are few and far between, and to the paucity of Elephants for the carriage of my camp. From the 1st February till the 20th March, when I was obliged to close work, the wheather was most unusually hazy, owing, I have reason to believe, to the absence of the few days rain which generally falls in Assam about Xmas. Very little was done during these two months, in comparison with what might have been effected, if the weather had been in a more satisfactory state for observations. With the exception of one day, I was unable during the whole season, to obtain morning observations and I regret that on one occasion only did I obtain a view, and that an imperfect one, of the snowy peaks. On the 20th March, having been 9 days at the last station without being able to get any observations, the weather still remaining hazy and showing no signs of clearing and fearing lest the establishment should be prostrated by fever, as they had been last year when I remained out till 2nd April, I thought it expedient to close work. I then marched to Gowhatty, where I was joined on 29th March by Mr. O'Sullivan with his party, he having been obliged to close work for similar reasons to mine, at the same time as I did, though he was nearly 100 miles further to the East. I may here observe that the weather remained the same up to the day I left Assam. The health of the establishment was tolerably good during the season, about 12 per cent of the entire party being the daily average on the sick list. There were no deaths and what sickness there was, of an ordinary type. Mr. O'Sullivan accompanied me till 15th January and acted as observatory recorder. From that date he was employed on the Approximate Series. On closing work he had completed the selection of 7 stations, arranged in polygons, covering a direct length of 64 miles. Roads had to be cut to each of those stations and the hill tops, cleared of forest and jungle. Mr. O'Sullivan appears to have had a very difficult country to deal with, it being covered with dense forest jungle and the population very sparse, so that great difficulty was experienced in getting supplies for the camp. He has throughout the season worked hard and considering the difficulties and delays met with, has done a very fair season's work."

EXTRACT FROM THE NARRATIVE REPORT OF W. C. ROSSENRODE, ESQ., DEPUTY SUPERINTENDENT, IN CHARGE EASTERN FRONTIER SERIES, NO. 42, DATED 8TH JULY, 1869.

(3.) Owing to the slow progress last season, for want of labor, I took the field early and left Moulmein on the 27th October 1868.

(6.) Accompanied by Messrs. Price and Gibson, I left Rangoon by the first River Steamer and reached Myanoung on the 3rd November. Messrs. Beverley and Connor had arrived there a week before, and could not leave Myanoung, owing to the country being still under water.

(7.) On my arrival at Myanoung, I was told by the Myanoung Authorities, that I had come too soon. They said the country was not dry and the roads were not open; and they, one and all, strongly advised me not to venture out until the beginning of January: to march they said was impossible and the danger of venturing out so early was very great; and that, if I made the attempt, I would certainly have my whole camp prostrated with fever. I however, determined to commence work, rather than lose two months of fine weather, by waiting at Myanoung for the country to dry and the roads to open. From my experience of last season, I found that December, January and the greater portion of February only, were clear months, during which final observations could be taken. I noticed last season that the jungles were fired in the latter end of February, and the smoke and haze prevented any signals being seen until the first falls of rain, in the beginning of May, when observations could be resumed. With such a short time of good observing weather, and knowing the difficulty of obtaining labor, I could not afford to lose the best months; and, without being disheartened, I commenced making my arrangements for beginning work at once.

(9.) I tried my very best to obtain coolies, to start Messrs. Beverley and Connor, to commence clearing the Rays and building the Towers. Not a single man, however, could be obtained. I decided therefore to send the above named assistants by steamer to Prome; and directed them to proceed from there to Poungday by the metaled road between those two stations, which was open all the year round for carts; and I requested them to commence work, and keep on the high ground, until the country was dry for building towers and clearing rays in the plains. By carrying out these arrangements, Messrs. Beverley and Connor were able to begin work on the 16th and 20th November, and their respective Native Establishments enjoyed good health, on the high ground they occupied, and when the country was dry they took up the rays on the low ground.

(10.) I was myself very anxious to commence the final operations, and tried my utmost to engage coolies to take me to Thungtong, my first station, which was 14 miles by the road from Myanoung. Failing to procure the men of the country, I made the attempt to engage the laborers from Upper Burma. Hordes of these on foot, and boat loads of them, were daily passing Myanoung. I employed influential contractors, by offering a high premium for a certain number of men. Not succeeding in this, I offered a daily per centage on each man supplied me. These Upper Burman laborers had come to work on the embankments, on the roads, and were also going on to Rangoon; and would listen to no overtures to accompany me to the jungles, when there was so great a demand for contract labor.

(14.) The final operations made good progress in December and January. I was detained at Keokidong H.S., owing to the ray not being clear, although it had been commenced more than a month before by Mr. Connor. The dense forest and the undulating ground, increased the difficulty of aligning the flags and carrying on the ray. The principal cause, however, was want of labor, in this, as in every other ray, owing to want of assistance in British Burma. The apathy and indifference shewn by the district and local officials, was most disheartening and distressing; and I failed completely in securing their co-operation, and overcoming the prejudice against the native establishment, composed, as you are aware, of men mostly from Upper India.

(15.) The signal parties this season were very seldom able to procure coolies, and when these were supplied, the charges were enormous, and much time was lost in the dilatory manner the orders were received and executed by the native officials; and the signal men took 10 and 15 days to reach their stations. To prevent the embarrassment caused by delays of this nature, I had to send men of the native establishment to aid them in reaching, or returning from, each station. The instrument bearers were detached on this duty, the day after I reached each new station, and they returned in time to convey the large theodolite to the next station. I felt the want of men, but I could not entertain spare men for this and other duties, as none were willing to take employment. The carriage of the lamp, heliotrope, oil, baggage of the men and the provisions they are generally required to carry, takes up five or six coolies. The lampman has his two assistants, carriers, and requires three or four extra men for the remainder of his loads. The number of men varies according to the station to which he is posted, whether inhabited or not. Where the villages are far removed, a large quantity of provisions are sent with him, and if any delay take place, and the observations to the station are not completed, a further supply is sent. My establishment is very much crippled, owing to the high wages paid to them; as the lowest pay now given to carriers is ten Rupees a month: not a single man can be entertained or kept on for less. Influential men were engaged to obtain coolies, by making it worth their while to supply them, by daily payment of one anna per head. This arrangement enabled each detachment to procure labor for clearing the rays and building towers. The coolie gongs, as they are called, always succeeded in inducing their relations and connections to accompany them; and, as it was their interest to provide as many men as they could, they exerted themselves to bring as large a number as they were able to collect. Although the supply fell far short of the demand, still coolies came in daily, and the work progressed. The progress, although sure, was very slow in forest rays; and each ray occupied, on an average, about two months to clear.

(18.) By the latter end of February the jungle and hills were fired; the haze set in; and nothing could be seen, consequently no final work could be done. I therefore employed myself in clearing rays, until the first falls of rain, after which only, I could resume final observations. In May the rains fairly set in, and the daily showers and storms caused very great inconvenience. Whenever a break occurred, the instrument was set up and observations were taken but, on the approach of a storm, it was dismantled and boxed. Persevering in this way, the observations were completed at Meododong and Tongtalung, and I reached Timukhi on the 8th of June; waited there until the whole of the detached parties joined me, and then marched to Rangoon, which place I reached on the 21st June.

(22.) The detentions last season for carriage, were very frequent, and the disaffection and discontent were apparently caused by the native officials being repeatedly urged to furnish the above aid, which they were required and requested to do by the orders of the Deputy Commissioner of the district. The native officials find it irksome to attend to such orders. Procuring carts and coolies entails labor; and labor is distasteful. To those acquainted with Burma and the Burmans, another reason for not providing labor and carriage is obvious. The Burmans are averse to carrying loads and to working as coolies. They are not disposed to hire their cattle and carts. The cattle are used for ploughing their paddy fields, after the setting in of the rains; and are also used when they personally require them, to cart in their grain from their fields, or their supplies from the nearest market towns, or in carrying bamboos, grass and other building materials from the jungles for their huts, when renewing or repairing them; or some who trade make use of them for this purpose; and, at all other times, the cattle are unemployed and allowed to graze. They keep their cattle and carts for their own convenience and use; and are unwilling to hire them.

(23.) The lower grades of Native Burman Officials, I allude to the village authorities, strive (it would appear) to be on the very best of terms with the villagers under them. To preserve and maintain their intimacy intact, they neglect Government work, and will rather incur the displeasure of their European superiors, than offend the people under them, by inducing them to render the needful aid, to enable the officer to reach his station and begin his work. Such a confederacy is manifest to all Government servants working in Burma; and those officials, who are armed with the purwanahs of the district officers, as we are, and require

the orders they contain promptly attended to, become unpopular; and false complaints and false statements are made, so that they may be saved the trouble of providing aid, at the risk of forfeiting their own popularity with the villagers.

(30) Mr. H. Beverley, Civil Assistant 2nd Grade, cleared five forest rays and built two towers, Tongtalung and Sahu-éng, during the season. Mr. W. C. Price, Sub-Assistant 3rd Grade, was engaged upon the base-line nearly the whole field season. He built the east end base station platform and the tower at the west end base station, and cleared the ray. Mr. E. J. Connor, Sub-Assistant 3rd Grade, cleared three rays and a portion of the fourth, and built the tower of Keingbeng-gyee. He was subsequently sent to Keoklada H.S. to observe the angles. Mr. R. Gibson, Probationer, recorded in the observatory and assisted generally in office duties. He has been taught the use of Vernier instruments, and has also been instructed in cutting rays. He cleared one and carried on two trial rays.

EXTRACT FROM THE NARRATIVE REPORT OF GEO. SHELVERTON, ESQ., DEPUTY SUPERINTENDENT, IN CHARGE BEDER LONGITUDINAL SERIES, NO. 11, DATED 31ST AUGUST, 1869.

(1.) On receiving your letter ordering me to begin, during the approaching field season, the triangulation of the Beder Longitudinal Series, I addressed the Resident at the court of His Highness the Nizam of Hyderabad, to notify to the authorities that my work, during field season 1868-69, would lie in the neighbourhood of Beder and Hyderabad: he was good enough to send a court official, "Mansabdar" Ghafar Beg, with a suitable escort, to wait my arrival at Ashwaraopetta, on the borders of the Hyderabad states, about 36 miles to the west by north of Rajahmundry. I beg here to record, that I am very much indebted to His Highness' Government for the valuable help that was rendered to me, during the whole of the field season.

(3.) The principal difficulties of the season having been surmounted, and the Approximate Series very nearly laid out, I began building the stations towards the Great Arc Series, and despatched Mr. Hickie to select the two flank stations of the Chinchalkot polygon, which he was soon able to do, as the country was remarkably favorable.

(4.) During the month of January 1869, I employed Mr. Hickie in building the stations of the Chinchalkot figure, and in cutting roads and clearing the hill tops of jungle; for the remainder of the field season, he was engaged on minor triangulation within the main series; he observed angles at 60 stations, and fixed the positions of about 100 villages. His out-turn of work is very large; I again beg to bring him to your favorable notice for promotion to the next superior grade of Civil Assistant: his exertions during the past field season have been very praiseworthy.

(5.) Mr. F. Bell began his field operations by connecting Khummummet hill fort with the Jubbulpore Meridional Series: I had intended him to supply the omissions of the Jubbulpore Meridional Series, during field season 1867-68, by employing him, during the field season under review, in minor triangulation, similar to that conducted by Mr. Hickie for the Beder Longitudinal Series; but, as in $2\frac{1}{2}$ months, Mr. Bell had not succeeded in observing at more than nine stations, from causes over which, he says, that he had no control, I cancelled my first instructions, as the season was pretty well advanced, and directed him to carry out, without any further delay, a series of route surveys such as you specified. Mr. Bell's triangulation is not satisfactory, inasmuch as, he failed to fix the positions of Warangal and Eilgundel, two out of four places of importance, that his minor series was specially designed to connect. During the months of March and April, Mr. Bell conducted route surveys, averaging each five miles in length, round 13 principal stations of the Jubbulpore Meridional Series, and thus fixed the positions of 37 villages; the progress of this work was very satisfactory, as Mr. Bell had to march over 300 miles of ground in the course of it.

(6.) Mr. E. P. Wrixon, assisted Mr. Hickie for about two months, and was of great service to him: after Mr. Low's resignation, I ordered Mr. Wrixon to join me, and he proved himself a very useful assistant throughout.

(8.) In marching to our ground, we adopted the shortest route, keeping along the Dekhan road for 11 days, and then striking across country for Ashwaraopetta, near the western confines of the Rajahmundry district. From Ashwaraopetta to Kallur, a distance of 50 miles, the road a good cart track, lay through dense forest; the villages here are small, and the cultivation scanty; from Kallur to Subler (60 miles) there was extensive cultivation, the villages were large, and water was abundantly stored up in fine tanks; from Subler to Itur (40 miles) the country was barren; the tanks and wells were very nearly dry in December, and the people had begun emigrating; this is a portion of the Nalgondah Talook whose chronic condition borders on famine. They have a saying in the country that when Nalgondah grows crops the Dekkan rejoices. From Itur onwards, as far as my work lay, the country (excepting the hilly portion) was free from jungle, had yielded an avarage harvest, and the labouring classes looked well fed and were well clad; from Itur we reached Jidkal in two marches.

Jidkal is noticeable for a great fair, that is held on the full of the moon, in "Kartik", which corresponded on the last occasion to 30th October 1868, and continued for 15 days—the attraction is a temple, sacred to "Mahadeo", built on a granite hillock, outside the village, and ministered by a small colony of Brahmans. These priests knew that there was to be a partial eclipse of the moon, on the 28th of January 1869, but did not assume great learning; their source of information was a Teligu almanac, published in Madras by one Siriram "Siddanti", which they produced. From Jidkal we marched to Kulpak, a large village, which must have been of some note once, as it is styled "Dakhin Kasi," or the Kasi of the south, in contradistinction to the holy city of Benares. There are 18 "mats" or temples of "Someshar" (Brahm Mahadeo) in the village itself, and tradition runs, that ten million "Lings" are to be found in the neighbourhood, within a radius of ten miles: there are still many temples and monoliths to be seen about the village grounds. From Kulpak I marched to Chinchalkot and began my reconnoissance of the country.

(9.) The principal forts that lay within the area of the triangulation, were Khummummett, Bhonaghir, Eilgundel, Mullangoor, Warangal and Medduck; all very formidable. Khummummett is built on an isolated granite hillock, that rises about 80 feet above the level of the country, and the town surrounds the hillock: the hillock looks like one entire block of stone, and is steep on all sides, save, at the entrance to the fort: there was water within the walls in a deep cleft of the rock. There were no guns in position, but some that were lying on the ramparts, purported to have been cast in the year 1180 of the Hegira (106 years ago) by order of Nawabs Rookan-ood-Dowlah and Zuffer-ood-Dowlah, in the foundry of Mahomed Kasim; the walls on the hill top were showing signs of decay, but the works at the entrance are in excellent preservation; they are very massive and strong. Bhonaghir is situated on rather a high hill of granite—only the western face, which is the weakest, is strongly fortified. Mr. Hickie wished to visit the hill but the garrison refused to admit him: on his representing the matter to His Highness the Nizam's Government, permission was obtained to enter the fort; but, with the injunction, that he was to build no Trigonometrical Stations on the hill or set up any kind of signals; this was fortunately of no consequence to us, as we subsequently learned that the view from the hill westwards was limited, by the neighbouring heights of Raghir. Warangal fort is situated in the plain; it has an inner wall of paka masonry and an outer kacha wall of great thickness, both surrounded by broad ditches. There were several breaches in the inner wall, within the fort, a watch tower, built on a small hillock overlooks the walls. Mullangoor fort is built on a steep granite hill, at the foot of which, the city of the same name, has sprung up; the side of the hill facing the town is strongly fortified, and the hill top is crowned with an inner and outer wall—the neighbouring heights are also fortified and cover the approaches to the fort. Eilgundel fort is built on an isolated hill; the town of the same name lies at the northern foot—the hill is said to be girdled from top to bottom by eight walls. The garrison at Eilgundel would not permit Mr. Bell to enter the fort; the hill is crowned by a mosque. Medduk fort is built on an isolated granite hill, which appears to be girdled with walls and bastions, from foot to summit, and is surmounted by a mosque, with four tall minarets; there is said to be an ample water supply within these forts.

(10.) In the country, through which the triangulation of the Beder Longitudinal Series ran, there was no valuable timber, though the hill ranges were covered with forest, dense enough to afford cover to tigers, which were numerous enough at all my hill stations. In the talooks of Bedar and Medduck, sugarcane was rather extensively cultivated and crystallized sugar, of good quality, manufactured: iron ore was plantiful at Botmili, Yerraballi and Anasagar, at the first two stations it lay near the surface, and the excavations seldom exceeded a depth of six feet, but at Anasagar they had to work deeper. I was shown there a shaft, that had tumbled in, killing all the diggers, variously reported as from 16 to 100 in number. Great blocks of stone, laid bare by the washing away of the soil, are to be found on most of the hill tops of the granite ranges of the country; some of these blocks are 30 feet high, and others of great size too, seem perilously balanced, one on top of the other.

EXTRACT FROM THE NARRATIVE REPORT OF H. KEELAN ESQ., DEPUTY SUPERINTENDENT, IN CHARGE SAMBALPUR SERIES NO. $\frac{47}{598}$, DATED 23RD AUGUST, 1869.

(2.) The party left Head Quarters on the 5th, arriving at Burdwan on the 9th November, to resume the revision and completion of the Calcutta Longitudinal Series. After satifying myself that the arrangements for taking the field were completed, and that the Assistants were furnished with instructions, for the conduct of the work allotted to each, the camp broke ground on the morning of the 15th, and I went, in the first instance, to examine the station marks of the Madhpur polygon, at which the operations closed the preceding season, and found them in good preservation. I returned to Madhpur T.S., to observe an Azimuth at that station.

(3.) Madhpur T.S. is the centre of the polygon, about 50 miles west of the Calcutta base-line, and over 50 miles east of any hills; at the same time, the new tower, built the preceding year, was strong and firm.

(4.) Azimuth observations to ϵ Ursæ Minoris, commenced on the 4th and were completed on the 12th December; cloudy and foggy weather delayed the observations. The incomplete sets were subsequently repeated; and, by the close of the month, three zeros of final angles were observed at Hakistapur T.S.

(5.) During January, final angles were completed at Hakistapur, Mobarakpur and Aknapur: the observations at Mobarakpur took 13 or 14 days, owing to the Madhpur heliotrope being only visible, by the aid of refraction, a little before sunset, and for a short while after sunrise: scarcely a lamp angle was taken to it on account of intense smoke. Whilst the observations at this station were giving trouble and causing delay, a violent earthquake was felt on the evening of the 10th January, and the following note was recorded in the angle book immediately after the occurrence:—

"Shortly after commencing the horizontal angles, this evening, and whilst intersecting the Madhpur heliotrope, a slight vibration was noticed in the telescope of the Theodolite, as if a person was treading heavily on top of the tower, gradually increasing in force, when it was found to be an earthquake. It became more and more violent, and the instrument, and everything on the tower, rocked to and fro for some time, creating no little alarm, when the shock suddenly ceased; I then looked at the level and the plumb line; the former was running violently backwards and forwards in the tube, whilst the latter was oscillating violently below. The shock was felt at about 4-45 P. M., and lasted fully one or two minutes; the direction of the motion being apparently north and south, as indicated by the oxcillation of the plumb line. On examining the instrument, after the level became steady, I found the plumb line slightly to the south of the dot, marking the station, on the summit of the tower, whilst the level seemed unaffected. The large plumb line was then let down to the markstone below, in the pavement, and found to agree. The instrument was then re-centered and levelled."

(6.) During the month of February, final angles were completed at Dastanpur, satten, Bhola and Dilakas.

(7.) In the early past of March, a second Azimuth was observed, at Aknapur T.S.: this tower station is the centre of a polygon, about 26 miles in a direct line from the Calcutta base-line. The Azimuthal observations were completed on the 9th, but the camp was unable to move next day, on account of heavy rain, to Nibria station, where you desired to inspect the instrument and party of this Series; late, however, in the afternoon of the 12th, after a forced march, the instrument arrived at Nibria, and I was glad to have it up ready, next morning, for your inspection.

(8.) The observations at Nibria and North End Base towers, were finished on the 25th March, on which date, I had the honor to report to you, the completion of the revisionary operations of the Calcutta Longitudinal Series.

(9.) Whilst the observations were in progress, at the North End Base, Mr. Sub-Assistant Moore, and a large number of men of the establishment, and private servants were suddenly taken with fever, and two men died of cholera. As the work was now completed, I left the Bengal district without delay; and, on the 30th March, the camp arrived at Burdwan, *en route* to the Hazaribaugh district, to observe the angles of two triangles of the Chendwar Series, to connect the new station of Chendwar, the old station having been destroyed.

(10.) The party arrived at Paraia hill station on the 16th April; and, after 9 days of stormy and hazy weather, the angles at this station were completed: observations at Sindraili H.S., were completed by the 29th April; at Chendwar after another delay of several days, on account of bad weather, on the 17th May; and at Kasiatu H.S., on the 23rd May; and as soon as the rectangular pillars were built up, and the platforms transferred to the village officials, the party marched up, for recess quarters, to Chunar by the Grand Trunk Road.

(11.) During the march to Chunar, the heat was so intense, that several cases of sunstroke occurred in camp, which the men of the establishment called Loo-ka-Mara: frequently on the line of march, as soon as the day dawned, travellers, men and women, used to be seen lying dead, on either side of the road, struck down by the terrible heat that prevailed, and there they remained till their corpses were removed by the Police.

(12.) Mr. Civil Assistant L. H. Clarke, who was posted to this Series for the approximate operations on the meridian of 82°, reached Mirzapore on the 3rd December, and soon after proceeded to the stations of the Calcutta Longitudinal Series, on that meridian, from whence an approximate series was carried down south by him, though not however without some difficulty.

(13.) The Series is double throughout, trends slightly to the east of the meridian of 82°, and is 100 miles in length. There are no hills further south of the base than Dalhea H.S. and Soti H.S., but an extensive plain, which, it is said, extends over a hundred miles, when the country again becomes hilly. This level country is in the sub-division of Belaspur, District Raipur, in the Central Provinces, and is well populated, though interspersed with jungle here and there. The Series in continuation will therefore need towers, of the height adapted for sides of 10 and 12 miles, until it reaches the highlands beyond.

(14.) Mr. Civil Assistant H. E. T. Keelan proceeded from Burdwan to the station of Dastanpur, selected by him the previous season, situated to the north of, and forming the hexagon round Aknapur as the rays from this station required to be tested, before the tower was taken in hand. There were three rays in all to be tested, and they were fortunately free from interruptions; as soon as this fact was ascertained, the building of the tower was taken in hand, and the rays cleared of trees by the end of December.

(15.) During January, Mr. Keelan cleared four rays, and in February, the last ray, Bhola to North End Base Tower, across the river Hooghly. He then marched up to the Grand Trunk Road to select one of the two milestones, fixed by the leveling operations, in order to determine the difference of level between the station of Sonakur and one of the above milestones. The 63rd milestone being nearest the station, levels were carried from it to the station, and back for verification. On completing the levels he next closed and transferred several of the Towers, and proceeded to the Hazareebagh district, to assist in the operations of the Chendwar Series.

(16.) Mr. Sub-Assistant H. W. Peychers was employed during the season in clearing rays of the Calcutta Longitudinal Series; in assisting in the star observations at Madhpur and Aknapur stations, and in closing and transferring several towers to the native officials. He subsequently proceeded to the Hazaribaugh district to build the rectangular pillars of the Chendwar Series.

(17.) Mr. J. F. Trotter was detached early in October to prepare materials for, and build the Dastanpur tower. He next removed the old Satten tower and built a new one over the station. He also renewed the upper parts of Dilakas, Bhola, Nibria and North End Base

towers, from which last station he proceeded by order to Calcutta for his examination for a commission. On his return he closed and transferred the towers of Satten, Dastanpur and Madhpur, and I next directed him to proceed to the Hazaribaugh district to build platforms and make roads to the hill stations of the Chendwar Series.

(18.) Mr Sub-Assistant A. Moore was employed during the season in recording principal horizontal and vertical angles in the observatory, and in current office duties.

(20.) I am happy to report, that the operations in the vicinity of the Metropolis were completed without any complaints on the part of the inhabitants, and without our being involved in any disputes with the owners of estates. For the three seasons that we have been working in Bengal proper, and particularly in the neighbourhood of Calcutta, I have labored under great anxiety on this head, and it is due to my establishments, both European and Native, to state, that in their dealings with the people of the country, they have conducted themselves to my entire satisfaction.

Report on the measurement of the Cape Comorin Base-Line.

EXTRACT FROM THE NARRATIVE REPORT OF CAPTAIN J. P. BASEVI, R.E., DEPUTY SUPERINTENDENT, IN CHARGE OF THE MEASUREMENT, NO. 19, DATED 12TH JULY, 1869.

Parties employed.

(2.) The following Parties were employed :—

1. Madras Party in charge of Captain Branfill.
2. Bombay ,, Do. Lieutenant Rogers, R.E.
3. No. 1 Extra Party Do. ,, Herschel, R.E.
4. No. 4 Extra Party Do. Captain Basevi, R.E.

The first two parties cleared the line and made all preliminary arrangements; the two others arrived on the ground on the 4th January, simultaneously with the apparatus, which under the superintendence of Lieutenant Herschel, had been conveyed from Bangalore by land.

General description of Base.

Position.

Divided into three sections.

(3.) The Base, selected by Captain Branfill during the preceding season, is 7·6 miles in length, having a direction of nearly north and south; its northern extremity is situated near the village of Rathapuram, and the southern on an elevated stony ridge, a mile from the sea, near the village of Kudankolam. It is divided into three sections by the stations of Paramespuram and Shanganeri, the extreme sections being each about three miles, and the middle section 1·68 miles in length. The Base is in the Tinnevelly district, and the southern extremity lies about 13 miles north-east of Cape Comorin.

Short Base to be repeatedly measured and extended by Triangulation.

(4.) You decided, in order to obtain data for the probable errors of a Base measured with Colonel Colby's apparatus, on measuring the middle section of 1·68 miles four times, instead of measuring the whole 7·6 miles once: but the entire length selected was to be preserved, by extending the measured portion by means of the triangulation, which has hitherto been termed, Base-line Minor Triangulation, and has served only as a sort of check on the measurement. This Triangulation, which consisted of a double hexagon, further strengthened by the observations of several of the cross rays, was selected principally by Lieutenant Rogers R.E.

Middle section described.

(5.) The middle section was a very favorable one for measurement, having very gentle slopes, and the soil throughout being very good: the length was 8,912 feet, making 141½ sets of the compensated Bar apparatus. The only drawback to it was that, owing to the ground rising intermediately, the two ends were not mutually visible. This circumstance did not however inconvenience the measurement, but for the triangulation masonry towers were necessary: they were designed and their building superintended by Captain Branfill.

Operations commenced on the 9th January.

(7.) By the 8th of January all the apparatus was unpacked and ready for work: Bar comparisons were taken on the 9th and 11th January, and the first measurement was commenced on the 13th, from Paramespuram, and completed on the 23rd January.

Bar comparisons all taken at Paramespuram, camp stationary there all the time.

(8.) The direction of the measurement was changed each time: between each measurement four days of Bar Comparisons, and after the fourth and last time of measurement, two days Bar Comparisons were taken. As there was a scarcity of water at Shanganeri, and as all supplies must have been carried from Paramespuram, the camp remained at the latter place during the whole time of measurement. The compari-

sons also were, for greater convenience, all taken there, the bars and tents being marched back for the purpose each time the measurement reached Shangaueri.

Completion of work and breaking up of camp.

(9.) All the operations connected with the measurement, were completed on the 12th March, and the following day the camp was broken up, and the several parties proceeded on the different duties allotted to them by you. Lieutenant Herschel superintended the repacking and transport of the apparatus to Tuticorin and thence to Calcutta: Captain Branfill undertook the connection of the Base with the principal triangulation: Lieutenant Rogers took up the Base extension triangulation; and I myself proceeded to Punnæ, to resume the Pendulum operations, which had been suspended during the measurement.

(10.) The times of the different measurements, and number of sets daily completed, were as follows:—

Detail of time and rate of measurement.

	1st Time.	2nd Time.	3rd Time.	4th Time.
Number of days, ...	10	9	7	7
Total hours of work, ..	74	65	56	53
Number of sets measured on the 1st day, ..	8	9½	16	13½
2nd „ ..	11	14	19	19
3rd „ ..	9	15	19	20
4th „ ..	14	20	16	19
5th „ ..	17	16	23	25
6th „ ..	12	21	23	27
7th „ ..	17	20	25½	18
8th „ ..	19	22		
9th „ ..	21	4		
10th „ ..	13½			

Distribution of Officers in the measurement.

(11.) In the measurement, the three more important posts, viz. boning instrument, advanced microscope, and rear microscope, were taken alternately by Lieutenant Herschel, Captain Branfill, Lieutenant Rogers, and myself; you yourself also took the boning instrument and a microscope on several occasions, during the first time of measurement. Mr. Potter superintended the laying of the trestles during the first two measurements, Mr. Macdougall during the third, and Mr. Anding during the fourth time of measurement. The following assistants had charge of microscopes at different times, viz.:—

Mr. Mitchell, Mr. Potter, } Madras Party.

Mr. Anding, Mr. Christie, Mr. Bond, } Bombay Party.

„ Belcham, No. 1 Extra Party.

„ Macdougall, No. 4 Extra Party.

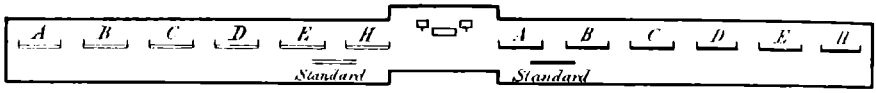
of these Messrs. Belcham and Macdougall were the only ones who had not previously handled a microscope.

The bar comparisons and runs of comparing microscopes, were taken by yourself, Lieutenant Herschel, Captain Branfill, Lieutenant Rogers and myself.

(12.) I will now proceed to describe with more detail the different parts of the operations, and first of all the comparisons.

(13.) The main principle held in view was to preserve, as far as possible, exact similarity of circumstances in the comparisons and measurements. The comparing bench was set up under two bar tents, and on *either* side a sufficient number of tents to receive the six compensated bars, were arranged in line, slightly in rear of the other two, parallel to the direction of the base. The arrangement is shewn in the accompanying diagram.

Comparisons.—Measures taken to preserve similarity of circumstances in comparisons and measurement.



The bars were placed in line, exactly as in the process of measurement, in one of the sets of tents, the right hand set for instance, and each bar was brought up in succession, compared and then carried on, and placed in a similar position, in the left hand set of tents. Care also was taken to raise and lower the purdahs of the tents, at the same time and to the same degree, during the comparisons as during the measurement.

(14.) The comparisons were taken at regular intervals, every half hour *continuously*, the first set being commenced at 6-30 A.M., and the last set commenced at 4 P.M.; these times were chosen so as just to overlap the hours of working in the measurement, which were from 6-45 A.M. to 4 P.M. The comparisons, for each time of measurement, were kept independent; thus, for the first time, which was from north to south when the tongues of the bars would point to the east, two days comparisons were taken before, and two days comparisons after the measurement, with the bars tongues east. For the second time of measurement, which was carried from south to north when the tongues would face the west, two days comparisons were taken, both before and after, with the bars tongues west, and so on.

Order in which comparisons were taken.

(15.) In order to make this change in taking the comparisons, it was necessary to turn round the comparing Microscopes on their piers. To facilitate this Lieutenent Herschel mounted the microscopes on finely dressed blocks of stone, which were made to rest on three points, on the top of the regular stone piers: when it was necessary to reverse the microscopes, these blocks, microscopes and all, had merely to be turned round on the piers. This arrangement was perfectly satisfactory.

Mode of mounting the Microscopes.

(16.) Each "set" of comparisons consisted of a reading of the standard, then of all the bars in order, and lastly a second reading of the standard.

Definition of a "set."

(17.) For the purpose of obtaining some information on the relative temperatures of the two components of a compensated Bar, Lieutenant Herschel, with your permission, pierced each component of bar B in two places for thermometers; this was done at Bangalore prior to the measurement. The readings of these four thermometers, were taken each time bar B was compared, and at each set in the measurement.

Compensated Bar B pierced for Thermometers.

(19.) The measurement. In this no change of procedure was introduced that I am aware of. Owing to the character of the ground, the gentleness and regularity of the slopes, the alignment by the boning instrument was able to be made, almost entirely, on the points fixed by the great Theodolite.

The measurement.—Nature of ground permits the use of few sight vanes.

(20.) As already mentioned, the object of measuring a short base he several times instead of a long base once, was to obtain a probable error of the measurement. This probable error is deduced from the differences between the values of the several measurements, and the greater the number of different measurements the

Measured portion of Base sub-divided into four sections. Mode used of recording the terminations of the different measurements.

more reliable is the probable error. So in order to obtain a greater number of independent measures, the base was sub-divided into four sections as follows; at the end of the 35th set a large stone of about five hundred pounds weight was firmly embedded, and to its upper surface a brass plate was attached, of a size sufficient, making due allowance for the deviations that were to be expected in length and direction, to receive the marks of the four measurements. Another brass was similarly fixed at the end of the 70th set, and a third at the end of the 105th. These plates were marked *X. Y. Z.* and the circles and dots denoting the several measurements were numbered 1. 2. 3. 4. The direction of the line was also laid down on each. On the completion of the measurement these brasses were taken off the stones, and the differences between the dots carefully measured.

Microscopes when compared.

(22.) The microscopes were compared with their scales *generally*, before the first measurement, once in the middle of each measurement, once between the measurements, and after the last measurement, that is nine times in all: but several were compared oftener. The collimation error and error of parallelism of the side telescopes were determined before the first and after each succeeding measurement.

Report on the reduction of the Cape Comorin Base-Line.

EXTRACT FROM THE REPORT OF LIEUTENANT J. HERSCHEL, R.E., DEPUTY SUPERINTENDENT, NO. 126, DATED 1ST JULY, 1869.

(1.) During the recess of 1868, the party was quartered at Bangalore; but during the months of July, August, and September, it was absent on special duty connected with the late solar eclipse.

(2.) During the ensuing field season it was employed, in connection with the Madras and Bombay parties, on the Cape Comorin base-line measurement.

(3.) A special report on the subject of the eclipse expedition having been submitted, and by you, printed in last years report, no further recurrence to that subject is needed here, except that, both in its preliminaries and actual event, the legitimate recess work was, to some extent, interfered with and retarded.

(4.) That work was the reduction of the base-line operations of the season 67-68. In carrying out those reductions I was led, by the circumstances of the case, into considerable modifications of existing records on similar subjects, and into a lengthy demi-official correspondence with you on various points arising out of them. Among the principal of these was the investigation of the behaviour of the measuring bars, during the comparisons between them and the standard; from which it became evident that the length of the former was subject to momentary changes, which were beyond the reach of existing means to account and allow for sufficiently.

(5.) The importance of these changes having been discussed and conceded, I was instructed by you to prepare one of the measuring bars for the reception, during the approaching measurement of another base-line, of delicate thermometers, for the purpose of supplying evidence on the surmised cause of the variability known to exist. This was accordingly done; and the facts thereby established, while they present some features of the utmost importance, as bearing on all previously measured base-lines, offer at the same time a range of enquiry and speculation into which I am unable to enter fully at present: this much was ascertained by a course of experimental observations of the temperatures of the bars, taken by myself during October and November last. Subsequent observations, during the measurement of the Cape Comorin base-line, have supplied a mass of data, now in course of reduction, which will, it is hoped, throw considerable light on the perplexing changes which these bars have seemed to undergo.

(6.) My party left Bangalore, in charge of Mr. Geo. Belcham, 2nd grade sub-assistant on the 11th December, escorting the base-line apparatus and stores to the scene of its next employment, near Cape Comorin. I followed myself (in your company) a fortnight later. The ground was reached on the 4th January 1869, and the first comparisons were taken on the 9th.

(7.) From the former date until the completion of the final comparisons after the measurement on the 10th March, the party formed part of the combined forces engaged on the abovementioned work. It is not therefore my province to report specially on that operation, witnessed as it was by yourself, in part, and superintended by my senior, Captain J. P. Basevi, R.E., from beginning to end. Nevertheless as, from the circumstances, I was specially interested in many parts of the work, the reduction of which was eventually entrusted to me, and is now in my hands, I may venture to presume that such remarks as I may now make upon it, will not be out of place, if confined to their proper limits, as bearing on previous discussions and present occupation.

(8.) The base-line, in question, was only one-fourth part of the one originally designed, but it was measured four times over, with the object of arriving at experimental data for an

estimate of practically attainable precision of such like measures. It naturally became a question, of no small import in its consequences, whether these repeated measurements should be *merely* repetitions, or repetitions under changed conditions. The latter alternative was adopted ; and with it the principle that the four operations should, while retaining their individual independence, be yet so arranged as to tend to betray sources of uncertainty in their results.

(9.) So far as the actual lengths of the measuring bars are concerned, it is already abundantly evident that these uncertainties are well worth hunting down. The modified form of reduction of comparisons, adopted last year, by which the actual excess of length of each bar above the normal standard, is obtained on the spot for every comparison, had already put it beyond question that these bars were particularly sensitive to changes of exposure. In illustration of this I may adduce the fact, that on one occasion the mean length fell 28 Micrometer divisions*, while the standard rose 55, and then rose 62, while the standard rose 121 more. The standard is an iron bar ; and the measuring bars were expressly designed to avoid the changes of length to which a simple iron bar is necessarily subject. Without therefore enquiring "what is the actual linear quantity represented by so and so many divisions?" it is here plainly in evidence that *sometimes* the compensated bar is half as sensitive as the simple bar, without any such simple key to the nature, or scale of the degree of that sensitiveness, *except under continual comparison* with a known length, an exception which is unfortunately the rule when these bars are in use.

(10.) Such changes as I have instanced, are not exceptional, although the range in this case *is* greater than usual. The point lies in the possibility of such changes.

(11.) It is clear that similarity of circumstance, which has always been more or less insisted upon or assumed, during comparisons and measurement, is the *only* safeguard against erroneous estimate of length during the latter ; short, of course, of doing what would equally have to be done were simple iron bars employed, viz., recording the temperature of the measuring apparatus.

(12.) I may justly say that recent investigation and discussion, leading to examination and experiment, had put it almost beyond doubt that this safeguard had been inadequately grasped, if it was not altogether out of reach from the first. At the Cape Comorin base a regular record of temperatures was kept (by means of the lately perforated bar *B*) which while on the one hand it almost entirely accounts for the variations in length *during comparisons*, shows equally how sensitive the temperature, and therefore the length, is to changes of weather during measurement ; changes which cannot be guarded against, nor allowed for except in this way.

(13.) I beg leave to avail myself of this opportunity to express my deliberate opinion, that the compensating apparatus does *not* compensate, by increased accuracy or diminished labor, for its greater complexity and instability ; and that, on the contrary, a set of simple bars, of equal (or less) weight, would enlist more confidence, secure greater accuracy, entail less labor on the whole than is now proved to be requisite, and be more handy in the field. I would not be understood to imply that such opinion is a novel one, but I believe that it should come with greater force when based on such facts as may now be adduced, than when it was merely a strong impression based on undefinable experience.

(14.) But the length of the measuring bars is not the only element of uncertainty in the measurement of a base-line. In the present instance (owing to the mass of data available for the purpose of obviating it) this element should be reduced to a minimum ; as I hope, will be shown to be the case in the reductions now in progress. If I am right in this, it follows that outstanding errors will be due to imperfections in other parts of the apparatus. I am sorry I am unable, as yet, to enforce more pointedly by this argument my strong conviction of the comparative uncertainty due to the complex and unstable "compensating microscopes."

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* 1 Micrometer division = $\frac{1}{21758}$ or 46 millionths of an inch.—J. T. W.

(15.) For fear however, that I should unintentionally have maligned the apparatus, and the results which it is capable of giving under a strict and time honoured system of manipulation, it is but just to give the actual discordances between the several re-measurements unreduced in any way. Premising that the total length was 2,972 yards, and assuming the first measurement to have been right,

			Inch.
the	II	Measurement made the distance less by,	0·17
„	III	ditto ditto,	0·22
„	IV	ditto greater by,	0·18

or if we consider the first and second measurements, out and home, as one continuous measurement, and likewise the third and fourth, the total distance being 5,944 yards, in each case the two circuits differed from each other by only 0·13 inch or 1 in 1,650,000.

(16.) As a further check on the measurements, the distance was divided into 4 equal portions, by 3 intermediate brass plates, on which, as each measurement passed, marks were engraved. The plates were afterwards taken up and measured. Assuming as before, that the 1st measurement was errorless, the errors were as follows* :—

Measurement.	1st Quarter.	2nd Quarter.	3rd Quarter.	4th Quarter.
By the II Measurement,	− ·08 inch.	− ·04 inch.	− ·09 inch.	+ ·04 inch.
„ III „	− ·02 „	− ·03 „	− ·07 „	− ·10 „
„ IV „	+ ·09 „	·00	+ ·01 „	+ ·08 „

(16*a*.) Some such palpable evidence of the order of accuracy of our operations, would seem to be desirable when, even to this day, we occasionally are charged with supplying trigonometrical data to Revenue Surveyors, which they can prove by chain and compass to be wrong; and imply that it arises from erroneous linear measures !

(17.) On the completion of the base-line measurement, and while the apparatus was being dismantled and packed, I assisted Captain Branfill in making copies of the standards as follows.

1.—A thin iron band on a wooden frame, intended as a Levelling Staff standard. Six silver plugs were let in, in pairs, three at each end, and 10 feet apart, on which dots were made of different degrees of grossness. Near the edge of this bar, coarse dots visible to the naked eye, representing 10 feet and 10 feet + and − 1, 2 and 3 inches, and 10 feet − 6, 9 and 12 inches were also made.

2.—Three well seasoned teak wood bars, which had been with the Madras party since 62, and were provided with brass plates near the ends, were marked in the same way, by 3 pairs of dots each, marked *E* (east) *W* (west) and *C* (centre). Comparisons were afterwards made, from which it appeared that, under normal conditions, the lengths of these copies would be as follows :—

Bar.	*E.*	*C.*	*W.*
Levelling staff iron guage, ..	*A* − 31 divisions.	*A* − 14 divisions.	*A* − 5 divisions.
Wooden Bar I, ...	− 8 „	− 12 „	− 48 „
„ II, ...	− 8 „	− 42 „	− 20 „
„ III, ...	− 22 „	− 23 „	− 21 „

$$1 \text{ division} = \frac{1}{21{,}758} \text{ inch} = \cdot 000{,}046 \text{ inch.}$$

* *Addendum, dated 6th September* 1869. It should however be stated that this concurrence of unreduced results, is almost certainly fortuitous, as the 6-inch microscopes are known to have been altered in length, both intentionally and accidentally, during the operations, to an extent more than sufficient to alone account for the above differences; while the comparisons of the 10 feet bars had shown that they likewise had altered considerably in mean length, from the effects of changes of temperature.

There is, of course, a good deal of uncertainty in estimating the normal length: in the case of the iron bar, both its actual temperature and its coefficient of expansion are uncertain; and in the case of wooden bars, the laws of expansion are empirical only. In this particular case one of the bars had been under comparison for several days, as an experiment, the result of which was, that the length was found to increase slowly, 30 to 50 divisions between 7 A.M. and 11 A.M. and then to decrease by about the same amount till 3 or 4 P.M., after which it decreased more rapidly.

(18.) Taking into consideration the scantling (3″ by 2″) and the unprotected condition of a plain unvarnished rod, and that the range of an iron bar of the same length, during the same hours, would be 4 times as great, I am inclined to think that a more massive and well protected wooden *beam* would be worth trying, as a support for comparing microscopes. The slow conduction of heat in wood, would make its bulk its own protector from any but the slowest changes, while protection from hygrometric influence might be insured against by a variety of different coatings of paint and varnish. I am the more inclined to hazard suggestions in this direction, from a conviction that permanence of datum is not only the best safeguard against erroneous, or dependent, or relative, coefficients of expansion, but also that it is practically attainable.

(19.) In accordance with your Departmental Order, No. 8 of 1869, dated February 8th, after the completion of the measurement, I transferred the marks defining the ends of the base, from the ground level to the summits of the perforated towers covering them. The importance of the step, which connects linear measure with triangular, is so great, that it is necessary I should place on record, in detail, the means by which it was effected, as the only guarantee of its correctness. It will suffice in this place, however, to say that the apparatus consisted of a first rate plummet, suspended by thin brass wire from an arrangement above, by which both horizontal and vertical motion could be given with precision independently. A rotatory motion as well, communicated to the wire above without affecting its position, enabled me to discover and eliminate whatever excentricity there might be in the point of the plummet, without causing it to spin. The complete *rest* and exactness of height, which can be ensured by the use of wire suspension, makes all the difference between a satisfactory and an unsatisfactory transference by plumbing, when the height is considerable. The plummet having been properly centred, and cross threads fixed above as a precaution, every one was ordered off the top of the tower and a sentry placed at the foot of the stairs: the plummet was unhooked, melted wax was poured over the mark, and the massive black granite covering block was brought in and deposited above it on a bed of mortar. This block was then adjusted in position.

(20.) After some hours, during which it was supposed to have taken a permanent bearing, the wire having been shortened *below*, the plummet was again suspended free of the new surface. A piece of paper gummed upon the latter received a prick from the point of a plummet slowly lowered from above, and the first transfer was complete. The wire, previously provided with a loop above, into which was hooked the *main* length, was now shortened and the plummet hooked on above, the solid stone plug having been first inserted into it's prepared socket in the 'millstone', upon which the theodolite was to be erected. I had some doubts about *fixing* the plug, and eventually contented myself with running dry sand into the narrow interstices and afterwards pouring over it a thin cream of lime and water. The plug *can* therefore be extracted if necessary, and reference made to the black-stone-mark below, without breaking into the vault. The plummet was then made to impress its normal as before. The marks thus made were, in each case, made permanent by carefully punched holes $\frac{1}{4}$ inch deep, the lower one $\frac{1}{10}$ inch, and the upper one rather less, in diameter. Lastly the upper mark was tested by the cross threads, the plummet arrangement having been removed for the purpose of making the hole.

(21.) The whole operation was repeated at the other terminus, and both were then handed over to Lieutenant Rogers for trigonometrical operations.

(27.) In conclusion I regret to have to report that Mr. Belcham's health appears to suffer much from exposure, and that the prospect of obtaining employment in another branch of the public service, may possibly decide him to leave the department. But this need not prevent me from reporting favorably on his conduct and exertions during the few months he has been under my orders.

EXTRACT FROM THE NARRATIVE REPORT OF CAPTAIN B. R. BRANFILL, DEPUTY SUPERINTENDENT, IN CHARGE MADRAS PARTY, DATED 5TH JULY 1869.

(2.) The party took the field on the 21st November, and arrived at Palamcottah on the 5th December, I having previously visited the harbour and light-house of Tuticorin, and decided that the former was suited for the proposed tidal observations, and the latter for use as a principal station of the series, when raised as was proposed, and a tower built at Trichendur.

The party reached the base-line near Cape Comorin on the 10th December, and began the buildings for the ends of the base-line measurement, for which two towers, 20 and 25 feet high respectively, were required.

Materials were obtained with much difficulty and of inferior quality, and apprehensions were entertained, that from the unavoidable speed with which the buildings were run up, their stability might be seriously affected. They were finished however in time, and used without accident.

During the measurement of the base-line, two of my assistants were usually available for carrying on the buildings on the base-line, which included an observatory at Kudankolam, the south station of extension, and a permanent pillar station at Rathapuram, the north station of extension, and centre of the polygon of connection; all these stations the building party completed before they were required. I have made arrangements with the civil authorities for purchasing the ground on which the four buildings, at the ends of the measured base and its extension, stand, half an acre at Parameshwaripuram, and an acre or more at each of the other three stations, Shanganeri T.S., Rathapuram S., and Kudankolam Observatory S.

On the completion of the measurement, and its closing operations, the principal triangulation was commenced at once, and an Azimuth, by *a* Ursæ Minoris, observed at Rathapuram.

The hazy hot weather set in before the end of March, and the observations were continued, with much interruption and difficulty, till 16th April, when the polygon of connection was complete.

During the hazy weather, I took the opportunity of visiting in person the great Mahendragherry mountain, one of Colonel Lambton's principal points, which I was anxious to fix accurately as a secondary point with a view of verifying its identity. I found my signal men had occupied a new and lower point, about $\frac{1}{4}$ mile south of Colonel Lambton's old station, which however, after repeated search, I was so fortunate as to find.

I ascertained the existence of several higher peaks in the neighbourhood, but was unable to observe the angles I wanted, in consequence of the haziness of the weather.

Being anxious, if possible, to complete the triangles adjacent to Trichendur and Tuticorin, I proceeded to Trichendur, but found the season too late to secure the observations. The 35-foot pillar which had been built on the highest ground available, a sand hill N.E. of the temple, surmounted by a stone "Mantapam", which Mr. Mitchell had made use of, was insufficient, at that season, to command a view of the Tuticorin light-house, which had not yet been raised; moreover, it was judged too insecure for use, a part of the "Mantapam" before-mentioned having already given way. I therefore gave up the idea of further observations, and marched on the 24th April towards Palamcottah, where I was joined on the 28th by Lieutenant Rogers, and on the 1st May we commenced our march northwards.

I sent Mr. Potter to Trichendur, to re-build the Trichendur pillar station and properly secure it, and made arrangements with the Superintending Engineer of the division that he should acquaint me with the progress made in raising the Tuticorin light-house, and provide means for our using it as a station of observation.

The party returned to Bangalore by the middle of May, and commenced the recess duties at once, interrupted, I regret to say, by every member of the party being laid up repeatedly by illness.

I am glad to have a favorable account to give of the labors of my assistants.

Mr. J. W. Mitchell, 2nd class Sub-Assistant, selected six, and built ten principal stations, besides taking a share in the Base-line measurement for a month: considering that he had to supervise the building of so many stations, as well as the duties of the Approximate Series to attend to, his out-turn of work seems creditable, the more so, as he was much hindered by illness.

Mr. O. V. Norris, 3rd class Sub-Assistant, was employed during the entire season in preparing the base-line and its buildings. He built the Shanganeri tower, the observatory at Kudankolam and an arched brick roof to the Punnæ observatory.

Mr. Norris's work is creditable to him, and shows that his education at the Civil Engineering College, Madras (of which he is a B.C.E.) was not thrown away.

Mr. C. D. Potter, 3rd class Sub-Assistant, was also engaged on the base-line preparations and buildings.

Mr. Potter accompanied me as observatory recorder and office assistant, and proved himself a promising member of the department.

EXTRACT FROM THE NARRATIVE REPORT OF LIEUTENANT M. W. ROGERS, R.E., ASSISTANT SUPERINTENDENT, IN CHARGE BOMBAY PARTY, NO. $\frac{74}{S}$, DATED JULY, 1869.

I arrived in Bangalore, on the 15th November 1868, and took over charge of the party from Lieutenant Campbell, R.E., who was about to proceed to Europe on furlough.

There being a considerable amount of work to be done at the Cape Comorin Base-line, previous to the measurement, I thought it advisable to take the field as soon as I had received charge, and therefore on the 23rd November, I despatched the party, under the charge of Mr. Anding, by rail to Trichinopoly, with orders to march from thence to Palamcottah, where I proposed to join them; Mr. Christie accompanied the party. At the request of Lieutenant Herschel, R.E., Mr. Bond was temporarily attached to his party, to aid in the computations and the conveyance of the base-line apparatus to Cape Comorin.

I remained at Bangalore until the 27th, being employed in helping Lieutenant Campbell to complete the computations of the minor Triangulation of the Bangalore Base-line.

I then proceeded to Beypore and thence by steamer to Tuticorin, and joined the party on their arrival at Palamcottah. I had beforehand arranged with Captain Branfill to divide the work, which remained to be done on the Base-line previous to the measurement. The part assigned to the Bombay party, was the observations necessary for the alignment of the Base, and the building and partial selection of the stations of the extension triangulation.

In the previous season, Captain Branfill had placed marks at the stations of Kudankolam and Rathapuram, the ends of the 7 mile Base, and also approximate marks at the section stations of Paramespuram and Shanganeri, and one at the centre of the Base. I observed with the great Theodolite, at the centre and two end stations, the angles necessary for correcting the approximate alignment.

Mr. Anding had charge of the eastern flank, and Mr. Christie of the western. After completing the alignment observations, I employed myself and the rest of the party in aiding in the selection of stations and ray-clearing: the whole, with the exception of one station on the western flank, was completed before the commencement of the Base-line.

When the measurement commenced, the party was placed at the disposal of Captain Basevi, R.E., and remained so during the measurement.

During this time you inspected the instrument of the party (Barrow's 24-inch Theodolite No. 2) and were led by the discrepancies shown in the observed azimuths at the Bangalore Base-line, to suspect that there was something wrong with the relieving apparatus, you therefore decided on dispensing with this apparatus and altered the instrument.

On the completion of the measurement, I deputed Mr. Anding to fix, by traversing from the extension triangulation stations, the position of all villages and permanent well-defined Revenue Survey marks, within, and immediately exterior to the triangulation.

Mr. Christie, after completing the remaining station on the western flank of the triangulation, was detached from the party and proceeded to Dehra Doon in charge of the Base-Line apparatus.

Taking with me Mr. Bond as Recorder, I proceeded to execute the extension triangulation of the Base-line. I commenced at Kudankolam, where in accordance with your instructions, I observed an azimuth with a view to testing the performance of the instrument in its altered condition.

I commenced observations on the 14th March, and finished on the 28th April, having observed at 11 stations.

The 21 triangles observed, give a mean triangular error of 0″·64 : the maximum weight reciprocal of the 45 angles is 0·25, the minimum 0·03, the mean 0·10.

In addition to the extension triangulation, I connected Colonel Lambton's latitude station of Punnæ with the modern triangulation, by a triangle with three angles observed.

A brick observatory has been built at this station for Pendulum observations, this includes the old observatory (which had been 10 feet square outside) and also a new portion, in which the pendulums were swung.

Mr. Anding, as before mentioned, was deputed to select and build the stations on the east flank of the extension triangulation. This work he completed in good time before the commencement of the Base-line, and the three stations under his charge were judiciously chosen. After the Base-line had been measured, he was employed in making a map of the country around the Base-line. This map has not yet been completed, but as far as can be judged from the field books and rough plots of the traverse, the work has been done creditably.

After I had finished the triangulation, Mr. Anding was employed in closing and handing over the stations on and around the Base-line.

He has given me general satisfaction since he came under my orders, and has worked hard and willingly.

Mr. Christie selected and built three stations on the west flank of the triangulation.

During the short period Mr. Christie was with me, I always found him willing and hard-working.

Mr. Bond accompanied me as recorder during my observations, he is an accurate computer, and a good recorder. He is quick at learning, and anxious to acquire knowledge of the departmental work by all the means in his power : I have had every reason to be satisfied with him.

The party left the Base-line on the 29th April, and marched to Trichinopoly, and thence by rail to Bangalore where they arrived on the 15th May.

On the 1st June, I handed over charge of the party to Lieutenant Trotter, R.E., who had returned from sick leave in England.

EXTRACT FROM THE NARRATIVE REPORT OF LIEUTENANT W. J. HEAVISIDE, R.E., IN CHARGE NO. 2 ASTRONOMICAL PARTY, DATED 5TH AUGUST, 1869.

(3.) The party left Ajmere on the 20th of October, and reached Jetgarh H.S., the first station for observations, on the 1st of November. A Collimator pillar had been built at Jetgarh by Mr. Wood during the previous field season, but some alterations had to be made before the new observatory tent could be put up, and I did not commence observing until the 7th of November. Observations were completed at Jetgarh on the 21st of November, and at Khamor H.S., on the 19th of December. The party then marched down to Neemuch, near which place is situated Arumlia H.S., the third station I had selected for observing at.

(4.) Having deposited most of the instruments and Camp equipage in Neemuch, Mr. Wood and I left that place on the 2nd of January to select two stations suitable for latitude observations, between Arumlia and the Nerbudda river. Mr. Wood went down the western side of the Khanpisura Series as far as Indrawan S., and I, down the eastern side to Singarchori H.S., which overlooks the Nerbudda valley, and is close to the Southern edge of the table-land of Central India. Returning northwards I met Mr. Wood near Arnasa S. on the 25th of January, and we marched together back to Arumlia, and reached that station on the 2nd of February. The result of this exploration was the selection of Deo Dongri H.S. and Arnasa S. as suitable for observing at.

(5.) I commenced observing at Arumlia on the 8th of February, and finished on the 20th; I then marched to Deo Dongri and completed a set of observations there on the 24th of March.

(6.) For reasons which I stated in my progress report for January, I considered that it was unadvisable to take a set of observations at Arnasa S. during the field season of 1868-69, and that I should better employ the portion that remained in proceeding further south, and selecting some more stations for next season's work. In marching, however, from Deo Dongri into Mhow, where the party was to recess, I passed close to Arnasa, so I put up the Instrument, and observed 6 pairs of stars on two nights, to find out whether Arnasa was as free from local attraction as I thought it. An abstract of the results thus obtained is attached to this report, and the final results are tabulated in para 9 with the results obtained at the stations where full sets of observations were taken.

(7.) The party reached Mhow on the 5th of April. I then dismissed a portion of the native establishment, and engaged a house where I could stow away the instruments and camp equipage, and which would also do for an office during the recess. I left Mhow on the 12th of of April and marched south, across the Nerbudda and Taptee rivers as far as Sirsala H.S., latitude 20° 30′. Returning by Dhoolia, I arrived again in Mhow on the 31st of May.

(8.) During the time I was away from Mhow, Mr. Wood was employed in protecting the Survey stations on both sides of the Nerbudda, and transferring them to the native officials.

(9.) Full sets of star observations have been taken this season at four stations; the results are shewn in the table below.

Names of Stations.	Series.	No. of pairs of stars observed.	No. of zeros.	$N - S$	Probable error.	$\lambda_o - \lambda_c$	Remarks.
Jetgarh H.S.	Gurhagarh, ...	35	1	$-0''{\cdot}13$	$\pm 0''{\cdot}053$	$+ 1''{\cdot}47 \pm 0''{\cdot}05$	λ_o indicates the observed latitude of a station.
Khamor H.S.	Do., ...	37	1	$-0''{\cdot}54$	$\pm 0''{\cdot}044$	$- 4''{\cdot}21 \pm 0''{\cdot}04$	
Arumlia H.S.	Do., ...	35	1	$-0''{\cdot}32$	$\pm 0''{\cdot}046$	$- 4''{\cdot}60 \pm 0''{\cdot}05$	λ_c, the value obtained by calculation through the triangulation from Kalianpur station of the Great Arc.
Deo Dongri H.S.	Khanpisura, ...	36	1	$-0''{\cdot}23$	$\pm 0''{\cdot}051$	$- 4''{\cdot}63 \pm 0''{\cdot}05$	
	Mean $N - S$ at 4 stations, ...			$-0''{\cdot}31$			
Arnasa S.	Khanpisura, ...	6	1	$-0''{\cdot}03$	$\pm 0''{\cdot}098$	$- 3''{\cdot}36 \pm 0''{\cdot}10$	

(13.) Mr. J. Wood, Sub-Assistant 1st Grade, was employed during the chief portion of the field season in recording my observations. He protected and transferred three stations, and sent in descriptions of 10 stations. He likewise erected collimator pillars, built up the platforms at five stations, and made a survey of the hill on which Deo Dongri station stands. Mr. Wood continues to work with industry, and to execute all he does in a creditable manner.

(15.) Owing to the small quantity of rain that fell in Rajpootana last year, I had expected, in commencing the field season, to encounter considerable difficulty in carrying on my work. The whole country was as dry in October, as it generally is in April : a large portion of the population had migrated, leaving only sufficient people in the villages to cultivate such fields as could be irrigated from wells, and in some places supplies were difficult to procure. I was enabled however, to send the camels I had with me into Ajmere for flour, and though occasionally done by the bunneahs, I managed to keep things going, and had worked my way out of Rajpootana before the country people began to suffer seriously from want of food. Between Neemuch and the Satpura range of hills, which separates the Nerbudda and Taptee valleys, there had been a fair quantity of rain during the monsoon; and in this favored tract, but more especially in western Malwa, were collected a great number of people who had migrated temporarily from the north, the east and the west. Outside nearly every village, there was an encampment of these unfortunate people, a handmill and a few bullocks and buffaloes being apparently their sole property. Some of them were employed on the road which is being made between Mhow and Neemuch, but many preferred out of the way spots in the jungles, where there was better grazing for the cattle, with a chance of an occasional job in the villages. Notwithstanding the straits to which these people must have been reduced, they did not beg, and report spoke of them as living most peaceably, fully exemplifying the patient equanimity with which natives bear hardship and suffering.

EXTRACT FROM THE NARRATIVE REPORT OF C. LANE, ESQ., IN CHARGE LEVELING PARTY, NO. 354, DATED 25TH AUGUST, 1869.

(2.) The party marched from Dehra on the 10th October 1868, *vid* Meerut, Moradabad, and Bareilly, arriving on the 10th November at Fatehganj, where the terminal G. T. S. Bench Mark of the preceding season had been embedded. After testing the permanence of this B.M. by connection with the two nearest mile-stones, the levelling operations were resumed by myself and Mr. Civil Assistant A. W. Donnelly, assisted by Native Surveyors. The work proceeded through the Stations of Shajehanpore, Seetapore, and Lucknow to Cawnpore, connecting the G. T. S. Bench-mark at the latter station; then returning to Lucknow, proceeded from thence to Fyzabad, and en route to Goruckpore, up to the 6th mile post from Bustee at Jagesar encamping ground. As each Meridional Series, Amua, Karara and Gurwani, was being crossed, branch lines were carried to connect three principal stations of each. Levelling across country is always slower work than along a trunk road, and with the single exception of Orajar Pillar Station, situated on a hillock, the upper markstones of all the stations were missing. The sides of Orajar hillock, within a short distance of the station pillar, are occupied by Gosains, whose presence no doubt has contributed to the safety and preservation of the markstone for these many years. Of each of the other stations the tower and buttress and, where such existed, the masonry pillar, had to be excavated to get at the ground level markstone, for connection. This always involved some delay, having to be done very carefully in the form of an arch, so that none of the superincumbent mass might fall in and crush or injure the men employed in the excavation. After connection, each excavation was duly restored to the original condition.

(4.) It was noticed that strong wind right against the front or rear of the line of levelling, tilted the telescope to the extent of 0·9 of a division of the level; to prevent errors from this cause, the indications of the bubble were narrowly watched for changes, by reading them both immediately before and after each reading of the staff. The axes of these standard levels Nos. 2 and 3 by Troughton and Simms, appear to be rather too slender for such length and weight of telescope as they have to bear.

(10.) I have pleasure in stating that Mr. Donnelly endeavoured to give satisfaction in the performance of his duties : he never succumbed to heat under a broiling sun, and zealously attended when called upon to do any work.

(11.) Native Surveyors, Amjad Ali and Nursing Doss, gave general satisfaction.

(13.) The party experienced incessant annoyance this season from thieves, throughout the districts of Shajehanpore, Seetapore, Lucknow and Fyzabad. Stones or bricks were frequently hurled at night among the tents and many attempts at robbery were made, but only in a single instance with any success.

(14.) The field work was closed on the 7th May 1869 on a G. T. S. Bench-mark, on the N. edge of the trunk road from Fyzabad to Bustee and Goruckpore, near the S.E. boundary pillar of Jagesar encamping ground, at the 6th mile post from Bustee. Between the above B.M. and the paka well of the said encamping ground, another G. T. S. B.M. has been embeded, as a temporary arrangement, simply with the view of having two durable points as tests of the permanency of the first mentioned or line B.M. for resumption of the operations next season.

(16.) The following is a summary of work performed :—

352 miles 60 chains of double levelling, embracing determination of
316 Paka points,
54 Revenue Survey trijunction platforms,
3 Ditto ditto Bench-marks,
5 Oude Irrigation Department Bench-marks,
4 Oude and Rohilkund Railway Bench-marks,
4 City drainage Bench-marks, viz., one at Lucknow and three at Fyzabad,

9 Tower stations, viz., three of each of the Amua, Karara and Gurwani Meridional Series,

12 G. T. S. Bench-marks embedded viz., at Pagha, Jalalpur, Attaria, Baksi-ka-Talao, Lucknow near the Ice House Nawabganj, Bara Banki Nawabganj, Sanehi-ghat Fyzabad Post Office, Barbar Khurd, (lesser or small) Amba and Jagesar exclusive of the 2nd B.M. temporarily embedded at the last place,

13 Pillars constructed, including one at Cawnpore, to indicate sites of G.T.S. Bench-marks.

I also crossed the River Ganges and Ghogra and Kaliani Nadi, besides the Goomti and other streams with bridges.

EXTRACT FROM THE NARRATIVE REPORT OF CAPTAIN J. P. BASEVI. R.E., IN CHARGE PENDULUM PARTY, NO. 22, DATED AUGUST 1869.

(2.) I had intended to begin Pendulum Observations at the S.W. End Bangalore Base on the 1st of September, but was prevented by heavy rains from leaving the station until the 16th, and could not commence actual work before the 21st September. There was a great deal of rain during the remainder of September and the early part of October, but I was generally able to get transits at night, and I finished off Pendulum Observations at both ends of the Bangalore Base without any further delay by the end of October.

Pendulum Observations commenced at S.W. End Bangalore Base on the 21st September 1868.

Completed at N.E. End by end of October.

(3.) I then, after a short halt in Bangalore, proceeded by rail to Erode and thence marched to Pachapolliam, where observations were commenced on the 16th November and completed on the 28th. This observatory was built close to the site of Colonel Lambton's latitude station; the mark-stones, both upper and lower, had been removed, but the villagers pointed out the place, and Mr. Macdougall also found the remains of the masonry pillar, so that there is no question about the identity of the station. He raised the pier for the Transit Instrument as nearly as possible over the centre of the old pillar but put down no mark-stone.

Pachapolliam.—Colonel Lambton's mark-stones not found but station identified by remains of pillar.

On completing observations I gave the station in charge to the District Authorities in order that it may be protected until it can be connected with the principal triangulation. Mr. Macdougall also identified the two ends of Colonel Lambton's Pachapolliam Base, erected pillars over them, and transferred them to the Civil Authorities. Pachapolliam is well suited for Pendulum and latitude observations; it is on high undulating ground and there are no hills in the immediate neighbourhood.

Transferred to Civil Authorities.

Ends of Colonel Lambton's Pachapolliam Base found and transferred to Civil Authorities.

(4.) From Pachapolliam I marched *vid* Madura to Mallapatti. Colonel Lambton's principal station of Kooteapanrae is close by, but as the Pendulum Observatory could not have been built at the station without very great expense, I authorized Mr. Macdougall to build at a short distance from it to the east, and named the station after the village on the lands of which it was situated. Kooteapanrae station is on a low rockey hill about 50 feet above the level of the country; the rock has been quarried away by the villages on all sides leaving barely room even for a small theodolite; should it be requisite to retain it as a principal station of the revision triangulation, a good deal of building up would be unavoidable. This station is very suitable for latitude observations, and there is ample room on the hill for an observatory at a short distance to the east. To avoid calculations of attraction I preferred placing the Pendulum Observatory below the hill and at such a distance that its disturbing effect could be safely neglected.

Mallapatti.—Observatory not built on the Kooteapanrae hill on account of expense.

Description of Kooteapanrae.

Suitable for latitude observations.

(5.) Observations at Mallapatti were completed on the 26th December, when I marched at once for Palamcottah in order to assist in the measurement of the Cape Comorin Base.

Mallapatti.—Observations finished. Joined Cape Comorin Base measurement.

(6.) Having no second assistant all this time, and Mr. Macdougall being employed in building, my wife, as last year, recorded for me at the above four stations.

(7.) The measurement of the base was completed by the 14th March, when I resumed Pendulum Observations, taking them first at Punnæ and afterwards at Kudankolam, the southern extremity of the extended base-line. These observations were completed on the 13th April, when directing the party in charge of Mr. Macdougall to proceed to Coimbatore, by the regular marches, I myself travelled up the western coast *vid* Travandrum, Quilon, Alleppey, and Cochin. I wished to select the most suitable station for Pendulum Observations next season, and to make inquiries as to the best means of getting to the Island of Minicoy. This Island is isolated and situated nearly in the same latitude as Punnæ, so that a comparison between the Pendulum results at these two places, would afford some data on the relative densities of the submarine and subterrane strata.

Pendulum Observations resumed at Punnæ on 15th March, and completed at Kudankolam on 13th April.

I return to quarters by western coast to select Pendulum Station and to enquire about Minicoy.

(10.) The out-turn of the past season's work consists of pendulum and magnetic observations at six stations, viz. : —

Out-turn of work.

Bangalore Base, N.E. end.
Ditto, S.W. end.
Pachapolliam.
Mallapatti.
Kudankolam.
Punnæ.

The party was also employed for two months on the Cape Comorin Base.

(11.) I have now to report on my assistants. Mr. J. W. Macdougall, 3rd Grade Sub-Assistant went out into camp on the 29th August, and built the observatories of Pachapolliam, Mallapatti and Punnæ. He assisted in the Base-line measurement, being in charge of laying the trestles during the third time of measurement, and taking a microscope during the fourth time. I was well satisfied with his building arrangements, and his observatories were on the whole very economically built. He is very energetic, always does his best, and I should be very glad if your arrangements admitted of his early promotion to a higher grade.

Mr. Macdougall.

(12.) Mr. C. P. Torrens, 4th Grade Sub-Assistant, was posted to this party on appointment to the Survey on 12th December 1868, and joined on the 17th January 1869. He acquired a familiarity with all the computations very quickly and promises well.

Mr. Torrens.

(13.) The results of the past season's work are given in the several tables appended to this report. The mean probable error of a star's transit over one wire, is $\pm 0^{s}060$ which affects the vibrations in a day by only $\pm 0{\cdot}015$.

Results and probable errors.

The mean probable error of the observation of a coincidence, is $\pm 0^{s}323$ and its affect on the vibrations per diem $= \pm 0{\cdot}006$.

The mean probable error of the number of vibrations per diem, at any station obtained from the results, is $\pm 0{\cdot}034$ for No. 4 Pendulum and $\pm 0{\cdot}036$ for No. 1821.

(14.) At Punnæ I swung each Pendulum for nearly the whole day in the following way. The Pendulum was started at about 5-30 P.M., giving it a large initial arc, (double arc $= 2\frac{1}{2}^{\circ}$) and observed; an observation was taken at about 9 o'clock, and again at 1-30 A.M. The next morning at about 7 o'clock three coincidences were observed and observations were taken as usual up to $4\frac{1}{2}$ P.M. The swing could thus be divided into a night and a day portion, during the former the temperature was continuously falling and during the latter continuously rising; the difference between the two results denoted that due to the sum of the errors of the mean temperatures, and half that sum would represent the amount of "lagging." Including the two

Determination of the amount of "lagging" at Punnæ.

observations taken last year at Damargida for the same purpose, the amount of "lagging" is as follows :

No. 4 Pendulum, ... 0·177 Vibrations = 0·37 Fahrenheit.
„ 1821 Do. .. .. 0·138 „ = 0·30 do.

consequently the results at each of the Indian stations should be *diminished* by the sum of these quantities *i. e.* 0·315 vibrations to make them comparable with the Kew results, where the observations I believe were all taken during the night. Also the results at each of the Indian stations should be diminished by half of 0·315 *i. e.* 0·158 vibrations to make them represent the true mean number of vibrations per diem at 72° Fahrenheit.

Endeavour to use clock pendulum as a third pendulum fails.

(15.) During this season I kept the clock pendulum adjusted in one position in the hope that it might be used differentially as a third pendulum, but the results by it are too wild to admit of any reliance being placed on it. I thought that this might be owing to the variations of the pressure and temperature of the air. Mr. F. Baily had swung a somewhat similar pendulum in air and vacuo and determined its correction to be about 0·48 vibrations per diem per inch of pressure, but the application of corrections to the clock rates based on this factor did not improve the results in any way.

Magnetic Results.—Dr. Lamont's method of observing Dip found convenient in low latitudes.

(16.) Table IV gives the magnetic results of the past seasons. It will be observed that the magnetic Equator cuts India in latitude 9° 30′ very nearly. Finding the operation of setting the Dip circle in the meridian very tedious in these low latitudes, as the slightest motion of the horizontal limb caused the needle to vibrate in large arcs, I tried at Kudankolam the method of observing the Dip of the needle in *any* four positions 90° apart, changing the face of, and reversing the poles of the needle as usual This method involves double the number of observations and some computation, but on the whole saves time and temper, and is, I think, more convenient in low magnetic latitudes than the ordinary one. It is given by Dr. Lamont in his hand-book of magnetism. The formula for computing the true Dip is

$$\text{Cot.}^2 i = \frac{2}{n} \times \text{sum of (cotangents)}^2 \text{ of observed dips where } n = \text{number of divisions}$$

of the circumference, which must be *even*.

EXTRACT FROM THE NARRATIVE REPORT OF J. B. N. HENNESSEY, ESQ., IN CHARGE COMPUTING OFFICE, DATED 1ST MAY 1869.

(4.) *Calculating branch.*—The Computers have been engaged chiefly on calculations connected with the reduction of the triangulation understood by the N.W. (or Sironj-Chach) Quadrilateral. The process of working this geodesical problem having been established theoretically, it became highly desirable to illustrate the practical application of the method on a comparatively limited extent of triangulation, before undertaking the entire quadrilateral. Accordingly the two circuits made up of the Jogi Tila Series and of portions of the Gurhagarh, N.W. Himalaya, Sutlej and Indus Series, were selected, and in order that this experimental calculation should the more fully illustrate the reduction of the entire triangulation, base-lines were assumed to exist at three of the four corners of the outer circuit where none were measured, so that these three imaginary base-lines, together with that measured on the plain of Chach, furnished a line of verification at each angle of the outer circuit, as is the case in the Quadrilateral Sironj-Chach.

Progress.

(5.) The calculation then before us was to find simultaneously 380 unknown quantities, subject to 11 equations of condition, by the "method of least squares." I pass over with but a brief notice the difficulties encountered and overcome in course of computation; such as the devising of checks, the preparation of forms which would reduce labour to a minimum and promote the maximum of accuracy, and the degree of arithmetical rigour to be maintained. The unavoidable magnitude of the calculations and their requirements, create so many new features in the ordinary application of the "method of least squares," that the process thus altered can hardly be recognised as the one in familiar departmental use. Premising this, I state the resulting facts as follows :—*

		ASSIGNED VALUE.	VALUE BY COMPUTATION.
Side.	e_1	+ 3·1631	+ 3·16329
	e_2	+ 4·2365	+ 4·23653
	e_3	− 9·2661	− 9·26664
	e_4	+ 9·7506	+ 9·75073
	e_5	+ 4·0038	+ 4·00380

		ASSIGNED VALUE.	VALUE BY COMPUTATION
λ_1	e_6	+ 0·037	+ 0·03695
L_1	e_7	− 0·286	− 0·28604
θ_1	e_8	− 4·236	− 4·23665
λ_2	e_9	− 0·004	− 0·00388
L_2	e_{10}	− 0·289	− 0·28899
θ_2	e_{11}	− 3·007	− 3·00725

(6.) The corrections were next applied to the angles; and, on completing the ordinary computations of triangles, latitudes, longitudes and azimuths, it was found that the triangulation had been made consistent with the following small residual discordancies.

In the 5 side equations.	*In the 2 Lat. Circuits.*	*In the 2 Long. circuits.*	*In the 2 Azth. circuits.*
Log feet.	"	"	"
(1) . . . . 0·000,0001,5	(6) . . . . . 0·001	(8) 7. . . . . 0·005	(10) . . . . 0·003
(2) . . . . 0·000,0000,9	(9) . . . . . 0·004	(9) 10. . . . 0·002	(11) . . . . 0·004
(3) . . . . 0·000,0000,2			
(4) . . . . 0·000,0000,7			
(5) . . . . 0·000,0000,9			

The largest angular change introduced to enforce this consistency amounted to only 0″·38. The average angular change employed is probably under 0″·15.

* e_1 . . . . . e_{11} are the absolute terms in the equations of condition, of which there were 5 between sides, 2 in Latitude (λ), 2 in Longitude (L) and 2 in Azimuth (θ).

(7.) The portions of ordinary work that can be tabulated readily are given hereafter:—

Subject.	Quantity.
Numbered pages of and indexed, ...	69 volumes of angle books.
Mean readings, computed, ...	75 openings do.
Do. examined or compared, ...	385 do. do.
Angles examined or compared, ...	385 do. do.
Abstracted observed angles, ...	330 angles.
Computed spherical excesses, ...	10 triangles.
Copied principal triangles, ...	403 do.
Compared Ditto, ...	1286 do. (in duplicate.)
Computed Ditto, ...	596 do. do.
Do. Log sines and log sides of principal Δ s, ..	80 do. do.
Do. Secondary triangles, ...	41 do. do.
Do. Latitudes longitudes azimuths of principal stations, ...	595 single deductions, do.
Do. Latitudes longitudes azimuths of secondary stations, ...	13 do. do.
Do. Weights of observed angles, ...	41 angles, do.
Do. Corrections to figures by the "method of least squares,"	6 quadrilaterals, 11 simple polygons, 5 compound figures, do.
Do. Indeterminate factors in terms of errors, ..	3 compound figures, do.
Do. Weight of side of continuation, ...	3 polygons, 1 compound figure, do.
Do. Nat. cotangents (to 4 places of decimals), ..	475 angles, do.
Do. do. (to 5 places of decimals), ..	2750 angles, do.
Compared proofs of	364 pages,
Transferred stations to care of district officers, ...	436 stations in 46 districts.
Supplied data called for by, ...	22 officers; (involving about 50 pages of numerals.)

(8.) *Miscellaneous work.*—A list was prepared shewing the latitude and longitude of points in the principal towns of the Bombay Presidency. A synopsis of common sides in the N.W. Quadrilateral was drawn up for guidance in finishing the triangles: a table of weights of corrected angles for the quadrilateral computed, and various calculations preliminary to this table performed. A somewhat similar table and calculations were partially made for the quadrilateral Sironj—Sonakhoda: the triangles and figures of the latter quadrilateral reduced and prepared for circuit tests: preliminary calculations made in connection with the weights of base-lines: charts to aid in the calculations arranged and examined, and various calculations for weights of functions of angles performed. Tabular data were prepared for the point Divy Chart. Certain questions, raised in connection with some of the points in the leveling operations of 1866-67, were examined. Lieutenant McCullagh was passed through the ordinary calculations of the Department: three candidates for Sub-Assistantships examined, and papers for 2 others prepared. The entire field records of the Survey, at Head Quarters have been arranged in suitable cases constructed for their reception. An observatory has been built, but not as yet quite finished, at the head quarter's office, including a transit room and a rotating dome connected by a covered passage and stair-case. The Superintending of the work-men, collecting materials &c., &c., in the construction of this building are due to Mr. R. Scott of the Superintendent's corresponding office. Meteorological observations at Dehra throughout the twelvemonth and at Mussooric for a portion of the year have been taken twice a day, and the former communicated monthly to the Reporter on Meteorology N.W. Provinces. Time has been observed and computed about once a fortnight and shown daily for local use. Advantage was taken of Mr. Chamarett's services to make a Survey of the new cantonment for the 2nd Goorkhas on a scale of 400 feet to one inch; about the same time 2 Native Surveyors of the Kumaon and Gurhwal party were partially trained in the use of the plane-table. Additions have been made to the library from time to time of such works of reference as appeared desirable, and I would here acknowledge with thanks, the kindness of the Presidents and Councils of the Royal, the Royal

Astronomical and the Royal Geographical Societies of London, in presenting the library with copies of their proceedings as soon as they are now published.— &c.

(9.) *Magnetic observations.*—These obervations have been continued 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.

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

Maps Photo-zincographed.	No. of parts.	No. of copies.
Kashmir Survey, section 7, ...	1	100
„ „ 8, ...	1	100
„ „ 9, ...	1	100
„ „ 10, ...	1	100
„ „ 14, ...	1	100
„ „ 15, ...	1	106
„ „ 15, ...	1	100
„ „ 16, ...	1	100
„ „ 18, ...	1	100
„ „ 19, ...	1	106
„ „ 20, ...	1	106
Index to above, ...	1	105
Turkestan, sheet No. 1, ...	1	175
„ „ „ 2, ...	1	24
„ „ „ 3, ...	1	397
„ „ „ 4, ...	1	444
Kumaon and Gurhwal No. 1 skeleton, ...	1	50
„ „ 7 „	1	50
„ „ 8 shaded, ...	1	100
„ „ 13 „	1	100
„ „ 15 „	1	106
„ „ 16 skeleton, ...	1	100
„ „ 16 shaded, ...	1	100
„ Degree sheet No. 1, ...	1	105
Mussooric and Landour, No. 7 shaded, ...	1	45
„ „ 9 „	1	100
„ „ 9 skeleton, ...	1	100
„ „ 14 shaded, ...	1	100
„ „ 1 skeleton, ...	1	256
Upper basins Indus and Sutlej, ...	1	260
New Cantonment Dehra, ...	2	30
Kattywar No. 6	1	103
„ „ 7	1	103
„ „ 8	1	103
„ „ 9	1	103
„ „ 15	1	11
Total, ..	37	4,288

Charts Zincographed.	No. of parts.	No. of copies.
North Eeast Quadrilateral, ...	1	50
Gurhagarh Meridional Series 1861-62, 1st part, ...	1	50
Do. do. 3rd part, ...	1	50
North West Quadrilateral 1st part, ...	1	50
Do. 2nd part, ...	1	10
Khagan and Peshawar, ...	1	50
Skeleton of Kattywar Topographical Survey, ...	1	250
Eastern Frontier Series 1867-68, ...	1	50
Rahun Meridional Series 1860-61, ...	2	50
Do. 1861-62, ...	1	50
Do. 1862-63, ...	1	50
Total, ..	12	710

The books of the office shew a *despatch* of 3,952 maps and 378 charts. Besides the printing of maps and charts, 10,800 forms and 540 diagrams have been struck off in compliance with indents.

(11.) The following table shews the total work executed in the past 3 years.—

Subjects.	1866-67 No. of prints.	1867-68 No of prints.	1868-69 No. of prints.
Maps, charts and diagrams, ...	7,118	7,376	5,538
Forms, ...	5,152	10,531	10,800

The number of maps, charts and diagrams struck off by the presses was less in the past year than in the two preceding, because in the two preceding years the maps required were mostly of small dimensions with little detail in them, the printing of which could be executed rapidly; whereas during the past year, the maps have almost without exception been departmental, the majority of the full size of the zinc plates, and all requiring great care and caution from the printer.

(12.) *Printing branch.*—This office composed 697 pages (foolscap size) and printed 155,025 impressions of them. Compared with the work of 1867-68, there were 56 pages more composed and 28,729 pages more printed.

Conclusion.

(13.) In conclusion, I take this opportunity to acknowledge the cordial co-operation and valuable aid rendered to me by Mr. W. H. Cole, M. A. In addition to his theoretical attainments, this gentleman is acquiring the skill by which delicate Instruments are successfully manipulated, and these qualifications combined with his patience, will, I fully expect, enable him to prove a highly useful member of the department.

(14.) I would also offer my best thanks to Mr. Wood, and Baboo Gunga Pershad for their hearty and skilful assistance in the various duties professional and miscellaneous which I have occasion to require them to discharge. I am glad to be able to speak in terms of commendation of Baboos Kally Mohun, Gopal Chunder, Tarapodo and Kally Coomar, nor have I any reasons to be otherwise than pleased with the rest of the Computers.

(15.) In the Photozincographic branch, Mr. Ollenbach continues to practise transferring to zinc with skill and neatness. Mr. Dyson is very useful in taking negatives and in general is a very willing lad.

(16.) Mr. O'Connor the printer deserves commendation at my hands, and I am glad to say that he conducts his duties with efficiency and earnestness.

P. S.—The following appear sufficiently interesting to be noticed in this report, though performed subsequent to 1st May 1869.

Postscript.

(1.)—*Dehra and Mussoorie observatories.*—Observations to fix these observatories were taken by Mr. W. H. Cole, M.A. with a 14 inch Theodolite by Troughton and Simms. Mr. Cole, visited five stations in course of the necessary operations and observed 12 angles. His average triangular error amounts to 2·9 seconds. This triangulation has furnished us with the much desired values of Latitude, Longitude and Azimuth at each of the two observatories.

(2.) *Expansion of Standard Bar A.*—The factor in departmental use for this bar is the value determined by Colonel Everest, Captain R. Wilcox and Mr. James Prinsep, in 1832. The procedure they adopted, when compared with the improved methods of modern times, is open to grave objections. In addition, the factor appears to be unduly large, since the average factor, deduced for eight base-lines, amounts to only ·0000064 while Everest's factor is ·000006801. As a preliminary method of determination, you decided on comparing standard *A* with the standard steel bar I_s at the highest and lowest temperatures of the day, selecting a time of the year when the daily range of temperature was the greatest. As the factor for I_s stands determined by Captain A. R. Clarke, R. E. of the Ordnance Survey, that for *A* would thus be obtained differentially. Accordingly 61 comparisons were made at Dehra between I_s and *A* during a portion of last May. The results are as follows:—

May 1869.		°	°		
18th	Range of temperature	77·33	to 99·39	factor for *A*	·000006546
19th	Ditto	77·10	to 98·89		6525
20th	Ditto	79·86	to 99·02		6525
21st	Ditto	82·37	to 99·20		6516
				Mean factor for *A*	·000006528
				Everest's factor,	·000006801
				Difference,	·000000273

This difference of factor would produce an alteration in the length of a base-line about 7 miles long, measured at a temperature differing from 62° by 10°, of 1·2 inches.

(3) *Comparison of inch (7—8) on Cary's brass scale (or L), with inch (a—b) on the standard steel foot (or F).* In determining the value of the Micrometer screw at base-lines, measured before the arrival of the steel foot from England, it was customary to employ the inch (7—8) on Cary's brass scale. As one of the steps involved in reducing all our linear measures to the same unit, it became desirable to express inch (7—8) in terms of (ten foot) standard *A*. Captain A. R. Clarke had already determined the subdivisions of the steel foot, it would therefore be sufficient for the purpose in view to compare (7—8) with a known inch on *F*. This comparison was made under your direction as follows. The Microscopes could not be set up at a less distance apart than 5 inches, the space 8 to 13 on *L* was therefore compared 30 times with *b* to *g* on *F*. After which the Microscopes were made to span 6 inches, and 30 comparisons taken between 7 to 13 on *L* and *a* to *g* on *F*. The observers were Major T. G. Montgomerie, R.E., J. B. N. Hennessey, Esq., Captain H. R. Thuillier, R.E., C. Lane, Esq., H. Keelan, Esq., and Lieutenant T. T. Carter, R.E. Each observer took 5 comparisons between the 5 inch spaces and as many between the 6 inch spaces.

The result gives

$$a—b) - (7—8) = 13·4 \pm 1·0 \text{ in millionths of a yard, and } \frac{A}{120} - (7—8) = 14·6$$

In this last equation, it has been assumed that $\frac{A}{120} - \frac{Y55}{36} = -0·17$, as determined through the Dehra comparisons of April 1867, a relation which is dependent on Everest's factor for *A*. Unless this relation be vastly altered, the corrections to our base-lines, arising from the difference between $\frac{A}{120}$ and (7—8) are all inappreciable.

EXTRACT FROM THE NARRATIVE REPORT OF MAJOR T. G. MONTGOMERIE, R.E., DEPUTY SUPERINTENDENT 1ST GRADE, IN CHARGE KUMAON AND GURHWAL SURVEY PARTY, NO. 359, DATED 4TH NOVEMBER 1869.

(1.) During the recess of 1868 all the computations connected with the previous season's triangulation were worked out, with the exception of a small portion that was completed during the subsequent field season. Three contoured sheets—including the sheet with the site of the new hill station of Ranikhet—two skeleton sheets and one exaggerated degree sheet of the Kumaon and Gurhwal maps, were completed and have subsequently been printed in the Photo-zincographic Department. Two Skeleton sheets of the Mussoorie and Landour Survey were also prepared and have since been published. Considerable progress was also made with various other sheets of the two surveys.

(2.) Major Montgomerie reports that in all of these sheets the draftsmen attached to the party have made marked improvement, both in the outlining and in the writing. The outlining is sharper and clearer than formerly; in the writing the progress is more especially marked, and it is now possible to at once determine the relative size of the various villages on the sheets, simply from the style of printing used; the smallest villages in the district having their names in the smallest italics, the next in a size larger, and so on.

(3.) Two degree sheets were commenced in the exaggerated style for reduction by photozincography from the one inch to the ½ inch scale. One sheet was completed and has been published, a large portion of the other was also finished.

(4.) The process of preparing maps for reduction being a new one, several small experiments were first carried out; and, by closely studying the results, a very fair approximation was made to the conditions which are necessary to produce a good reduced map, such as the proper strength of the cantour lines, and of the distance between them, the size and strength of the writing, strength of the outlining &c. The difficulty of doing this was of course greatly enhanced in reducing by so much as a fourth, and without some preliminary experiments, the results could not have been satisfactory, for even with them they are not as yet all that is required.

(5.) The first reduced sheet published, will it is hoped supply all that is necessary as geographical material for the Atlas of India, but certain small defects were noted, and have been provided against as far as possible in the 2nd Degree Sheet, which is now in course of preparation.

(6.) At first sight, preparing a map in the exaggerated style may appear a simple matter, when the size to which the writing &c., is to be reduced has been decided on, but to produce the proper amount of exaggeration in every particular, is by no means easy—the difficulty of producing the proper effect in the contour shading by a number of lines at a very considerable distance apart, being in itself very puzzling, and the preservation of the proper proportion of the various parts of the letters requiring close attention. The necessity for the constant use of the proportional compasses was soon apparent, as the eye of the draftsman could very seldom be trusted to decide as to what was necessary.

(7.) The reduction being required for the Atlas of India, one of the sheets last published was taken as the standard to which every thing was to be reduced, and as far as possible every thing put upon the exaggerated sheets, was made four times the size of that on the Atlas sheet.

(8.) The result so far has been tolerably successful, and the reduced map is much clearer and sharper than could have been secured if the drawing had been originally done on the same scale.

(9.) The saving in time, as compared with hand reduction, has not been very great as yet, but as soon as the Draftsmen become accustomed to the process, and have precise rules to go by, the saving will no doubt be very great.

(12.) During the recess, operations connected with the Mussoorie and Landour Survey were prosecuted, as far as the office work and weather would permit. The positions of the first 36 pillars, (which were built on that portion of the boundary referred to in para. 5 of the Narrative Report of 1867-68), were finally fixed on the field sheets and will be entered on the maps.

(13.) The re-demarcation of a farther portion of the boundary was taken up, and about 4,700 yards were retraced to the south of Hatipaon. Arrangements were made to retrace more of the boundary, but as the Civil Authorities were unable to send any officer to accompany the Surveyor, and held out no hopes of being able to do so within a reasonable time, the boundary operations were suspended, and the Surveyor was sent upon other work.

(14.) Towards the end of the recess arrangements were made to complete the triangulation and sketching of the Mussoorie and Landour settlements, one triangulating party and three sketching parties were put upon this work, and were employed on it nearly the whole of the field-sason.

(16.) The sketching of 13,173 acres on the 12 inch scale, was turned out, completing the survey of the whole of the Mussoorie and Landour settlements, with the exception of a small portion near Rajpore. The sketching was, in all cases, extended to some distance beyond the bounday line indicated on Brown's Map; so that in case of dispute there will be no difficulty in entering on the maps the boundary line finally fixed on, unless it is made to deviate very much from that of Brown's.

(17.) Captain Pullan was at first employed on the triangulation—he visited 30 stations, fixed 75 points, 48 of which had their heights determined, and he sketched 5,168 acres on the scale of 12 inches to the mile, fixing his plane-table 516 times.

(18.) Captain Pullan observed with an 8 inch theodolite, and his 33 triangles show an average error of about 18 seconds. The points fixed were well selected and have proved ample for the sketching; altogether his progress with the triangulation was very satisfactory. His sketching has been done artistically, and the ground has been accurately represented.

(19.) During the recess, Captain Pullan took a share in the computations,—he also did the contour shading of one of the Gurhwal sheets, one of Landour, and portions of two of the exaggerated sheets for reduction; in both, his contouring was very artistic, and his success with the exaggerated maps was very considerable, his bold style being more especially suited to the latter.

(33.) Aneroid barometers were supplied to each of the topographers, and with them they were able to determine the heights of a number of passes, junctions of rivers, &c., which, in addition to the large number of trigonometrical heights, supply ample means of judging of the general relief of the country, independently of the contour shading, which, however well done, is of itself not quite sufficiently explanatory, even to a practiced eye, and conveys the relief but very partially to those who have not studied the subject.

(34.) Major Montgomerie was able to take a complete set of Magnetic observations at four different stations with the unifilar magnetometer and declinometer and dip circle, *viz.*, near Ramnagar, Bheem Tal, Nynee Tal, and Bagesur.

(36.) Lieutenant Hill assisted in the computations during the recess, but not having fully recovered his health, which suffered at the end of the last field season, was obliged to take leave to Europe on sick certificate from the 1st of October.

(37.) Mr. Beverley rejoined the party on the 23rd of July 1868, and assisted very much in bringing up the computations during the recess, completing a very large amount of work.

Taking the field early, he proceeded to extend the triangulation to the east of Almorah. He carried the work successfully over several ranges of rugged mountains, some portions of which were difficult, owing to the dense forest, while the other portions to the north were still more difficult, owing to their great elevation and consequent liability to falls of snow and clouds. Notwithstanding these and other difficulties as to coolies and supplies, Mr. Beverley was able to complete 1,100 square miles of triangulation, fixing 466 points with 249 heights.

(38.) His triangles have been well selected, so as to cover the whole of the ground equally, and with reference to his heights, which are very numerous, he has fully carried out Major Montgomerie's instructions, to determine some of the lowest points in his ground as well as the highest, which in a mountainous country are apt to absorb the greatest amount of a Surveyor's attention. He also computed, out in the field, a considerable number of fresh points which were required for current topographical work, a task which added very considerably to his labors.

Altogether Mr. Beverley turned out a capital season's work, and has fully sustained the reputation which he deservedly earned on the Kashmir and Ladak survey operations.

(40.) Mr. Ryall was employed during part of the recess on the re-demarcation of the Mussoorie and Landour boundary. He retraced 4,700 yards, and pointed out to the Civil Authorities the proper sites for permanent pillars along that portion. He had also arranged to retrace a still farther portion, and was retained for that purpose at the beginning of the field season. The Civil Authorities however were at that time unable to send any officer with him, and as it was of no use to retrace it without the presence of a civil official, and there appeared no chance of one being available within a reasonable time, Mr. Ryall was directed to take up the work originally assigned to him in the north-east of Gurhwal.

(41.) Owing to the delay about the boundary, Mr. Ryall was not able to start early, and on arriving at his ground the snow had already come so low down that he was only able to select the stations and lay out the work for the next season; a large amount was thus prepared which will save a good deal of time hereafter.

(42.) He also managed, while laying out the above work, to start Mr. Bryson on his triangulation, and succeeded in showing him how to overcome the difficulties which hindered him at the beginning of the previous season.

(43.) Returning from the higher ground at the end of the year, Mr. Ryall proceeded to take up a very difficult plane-table section near Ramnuggur, including a large amount of Terai land and forest, as well as some rather high wooded mountains. The sketching of the Terai land and forest involved a large amount of traversing, both with the theodolite and the plane-table, and the lines had in many cases to be actually cleared through the dense jungle. This ground, though in parts apparently level, was in reality so intersected with ravines that moving about it was positively more difficult than in the hilly ground. The jungle in parts was so very dense, and tigers so numerous, that without the assistance of an elephant but little survey could have been accomplished.

Mr. Ryall devoted all his energies to the work, and having made good arrangements as to supplies and labor, was able to make capital progress, completing the sketch of an area of 346 square miles on the one inch scale, fixing his plane-table 505 times, including 49 traverse stations fixed with the theodolite, besides running 47 short traverse lines with the plane-table.

(44.) The greater part of the ground was inspected by Major Montgomerie, and the sketching of it was found to be very accurately and artistically done, Mr. Ryall having succeeded in showing both the high ground and low ground well. The latter from its intricacy and lowness being especially difficult to delineate well, when in such close contact with higher ground.

(46.) Mr. Peyton was employed during the recess on the contour shading of the fair sheets on the one inch scale—this he did most artistically, and his success in combining the hill shading of two or more Surveyors on one sheet, is highly commendable, as his rendering in almost all cases, makes the work appear to be homogeneous, a difficult task when the work of an experienced topographer comes next to that of a beginner.

(47.) A large number of sheets having been prepared, Mr. Peyton was not able to take the field early. He commenced with some low ground near Ramnuggur, and then took up the sketching between Ranikhet and Almorah, in continuation of his last season's work. The lower ground was very intricate, and covered with dense forest and jungle, making all progress difficult. The higher ground was on the other hand intricate, from the great number of villages and the cultivation around them; this section including the most populous part of the Baramundal Pergunnah, the heart of the province of Kumaon; on 30 square miles no less than 70 villages were found, in both the higher and lower ground. Mr. Peyton's sketching has been well done, and the detail was found to have been very accurately laid down.

Total area sketched 263 square miles with 352 plane table points. Progress during the short time available very good.

(48.) Mr. Low started early to take up the sketching of the eastern or Mudmesur branch of the Mundagnee River, including some very high ground running up to, and along the southern face of the Badrinath range, which rises to 23,000 feet above the sea. The sketching of this ground involved a great deal of exposure and hardship, as great heights had to be visited, and towards the end of the fine weather the cold was very great. Mr. Low worked hard and was able to complete this portion by the end of the year, before the fresh snow came low down. Subsequently Mr. Low took up lower ground to the east of Almorah and altogether made very good progress. A portion of his work was examined in detail and was found to be very accurate.

Total area sketched 338 square miles with 703 plane table points, the average in the lower mountains being about 3·3 points in each square mile. Progress very satisfactory.

(49.) Mr. Atkinson did a large amount of computing during the recess, and assisted Major Montgomerie with the translation of the Pundits' Trans-Himalayan route-surveys, and in the computations connected with them. He also carried on the Current Office work of the Party.

(50.) During the field season Mr. Atkinson was at first employed in computing out the observations of the Mussoorie and Landour Triangulation, which was urgently required for the sketching then in progress. This he was able to accomplish by hard work, and the sketching was consequently never interrupted. Subsequently he took a large number of observations with aneroids, to determine the heights of various obligatory points in the first and also in the new portions of the survey, which could not have been determined by the triangulation, except at a great increase of expense. The heights thus fixed will form a great addition to the maps. Mr. Atkinson worked capitally and his out-turn of work altogether has been very satisfactory and creditable.

(51.) Mr. Braithwaite started early to take up the sketching of the western branch of the Mundagnee or Kaligunga River, including some very high ground running up to the Kidernath peaks, 22,800 feet above the sea. He made good progress with this piece of ground and managed to finish it by the middle of December, and had he carried on his sketching in the lower ground assigned to him, he ought to have done well; he however took upon himself to abandon his work under circumstances which have been separately reported on. He was ultimately granted leave on Medical Certificate, his health having completely broken down. No portion of Mr. Braithwaite's sketching could be examined, but it will be reported on at the end of next season. Area sketched 182 square miles with 190 plane table points.

(52.) Mr. Pocock was at first employed on the Mussoorie Survey, practising with the plane table under Mr. Ryall, and at the same time fixing some additional Trigonometrical points along the boundary. He very soon mastered the use of the plane table, and was able to do an

area of 2,740 acres of sketching on the 12 inch scale with 202 plane table points. This portion of his work was closely examined by Captain Pullan, and found to be very accurately sketched. After finishing the above, Mr. Pocock was transferred to Kumaon where he took up sketching on the one inch scale on a portion of Mr. Ryall's section; he was not long in adapting himself to the smaller scale and, with Mr. Ryall's assistance, he was able to turn out 65 square miles with 98 plane table points, in some of the bold ground north of the Kotah Doon. This piece of sketching is very neatly drawn and was found to be accurately executed. Mr. Pocock also assisted Mr. Ryall with the very heavy traverse work in the low ground, and generally made himself useful wherever his services were required: altogether, Mr. Pocock made capital progress.

(53.) Mr. H. Todd was at first employed on a section of the Mussoorie map, and surveyed 1,382 acres on the 12 inch scale with 253 plane-table points; this was accurately sketched and the ground has been artistically delineated, the variations of the ground being carefully shown. Subsequently Mr. Todd was transferred to Kumaon, and completed 144 square miles on the one inch scale with 363 plane-table stations. This piece of his work is very neatly done and represents the ground well. The small portion examined was found to be accurately done, a farther portion will be examined during the ensuing season.

(55.) Mr. Bryson was at first employed on the triangulation of the Pindur valley in Gurhwal. Having the benefit of Mr. Ryall's aid at starting he was able to fix 66 stations in that part, subsequently he was transferred to Kumaon and fixed 129 points from auxiliary stations, in connection with Mr. Beverley's triangulation, working immediately under Mr. Beverley's orders. He observed from 35 stations, fixing altogether in the two portions of his work 195 points. He made good progress and his out-turn of work altogether shews a marked improvement on that of the previous season.

(56.) Mr. Kinney joined the party on the 1st of August 1868. He was at first employed in computing and made some progress. Towards the end of the recess a portion of sketching on the scale of 12 inches to the mile was assigned to him, in order that he might accompany Mr. Ryall and get some training in the use of the plane-table whilst the latter was fixing a portion of the Mussoorie boundary; in this way Mr. Kinney was able to make considerable progress—afterwards he was put under Captain Pullan who completed his training on the 12 inch scale.

(57.) Mr. Kinney's first piece of sketching showed great promise, and each section that he afterwards took up showed continued improvement. His contour shading has been very well done and the ground was found to be both accurately and characteristically represented. He was employed throughout the field season on the Mussoorie and Landour Survey, completing the sketch of 3,880 acres with 330 plane-table points. Altogether he made very good progress.

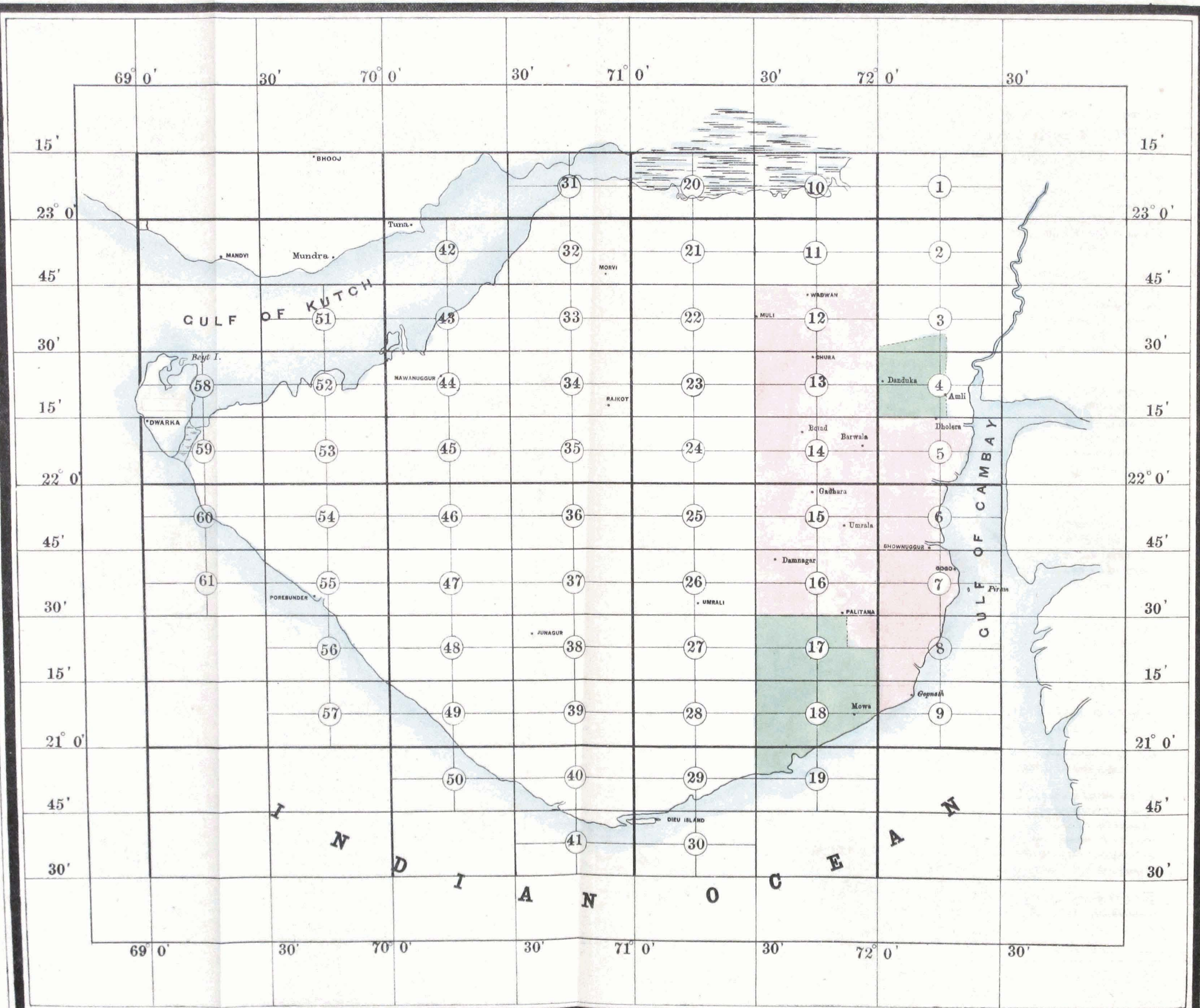
(58.) The men of the native establishment have worked well and given satisfaction. Their health has been generally good and there have been no cases of severe illness.

(59.) The Civil Authorities of the Province have continued to give cordial assistance in all the operations of the survey, and have thereby considerably facilitated its progress.

(61.) During the ensuing field season the triangulation will be pushed on in the higher part of Gurhwal on the main stream of the Alaknunda River and on its two upper branches, viz., the Vishnoo Gunga and Dhauli Rivers. In Kumaon the triangulation will be extended to the north east of Almorah, and also along the foot of the hills and Terai land east of Huldwani. The Topographical work will include a small portion of Gurhwal, but will be mostly confined to Kumaon, to the north and east of Almorah, with a portion of the lower ground near Huldwani.

The Trigonometrical data available from the last season's work, is sufficient to keep all the Topographers fully employed and at the same time to leave a reserve for future operations.

Index Chart of the KATTYWAR TOPOGRAPHICAL SURVEY.



DRAWN BY E. M. WYATT.

Scale 24 Miles = 1 Inch.

Photozincographed at the Office of the Supdt. Great Trigonometrical Survey, Dehra Doon, November 1869.

Denotes Country Triangulated up to season 1868-69

do. . . . Topographically surveyed up to season 1868-69.

EXTRACT FROM THE NARRATIVE REPORT OF CAPTAIN C. T. HAIG, R.E., DEPY. SUPDT. 2ND GRADE, IN CHARGE KATTYWAR PARTY, NO. $\frac{S}{29}$, DATED 20TH SEPTEMBER, 1869.

(2.) The party left recess quarters on the 1st December, but availing myself of a month's privilege leave granted in your letter No. $\frac{46}{1,037}$ of November, I only left Poona on the 25th December.

(3.) We took the field considerably augmented in numerical strength; for, in addition to the four lately joined sub-assistants belonging to the Guzerat party, who had not taken part in the previous season's operations, Lieutenant Baird, R.E., joined the party on the 4th December as 2nd Grade Assistant Surveyor and Mr. W. Todd, Civil Assistant, formerly employed with the Kumaon and Gurhwal party, returning from England from sick leave, joined the party on the 1st December 1868.

(5.) The out-turn of work comprises the topographical surveying of sheets 5, 12, 13, 14 and half of sheet 16, the other half having been filled in during season 1866-67. The minor triangulation was extended over half of sheet 5, half sheet 12, half sheet 13 and nearly all sheet 17 sheet 18 and sheet 19. Sheets 18 and 19 being on the sea coast embrace both together about one full sheet. The boundary survey operations comprise the whole of the demarcated boundaries in the 5 sheets which have been topographically surveyed this season but no more.

(6.) The increased strength in the number of our plane-table surveyors, rendered it imperative to adopt extraordinary measures to drive forward both the triangulation and the boundary surveys; I therefore attached Wissajee Raggoonath, native surveyor, to Mr. McGill as a recorder and co-computer, and Mr. McGill with his assistance completed the latitudes and longitudes of all the stations of his work in sheets 12 and 13 in the field.

(7.) Mr. Todd's opportune arrival enabled me to relieve Mr. D'Souza of the duty of instructing two new sub-assistants of the Guzerat party in plane-tabling, which he made over to Mr. Todd on the 5th January, and I then sent Mr. D'Souza to triangulate in sheets 3 and 4.

(8.) Lieutenant Baird's joining I had of course anticipated, and I had therefore a party and equipment ready for him. As he started for Kattywar nearly a month before myself, I sent him to accompany Mr. McGill for a short time, to familiarize him with the modus operandi of the department, and then sent him south to triangulate in sheets 17, 18, and 19.

(9.) I append hereto a tinted sketch showing the progress of both triangulation and plane-tabling during the season, and a tabular statement showing exactly the quantities and value of work of all descriptions turned out by the whole party.

(13.) As soon as Mr. McGill had completed the triangulation of sheet 12, I directed him to proceed south and to work in concert with Lieutenant Baird, so as to ensure the completion of the triangulation of sheets 18 and 19 during the season. It was most fortunate that I did so, for near the close of the season, Lieutenant Baird was put utterly *hors-de-combat* by a sun-stroke or something of that nature, and Mr. McGill completed the triangulation I desired to be done.

(14.) During the past field season, being anxious to ascertain whether I could not employ aneroid barometers to determine heights, with sufficient accuracy to make the results a valuable addition to the Kattywar maps, I erected a small observatory at Sonepuri in sheet 16 N.E. section, and connected it vertically and horizontally by means of a 14-inch theodolite with two stations, Chambardi H.S. and Trambak H.S., of the principal triangulation, and set up a mercurial barometer by Adie, wet and dry bulb detached thermometers, and maximum and minimum thermometers, and I stationed two native surveyors to record the observations every half hour from day-light in the morning till dark in the evening, except between the hours 10 and 2, when only hourly observations were recorded, and on Sundays when

observations were recorded only at 4 A. M., 10 A. M., 4 P. M. and 10 P. M. The observations have been daily kept during the recess similar to the field season Sunday's observations.

(15.) I gave three aneroids (which I obtained from among the stores returned by the Survey Party from Abyssinia) to those assistants whose plane-tables contain the most hills, and with the aneroids I also gave a couple of thermometers and I carried with myself a mercurial mountain barometer and accompanying thermometers.

(16.) I gave the Surveyors with the aneroids detailed instructions regarding the method of recording their observations, and directed them never to omit to take observations at any of the trigonometrical stations within their plane-tables; but I regret to say the results are of not sufficient value to warrant their entry in the maps. An aneroid observed at the top of a hill and carried immediately to the bottom and observed again, would give a fair approximation to the difference of height between the top and the bottom, but used as they were it was found that the index error was constantly changing.

(17.) Using the mountain barometer in connection with the fixed barometer at Sonepuri, I determined some heights which I believe to be reliable. I was unfortunately only able to check my results at three trigonometrical stations; the discrepancies between my barometer heights and the trigonometrical heights at these three stations were respectively + 6 feet, − 9 feet, + 7 feet.

(18.) The work during the present recess will comprise as under :—

Mapping.—Preparations of Sheets 5, 12, 13, 14 and 16 on the scale of 2 inches to a mile, and Sheets 6, 7, 8, 9 and 15, on the scale of 1 inch to a mile, exaggerated for reduction to the ¼ inch.

Duplicate computations of	380	Triangles Secondary Stations.
Do.	1,239	do. Intersected Points.
Do.	200	Latitudes, Longitudes, Back Azimuths, Secondary Stations.
Do.	63	do. do. of Intersected Points.
Do.	188	Heights of Secondary Stations.
Do.	78	do. of Intersected Points.
Do.	17	Barometrical heights of Stations.

TABULAR STATEMENT OF OUT-TURN OF WORK IN KATTYWAR DURING THE FIELD SEASON 1868-69.

Triangulation.

Observers Names.	Instrument used.	Area triangulated.	Mean discrepancy per mile derived from comparisons of common sides.							Remarks.
			No. of stations visited.	3 *angles observed.*				2 *angles observed.*			
				Triangles.	Triangular error.	Error per mile.	No. of heights.	Triangles.	Error per mile.	No. of points.	
					"	feet.			feet.		
Lieutenant Baird R.E., ...	7-inch by Cooke & Son,	561	62	114	13·0	1·3	70	416	1·5	244	
Mr. J. McGill, ...	6-inch by Troughton & Simms,	850	89	180	15·7	0·6	154	591	1·7	369	
„ A. D'Souza, ...	6-inch by Cooke & Son,	425	57	86	15·2	0·8	43	232	2·1	132	
					mean	mean			mean		
Total, ...		1836	208	380	14·6	0·9	267	1239	1·8	745	

Plane-Tabling.

	Names.	Plane-tabling.	Stations per square mile.	Remarks.
		square miles.		
1	Mr. Todd, ...	180·5	7·5	
2	„ D'Souza, ...	10·5	6·0	
3	„ Gwinn, ...	167·0	7·1	
4	„ McA'Fee, ...	210·0	4·7	
5	„ T. Rendell, ...	253·0	4·2	
6	„ E. Wyatt, ...	267·5	6·6	
7	„ J. Rendell, ...	180·0	4·9	
8	„ J. Hickie, ...	164·0	5·9	
9	„ W. Fielding, ...	164·0	7·4	
10	„ G. Cusson, ...	181·0	5·0	
11	„ C. Goslin, ...	112·0	6·2	
	Native Surveyors.			
1	Vissajee Ragonath, ...	68·0	3·3	
2	Govindjee Mahalay, ...	185·0	3·8	
3	Vishnu Moreshwar, ...	175·0	4·5	
4	Ganesh Bapojee, ...	14·0	7·5	
	Total, ...	2,334·5	5·6	

Boundary Surveys.

Names.	Linear miles of boundary.	Linear miles of check lines.	Remarks.
Gopal Vishnu, ...	77·04	82·37	Employed at Sonpuri observatory 1 month and 18 days.
Narsu Dinkar, ...	76·96	63·68	Employed at Sonpuri observatory 2 months and 15 days.
Bholuji Bhosekar, ...	73·63	...	Absent for 1 month, leave without pay.
Krishna Govind, ...	87·32	...	Employed at Sonpuri observatory 1 month.
Ganesh Bapojee, ...	79·59	39·74	Plane Tabling 2 months, covering Stations 1 month.
Krishna Dinkar, ...	61·70		
Rnoji Narayen, ...	15·21	...	At Sonpuri observatory 4 months.
Tookaram Chowdry, ...	103·61	...	Do. 1 month and 18 days.
Namdeo Gujar, ...	83·47	...	Do. 15 days.
Shreedhar Sukaram	66·25		
	724·79	185·79	

ADDENDA TO CAPTAIN HAIG'S REPORT ON THE KATTYWAR SURVEY; SUBMITTED BY LIEUTENANT TROTTER, ON THE 24TH NOVEMBER 1869.

(2.) Lieutenant Baird, R.E., was employed throughout this, his first season in the Department, in triangulation. To enable him to become acquainted with the practical operations of the survey, he was directed to accompany Mr. McGill, who was employed in breaking up the old triangulation and fixing points for the plane-tablers in sheets Nos. 12 and 13. After remaining in company for two and a half weeks, he commenced work in January on his own account in sheets 17 and 18 in the south portion of the peninsula. That he did good work is shown by the fact that in spite of being delayed and stopped by a sun-stroke, he triangulated over 561 square miles, visiting 62 stations, determining the heights of 70 points and fixing 416 intersected points. His triangular error with a 7-inch theodolite by Cooke and Son was 13″.

(3.) Mr. J. McGill turned out a first rate season's work. He was employed the whole time in triangulation. He worked over 850 square miles, visited 89 stations, determined the heights of 70 points and fixed 369 points for the plane-tablers. His average error was 13″ working with a 6-inch Theodolite by Troughton and Simms. In addition to the regular field work, and in order to provide work for the plane-table surveyors, Mr. McGill, when at work in sheets 12 and 13, not only triangulated, but at the same time (with the assistance of Vissajee Raggonath) brought up the computations connected therewith, so that more than half of those sheets were both triangulated and topographically surveyed during the same season.

(4.) Mr. A. D'Souza was employed part of the time in triangulating 425 square miles, and part in training some of the last joined assistants in plane-tabling, for which service I understand he was eminently qualified. The results as shewn by the work of the Juniors is highly satifactory.

(5.) Mr. W. Todd, Civil Assistant, late of the Kumaon Survey, joined the Kattywar Party for the first time in December and did a good season's plane-tabling, having turned out 180 square miles in creditable style. His time was also partly occupied in training Messrs. Hickie and Goslin.

(6.) Of the other old hands Messrs. Gwinn, McA'Fee, T. Rendell and E. Wyatt surveyed respectively 167, 210, 253, and 267 square miles. The whole of their work was good and stood well, the severe tests that are applied in this Survey, of traverses run sometimes around the different talookas situated within the sheet, sometimes along the meridian or parallel bounding the sheet. Mr. Wyatt turned out a very large amount under peculiarly difficult circumstances, nearly the whole of his work, east of sheet 5, consisting of swamps covered with mangrove trees, but nearly devoid of villages, there being only *one* in one plane-table section of 64 square miles. He had to travel about in boats or wade in the mud and work at long distances from his camp. Mr. Gwinn's work was somewhat less than the others, owing to its situation in a hilly and difficult country. He was also employed in teaching Mr. Fielding his work.

(7.) Of the assistants who had only just previously joined the party, Messrs. J. Rendell, Hickie, Fielding, Cusson, and Goslin, the work is on the whole very satisfactory. In proving their work by the tests I have mentioned, I think Mr. Fielding's is perhaps the most accurate. The early portion of Mr. Goslin's work as you are aware, would not bear these tests satisfactorily and some of it will have to be done over again this season.

(8.) During the recess Mr. McGill has been in charge of the computations, and the mapping has been almost entirely compiled by Messrs. Gwinn and Wyatt assisted by the Messrs. Rendell.

(9.) Of the Native Surveyors, Vissajee Raggonath assisted Mr. McGill in his field computations and executed some accurate plane-tabling over easy ground, Govindjee Mahalay and Vishnu Moreshwar (the former of whom is now invalided) turned out good and accurate work.

(10.) Of the ten Native Surveyors employed in traversing the Talooka Boundaries, Gopal Vishnu, Ganesh Bappojee, Narsoo Dinkar and Tookaram have turned out the largest quantity of work. Of these Narsoo Dinkar's stands best the tests that have been applied.

Gopal Narain, Mahratta Karkhoar, has as usual done good miscellaneous service.

ANNUAL RETURN OF AMOUNT OF WORK EXECUTED IN THE DRAWING BRANCH OF THE OFFICE OF THE SUPERINTENDENT G. T. SURVEY FROM 1ST MAY 1868 TO 30TH APRIL 1869.

DESCRIPTION OF WORK.	REMARKS.
Sheet No. 3 Map of Turkestan (Compilation) *Vide Annual Return for* 1867-68, ...	For Photozincography.
Do. No. 4 ditto ditto ditto, ...	Ditto.
Do. No. 5 Spirit Levels and Trigonometrical Heights of the G. T. Survey of India, (Compilation), *Vide Annual Return for* 1867-68, ...	Ditto.
Sections Nos. 10, 14, 18, 19 and 20 Kashmir Survey Scale 8 miles=1 inch	Ditto.
Do. Nos. 7, 8, and 9 ditto Scale 4 miles=1 inch	For reduction by Photography.
Sheet No. 6 Spirit Levels and Trigonometrical Heights of the G. T. Survey of India, (Compilation), ...	For Photozincography.
Do. No. 7 ditto ditto ditto For Photozincography,...	Finished in pencil.
Do. No. 8 ditto ditto ditto ditto, ...	Outlining finished in ink.
Do. No. 9 ditto ditto ditto ditto, ...	About ¾ of the outlining and printing finished.
Do. No. 10 ditto ditto ditto ditto, ...	Finished in pencil.
Do. No. 11 ditto ditto ditto ditto, ...	Ditto.
Do. No. 12 ditto ditto ditto ditto, ...	Ditto.
Do. No. 13 ditto ditto ditto ditto, ...	Ditto.
Do. No. 14 ditto ditto ditto ditto, ...	Ditto.
Do. No. 15 ditto ditto ditto ditto, ...	Ditto.
Do. No. 16 ditto ditto ditto ditto, ...	Half of the outlining and printing finished.
Do. No. 17 ditto ditto ditto ditto, ...	Finished in pencil.
Do. No. 18 ditto ditto ditto ditto, ...	Ditto.
Prepared Skeleton Chart of portions of the Rahoon Series, Gurhagarh Series, and Sutlej Series, ...	For Captain Home, R.E.
Do. An Extract from Colonel Lambton's Madras Triangulations, ...	For the Surveyor General of Ceylon.
Do. ditto. from Khagan Triangulation, ...	For the use of Quarter Master General's department.
Do. An Index to the Photozincographed Sections of the Kashmir Survey, ...	For Photozincography.
Skeleton Sheet No. 9 Mussooric and Landour Survey, ...	Ditto.
Ditto No. 14 ditto ditto.	Ditto.
Painted Exaggerated Sheet No. 6 Kumaon and British Gurhwal, ...	For Major Montgomerie, R.E.
Preliminary Chart of the Peshawur and Khagan Triangulations on transfer paper, ...	For Zincography.
Prepared Skeleton Chart to illustrate the progress of the Kattywar Topographical Survey on transfer paper, ...	Ditto.
Do. A List of Latitudes and Longitudes of places in the Bombay Presidency, ...	
Preliminary Chart of the Rahoon Meridional Series, Season 1860-61, on transfer paper, ...	Ditto.
Ditto ditto 1861-62, ditto, ...	Ditto.
Ditto ditto 1862-63, ditto, ...	Ditto.
Ditto of the Eastern Frontier Series, Season 1867-68, ditto, ...	Ditto.
Ditto of the Point Divy Minor Series, ...	For Photozincography.
Colored 2,305 copies of topographical and geographical maps.	
Examined proofs of Atlas Sheets for Surveyor General, and performed various other miscellaneous duties.	

REPORT

ON

THE TRANS-HIMALAYAN EXPLORATIONS

IN CONNECTION WITH THE

GREAT TRIGONOMETRICAL SURVEY OF INDIA,

DURING 1868.

DRAWN UP BY

MAJOR T. G. MONTGOMERIE, R.E.,

IN CHARGE TRANS-HIMALAYAN EXPLORING PARTIES.

NARRATIVE REPORT OF THE TRANS-HIMALAYAN EXPLORATIONS MADE DURING 1868, DRAWN UP BY MAJOR T. G. MONTGOMERIE, R.E., C. T. SURVEY OF INDIA, FROM THE ORIGINAL JOURNALS &c., OF THE TRANS-HIMALAYAN EXPLORING PARTIES.

Early in 1868 preparations were made for sending an exploring expedition beyond the eastern watershed of the Upper Indus river.

The explorations of the Pundits during 1867, had supplied tolerably certain information as to various Tibetan districts lying between Rudok and the Thok-Jalung gold field, and between the latter and the Tadum monastery, on the great Lhasa road; more vague information had also been received, as to an upper road running from Thok-Jalung through various gold fields to the great Tengri-noor, or Nam-tso-Chimbo lake, and thence to Lhasa: several traders had been met with who had actually travelled along this upper road, but they were all rather reluctant to tell the Pundits much about it, being afraid of spoiling their market. Having the above information to go upon, Major Montgomerie decided upon sending the exploring party to Rudok, and thence through the districts of Rawung and Tingche, to the north of the great Aling-Gangri group of peaks, which were discovered last year.

From Thok-Jalung the exploration was to be carried, if possible, along the upper road to the Tengri-noor lake and thence to Lhasa; failing that, to take the route through Majin and Shellifuk towards the Tadum monastery.

The Chief Pundit required a rest after his last expedition, and the 3rd Pundit was consequently selected for the work.

This Pundit assumed the character of a Bisahiri, and taking a few loads of merchandize started in April with a party of real Bisahiris, (or men of Koonoo), whom he had induced to accompany him. He made his way from Spiti, through the upper part of Chumurti and Ladak, to Demchok on the upper Indus. Here the 3rd Pundit measured the velocity of the Indus by throwing a piece of wood into it and then noting how long it took to float down 300 paces. The velocity turned out to be $2\frac{3}{10}$ miles per hour with a depth of 5 feet, and a breadth of about 270 feet in the month of July. From Demchok he went northwards through Churkang and Rooksum, (or Rokjung), to Rudok—vide the map accompanying the report of 1867.

Churkang was found to be a favorite place for holding monthly fairs. Rooksum turned out to be a large standing camp where one great annual fair only is held, but that a very large one, the Jongpon (or Zongpon) always attending it in person.

Rudok has hitherto never been actually visited by any European, for although Captain H. Strachey reached a point about 12 miles to the east of the Fort, and Captain Austen another point about the same distance to the north, they were neither of them able to advance any farther, and could never get an actual view of the place itself, owing to the jealousy of the Jongpon who resides there, and governs this most north-westerly district of Tibet.

Though there was but little doubt that the position assigned to Rudok was nearly correct, it was hardly satisfactory not to have a trustworthy account of the place, and the 3rd Pundit was ordered to get all information about it, and to take observations for its latitude and height, and this he succeeded in doing.

He found that the Fort was built on a low rocky hill, rising about 250 feet above the flat ground at its base, having the Budhist monasteries of Sharjo, Lakhang, Marpo and Nubradan close up to it on the east, south, and west with about 150 scattered houses along the foot of the hill.

A stream called the Chuling-chu passes the Fort, and flowing in a north-easterly direction for 3 or 4 miles, joins the Churkang-chu, another large southern feeder of the great Pangkong lake which is about 9 miles from the Rudok Fort.

The 3rd Pundit heard that there is a small lake, about 2½ miles north of Rudok, which has not hitherto been shown on any map; it swarms with wild fowl and is celebrated on account of a place called Kalpee Mhai, on its north-eastern shore, where the ground is so intensely hot that it smokes, and readily burns any wood, &c. that may be thrown into it. This place is much resorted to for the purpose of worship. The three monasteries round the Fort contain about 150 Monks.

The 3rd Pundit remained a couple of days at Rudok, and in his assumed character as a Bisahiri, he and his party excited no suspicion though they were summoned before the Jongpon.

Leaving Rudok on the 22nd of July the party marched back to Rooksum, and then turning eastward by a new road, advanced through the districts of Rawung and Tingche to Dak-korkor, a large standing camp, where an annual fair is held. Several small lakes and a large salt lake called Rawung-Chaka, or Phondok-cho, were passed on the way. These lakes supply salt to Bisahir, Spiti &c.

During the last three marches to Dak-korkor no water of any kind was met with, and the party were forced to carry a supply in skins. In this arid part of the country the soil was of a dazzling white, a peculiarity which extended as far as the Pundit could see.

The Pundit was informed that 5 days march to the north there was a large district called Jung Phaiyu-Pooyu, and that throughout its whole extent the earth is of the same white kind as that they were crossing over, so white in fact that the eyes of people who are unaccustomed to it get inflamed from its glare, just as if they were suffering from snow-blindness. The district is inhabited by Dokpa people, it is under Lhasa but said not to form part of Narikhorsum, having a separate Sarpon, or gold commissioner, of its own. The largest encampment in it is called Thok-daurapa said to have at least 200 tents. The district abounds in small tarns. It must be very elevated as the inhabitants are said to eat very little if any grain.

A large river is said to flow from Jung Phaiyu-Pooyu northwards and then to the east towards China. The district is said to take its name from some high snowy peaks which are probably those at the eastern end of the Kiun-Lun range.

The Whor (or Hor) country is said to be due north of the district, and from information gathered elsewhere there is little doubt but that Whor (or Hor) is the Tibetan name for eastern Turkistan.

As to the district of Phaiyu-Pooyu, with its river flowing towards China, it is difficult to decide whether it is known by any other name, but it probably lies considerably to the east of north, communicating with Lhasa by the Tengri-noor lake district. A similar white soil has been noticed to the east of the Chang-chenmo, and Mr. Johnson, when seven marchs to the north of that valley at a place called Yangpa, reported that "on looking down from a height the whole plain has the appearance of being covered with snow." He attributed this to saltpetre. Mahommed Ameen, in the route he supplied, said that "beyond the pass (north of Changchenmo) lies the Aksai-Chin, or as the term implies the great Chinese white desert or plain. It is sandy and gravelly and covered with brush-wood. Its breadth here from south to north may be reckoned to be about sixty kos." "It extends into Chinese Territory, to the east. There are several lakes and gold mines in it &c." This quite answers to the accounts that the 3rd Pundit heard, a separate gold Commissioner proving the existence of many gold fields. No high peaks were seen to the east of the Chang-chenmo, Mr. Johnson having noticed from the peaks he ascended large plains to the east and south-east, which are believed to merge into the Changthang plains of Rudok. Whilst he also gathered that the Kiun-Lun range only ran about 100 miles east of the Karakash river and then terminated on an extensive plain also communicating with the Chang-thang plains.

The Pundit whilst marching from Rudok to Thok-Jalung saw no high peaks to the north or east, evidence which all tends to prove the existence of a large plain in that direction, the term Chang-thang meaning moreover the great plain.

According to modern maps this plain extends a great way east, nearly up to the end of the great wall of China near the city of Sewchoo, to which place the Chief Pundit appears to have got a rough route when in Lhasa. In his first journal he referred to a place, which he called Jiling, about one month's journey north of Lhasa. This turns out from farther inquiries made by Major Montgomerie to be the same as Siling. The Chief Pundit says that the Lhasa people call it Jiling, but he heard others calling it Siling, and from what he says it is evidently identical with Siling or Sining in North Latitude 37°, East Longitude 102°, which Astley describes as "a great and populous city, built at the vast wall of China, through the gate of which the merchants from India enter Katay or China."

Lord Strangford, who took great interest in the travels of the Pundit, and was able to identify nearly all the places mentioned by him, was greatly puzzled by the Pundit's description of Jiling, given in his first journal, where it is said to be in Tartary and to produce gold lace, silks, carpets, and other products of a tolerably civilized country. At first the Pundit understood that it was a month or two month's journey to the north of Lhasa, but from farther inquiries during his second expedition, he made out that it was considerably to the east of north, and having this hint, there was no great difficulty in identifying it with the large town of Sining on the borders of China proper, the only place from which such civilized products were likely to reach Lhasa from the northwards.

The Dak-korkor Camp, which the 3rd Pundit reached, lies about 20 miles to the north of the Aling Gangri peaks, on the right bank of the Aling-chu river and not very far from the Thok-Nianmo gold field. He arrived just as the annual fair was commencing; about 150 tents were already pitched and both the Jongpon and Sarpon were present; but in spite of their presence a band of mounted robbers came down upon the camp and threatened to loot it. These robbers seem to be numerous all over Tibet. This particular band was said to come from the great Namtso lake district. The men actually began to rob, but the Jongpon told them to stop, and he would make each tent contribute something as black mail. The Jongpon then made out a list of those assembled and ordered each tent to contribute a parcha (of about 5 lbs.) of tea, and each trader to give from 1 to 2 rupees according to their means. This arrangement was agreed to, and the proceeds having been collected were handed over by the Jongpon to the robbers who took their departure.

The Chief Pundit in describing the above, expressed an opinion that the Jongpon was in some mysterious way benefited by the contributions, possibly retaining a considerable share, as it is well known that the robbers never succeed in looting his camp nor that of the Sarpon; both of them perfectly understanding how to defend themselves against all comers on the plateaux of Tibet.

The 3rd Pundit paid his contribution and saw the robbers depart, but he came to the conclusion that they might appear again at any time, and that it would not be safe to take his merchandize with him, he consequently, after consultation with his Bisahiri friends, decided upon sending the greater part of his goods back by the Indus so as to meet him at Lhasa, or on the great road to that place. One of his men was despatched for this purpose; his adventures will be adverted to.

The 3rd Pundit, starting again from Dak-korkor, continued his march eastward down the Aling-chu river till it fell into the Hagong-cho, a large brackish lake which appeared to have no exit for discharging superfluous water, though the Aling-chu river which feeds it was found to be 150 paces in width with a rapid stream just before it fell into the lake. The shores of the lake had marks which showed that it had once been more extensive. Continuing his journey the Pundit passed the Chak-chaka salt lake from which the greater part of the Tibetan salt, which goes down to Almorah, Nepal &c., is extracted. The salt from Tibet is preferred by the people of Kumaon and most hill men, though the salt from the plains is to be had at much the same price.

The Pundit heard of another salt lake to the east of Chak-chaka, which with other similar lakes probably supplies a portion of that which is generally understood to come from Chak-chaka.

The next place of importance seen by the Pundit was Thok-Sarlung which at one time had been the chief gold field of the district, but had been in a great measure abandoned on the discovery of the Thok-Jalung gold field. The Pundit passed a great excavation, some 30 to 40 feet deep and 200 feet in width and two miles in length, from which the gold had been extracted. He heard of another gold field to the west, but his route took him direct to the Thok-Jalung gold field, which he found in much the same state as when visited by the Chief Pundit. The Pundit and his party excited no particular notice, and they were consequently able to march on after halting a day to rest.

From Thok-Jalung they passed through the Majin country, partly undulating, and partly quite level, but all about the same altitude, viz:—15 to 16,000 feet above the sea. The drainage sloped towards the east, and nothing but comparatively low rounded hills were visible in that direction; whilst on the west the party skirted a large plain of a yellowish clour said to be drained by the Upper Indus.

The party passed numerous lakes producing salt and borax, and after 9 days' journey in a south easterly direction, found themselves at Kinglo, a large camp on the banks of a river called the Chu-sangpo, which is so large that it cannot be forded during the summer. This river flows eastward and falls into the lake called Nala-Ring-cho or Cho-Sildu, said to be about the same size as the Mansarowar lake; it has a small island in the centre. The lake is reported to receive a large stream from the south, another from the east, and a third from the north, the latter draining part of the Phaiyu-Pooyu district. Though receiving so many streams, (one of which, as noted above, is a large one), the lake is nevertheless said to have no exit.

To the south of the lake there is a well known monastery called Shellifuk, the residence of a great Lama. Still farther to the south there are some high snowy peaks, and a district called Roonjor, while to the north are the districts called Gyachun and Girke, the latter probably adjoining Phaiyu-Pooyu. To the east he heard of another district called Shingwar.

From Kinglo the Pundit wished to march on to Lhasa by the northern route past the Tengri-noor lake, but the Chief of Majin (Kinglo) would not permit it, and the party were consequently obliged to take a south-westerly route to the Mansarowar lake.—They followed the course of the Sangpo-chu nearly to its source, crossing one very high range called Nak-chail, and another called Riego, and finally descending to the Mansarowar lake. The Nagchail and Riego ranges are evidently off-shoots of the Kailas peak. The Nagchail peaks appeared to be very high both on the east and west.

When crossing the range the Pundit saw a very large herd of wild yaks; his party counted over 300 of all sizes before the herd ran off: the yaks were all black. These wild yaks are called "Dong"; they were mostly seen between Majin-Kinglo and the Mansarowar lake. Great herds of wild asses were seen throughout; sometimes as many as 200 were in sight at the same time when the plateaux were extensive. The Hodgsonian antelope, wild goats, and sheep, (the latter including the gigantic ovis ammon), were all seen in numbers. Large grey wolves were constantly seen but never more than two or three at a time, though packs of them were often heard yelling at night. Numbers of reddish hares and a kind of fox were seen on every march. Marmots were very numerous, their subterranean villages being met with wherever grass and water were at hand. Quantities of geese, ducks, and storks were seen on the lakes. Eagles and vultures appeared to be the same as those in the Himalayas, and were seen every where.

Whilst marching from Rudok to Thok-Jalung the Pundit heard minute descriptions of no less than 7 seperate gold fields, viz: those of Thok-Sarkong, Thok-Dikla, Thok-Ragyok, Thok-Thasang, Thok-Maroobhoob, Gunjec-Thok and Thok-Nianmo, besides those of Thok-Sarlung and Thok-Jalung which he actually visited, and those of Phaiyu-Pooyu of which he heard vaguely. The Pundit understands the word Thok to mean a mine.

Several salt lakes were passed and others heard of. He describes the celebrated Chak-chaka salt lake as being all but connected with the Hagong-cho lake, and stated that an area of about

20 miles by 10 is all about on a level with those lakes. This space is filled with salt, the water having evidently at one time covered the whole.

Borax fields were seen at Rooksum and Chak-chaka, and numbers of people were working on them. No gold or salt mines were seen or heard of between Thok-Jalung and the Mansarowar lake; but numerous borax fields were seen, at one of which about 100 men were at work near a camp of some thirty tents. The other fields were not being worked when the Pundit passed. The borax generally was said to find its way down to Kumaon, Nepal &c. Altogether this portion of the third Pundit's route has brought to light the positions of a large number of gold, borax, and salt fields, testifying to an amount of mineral wealth, as to the value of which we have hitherto had no information. In marching south from Thok-Jalung the Pundit appears to have left the gold bearing rocks, and from the information he received, the line of gold fields is continued more to the north; but it is evident that this part of Tibet contains an inexhaustible supply of gold.

As to borax, there appears to be any amount of it to be had for the digging, the Lhasa authorities only taking a nominal tax of about 8 annas (or a shilling) for ten sheep, or goat loads, probably about 3 maunds or 240 lbs. Borax sufficient to supply the potteries of Staffordshire and all Europe would be forthcoming, if the supply from Tuscany should ever run short.

The salt fields appear to be the source from which the hill population from Nepal to Kashmir draws the greater part of its supply of salt.

Throughout his march, the Pundit was at an elevation of over 15,000 feet, and yet an encampment was met with nearly every day. Thieves were numerous, and threatened the party several times; but on seeing that the Pundit's party were armed, they invariably went off again, not liking the look of an English gun. The party arrived at Mansarowar in safety; and the Pundit decided upon waiting for the Ladak Kafila, which was known to be on its way to Lhasa. Whilst there, the Pundit made a careful traverse of the Mansarowar lake, with bearings to the peaks north and south. A map of the lake will be given hereafter. Though the water was sweet no exit was seen: at one point on the west the ground near the Ju monastery was low, and looked as if water had perhaps at one time flowed through, towards the Rakas Tal lake, though it is now too much above the lake to admit of it.

The Pundit was unable to join the Ladak Kafila; but made his way by himself along the great road to Shigatze, where he was stopped. This he found was by an order of the Gartok Garpon, sent after him by the couriers. He was unable to advance farther. Whilst marching between the Mansarowar and Shigatze he was able to take bearings to various peaks north and south of the road, which no doubt will add considerably to our knowledge of the mountains on either side of that route; but as the Pundit has only just returned, there is no time to give any further account of his route and adventures in the present report.

His servant, who was sent back from Dak-korkor, managed to join part of the Ladak Kafila, and reached the Tadum monastery; but the mounted messengers of the Gartok Garpon found him out there and prevented him from advancing farther. He very narrowly escaped being sent back to Gartok, and would have been lucky to have escaped severe punishment. The Ladak merchant fortunately remembered his old friend the Chief Pundit, and on being told that the man was carrying merchandize on his account, did what he could to protect him; and though he said it was impossible to take him to Lhasa, he managed to get him released, and ultimately the man was allowed to cross over the Himalayas by a southerly road past Muktinath into Nepal. In this way he was able to join on to the route the 2nd Pundit traversed during their first explorations. The permission to take a new route, is surprising, as the Lhasa officials are always careful to make suspected individuals return by the road they entered, so that they may at any rate not get fresh information as to the country. Their carelessness in the present instance was probably due to the humble and rather stupid look of the man, but it has supplied an important link between the Tadum monastery and the Muktinath shrine on the Saligrami, a great feeder of the Gunduk river. The man, an inhabitant of Zaskar, in spite of his appearance, has a shrewd idea of distances and of the points of the compass; he was able to give a very intelligible though rough route between the two points, which agrees very fairly with the positions assigned to them by the 1st and 2nd Pundits.

When this Zaskari found that he would not be allowed to go to Lhasa, he told the Ladak merchant that an agent of the Chief Pundit had gone on ahead, to whom he was to have delivered some goods, and requested that he would see that they were delivered to the agent: the merchant promised to do this and took charge of the packages. The Zaskari then put his own baggage on a couple of sheep and started off south. Though early in December he was able to cross the Brahmaputra river on the ice, which was then strong enough to bear laden yaks. The first day he reached the Likche monastery, where he found two men from Lohba in the Mustang district north of Muktinath. These men had gone beyond, to the north of Tadum, for salt and were returning with it. The Zaskari managed to make their acquaintance, and on hearing that he was a Bisahiri (or man of Koonoo) going to worship at Muktinath, they agreed to take him with them. Their salt was laden on about sixty yaks, each carrying from 1½ to 2 maunds (120 to 160 lbs). The two men were able to manage this large number of yaks as the road was a good one.

From Likche they ascended gradually over a great plain or plateau, with plenty of grass and scrub; the latter making good fuel even when green. Three easy marches took them over this plain and landed them at Lohtod, four or five miles beyond or south of the Himalayan watershed. The plain had a few small knolls on it, but was otherwise flat or undulating. The ascent, even up to the watershed, was very slight indeed. From the pass, which the man hardly thought worthy of calling a pass, there was a slight descent for four or five miles. He got a good view of Lohtod, a village of sixty houses surrounded by a number of scattered houses, which he thought might make a total of several hundreds: the houses were all built of sun-dried bricks. He noticed a great many fields, and found that they cultivated barley, buckwheat, mustard, radishes, and a small proportion of wheat, all indicating a moderate altitude, though the only trees visible were two or three poor willows. This is confirmed by the easy slope of the ground to Muktinath, which the 2nd Pundit found to be 13,100 feet. The next day the Zaskari reached Loh-mantang, where the Loh Gyalbo (or Raja) lives in a stone fortlet, near a small town of some 200 houses, surrounded by a great deal of cultivation.

Erom Loh-mantang three days' easy march landed the Zaskari at Muktinath. On the route he passed a large village called Asrang, where the Gyalbo has a house, and at every three or four miles he saw a group of a few houses, mostly to the west of his road, but he met with no tents south of the Himalayan watershed.

Muktinath (or Lohchumik) stands in an open spot, with 4 villages of about 50 houses each, lying a mile to the south of the shrine.

The Zaskari has given some farther routes which are new and will no doubt prove useful hereafter. The route given above is more especially interesting, as giving another line across the Himalayas: it makes the crest very much as given in the map with the first report of the Pundit's explorations, and shows how very far behind, or north of the great peaks, the Himalayan watershed actually lies, and what a great breadth the highest parts of the range cover.

Another explorer was employed to the east, who made a route-survey of 1,190 miles in length, advancing by one route 640 miles and returning by another 550 miles in length.

A small portion of this man's route was quite new, as he managed to penetrate behind or north of the great Mont Everest peak. His progress in that direction was checked by the obduracy of the Lhasa officials on the Tingri-maidan. As far as it goes this portion of the route is however interesting, insomuch as it gives another determination of the Himalayan watershed, and throws a little more light on that part of the mountains which lies behind or north of the great peaks seen from the Hindustan side.

The remainder of the route is in a great part new; but some of the former explorations went over portions of the same ground, and the positions of several places have been entered on published maps from various information, though hitherto without any regular connection. These new routes will supply the necessary connection, and when combined with former explorations, will add much towards the elucidation of the Eastern Himalayas. A map will be

prepared on this basis, but no reference can for obvious reasons be made to names &c., whilst the work is in progress, the explorers having been somewhat impeded by the publicity given to the results of former expeditions.

On the north western frontier of India a Mahommedan gentleman, generally known as the Mirza, has been employed for some time in exploring the countries beyond the Hindoo-Koosh, the Mustagh, and Karakoram ranges. The Mirza was regularly trained, and having acquired the necessary facility in the use of a sextant, and in the method of route-surveying practised in these explorations, was started on an expedtion viâ Afghanistan. He made his way to Candahar; but there his progress was for a time arrested owing to the war which resulted in re-seating the Amir Ali on the Cabul throne.

The Mirza, it may be as well to state here, was one of the lads brought originally from Herat by Pottinger, and had received a partial English education, by which he has benefited considerably. Being a native of Afghanistan he has kept up his acquaintance with that country, and though for some time in the British service, has spent the greater part of his life in that country. His former residence in Cabul more especially favored him, and he was at once able to accompany the Amir. He witnessed various actions that took place during the Amir's advance from Candahar, and supplied our Government with accounts of them and the general state of affairs; accounts which at the time were rather valuable, as it was difficult to get any other accurate information. The Mirza was detained for some time at Cabul, owing to the disturbed state of the country, but ultimately was able to pass over to Badukshan, thence he ascended, through the Upper Valley of the Oxus, to Lieutenant Wood's Sirikul (or Victoria) Lake. From this lake he made his way through a part of Sirikul district to Tashkurgan, crossing the watershed which divides the Oxus from Eastern Turkistan. At Tashkurgan he was placed in a sort of open arrest, being allowed to do what he pleased, though always watched. From Tashkurgan he made his way over the mountains direct to Kashghar, still accompanied by men from Tashkurgan, who insisted upon seeing him into Kashghar; fortunately they did not interfere with his using his instruments, and he was able to continue his route-survey.

At Kashghar he was detained for some time by the Koosh-Begie, or Atalig Ghazi. He asked for permission to go on to Kokhan, but it was refused; and he was ultimately glad to be allowed to return viâ Yarkund and the Karakoram pass to Ladak, and thence into British territory.

The Mirza has just returned, and there has only been time to roughly plot his routes, which are complete from Cabul to Kashghar, and from the latter to the vicinity of the Karakoram.

His route from the Sirikul lake to Kashghar, is entirely new, and promises to be the most interesting portion of his work. It may perhaps throw some light on Marco Polo's route from Europe to China, as that traveller stated that he went direct from Budukshan to Kashghar without passing through any larger town.

No particulars can be given as to the Mirza's work, but the whole of his route-surveys, &c. will be reported on as soon as they have been worked out and tested.

With reference to farther explorations, an attempt will be made to advance farther along the margin of the Aksai Cheen, or great white desert, and if possible to cross it, and generally to explore farther east towards the end of the great wall of China; but the jealousy of the Chino-Tibetan officials renders success very doubtful.

Expeditions are being organized to carry the explorations still farther to the north of the Hindoo-Koosh, so as to account for the geography of the upper branches of the Oxus, of the Pamir Steppe, &c.; and there is some chance that in the present state of Afghanistan it will be possible to carry out these projects, and thus to reduce the absolutely unknown ground in that direction to a small area within a reasonable time.

Further routes will be made with a view to complete our knowledge of the geography of the Eastern Himalayas; and it is hoped that the obstacles in that direction may be surmounted within a short time.

The total length of route-surveys amounts to 1,820 miles with 66 latitudes and 61 heights of various places. The area of altogether new ground of which the geography has been determined, is about 20,000 square miles, irrespective of a very large area of partially new country, for the geography of which improved materials have been collected.

NOTES ON THE TINNEVELLY DISTRICT

BY

CAPTAIN B. R. BRANFILL,

AND

A NOTE ON THE CLIMATE OF SOUTH TINNEVELLY

BY

REVD. R. CALDWELL L. L. D.

1869.

TABLE OF ERRATA AND CORRIGENDA TO NOTES ON THE TINNEVELLY DISTRICT 1868-69. BY CAPTAIN B. R. BRANFILL.

PAGE	II.	Top of page for "Note" read "Notes"
"	"	3rd line insert commas before and after, "the Western Ghâts,"
"	"	21st " for "sand" read "sandy"
"	"	in the 4th line from bottom erase the first "and"
"	"	in Note (1) expunge the semicolon after Tinnevelly
"	"	in Note (2) for (angl-Mothuray)—read "(Angl. Mothuray)"
"	"	in Note (3) for "Kanyà Kumâri the great virgin maid"—"or the &c." read Kanyá Kumâri "The great virgin maid" or "The Virg. &c."
"	"	Read Note (5) Travancore for Tiruvankodu, short for Tiruvanandakodu. "Saint Anand's forest."
"	V.	5th line erase "its causes" and read "by obvious local influences"
"	"	12th " for "varified" read "rarified"
"	"	13th " for "prevails" read "prevailing"
"	"	18th " for "see clouds" read "sea clouds"
"	"	21st from bottom insert "but" immediately before "although"
"	"	20th, 21st and 22nd from bottom for "lightening." read lightning"
"	"	7th line from the bottom insert (.) a full stop after "sunset"
"	VI.	25th line for "wastes. Also" read "wastes, and"
"	VIII.	19th line from bottom for "encroached. Near" read "encroached near"
"	X.	above 9th line from bottom insert heading "Note on the Palmyra"
"	"	opposite 4th line from bottom add marginal note "Uses of the Palmyra"
"	XI.	para. (10) for "parts" read "part"
"	"	3rd line from bottom for "seams" read "seems"
"	"	read latter part of foot note. Tiruvandapuram (Saint Anand's town) the capital of Tiruvanandakodu (Travancore.)
"	XII.	6th line for "when" read "where"

NOTES ON THE TINNEVELLY DISTRICT

1868-69.

By Captain B. R. Branfill.

Having been called upon by the Superintendent of the Great Trigonometrical Survey of India to examine and report upon the coast of Southern India near Cape Comorin with a view to the selection of the best site and the most proper time of year, for some tidal observations in contemplation, and having been employed for eight months during the years 1868-69 as Executive Officer in charge of the Madras Party of the Great Trigonometrical Survey in South Tinnevelly, the following notes upon the country, the weather, and some tables of the rainfall are offered as of considerable local and perhaps also of some little general interest.

In consequence of the engrossing nature of my ordinary duties I have been unable to collect any but a small portion of the data available for the purpose; but it is hoped that what is given is truly characteristic and trustworthy so far as it goes.

It may be mentioned that many valuable series of meteorological observations exist in this country, some of them still in progress, and some buried in local or private collections of records. If these were collected and reduced it can scarcely be doubted that some valuable information might be acquired, and made available for public use and instruction. They would also help to fill up the great gaps between the provincial observatories now existing.

With regard to the latter it seems advisable that steps should be taken to ensure the uniformity and to examine and test the accuracy of the very extensive series of observations being made in them. Unless the circumstances of all the series can be rendered unquestionably similar no rigorous comparison can be made between them, and the results must necessarily lose, for scientific purposes, a serious proportion of their value.

A good way of ensuring the utmost similarity of condition appears to be the employment of one duly expert person to visit every observatory and be responsible for exact uniformity so far as it can be obtained, and to report minutely every deviation from a certain standard of perfection in the conditions of each.

It should be the duty of the same person to find out any available series of meteorological observations and report its value, and if worth reducing and publishing, procure its transmission to a central meteorological or statistical office.

Of course one chief use of such an officer would be the conveyance of the best portable standards by which to compare and correct all the meteorological instruments met with in use.

I am much indebted to Mr. C. T. Longley, Acting Collector, for giving me access to the rain registers and other records in his office—and especially to Dr. Caldwell, the distinguished and learned missionary and observer, for much oral and written information about the district: also to Captain G. A. Phipps, Master Attendant, Tuticorin, for the register of a year's meteorological observations, part of them kindly undertaken by him at my request—to the Revd. J. Brotherton of Nazareth and J. Thomas of Mengnanapuram, and to all whether private, civil or military persons from whom I sought information.

B. R. Branfill, *Captain*
Great Trigonometrical Survey of India.

Note on the Tinnevelly district to accompany tables of the rain-fall &c.

Area and geographical position.

Tinnevelly[1] (more properly Tirnavelly) the southernmost district (or collectorate) of India on the Eastern side of the mountain range the Western-ghats is a plain of 5145 square miles area lying between 8° 5′ and 9° 45′ N. latitude, and between 77° 20′ and and 78° 20′ East longitude.

Its extreme length is 120 miles from the Madura[2] boundary on the north to the sea coast 8 miles north of Cape Comorin[3] on the south.

Its extreme breath is about 75 miles between Tuticorin[4] on the gulf of Manar on the east, and the Travancore[5] boundary at the eastern foot of the western ghats, on the west.

Slope of the country.

The slope of country is a gradual rise of about 2 feet in the mile for 15 or 20 miles inland from the sea increasing to 3, 4 and 5 feet a mile in the next 15 or 20, and increasing more rapidly as it nears the mountain range.

It is estimated that four-tenths of the country is under cultivation, producing large crops of cotton and rice for export. The population is stated to be 1,500,000, or about 290 to the square mile.

The Tinnevelly collectorate comprises four distinct tracts of country.

1*st*.—The rich rice growing river basin.

4 tracts of country.

2*nd*.—The Red soil uplands, its colour being a conspicuous feature in every Tinnevelly landscape.

3*rd*.—The fertile cotton producing black soil.

4*th*.—The sand country of the Palmyra forest.

1*st* the Tamrapurni river basin.

1*st*.—The basin of the Tamrapurni[6] river and its affluents (of which the Chittar is the principal) is generally, a rich alluvial soil, overlying a stratum of clay, and occupies about one half of the district. The value of the irrigated (nanjei or wet land) portion is very great. Rs. 1,000 the acre is not an uncommon price for this land.

Large fields are to be seen, the surface of which has been lowered by excavation, in some cases, it was stated, as much as 3 feet and not unfrequently two (2) feet below the level of the surrounding land, to allow the water from the old irrigation channels to flow over it.

The excavated soil is piled up in huge masses, the surface of which is used for dry cultivation (punjei).

2*nd* the red soil tract.

2*nd*.—The second division is that of the red soil lying all along the foot of the Western Ghats and extending 10 to 20 miles into the plains, and occupying about (¼) one fourth of the whole district. The high and dry portions of this tract are poor and denuded of their finer soil, but the hollows are said to be fertile under cultivation.

NOTES.—(1) Tinnevelly; is commonly pronounced Tirnavelly by the natives, short for Tiru-nel-veli (sacred-rice-hedge) probably from the situation of the town amidst a magnificent stretch of rice cultivation.

(2) Madura commonly pronounced as if it were written Mathurai (angl-Mothurny).

(3) Cape Comorin called Kanniya Kumari by the natives, more properly "Kanyà Kumári the great-virgin maid"—"or the virgin of virgins" from the temple of Párvati there.

(4) Tuticorin for Tuttukudi (scattered-habitation) the Indian port of the Gulf of Manar, famous for its pearl fisheries.

(5) Travancore for Tiruvankadu short for Tiru-(u)-ananda-kodu-Saint-Anands-forest.

(6) Tamrapurni, for "Tambura-varna." "Copper colour," or "Copper leaf."

A large extent of the upland is ploughed after the rains[7] and dry rice (sami arsi) sown. This crop depends upon the showers and dews of January and February, and too often fails. The surface soil is light and becomes extremely hot. Early in April it was found by several experiments to be 148° at 1 P. M., the air at the same time being 98° in the shade.

The red soil tract.

Heat of surface soil.

As the atmosphere then was very thick and hazy there can be little doubt that it is sometimes much higher.

The inhabitants keep large flocks and herds of cattle for agricultural purposes, and chiefly to provide manure. They graze these by day on the wastes and fallows, and on the stubble fields after harvest, and herd or pen them at night on the gardens and fields next for tillage. They have a custom of waking up and disturbing them several times during the night and frightening them in order to make them drop more manure; and the plan is by no means unsuccessful.

3rd.—The (3rd) third division of the district is the black cotton soil plain, lying to the north of the Tamrapurni basin and east of the red soil tract, and occupying one ninth of the whole district.

3rd.—The black cotton soil.

This is stated to be a deep alluvial deposit overlying limestone. The whole of it is under tillage for cotton and cholam (sorghum vulgare) of which it produces two crops a year, and although dry land (punjei), that is without any channel irrigation, is said to be as valuable as irrigated land (nanjei) in other places.

The Tinnevelly cotton commands rather a better price at Tuticorin than some other country sorts at Madras :—So much so that cotton from the Coimbatore and Dindigal districts finds its way by cart to Tuticorin instead of going by rail to Bepur and Callicut on the west, or Madras and Negapatam on the east.

The cultivators and traders have amassed very large sums of money from the late high prices of cotton, and the towns and villages have been much improved in consequence.

The (4th) fourth division is the sandy tract on the south-east of the district, south of the Tamrapurni basin, extending about 50 miles along the coast and 5 to 10 miles inland, and occupying about one seventeenth of the whole district. The soil is generally a deep sand not unmixed with loam, overlying a light-grey sand stone, or a dark red glomerate. It is covered to a considerable extent with forest of the Palmyra Palm, the chief source of food and wealth to the inhabitants, who are mostly Shānārs, a low and poor caste of people, said to have come from Ceylon, addicted to demonolatry, but clever toddy (tadi) climbers. (see note on the Palmyra.) This belt of palm forest, which fringes the coast, has a curious gap of 6 or 8 miles, the south-west edge of which is about 9 miles north-east of Cape Comorin, defining the eastern limit of the Travancore palm forest, which has its rain, and consequently its flowering and fruiting season, at a different time of year from that of the Tinnevelly district.

4th.—The sandy tract.

The palm forest.

The mountain range of the Western (sometimes here termed the Southern) Ghats ends rather abruptly 10 or 12 miles North of the Cape, the summit of Mahendragherry[8] about 5430 feet above the sea, being only 20 miles inland. There are several peaks higher, of which Agastyar Mallei is supposed to be the highest (about 6,200 feet), 30 miles farther north.

The mountain range.

The two gaps or passes over the range, north and south of Mahendragherry are 2,870 and 3,780 feet above the sea. The steepest declivities and cliffs at this part of the range are on the eastern side of the mountains an arrangement that with few exceptions is said to prevail as far north as the Palnei (Parani) hills.

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(7) "The rains" of the Tinnevelly plains accompany the N.E. monsoon in October, November and December.

(8) Mahendragherry locally pronounced Mayendra-giri. I have been informed that the remarkable bluff peak which stands out on the east side of the range, from which Hanuman according to Hindu tradition, leapt across into Lanka (150 miles east), is properly called Mahendragherry, but the natives in the vicinity call it Tiruvanamallei, or by another name (Kuruva mallei) signifying "the cleft mountain."

The mountains are well clothed with forest or verdure to their summits. The plantain is to be seen growing wild, about 4,000 feet and a wild palm flourishes at an elevation of 5,400 feet close to the summit of Mahendragherry.

Annual course of the weather in South Tinnevelly.

January showers.

The month of January begins with the last showers of the (so called) "North-East Monsoon" or trade-wind season, offering the cultivator hopes of a good crop from the high and dry plains of the district which must otherwise fail of their produce.

N. gales.

Northerly gales prevail for several weeks and only begin to abate after the third week in January has passed. These gales are the N.E. trade-winds, and it may be noted that here the polar current attains its maximum about 25 days after the solstice.

The difference of velocity of the diurnal rotation for different places on the same meridian in this low latitude being so small, the polar and equatorial currents have but little easting and westing in them due to that account.

Fine weather.

A spell of fine dry weather succeeds the early January showers, and may be expected to last in the dry parts on the S.E. of the district 9 or 10 weeks.

February.
Easting of the wind.

In February the wind becomes variable gradually veering round from N.N.W. at dawn, to the east as the day grows older, and more and more so, as the season advances.

Fleeting clouds from the N.E. pass continually not far overhead, shewing the presence of the trade-wind irrespective of the surface breezes which are modified by local influences. These clouds sometimes gather for several days and come up in masses of nimbus from the sea affording in the more favoured parts of the district sufficient rain or dew to perfect the upland crops which would otherwise fail.

Rapid rise of the temperature.

The midday temperature rises very rapidly in February and in March is often 96° in the shade almost as high as ever it is by day, except in the "fire-days" at the end of April and early part of May.

The solar radiation is felt very greatly in the clear weather of this season (February).

On one occasion the black bulb thermometer "in vacuo" was left exposed to the sun lying on the white cotton wool in its packing case. About 11 o'clock it was observed at 176°, and in the next two hours was found to have registered a maximum of 191°.

March.
Regular diurnal course of the wind.

By the middle of March the diurnal change of the wind is very marked. At dawn there is a cool (77° to 79°) N.W. breeze from the mountains, with a clear sky inland and dew in moist places, volumes of cumuli are seen rising from the sea, all round the coast, to a height of a few hundred feet apparently, whilst the mountain tops in the neighbourhood are capped with graceful folds of silver mist. This state of things continues during several hours until the temperature has risen some 10° higher, and whilst the breeze draws round through all points about the north and dies away in the N.E. quarter, shortly to revive as an eastering and freshening wind from the seaward. About 9 or 10 A. M. the masses of cumuli over the sea are seen rapidly rising and breaking up into small detached fleecy clouds, which are carried off by a north-east (the trade wind) current prevailing a little higher, over the low lands near the coast to the vicinity of the mountains on the west, where they disappear from view. Soon after 10 o'clock, on the coast, the sea-breeze gradually sets in, but later and more suddenly as you go farther inland; sometimes as late as sunset, or even later still at the distance of 25 to 30 miles from the sea. The sea breeze commences as a "long-shore" wind from the N.E. At noon it is easterly; by 3 P. M. S.E., and at its maximum; and it has usually reached a point or two west of south by sunset when it suddenly dies away, and the calm which immediately

succeeds is a noticeable feature. At 8 or 9 P. M., a gentle breeze rises from the S.W. to be followed during the night by a westerly and N.W. wind from the mountains, which is often a violent and injurious "land wind", and lasts till day light, and so continues the daily round. This diurnal circling of the wind is very constant for some weeks and may be for the most part accounted for by its causes obvious local influences. Thus, the west to N.W. wind in the early morning is the ordinary land-wind blowing out to sea, the sea being some degrees (not less than 4° or 5° probably) warmer than the land at that time;—it is perhaps increased by a tendency of the air to flow towards the rising sun, and the place (meridian) of low barometric pressure (the 4 A. M. minimum). As these causes fail the polar current asserts itself as the northerly wind which prevails for several hours in the morning. But the bare red plains of South Tinnevelly are soon heated by the hot forenoon sun above the temperature of the sea, and the varified air rises over them and demands an inflow of the cooler denser air from the seaward; at first affected by the previously prevails northerly wind, which however is ultimately completely reversed. It may be noted here that at the distance of a few miles inland the onset of the sea breeze is marked by violent whirlwinds of small extent travelling with the prevailing wind but rotating on their own axis, (so far as could be learned or observed during two seasons) (thus, ) against the ordinary watch-hands' motion.

The sea breeze would not seem to extend to any great height, for the see clouds continue all day to course over the district in the upper strata from the N.E., their normal direction for this and the preceding seasons, at an elevation (by estimation) of perhaps 1,000 to 2,000 feet unaffected by it.

The southing of the sea breeze in the afternoon seems sufficiently accounted for by the extended influence of the heated plains of Tinnevelly and Madura, to the North, but the evening westing of the sea breeze may possibly require some farther force, such as the indraught demanded by the West-coast of Ceylon in the after-noon.

Sea breeze on the West coast.

In February and throughout March the daily sea breeze prevails on the Western coast of India in Travancore. Grand masses of cloud are seen forming on the western slopes of the mountains and rising above the gaps and ridges of the range, higher and higher as the season advances. When they over top the range and meet the N.E. current and its stratum of clouds, great atmospheric disturbance and a grand electric display ensue, and may be seen every afternoon or evening for several weeks together, although there is a continuous play of lightening seen on the clouds for some hours, apparently no rain-falls. These aereal cloud and lightening storms seem to have favorite haunts amongst the mountains, one of which lies between Kalkad and Agastiyar Mallei about the sources of the Tamrapurni river.

Lightening storms in the mountains.

A similar display is frequently seen also some miles out at sea in the gulf of Manar about this season.

Sometimes light fleecy clouds are to be seen proceeding from the S. West in a still higher stratum of the air than that of the N.E. current.

April.

About the beginning of April clouds from the West settle on the mountains in the afternoon, and evening thunder-showers occur in their neighbourhood. Thunder-storms also come up from the East during this month, and break in favorable spots in cool and refreshing but partial showers accompanied or preceded by dust storm and sudden changes of wind.

Interference fringes common.

The phenomenon of interference fringes is not uncommonly seen on the clouds about the Western hills an hour or so before sunset when the piles of cumuli have mounted to a height of several thousand feet and their summits are surmounted by thin sinuous streaks of mist or cirro stratus cloud, distinct but pale fringes of the prismatic colors appear on these streaks and on the fleecy mist hanging about the denser cloud, at a distance of about 15° from the sun which is hidden from view. Very frequent and beautiful displays of this phenomenon have been observed by the writer on similar clouds along the Eastern Ghats after the afternoon thunder-stroms which occur from May to August.

In April the S.W. monsoon (wind) commences with several days blow from the S.W. accompanied by excessive haziness and heat.

S.W. monsoon wind begins.

The sea breeze on the eastern coast fails, or is only felt close to the sea, and then probably as a "long-shore" wind. The N.E. wind has also disappeared, or is only to be traced in the upper regions of the atmosphere.

Towards the end of April the hot westerly winds set in more regularly and with some violence.

Hot westerly winds.

On the south coast they are (S.Wly.) "long shore" winds: farther inland they are hot westerly dusty winds and in the central and northern parts of the district they blow from a point or two north of west.

May.

The last few days of April and the 1st fortnight in May are the hottest in the year, the proverbial "fire-days" of the Tamil inhabitants, the temperature of the air in the shade out of doors not uncommonly rising to 100° Fahrenheit from 11 A. M. till 3 P. M. It has been witnessed at 108° daily for a week in a large double-fly tent.

The "fire-days."

At 10 A. M. it is usually about 90° and at dawn 85°. Dust-storms accompanied by thunder-showers, and occasionally, but rarely, by a fall of hail, occur in some parts of the district lowering the temperature considerably.

Thunder-showers with dust and occasionally hail.

The prevailing wind throughout May is westerly or a point or two north of west.

The westerly direction of the s.w. monsoon wind.

This westerly declension of the so called south-west monsoon wind is a curious fact very commonly noticed by ordinary observers in southern India. Local or provincial influences that may help to cause it exist in the fact of the excessive heat of the eastern and south-eastern parts of the district which are, in Tinnevelly, arid sand wastes. Also in the probability that the supply of fresh air for rarefaction in this furnace is drawn from the uplands and mountains on the west and N.W. of the district. The low heated plains of the northern part of Ceylon and the shallows of the gulf of Manar may also assist.

Causes suggested.

But all this seems inadequate to produce even the local part of the phenomenon, which in fact obtains far more generally, and probably some more general influence exists which causes the equatorial current, (that is the indraught of denser air to supply the rarefaction of the more heated districts—) which in this instance one would suppose to be a southerly wind to supply the greater rarefaction going on in the more heated districts where the sun is vertical and the mean monthly temperature so much higher as it is in the plains of northern India and southern Asia, to flow from the west.

The fact remains that the prevailing wind during May, June and July over the greater portion of southern India is more west than south-west, the sea breeze on the east coast is reversed and in some parts of the west coast (see table IV) arrives from a quarter considerably north of west. The direction of this wind accords generally with the slope of the country east of the W. Ghats and it is not difficult to conceive a sufficient want of statical equilibrium to account even for such violent effects as those here observed. The difference of temperature of the surface of the Bay of Bengal and the Indian Ocean may be an efficient cause of the phenomenon commented on.

June.

Early in June the so called S.W. monsoon "breaks" on the Western Ghats in torrents of rain and the first freshes flood the Tamrapurni. The rain does not extend, except in partial and light showers east of the mountains but the temperature of the air is lowered and cloudy weather prevails. The climate of Kurtallam[9] is very agreeable at this season and much resorted to for health and comfort. The place (in Lat. 8° 56′ N.) is favourably situated in a bay or recess in the mountains, (near Tenkashi) at the eastern entrance of the Ariangaval pass, and at the falls of one of the chief affluents of the Chittar river.

Rainy season on the Western Coast.

Kurtallam.

NOTE.—(9) Kurtallam (vulg. Courtallum) from "Kuttru-alam" the antidote of sin.

It enjoys the benefit of the western wind as from a funnel, after it has passed through the gaps in the mountains and lost most of its moisture and now descends in cool breezes whilst perpetual clouds overhead shelter it from the sun.

With an elevation of only 300 feet to 400 feet, the temperature of the air is 10° cooler than it is a few miles distant in the plains to the eastward.

July and August. Westerly gales.

Throughout July and August the westerly gales continue to prevail and often blow with extreme violence, tearing up the light surface soil, raising clouds of dust and carrying the finer parts far away. The sails of vessels at Pambam, about 120 miles to N.E., are said to be coloured by the red dust of S.E. Tinnevelly, thus shewing that although westerly on the surface of the land there is an upper current of S.W. wind at this season.

Long drought.

The absence of rain is most marked during June, July, August and September, the mean duration of the rainless period being recorded as 16 weeks from a register kept for 22 years. This drought and the denudation of the surface soil of its finer or lighter portions by the violent W. winds are principal causes of the sand wastes of S. Tinnevelly. *(See note on the Theri.)* Meanwhile the rainy season continues to deluge the western coast producing the tropical luxuriance of foliage for which it is as remarkable as S. Tinnevelly is for its absence.

September.

In September the westerly gales begin to fail, and in October the polar current again comes into play alternating with the equatorial as a surface wind, and eventually becoming a moist warm N.E. wind from the Bay of Bengal.

Octr. and Novr. "The rains" of the east coast set in.

About the middle of October after some fitful showers and changes, the North-East monsoon and with it the rainy season of Tinnevelly (and generally that of S. Eastern India) sets in, and the showers attain their maximum frequency by the end of the month.

Particulars from Dr. Caldwell's register at Edeyengudi.

From Doctor Caldwell's rain register kept since 1845 at Edeyengudi, a mission station two miles inland on the south coast, it appears that in the two weeks, one before and the other after the 31st October an inch (0″·95) of rain per diem falls on four (4·2) days every year, also one (1·0) inch per diem falls on two or three (2·5) days in the first week in November every year. The heaviest falls of rain occur in the last fortnight in November when the mean fall is an inch and a half (1″·4) per diem on three (3·1) days.

The rainy weather is not without intermission and there appear some marked periods without rain, as for instance the 18th and 26th October, and 8th November on which days less than an inch of rain fell in 22 years. November is the rainiest month, the mean fall at Edeyengudi (where the annual fall is about one-third (¼) less than the mean of the whole district) being (7″·87) nearly eight inches, on seven or eight (7·59) days in the month.

December.

The rains begin to fail about the first week in December, but a week of cloudy showery weather may be expected about the end of the month.

The rainfall.

Taking the rainfall as registered at ten places in the district (for the ten years 1853-62) as a fair average of the whole, the mean annual rainfall in Tinnevelly is 35 inches (between 59 inches in 1854 and 20 inches in 1857), nearly two thirds (0·6) of which falls during "the rains", that is, in October, November and December, in the N.E. monsoon.

Locally, the annual rainfall seems to increase with the distance from the sea on the S. or S.E. coast and with the proximity to the mountains on the west of the district (see table III).

Places situated along the skirts of the Western Ghats and opposite gaps in the range have a much larger rainfall than others out in the plains to which the early spring showers and the western monsoon contribute a considerable share.

The general character of "the rains" consists in several spells of cloudy rainy weather lasting from 4 to 9 days at a time, and in the irregularity of the date and amount of the fall. At Edeyengudi the heaviest N.E. Monsoon rain of late years was 36·7 inches, which fell in 1862 (which was generally a year of excessive rain throughout the district), more than three quarters (0·8) of the fall for the twelve-month.

In 1856 only 5·6 inches fell in "the rains" out of 7·4 inches for that year.

The N.E.Monsoon rain is not recorded to have failed entirely.

The rainfall. Tendency to periodicity.

The successive recurrence of relatively wet and dry seasons compared with the mean of 22 years' register at one station and of 10 years at nine other stations, shews a tendency to periodicity; thus, from the average or general mean, which for the former is 22 and the latter 35 inches per annum.

The 3 years	1845-46 and 47,	shew a mean	excess of	9·6	inches.	from a single register.
„ 4 „	1848-49-50 and 51,	do.	defect of	7·6	„	
„ 5 „	1852-53-54-55 and 56,	do.	excess of	10·9	„	includes the results of 10 registers.
„ 5 „	1857-58-59-60 and 61,	do.	defect of	10·3	„	
„ 2 „	1862, and 63,	do.	excess of	9·6	„	from a single register.
„ 4 „	1864-65-66 and 67,	do.	defect of	4·9	„	

The year 1846 is exceptional, but not sufficiently so to alter the apparent tendency to excess in the mean of the 3 years. It is a curious fact that these periods agree to some extent with the periods of maximum and minimum spots in the sun, supposing the maxima to have occurred about 1850 and 1860, and the minima about the years 1845-55 and 1866 with the single exception of the last instance.

Note on the "therei" (red-sand-wastes) of S.E. Tinnevelly.

Locality.

The Theri(s) or red-sand-wastes are a peculiar feature of the district, and seem to call for special notice as being of serious interest to the inhabitants and the subject of curiosity to all who have observed them, and on account of the instance of rapid physical change on the earths surface which they offer.

The Theri is found in patches of 10 or 15 square miles extent, more or less continuously for 40 or 50 miles along the south-east coast, from Vijayapathi running 25 miles N.E. by E. to near Kulasekharapatanam and Trichendur, and thence turning northwards with the coast line for about 20 miles to the basin of the Tamrapurni river, on which it has encroached. Near Alvar Tirunagari (often miscalled Alvar Tinnevelly).

Mengnanapuram.

Each part of the Theri has a different local name, that of the largest lying east of the mission station of Mengnanapuram (Gospel town) is called "Karrukuvalan-koil Therei" and on the north side Nadukandan (country over-looking) Therei. This Theri is said to be 9 miles long N. and S., and 4 or 5 miles wide, E. and W.

Features.

The Theri consists of a tract of wavy slopes and hillocks of bright red drift sand, culminating in drift heaps 30 to 50 feet above the rest of the Theri, and perhaps 80 to 100 feet above the surrounding plain.

The colour is a bright orange or brick red, and has been called a "rose-red" by one of the residents. The depth of the loose sand varies from ½ a foot on the western slopes to 5 or 6 feet, and in the drifts to 20 feet and upwards.

Features of the Theri.

The sand is composed of coarse and fine grains of quartz and perhaps other ingredients, and a considerable admixture of fine black grains of iron ore.

Below the drift sand a darker red soil is found, more or less indurated, and from 5 to 8 feet in thickness. In the wind gullies this is exposed to view and appears to be much cut up by running water. This soil seems to be composed of much the same ingredients as the sand above with the addition of ochre like clay or loam:—it is easily affected by water, and when separated and dry affords an impalpable brick dust powder.

Below the compact red soil again there is a substratum of grey sand-stone, said to contain flints embedded in it, and here and there, mixed with, or replaced by, limestone glomerate.

Irrigation from ooze springs.

A peculiar feature of the Theri lies in the fact that a spring of water, in some cases perennial, flows or rather oozes from beneath the sand at the edge of the Theri in sufficient quantity to allow of regular wet cultivation from it.

The plantain is a common produce from the ooze fields or gardens under the Theri. The ooze is chiefly on the eastern side of the Theri, also on the N. east and S.E., but scarcely at all on the west.

The Theri.

The native inhabitants regard the Theri as the result of superhuman agency, and they have various traditions on the subject. By the English, it is said, the Theri has been regarded as an unique phenomenon, hitherto unexplained.

The following considerations and suggestions were gathered during a fortnight's personal observation in the Theri country in April 1869, and from the accounts of the natives, and from the missionary residents in the neighbourhood.

Explanation suggested.

The Theri appears (to the writer) as if it were the small remnant of a much larger tract of similar formation which once occupied the low country of S. Tinnevelly, east of the mountains.

Considerations about the formation of the Theri.

The soil seems to have been composed of the detritus of gneiss and other rock in which quartz (and perhaps felspar) was very plentiful, such as that which is so commonly seen in the pink (red and white) "parrambu(s)" "gravel wastes" of Tinnevelly, together with some iron ore in the shape of fine black grains, like "diamond gunpowder", and a large proportion of clayey soil mixed.

Considerations regarding the Theri.

It is readily affected by the weather, and 20 to 30 inches of rain per annum is sufficient to wash the surface clear of the soil and leave pure sand at the top which the violent westerly winds have no difficulty in moving. The finer and lighter portions of the soil are taken up and carried to a great distance, (the sails of vessels at Pambam, 100 miles N.E. by E. are said to be coloured red by this dust) whilst the larger and heavier grains remain tossed into regular billows, drifts and hillocks of pure bright red sand, which travel at a rapid rate eastward with the prevailing wind which is westerly and blows violently for three or four months every year.

It is a curious fact that the intervening tract between the Theri and the sea on the leeward, (i. e. the eastward) side, several miles in width is not covered or coloured by the duststorms blowing over it.

The natives on the western side asserted that the edge of the Theri does not alter, but those on the east, north-east and south-east have quite a different tale, and there can be no doubt that the whole body of the drift sand does move eastward year by year.

East-ward motion.

A report is on record in the Collector's Office that the sand in 1848 had moved 20 chains eastward during the previous four years; and both before and since that time annual complaints have been made that the irrigation channels on the N.E. have been silted up by the drift sand; and large sums have been sanctioned and spent in clearing them.

Village overwhelmed.

Villages are said to have been buried on the east side. One village named Senkuli, on the N. east, is stated to have been overwhelmed by the sand about 40 years ago (about 1829), and its site is still marked by some half buried mango trees and the remains of a well.

The encroachments of the drift sand would seem to incline to the north of east, in as much as in April and May during the hottest weather and before the westerly gales set in

a southerly or south-westerly breeze obtains for some hours every day. Perhaps also the regular westerly gales deviate more towards the south-west than towards the north-west.

On the western side the palm forest seems to be slowly creeping eastward after the retreating sand and probably the whole of it as far as the Nat-aru, (the Naut-aur of the old atlas sheets,) 10 or 15 miles to the west, and 20 miles to the S.W., is reclaimed Theri.

The fact that the moisture stored in the Theri oozes out and flows on the seaward and the river basin sides points to the antiquity of the red soil stratum, and would seem to shew that these peculiar sandhills are not a recent local deposit made by the prevailing winds.

Efforts to stop the encroachments.

Efforts have been and are being made by the inhabitants to stop the encroachments of the Theri, and the Collectors of the district have given the matter their attention, and have been supported by the Government in encouraging planting out the drift by exempting trees grown upon it from taxation. The success does not appear to have been great hitherto. Without doubt the growth of creepers, grass and weeds must have a good restraining effect—but nothing can prevent the onward progress of the drift as long as there is soil left to provide fresh sand of sufficient lightness to be drifted, unless it is stopped on the windward, *i. e.* the westward side, where the most strenuous efforts should be made. But the inhabitants who suffer most do not live on the windward side, and unless special steps are taken on their behalf the deluge of driven sand must roll on, and, if slowly, not the less surely, sooner or later overtake them.

Unsuccessful.

Palmyra unsuited for planting out the drift.

The Palmyra palm though congenial to the soil and the habits of the people does not seem well chosen to reclaim the Theri: for, though it will spring up readily in the sand, it has no sooner formed a head of leaves than the scour of the wind denudes its roots, and in this way a large proportion of the plants die.

From observations made during very hot weather in April, the heat of the Theri does not appear to be so excessive as one might expect, nor does it penetrate to any considerable depth; hence the rain water stored in these sand wastes (and little or none of it is lost by surface drainage) does not evaporate rapidly.

Surface temperature.

A thermometer just covered by sand in the middle of the Theri registered 128° whilst one similarly exposed in the soil off the Theri registered 130°, the air temperature at 5 feet from the ground in the shade being 100° Fahrenheit.

Banian stakes to be planted to windward suggested.

It seems probable that Banian stakes if planted deeply enough to reach the moist subsoil would grow readily, and together with the indigenous thorn bush afford shelter for other and more profitable species, or at least help to break the force of the wind. But whatever is done in this way should be begun on the windward side, and little or no permanent success can be expected from planting on the leeward side alone.

Unless something is done to prevent it, it is much to be feared that the southern branch of the Tamrapurni irrigation project, now in progress, will prove more or less of a failure from the expense of clearing out the channels near the eastern side of the Theri.

The palmyra palm may be said to be almost the life and wealth of the Shanar inhabitants of the sandy tracts of south-east Tinnevelly:—little else will grow in such a soil and produce a crop without artificial irrigation.

A Tamil poem enumerates 800 uses to which the palmyra and its produce are put. The following are a few of the principal uses.

(1.) The juice which flows from the cut or pressed flower is tadi ("toddy") to drink, and if left to ferment becomes intoxicating in a few hours.

(2.) The same juice when gathered in lime-washed vessels does not ferment, and is called "pathani". This "pathani" when boiled down becomes jagari (jaggery) a coarse dark

sugar which is one of the chief articles of food amongst the people and is said to be wholesome.

Sugarcandy (Pannakal kandu) is made by allowing the boiled juice (pathani) to remain and crystallize.

(3.) The husk or outer pulp of the fruit (Nungu) when ripe and roasted is edible and so is the pulp inside the three kernels composing the fruit.

(4.) The fruit (Nungu) after being buried 3 months sends forth shoots or sprouts (Kayangu) which are eaten roasted. If left for a year each kernel should produce a plant which after 10 years favorable growth bears fruit.

Uses of the Palmyra.

The leaf of the Palmyra is used for:

(5.) Thatching houses, the walls of sheds and huts, for screens and all kinds of shelter from sun, wind and rain.

(6.) The paper and books of the country.

(7.) Water vessels of all sizes from well buckets to drinking cups.

(8.) Basket-work, sieves, matting, umbrellas, hats, sandals, fans, and ornamental work.

(9.) The fibre of the leaf stalk is used to make all kinds of rope, yarn, and twine.

(10.) The refuse parts of the leaf stalks and leaves is the fuel of the country, especially useful for boiling down the juice on the spot where it is gathered.

(11.) On felling a palm tree the cabbage or heart of the leaves at the top is eagerly cut off and eaten.

(12.) The seasoned wood of a full grown tree is valuable for builders and carpenters use. It is used entire for upright posts and piles, and for beams: also when cut for rafters and planks; is hollowed out for troughs, channels, tube drains, canoes &c., and the bole at the root forms a large and handsome well bucket.

It is said that forty to sixty trees are required to support one family, and the Shanar "pater-familias" has to climb his fifty trees twice a day; and in the best season even three times:—no easy lot, when the trees are about 40 feet in height.

Explanation of the Tables and sources of information.

The foregoing description of the country is chiefly derived from the printed report on the district by Mr. R. K. Puckle, c.s., the Collector. The annual course of the weather is principally from Doctor Caldwell's information and his interesting note attached.

Table I. is from a copy of the rain register of the Revd. R. Caldwell, L.L.D., made at Edeyengudi a mission station of the Society for the Propagation of the Gospel, two miles inland from the sea on the south coast of Tinnevelly, and on the "Theri" or red sand waste and palm forest country. The columns "wind" and "remarks" have been filled up from local information.

Table II. is derived from the same sources.

Table III. has been compiled from the civil district (Taluk Kacheri) rain registers deposited in the Collector's office at Tinnevelly and from Doctor Caldwell's register, beforementioned:—there seams reason for supposing the results tolerably accurate.

Table IV. The first (left hand) half of table IV is derived from the values obtained at the Trevandrum* observatory published in the Trivandrum almanac for 1869. The other half

* Trevandrum ordinarily pronounced Tiruvandarrum, short for Tiru(v) Ananda-puram-Saint-Anand's Town. The Capital of Tiru Ananda kodur.

is the result of one years observations made in the office of Captain G. A. Phipps, Master Attendant at Tuticorin, except the column for the rain which is from table II and the temperature column which is derived from casual observations and local information and the mean from analogy.

This table (IV) is intended to convey an idea of the climate on the east and west coasts of southern India in latitude 8° 30′ to 8° 45′ when they are only about 100 miles apart.

The spelling of the names of places in these notes is generally that adopted by scientific men. In doubtful cases an attempt has been made to convey the pronunciation by a use of phonetic spelling; the names of well known places are spelt as they are most commonly printed.

B. R. Branfill, *Captain*
Great Trigonometrical Survey of India.

MONTHLY rainfall and number of wet days at Edeyenguḍi, South Tinnevelly District from the Rev. Dr. Caldwells Rain register for 22 years 1845-1867.

Remarks.	Sums. Annual Amount / Wet days.	Decr. Amount / Wet days.	Novr. Amount / Wet days.	Octr. Amount / Wet days.	Septr. Amount / Wet days.	August Amount / Wet days.	July Amount / Wet days.	June Amount / Wet days.	May Amount / Wet days.	April Amount / Wet days.	March Amount / Wet days.	Feby. Amount / Wet days.	Jany. Amount / Wet days.	Year.
Excess of 12″·0 over 22 years mean.	Inches. 34·03 31	″ 9·45 6	″ 4·50 10	″ 11·08 10	No rain fell during 6 months and 18 days.						″ 6·50 4	″ 2·50 1	7 weeks	1845
1845-46 and 1847, shew a mean excess of 9·1 inches over mean of 22 years.	17·35 25	3·25 4	5·80 6	0·75 3	14 weeks.			0·55 1	2·30 3	0·60 1	2·95 5	0·40 1	0·75 1	1846
Excess of 20″·5 maxm. frequency.	42·44 56	7·30 6	8·95 12	4·65 5	·32 2	6 weeks.	·59 2	1·65 3	2·30 3	7·96 9	3·11 6	5·31 7	·30 1	1847
Minimum daily fall = 0″·48	9·65 18	2·20 6	3·30 4	1·90 3	22 weeks.				·15 1	·85 2	1·15 1	·10 1	7 weeks.	1848
1848-49-50 and 1851, shew a mean defect of 7·6 inches below 22 years mean.	15·40 32	·45 2	6·10 10	·30 3	·35 3	1·55 6	11 weeks.	·75 1	·25 1	1·20 1	2·90 3	8 weeks.	1·55 2	1849
	17·45 20	3·75 5	8·90 10	1·00 3	21 weeks.				2·50 1	12 weeks.		1·30 1	6 weeks.	1850
	15·98 19	1·30 2	5·65 5	2·55 3	22 weeks.				5·30 2	·80 4	·20 1	·18 2	5 weeks.	1851
Excess of 17″·4	39·60 36	7·85 8	25·05 15	·85 2	11 weeks.		1·40 2	·45 2	3·95 6	8 weeks.		·05 1	8 weeks.	1852
1852-53 and 1854, shew a mean excess of 4·7 inches over 22 years mean.	15·80 22	7 weeks.	1·15 3	9·25 8	No rain for 22 weeks.					·80 3	·45 1	1·50 1	2·65 6	1853
	25·25 29	1·60 2	12·05 11	7·80 7	10 weeks.	·25 1	·20 2	9 weeks.	1·60 3	·35 1	·40 1	1·00 1	6 weeks.	1854
No record at Edeyenguḍi.	No record this year.													1855
defect of 14″·8 The Minimum.	7·40 13	4·05 5	0·50 2	1·00 3	·60 1	No rain for 28 weeks.					1·25 2	9 weeks.		1856
Maximum daily fall = 1″·21	16·45 13	9 weeks.		7·90 6	22 weeks.				·70 1	4·35 4	16 weeks.		3·50 2	1857
1856-57-58-59 and 1860, shew a mean defect of 6·4 inches below 22 years mean.	14·75 21	·15 1	5·70 9	2·25 4	7 weeks.	·50 1	12 weeks.		3·85 5	1·90 2	·25 1	0·15 1	7 weeks.	1858
	26·99 28	2·55 5	17·15 12	3·67 4	·37 2	1·65 1	9 weeks.	·15 1	10 weeks.	·55 1	·90 2	12 weeks.		1859
	13·50 17	7·15 6	2·00 3	3·85 7	20 weeks.				·50 1	20 weeks.				1860

from Dr. Caldwells register 1845-1867.

1861	1862	1863	1864	1865	1866	1867	22 years sums amount wet days.	Mean Monthly fall & wet days.	Proportion of wet and dry seasons.	MONTHLY. Mean fall on wet days inches.	MONTHLY. No. of wet days.	The wind.	REMARKS.
·55 3	1·40 2	2·15 1	5 weeks.	22 weeks without rain.	2·50 2	8 weeks.	″ 15·35 20	″ 0.70 0·91	In January. In 9 out of 22 yrs. „ 13 „ 22 „	″ 0·77 none	2·2 days.	Northerly gales.	
5 weeks.	2·70 3	1·90 2	·90 1		2·52 2	1·65 2	″ 22·16 27	″ 1·01 1·23	In February. „ 15 out of 22 yrs. „ 7 „ 22 „	″ ·82 none	1·8 „	N. easterly.	A mean period of 9 weeks without rain occurs after N.E. Monsoon.
4·65 2	12 weeks.	1·40 3	11 weeks.		·62 1	11 weeks.	″ 26·73 33	″ 1·22 1·50	In March. „ 14 out of 22 yrs. „ 8 „ 22 „	″ ·81 none	2·4 „	Variable, and sea breezes.	
6·85 3		7·35 5	3·40 3		14 weeks.	·60 2	″ 37·56 41	″ 1·71 1·86	In April. „ 14 out of 22 yrs. „ 8 „ 22 „	″ ·92 none	3·0 „		
16 weeks.	2·45 1	19 weeks.	1·25 2			·63 1	″ 27·70 31	″ 1·26 1·41	In May. „ 14 out of 22 yrs. „ 8 „ 22 „	″ ·90 none	2·0 „		Hazy weather.
	14 weeks.		1·60 4	·75 1	5·36 4	11 weeks.	″ 11·26 17	″ ·51 ·77	In June. „ 8 out of 22 yrs. „ 14 „ 22 „	″ ·66 none	2·1 „	Strong Westerly Gales The South West Monsoon.	A mean period of 16 weeks without rain occurs just before N.E. Monsoon. Season of dust storms.
			10 weeks.	2·15 3	16 weeks.	1·45 2	″ 5·79 11	″ ·26 ·50	In July. „ 5 out of 22 yrs. „ 17 „ 22 „	″ ·53 none	2·2 „		
1·95 4	1·10 2		·50 1	9 weeks.		8 weeks.	″ 7·50 16	″ ·34 ·73	In August. „ 7 out of 22 yrs. „ 15 „ 22 „	″ ·47 none	2·3 „		
·45 1	7 weeks.	·25 1	1·75 1			·65 2	″ 4·94 13	″ ·22 ·59	In September. „ 8 out of 22 yrs. „ 14 „ 22 „	″ ·33 none	3·3 „	Variable and calms.	
3.70 8	6·77 5	8 weeks.	4·85 5	5·54 6	1·87 4	10·70 6	″ 92·23 108	″ 4·19 4·91	In October. „ 21 out of 22 yrs. „ 1 „ 22 „	″ ·85 none	5·1 „	North-East Monsoon.	"The Rains."
7·72 6	28·43 17	18·00 11	·70 4	·75 2	7·35 9	2·95 6	″ 173·20 167	″ 7·87 7·59	In November. „ 21 out of 22 yrs. „ 1 „ 22 „	″ 1·04 none	8·0 „		
6 weeks.	1·50 6	5·35 6	1·00 2	3·49 3	·37 1	·35 1	″ 63·31 77	″ 2·88 3·50	In December. „ 19 out of 22 yrs. „ 3 „ 22 „	″ 0·82 none	4·1 „		
25·87 27	44·35 36	36·40 29	15·95 23	12·68 18	21·09 23	19·38 22	″ 487·76 561	″ 22·17 25·5	In 22 years. 155 mos. } Wet in 264 no 109 mos. } rain.	″ 0·87	25·5 „	Wind.	
Excess 22″·18 The maximum double the mean. 1861-62 and 1863, shew a mean excess of 18·4 over 22 years mean.			1864-65-66 and 1867, shew a mean defect of 4·9 inches below 22 years mean.				22 Years Sums { inches. wet days.	22 Years Means { inches. wet days.					

The maximum annual variation is 37 inches between 7″·4 in 1856 and 44″·4 in 1862. The mean annual fall at Edeyongudi is about $\frac{3}{5}$ths that of the whole district.

TABLE II.—*Monthly sums and means of the rainfall at Edeyengudi, on the S.S.E. coast of Tinnevelly, two miles inland, deduced from 22 years observations registered by the Revd. R. Caldwell L.L.D. &c.,* 1845-1867.

MONTH.	22 YEARS RAINFALL. Amount in inches and No. of wet days. Sums.	Means.	Months without rain in 22 years.	Mean fall and wet days excluding dry seasons.	MONTHLY DISTRIBUTION AND REMARKS.
JANUARY, ... Amount,	15·35	Annual. 0·70	13	1·71 ins.	Chiefly in the first week as the end of the (N.E. monsoon) rains. Strong northerly gales prevail steadily the 2nd and 3rd week, abating the 4th and with an occasional heavy shower and cloudy weather. The rain failed twice in 3 years.
No of wet days,	20	·9		2·2 days.	
FEBRUARY, ...	22·16	1·01	7	1·48	Nearly all of it between 4th and 20th once in three years no rain fell in February.
	27	1·2		1·8	
MARCH, ...	26·73	1·22	8	1·91	Mostly about the middle of the month but failed altogether 4 times in 11 years.
	39	1·5		2·4	
APRIL, ...	37·56	1·71	8	2·68	Principally thunder showers in the 3rd week and again at the end of the month, but failed entirely 4 out of 11 years.
	41	1·9		3·0	
MAY, ...	27·70	1·26	8	1·98	Thunder showers at the beginning of the month.—S.W. monsoon wind with an occasional shower and clouds during the last few days. No rain at all 4 years out of 11.
	31	1·4		2·0	
JUNE, ...	11·26	·51	14	1·41	Clouds and drizzle the first few days and occasionally a shower or two about the 18th, the rest of June is rainless. The rain failed altogether twice in 3 years.
	17	·8		2·1	
JULY, ...	5·79	·26	17	1·16	No rain fell between 2nd and 15th, or between 19th and 27th and it failed altogether in 3 years out of 4, oftener than any other month, *i. e.* the month of least frequency.
	11	·5		2·2	
AUGUST, ...	7·50	·34	15	1·07	Failed altogether 5 times out of 7 years. A mean period of 16 weeks without rain immediately preceded the beginning of the N.E. monsoon in October.
	16	·7		2·3	
SEPTEMBER, ...	4·94	·22	14	·62	No rain in 2 years out of 3. September is the month of least rain.
	13	·6		3·3	
OCTOBER, ...	92·23	4·19	1	4·39	Failed once in 22 years. The N.E. monsoon rains began about 10th and with a pause about the 17th, increased in frequency and amount till the 6th November.
	108	4·9		5·1	
NOVEMBER, ...	173·20	7·87	1	8·25	At the height of the monsoon rains, an inch fell 2 or 3 times a week. A marked abatement occurs in the 2nd week in November, but a 2nd maximum occurs about the 20th when the rain is the heaviest 1″·6 falling once or twice in the week. After this the rain decreases in amount. Failed once in 22 years.
	167	7·6		8·0	
DECEMBER, ...	63·31	2·88	3	3·33	The rains cease about the 9th and a break occurs with scarcely any rain till 24th when a few rainy days may be expected to occur with cloudy weather during the last week in December or first week in January. Failed 3 times in 22 years.
	77	3·5		4·1	
Total amount, ...	″ 487·76	22·17	Months. 109 in 264	Mean fall on wet days. 0·87 ins.	
Wet days, ...	561	25·5			

TABLE III.—*The Rainfall at ten stations in the Tinnevelly district* 1853-1862.

YEAR.	Edeyengudi.	Tuticorin.	Otapidaram.	Srivaigundam.	Nanguneri.	Satur.	Tinnevelly.	Shankaranainarkokovil.	Strivelliputhur.	Tenkashi.	Mean annual fall	REMARKS.
	Inches.	"	"	"	"	"	"	"	"	"	Inches.	
1853	15·8	37·2	47·1	46·8	36·5	50·9	54·5	51·4	51·2	50·2	44·2	
1854	25·3	79·0	74·6	60·2	46·6	50·8	60·4	45·6	67·7	79·9	59·0	The 4 years 1853 to 1856 shew a mean excess of 9·2 inches over the 10 years mean.
1855	No record	30·3	41·6	31·8	33·9	37·4	28·9	42·4	43·8	55·2	38·9	
1856	7·4	24·5	34·6	21·6	38·3	61·7	30·9	39·9	40·5	57·0	35·6	
1857	16·4	18·8	24·3	15·1	17·9	16·6	25·0	11·3	8·4	41·7	19·6	
1858	14·8	16·6	24·0	25·7	29·3	26·3	29·2	31·2	72·1	46·0	29·4	
1859	27·0	27·2	28·8	39·7	43·8	33·6	44·7	39·9	29·5	58·3	27·3	The 5 years 1857 to 1861 shew a mean defect of 10·3 inches below the ten years mean.
1860	13·5	12·2	17·4	21·6	13·2	32·4	24·5	30·5	19·8	16·9	20·2	
1861	25·9	26·6	17·2	17·9	27·6	25·4	30·9	33·9	29·3	43·3	27·8	
1862	44·3	43·8	50·0	24·2	41·0	30·5	62·5	39·3	26·6	No record	40·2	Year of heavy and long monsoon rains.
Mean	21·2	31·6	36·0	30·5	32·8	36·6	39·2	36·5	38·9	49·8	35·2	
Distance and direction of nearest sea shore,	2 *ms.* S.S.E.	½ *m.* E.	10 *ms.* E.	17 *ms.* E.	19*ms.*S.E. × S.	35 *ms.* S.E.	34 *ms.* E.	47 *ms.* E.S.E.	55*ms.*S.E. × S.	60 *ms.* E.	(28*ms.*E.S.E.)	The General slope of the plain country is 2 to 6 feet a mile from E. S. E. to W. N. W.
Distance and direction of the mountains, ...	24 „ W.	52 „W. × S.	50 „ W.	28 „ W.	9 „ W.	30 „ W.	18 „ S.W.	12 „ W.	12 „ W.N.W.	4 „ S.W.	(24 „ W.)	

From Doctor Caldwell's Rain Register.

The rainfall at the nine stations above named is taken from the district (Taluk Kacherry) Rain Registers in the Collector's Office at Tinnevelly.

TABLE IV.

	West Coast Travancore at Trevandrum Observatory 197 feet above sea.								East Coast Tinnevelly at Master Attendant's Office on Beach Tuticorin harbour.										
	Barometer 197 feet above sea.		*Temperature.*			*Rainfall.*		*Wind.*	*Barometer about 20 feet above sea. Mean of observations at 10 a. m. and 4 p. m. un-reduced.*			*Temperature.*			*Rainfall.*	*Wind and number of days.*		
	Reduced mean pressure.	Mean daily range.	Air.	Range.	Wet bulb below dry.	Amount.	Wet days.		Max. & Min. 2	Range.	Thermometer.	Maximum.	Minimum.	Mean.	22 years mean fall at Edeyengudi.	North-East monsoon.	Sea breezes.	S. West monsoon.
	Inches.	Inches.	°	°	°	Inches.	Days.		Inches.	Inches.	°	°	°	°	Inches.	Days.	Days.	Days.	Days.
January, ...	29·736	·144	76·17	21·8	6·1	0·839	2·6	W.	30·03	·054	82	88	77	81	0·70	0·9	N.E. 31		
February, ...	·720	·120	77·90	21·9	6·7	·588	1·5	W. by S.	30·00	·056	84	90	78	83	1·01	1·2	N.E. by E. 27	Variable 1	
March, ...	·688	·149	80·52	20·4	5·9	1·842	3·9	W. by N.	29·95	·074	87	93	79	85	1·22	1·5	N.E. to E. 17	E. to S.E. 14	
April, ...	·643	·146	81·21	18·5	5·1	4·582	9·8	W. by N.	29·89	·057	89	97	81	88	1·71	1·9	E.N.E. 6	S.E. by E. 22	Variable 2
May, ...	·643	·136	79·25	16·3	4·2	12·806	16·4	N.W. by W.	29·84	·069	91	98	82	90	1·26	1·4		E.S.E. to S. 19	Variable 12
June, ...	·638	·135	77·85	15·2	3·2	12·253	22·9	N.W. by W.	29·90	·052	92	96	83	89	0·51	·8		Variable 4	W.S.W. 26
July, ...	·651	·115	76·73	14·6	3·0	7·101	19·0	N.W. ½ W.	29·87	·041	88	93	84	87	·26	·5		E.S.E. 11	W.S.W. 16
August, ...	·663	·109	76·52	13·5	3·2	4·351	15·4	N.W. ½ W.	29·89	·050	89	91	85	87	·34	·7		E.S.E. 18	W.S.W. 13
September, .	·685	·112	77·18	14·9	3·6	3·314	10·3	N.W. by W.	29·90	·050	89	90	83	86	·22	·6	Variable 5	S.E. by E. 12	W. by S. 13
October, ...	·689	·157	76·86	15·1	3·4	11·301	16·1	W.N. W.	29·92	·070	83	87	80	82	4·19	4·9	N.E. to E. 13	E. to S.E. 13	
November, .	·707	·126	76·83	17·5	3·5	6·671	13·1	W. by N.	29·98	·054	83	86	79	81	7·87	7·6	N.E. 23	S.E. 6	
December, .	·728	·123	75·92	21·8	5·1	2·831	5·3	W.N. W.	30·02	·051	81	85	78	80	2·88	3·5	N.E. 31		
Means, ...	29·683	·131	77·74	17·63	4·4 Sums	68·473	136·3	W.N.W.	29·97	·057	86·3	91	81	85	22·17	25·5	N.E. by E. 148	E.S.E. 121	W.S.W. 68 Variable or calm 28 days

Marine barometer in wooden case and scale on bone by P. P. Gaily and Co.

These quantities are about half those shown by an aneroid.

Thermometer by Vincent.

The highest observations.

The lowest observations.

Estimated or inferred.

Station 2 miles inland 40 or 50 miles S.W. of Tuticorin.

Relative heights above the sea of some places in the Tinnevelly District and of the Travellers' bangalows on the road from Palamcottah to Trichinopoly, viâ Madura, by aneroid observations.

District.	Name of place or station.	Height by observations made in April and May 1869.	Deduced from 3 daily readings of one aneroid in November and December 1868.	Colonel Lambton's trigonometrical values altered slightly.	Remarks.
	Sea level at Trichendur.	Middle of April. feet.	feet.	0 (A) feet.	
South Tinnevelly.	Odangudi Christianagram,	55			Mission house close to Angl. Prot. Church.
	Satankolam,	90			Camp north side of village.
	Ittamoli,	70			Do. Do. Do.
	Thika Vijayanarayanam,	135			Do. South-East of lesser Vijayanarayanam.
	Valliur,	270			Do. On plain N.W. of village and E. of road.
	Tirukurungudi,	400			High road west of town.
	Entrance to hills coffee sheds,	710			On grants road to Swami Kuchi Mallei pass.
Travankore hills.	Foot of Pass,	920	From one or two observations with a single aneroid compared with (A) and (B).		Washermans stream at base of steep ascent.
	Swami kuchi Mallei gap,	2870			Saddle of pass to coffee plantations.
	Mahendragherry coffee estate,	3540			Grant's and Fraser's house at top of the plantation.
	Ditto ditto,	2300			Stream at bottom of the plantation.
	Assambu, General Cullens,	3000			Old botanical fruit and coffee garden.
	Miranji Mian's gap,	3780			Saddle S. of Mahendragherry Pannagudi pass.
	Mahendragherry highest,	5430		5464	Old Survey station.
Tinnevelly District.	Kannimapottei H.S.,	...		700(B)	Corrected value by Colonel Lambton (1810).
	Pannagudi,	...	290		Travellers bangalow on Cape Comorin road.
	Nangueri,	340	330		Do. Do. Do.
	Palamcottah,	200	180		Do. Do. Do.
	Knitar,	215	240		Do. Do. on Madura road.
	Koilpathi,	310	„		Do. Do. Do.
	Satur,	185	240		Do. Do. Do.
	"Kootcapaurne" (Kuteaparai),	...		400 (C)	Old Survey and new Pendulum station near.
	Mallapathi,	...		330 (D)	Arupukota, Madura district.
	Virdupathi,	330	420		Travellers bangalow Tinnevelly & Madura road.
Madura district.	Tirumangalam,	440	510		Do. Do. Do.
	Madura,	460	580		Do. Do. on Dindigal road ¼ mile W. of town.
	Melur,	515			Do. Do. on Trichinopoly road.
	Kotampathi,	610			Do. Do. Do.
Trichinopoly district.	Thoverankurchi,	820			Do. Do. Do.
	Veralemallei,	550			Do. Do. Do.
	Trichinopoly,	360			Native Infantry parade ground.
	Ditto summit of rock,	600			In highest temple.
	Ditto Srirangam temple,	340			Taken at base of S. unfinished Gopuram.
Coimbatore.	Pachapaliam,	...		980(E)	Trigonometrical and Pendulum Station near Kangiam.
Maisur	Bangalore, Commissioners,	3190		3055	Flag Staff shew an error of 4½ per cent excess compared with G. T. Survey value 1868.

From daily maximum and minimum observations with aneroids the mean used.

From D. only.

From D. and E.

Note.—Column 3 contains the approximate height in feet, above sea level, of the places named in column 2, as deduced from the readings of three aneroid barometers daily at the 9-30 A. M. maximum and the 4 P. M. minimum, compared with corresponding observations at the sea level at Trichendur on the south coast of Tinnevelly in the middle of April 1869. The observations were made between the 1st April and 14th May 1869.

Column 4 contains the results of observations made at some of the same places by Captain Basevi, who registered his aneroid readings thrice daily, at 10 A. M. at noon and at 3 P. M. during November and December 1868, compared with his corresponding observations at the trigonometrical stations, the heights of which are given in column 5 diminished by about 10 feet for Colonel Lambtons closing error at the sea near Punnei.

The old trigonometrical value of the height of Pachapolliam, has also been diminished by 30 feet, for a mean excess of that amount which is found in most of Colonel Lambtons published heights of the Great Arc Series compared with the values obtained now in the Great Arc Revision.

It is to be remarked that April and May is an unfavorable time of year for these observations, including as it does the period of the change of monsoons and the irregular weather then prevailing.

B. R. Branfill,

Bangalore,)
6th August 1869.)

NOTE ON THE CLIMATE OF SOUTH TINNEVELLY

1869.

By the Revd. R. Caldwell, L.L.D.

The climate of Tinnevelly is one of the driest and hottest in India : the heat, it is true, is never at any time so great as in most districts of northern and central India during the hot season, but on the other hand, there is nothing that can be called cold in the cold season, so that the aggregate annual amount of heat is very great. I consider the heat, especially in the southern part of the district, somewhat less than in Madura, the adjacent district to the north, but considerably greater than in Travancore, the territory adjoining Tinnevelly to the west. The hottest weather is in the month of May, shortly after the sun's passage to the north, and before the south-west monsoon sets in. The highest temperature I have noticed at Edeyengudi, which is situated about two miles from the sea coast and about 25 miles to north-east of Cape Comorin, is 98°: this was in May 1866, but the highest point the thermometer ordinarily reaches in May at Edeyengudi is 95° 93° and is still more common. This is the reading in a room open to the wind at the hottest time of the day, viz., about 3 P M. From the setting in of the south-west monsoon in June, till its termination in October, the temperature varies from 80° to 90°; in November it sinks to about 80° and in December and January, which we regard as our cold season, the thermometer is generally under 82°. The greatest cold I have noticed during this period was 72°; this was on one occasion only, and before dawn. The ordinary temperature in the early morning during the cold season is 77°; during February and March it rises to about 85°. The daily range of the thermometer in the shade is extremely small, being rarely more than 6 degrees.

The rainfall at Edeyengudi during the past twenty-two years, has averaged only 22 inches. This accounts for the remarkable dryness of the air during the greater part of the year, but it also accounts for the scantiness of the vegetation and the extreme dustiness of the greater portion of the district. The rainfall is still less than this in the neighbourhood of Parameshwaripuram,* the place where the Cape Comorin base has been measured. I am sure of the fact, but am unable to give an exact estimate of the amount of the difference.

In the adjacent territory of Travancore, the rain fall is generally double, in some places treble, what it is in Tinnevelly, and hence when one sees both districts at once from the top of any of the peaks in the Ghauts, the contrast between the green, well wooded, well watered district of Travancore and the bare sun burnt fiery looking district of Tinnevelly is very striking.

I attribute the smallness of the rainfall in the south of Tinnevelly, and especially in the neighbourhood of the base line, to the rapid diminution in height and final break down of the mountain range of the Ghauts, in consequence of which currents of heated air, coming from the region opposite to that in which the rain falls, meet the currents of moisture in the lower strata of the atmosphere and give them an upward direction.

The only monsoon which brings rain with it, in the greater part of Tinnevelly, is the north-east monsoon, and this is very variable and unreliable. The south west monsoon, which supplies the Travancore country so regularly and plentifully with rain, brings with it to Tinnevelly nothing that can be called rain, but only at times a few light showers, which are useless for purposes of cultivation, except in the immediate neighbourhood of the mountains. This wind often brings with it a scarcely palpable amount of moisture which cools the atmosphere and refreshes the constitution, though it produces no effect on the soil. This is the same wind, produced by the same causes, as that which is called the hot land wind at Madras; but in the southern part of Tinnevelly, the sea is so near that it scarcely ever feels hot, though it is almost always drier than the North East wind. The chief peculiarity of the South West monsoon wind is its great strength. It is so violent that it is scarcely possible for a tent to stand in it without some special shelter or protection, and in some places it keeps the land in a state of perpetual barrenness by preventing vegetation and even blowing away the fine surface soil.

* Where there is no palm forest.

The rainfall connected with the south west monsoon, commences generally about the 8th of June, and for about eight days after this the sky is wholly or partially overspread with clouds day and night; this is generally called by Europeans the setting in of the monsoon: but the monsoon is properly the monsoonwind, the wind of the season, and this always sets in some weeks earlier. A Tamil proverbial verse says, "the great wind" (that is, the wind of this monsoon) "makes its appearance on the 10th of Chitrai" (the 21st of April), "and retires to its chamber on the 10th of Aippasi" (the 25th of October.) This is pretty nearly accurate as a general rule, but the wind sometimes sets in or terminates sooner or later than this. I have also occasionally known an irregular irruption of the south-west monsoon in March and once as early even as February; occasionally also after the commencement of the north-east monsoon, and even after a heavy fall of rain, I have known a return of the south-west monsoon as late as the middle of November. During the whole time of the continuance of each monsoon the opposite monsoon shows, at least in the higher regions of the atmosphere, an endeavour to re-assert its authority. Clouds connected with the opposite monsoon will be seen from time to time gathering in sheltered loops of the mountain ranges; and when the one monsoon wind falls off a little, clouds will immediately be seen collecting in open defiance of it at the opposite quarter.

The north-east monsoon sets in late in Tinnevelly. It is generally preceded by partial showers from the same direction in September and October, and sometimes as early as August: but the real rains of the season do not set in, in south Tinnevelly, as a general rule before the 1st of November. Sometimes they set in from the beginning of October, more frequently about the middle of October; but in that event there is generally a failure of the November rains. The rainfall is generally about a week later in Tinnevelly than in Madras. The North-east wind sets in ordinarily about a week before the rains; sometimes a fortnight or even a month earlier, but in that event it never blows strongly or steadily. The rainfall connected with the north-east monsoon continues more or less throughout November. Rain is also expected at intervals in December and even in January. Rain about the end of January may generally be expected in Tinnevelly, a circumstance which is I believe peculiar to this district. The north-east monsoon, that is, the north-east wind, continues generally to the middle of February, when it begins to fall off. It sometimes blows with considerable strength, especially between Christmas and the middle of January, but never equals in strength the average strength of the south-west monsoon. From the middle of February to the end of April, when the south-west monsoon is expected, the direction of the wind is very variable, sometimes from the north-east, sometimes from the south, whilst sometimes it fails altogether. As a general rule the land wind, or wind from the north or north-west, blows during the night at this period, and a sea breeze during the day. The sea breeze generally sets in about 10 o'clock A. M., by the time the surface of the soil is warmed by the sun. As the season advances the sea breeze, which begins with the north-east veers round to east, south-east, south, and south-west. The sea breeze of April generally blows from S.S.W.

During this intervening period between the two monsoons, from the middle of February to the end of April, there is generally a good deal of atmospheric disturbance; sometimes a great deal. There is frequent lightning to the South East and North West, that is, out at sea in the direction of Ceylon and over the Ghauts: there are occasional showers, especially in the end of March, about the time called the "petty monsoon" in Madras; and more rarely there have been squalls, generally from the North East, with heavy rain. On one occasion we had a heavy down pour of 6 inches of rain about the middle of March, in connection with a hurricane, which made itself felt at Cochin and to the North West. It is mentioned also in Orme that in March 1747 military operations had to be suspended in consequence of a heavy fall of rain, which covered the country with water.

Tinnevelly is very rarely visited by hurricanes. Only one has been known within the present century: this took place in December 1845; I was in the district at the time, and the loss of life and property was considerable. I have met with a tradition amongst the people of only one hurricane previous to this.

The sky in Tinnevelly is generally tolerably free from clouds, especially at night; rain generally falls during the day much more rarely at night; so that the district is favourably

situated for astronomical observations. On the other hand though the sky is often free from clouds it is still more frequently hazy; so that though there are very few days in the year, perhaps not ten in the whole year, when the sun is invisible the whole day; and though there are still fewer nights in which observations of the moon and the principal stars cannot be taken, yet the atmosphere is generally so hazy as to be unfavorable to the observation of eclipses and other celestial phenomena: occasionally however the sky is perfectly clear and serene, especially after rain. The most favourable period throughout the year for observations is in December and January, during the greater portion of which months the clearness of the atmosphere day and night, is almost every thing that could be desired.

I have long endeavoured to ascertain whether there was any truth in the notion, which is equally common amongst Europeans and Hindoos, that the phases of the moon exercise an influence on the fall of rain. It appears to me certain that the light of the moon tends to cause the clouds to clear away and the rain to cease; but beyond this I have not seen any foundation for the popular notion.

On the whole also it appears to me that there is more rain in these regions after the full moon than before.

Names of places adjacent to the Cape Comorin base, with their meanings.

1. Parameshwaripuram; the town of Parvati. Siva is called by his votaries Parameshwara, the supreme God: hence his wife Parvati is sometimes called Parameshwari. Probably this name has been given to the place in consequence of its vicinity to Rathapuram, where there is a considerable temple to Parvati.

2. Rathapuram apparently means the town of Radha, Krishna's favourite mistress: but the people of the place deny that this is the origin of the name, and say that Radha is a corruption of Raja. They assert that the original name of the place was Raja-raja-puram, and that it was called so after a king, a certain, Raja-raja Chola.

3. Sanganeri: Sangan's tank. Sangan is regarded as a man's name, derived from the Sangam or "Chank" of Vishnu. One of the words for a tank in Tamil is Eri, sometimes in Tinnevelly corrupted into Neri.

4. Kudenkulam: Kuden's tank. Kuden must have been a man's name, but the name is not now in use. The root of the name is Kuda, to join.

5. Vijayapati "Vijaya's lord," that is, Siva. Vijaya is a name of Parvati. Names of this sort are not uncommon, *e. g.* Tripetty near Madras, properly Tirupati," Lakshmi's lord, that is Vishnu.

6. Manpottei: the earth hill. "Man," properly earth, here means sand, as any one who visits the place must see, an immense bank of sand sloping down from a crest of gneiss. Pottei means a rock, a small hill. The original meaning was a heap or lump.

7. Pannei: homestead. The name denotes the family property, the ancestral property, as distinguished from property that has been acquired by one member of the family.

8. Kanniya-Kumari; the Tamil pronunciation of the Sanskrit name of the place, Kanya Kumari; the Cape Comorin of the English. Kanya and Kumari are nearly identical in meaning, the former being commonly rendered "virgin," the latter "maid." The "virgin-maid" referred to, from whom the place takes its name, is Parvati, the wife of Siva, of whose adventures, prior to her marriage with Siva many legends are related. Her father was the Himalayas personified, hence her name Parvati, "the mountain nymph." Her local name at Cape Comorin is Bhagavati. Cape Comorin is reckoned by some Hindus as one of "the seven sacred bathing places." It is but little visited or regarded now, but it is recorded by Ptolemy that, when the Greek merchants came to India about the beginning of the Christian era, it was visited monthly by pilgrims, who came to bathe there in honour of a certain goddess. The pearl fishery extended then from Cape Comorin to Kolkhoi, at the mouth of the Tamraparne river. The Greek name of the Cape was Komar, or Komaria Akron.

9. Mahendragherry, "the mountain Mahendra." The place called by this name by Hindus is the fine precipitous rock which is called by mariners Cape Comorin Nose; by European residents in Tinnevelly, the Nose, or Lord Brougham's Nose. This is a spur from the mountain called by Europeans (but not by natives) Mahendragherry, on which there is a Trigonometrical Station, and which is the highest mountain in the Southern Ghauts, south of the great Agastier. From the Nose, or the true Mahendragherry, the most wonderful leap on record was taken; Hanuman, the monkey god having leaped from the top of it, they say, to Ceylon!

10. Agastier-malei, commonly called by Europeans Agastier. This noble conical mountain, the highest in the range of the southern Ghauts, takes its name from the Rishi Agastya, the traditional civilizer of southern India, who is supposed to have taken up his final residence in this mountain. This mountain was regarded by Hindus as inaccessible, till Europeans found their way to the top of it, and Agastya himself used occasionally to allow himself to be seen perior to the arrival of Europeans. The rain fall on the top of Agastier has been found to amount to no less than 300 inches per annum, whilst the rainfall at Palamcottah, within 40 miles of the base of it is only 23 inches. The river Tamraparni, which irrigates and enriches the central portion of Tinnevelly, takes its rise from this wonderful rain fall. The river is supplied by both the north-east and the south-west monsoon and furnishes abundance of water for two crops a year. Agastya is regarded by Hindus as identical with the star Canopies, the brightest in the southern sky.

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