GENERAL REPORT

ON THE OPERATIONS

OF THE

GREAT TRIGONOMETRICAL SURVEY OF INDIA,

DURING

1870-71,

Prepared for submission to the Government of India.

BY

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Dehra Doon:

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

M. J. O'CONNOR.

1871.

THE OPERATIONS OF THE

GREAT TRIGONOMETRICAL SURVEY OF INDIA,

IN 1870-71.

(1.) The Great Trigonometrical Survey operations carried on during 1870-71 have, in continuation of the general plan for the triangulation of India, produced the following out-turn; viz., of Principal Triangulation with great theodolites 59 triangles, covering an area of 11,203 square miles with a total direct length of 403 miles, and observations for 3 azimuths of verification; of secondary triangulation with smaller theodolites an area of 10,076 square miles on which the positions of 1676 points were fixed and the heights of 467 were determined; of Trigo-topographical Surveying on the one inch to the mile scale 301 square miles, on the two inches to the mile 2,291 square miles, and on the 6-inches to the mile 60,027 acres; of boundary lines and check lines 780 miles; of main lines of double leveling 308 miles by means of which the heights of 166 points of reference were finally determined; of Astronomical Latitude observations 1,353 were taken by which the Latitudes of 15 points were determined; of geographical explorations the reduction of 289 miles of Route-Survey by which the geography of an area of about 13,000 square miles of *terra incognita* has been unravelled.

Out-turn of final work.

(2.) The observations have as usual been made with great care, and a reference to the table given in the margin shows to what a great degree of precision the observers have attained by a steady adherence to the rigorous and scientific system which is prescribed in this Department. The average probable error in measuring an angle being only two tenths of a second.

Observations.

Series.	Probable Errors of Observed Angles.		Errors of Triangles.	
	Number.	Amount.	Number.	Amount.
III ...	15	±0″·26	5	0″·05
IV ...	36	·26	12	·32
V ...	60	·18	20	·44
VI ...	30	·18	10	·54
Averages ...		±0″·22	...	0″·34

(3.) In addition to the above main items there has been the usual out-turn of approximate work for the ensuing season's operations including the selection and building of new stations in extension over a total distance of 453 miles, clearing of hill tops of forest, cutting of rays &c., so as to prevent any delay in the steady advance of the operations at the opening of the field season.

Out-turn of Approximate work.

(4.) The Computing Office has as usual completed a large amount of work and supplied a larger demand for data than even in previous years.

Data supplied.

(5.) A great deal of time and attention has been devoted to the completion and publication of the 1st Volume of Colonel Walker's "Account of the Operations of the Great Trigonometrical Survey," a most difficult and laborious task. This volume was submitted to His Excellency the Viceroy and Governor-General in Council and by his authority copies have since been presented to various individuals and institutions in India and elsewhere. Other copies have been despatched to the Right Honorable the Secretary of State under whose authority copies are now being presented to the various scientific institutions and individuals in Europe, America, &c. The first portion of this important publication may therefore now be considered to be safe from all ordinary accidents. The publication of another volume is being proceeded with as rapidly as is possible with the limited means available for the purpose. Some progress has already been made, but owing to the greatly increased demand for Trigonometrical data the publication cannot be expected to progress even as much as in previous years, unless increased means are placed at my disposal as I now understand they will be, it being not only necessary to place these national records beyond all accidents, but at the same time it being a matter of great importance to make them readily accessible for general purposes.

Publication of Observations &c.,

(6.) During the year considerable progress has been made with the publication of the triangulation charts of the earlier operations and the whole of those appertaining to the present year have already been photozincographed and are now in course of distribution. Considering the very large area of the earlier operations for which

Triangulation Charts.

no charts have as yet been published, it is very desirable that further means should be made available in order to complete them within a reasonable time. These charts are most useful compilations quite complete in themselves containing as they do a very large amount of condensed data. They are usually sufficient to supply data for general purposes and for all ordinary surveys. When not sufficient they are a valuable guide for Superintending Officers who can at once select from them the points &c., which are best suited to act as a basis and check on their proposed work and can indent on this Department for further details regarding the necessary points only. At present Superintending Officers are too much in the habit of indenting wholesale for every point available in a given area whereas with a printed chart before them there is no doubt but that one tenth of the points would generally be more than ample for their purposes. A reduction in this direction is very desirable and this as stated above would to a certain extent be gradually effected by increased means for publishing the charts which would at once enable an officer to limit his demand by a judicious selection.

Records.

(7.) Great attention has been paid to the preservation of the records, in India one duplicate copy in the Surveyor General's Office has in the course of the year been made complete, and Colonel Thuillier, C. S. I., has at my request kindly directed that one of his officers shall report on their state from time to time when an officer of the Trigonometrical Survey does not happen to be available for the purpose. Inquiries are being made as to the state of that portion of the records that was deposited for safety in the India Office; the deplorable loss there of one large volume of the G. T. Survey records points to the necessity for some annual return on this subject to a responsible official in the India Office, or elsewhere, and the Government will be addressed as to this as soon as I am fully informed regarding it. The records in the Head Quarters Office of the G. T. Survey are arranged so as to be readily accessible, they have been carefully attended to, and are all in proper order. Every endeavour will be made as heretofore to protect them thoroughly.

Charts of levels.

(8.) A considerable advance has been made with the reduction and publication of the charts of the various sets of levels in upper India. A large addition has been made to the Tables of heights with descriptions of the G. T. Survey Bench-marks and the publication of them has been brought up to date. The usefulness of these tables is shown by the largely increased demand for copies of them.

Leveling operations.

(9.) The main leveling operations of the G. T. Survey have been carried on according to Colonel Walker's original design; they were taken up for the purpose of reducing all the levels determined by other Departments throughout India to one datum, with a view to making them generally useful for new irrigation, railway, and other projects for public works. The numerous lines of levels executed all over the country having hitherto been all but useless for anything but their original purpose, partly owing to their inaccessibility, and to ignorance as to their existence, but still more because they were all in different terms and not referred to any common datum such as would enable an officer to use one set in combination with another.

(10.) Owing to the financial reductions the projected leveling operations in the Bombay Presidency have necessarily been suspended, but as soon as an officer is again available for the purpose, a proposition for their resumption will be submitted to Government as the necessity for connecting the numerous separate sets of levels that have been executed in Bombay has become still more urgent, the Irrigation Department being especially anxious to avail themselves of them in a combined shape both for new projects and extensions of old ones.

Preservation of Stations.

(11.) The measures prescribed by the Government of India for the protection of the principal stations of observation have been diligently carried out and are now progressing satisfactorily. The importance of these measures was not generally appreciated at first and even now it may be as well to reiterate here, that the entire basis not only for all present surveys but also for all future surveys depends upon the efficient protection of these national landmarks: if they are kept in preservation the geogra-

phy of India may be said to rest on a permanent foundation, and at any future time it will be possible to supply accurate bases for new surveys on as large a scale as the value of the land at the time may demand.

(12.) The measures for the better protection of the marks of the G. T. Survey were first sanctioned in 1865; at that time there were about 2,600 principal stations scattered over 325 districts of India. At first the work necessarily proceeded very slowly, the labour involved in preparing lists and descriptions of the stations in each district being in itself very great and the information having to be compiled from numerous manuscript books; this labour was moreover much increased by the fact that during the last forty years the boundaries and sometimes even the names of districts have in many cases been altered, thus rendering it a very difficult matter to find out what local authority should be addressed regarding them.

(13.) The lists with the necessary instructions were issued as prepared but owing to various causes it was some time before much progress could be made, the district officers not at first quite understanding what was required, and naturally having some difficulty in finding the marks which were built many years ago. Gradually however the proper means for securing what is required have been elaborated and the work has each year progressed more rapidly and it is now a more simple matter to get any individual tower or station attended to. Instructions, lists and letters have been printed in such a form as is likely to meet any ordinary case.

Progress in the measures for protection.

(14.) During the period 1865 to 1870, about 650 stations scattered over 91 districts were repaired and taken over by the local authorities, and during the year 1870-71 now under review, the progress has been very satisfactory,—no less than 790 other stations having been similarly treated in 109 new districts. Still further progress might perhaps have been made had it not been for some misapprehensions on the part of the authorities of Bombay, Madras, and of the Indore Agency where there is still a large number of stations that have not been protected.

(15.) Every endeavour is being made to complete the protection of the remaining stations and it is hoped that the greater part of them will be placed beyond the danger of ordinary accidents within the next 3 years, and this once done, there will only remain the important duty of maintaining the stations in repair, which though laborious will then be within a reasonable compass and be in the main provided for by the annual returns. As a general rule the District Officers have exhibited a very laudable zeal in doing what is required, most of them appreciating its importance as soon as the subject was brought to their notice, but there have, I regret to say, been some cases where it has not been so; in one case a gentleman had been allowed to build a house over a mark, and in another case reported within the last month, a District Officer had actually adapted a Trigonometrical Tower to the purposes of a local Fair of which it seems to have been made the central building by means of various additions of his own, and it is not yet known whether any permanent damage has been done; in another the upper mark-stone originally horizontal was found to be set vertically in a neighbouring wall; some had been altogether pulled down and so on. These cases of Vandalism and the fact that one District Officer has actually expressed (in writing) his incapability of seeing any use in such land-marks or indeed in defined boundaries of any kind, proves that it was high time to institute these measures of protection, for though, owing to the great care which from the very beginning has been taken to preserve the Trigonometrical marks the absolute loss of a point has, as far as our inquiries have gone, very rarely occurred, yet such action being possible even among officials there was no saying how soon the losses might have been added to, in spite of the invariable precaution that has been adopted from the beginning of having a lower mark on the rock *in situ* or buried under the ground in addition to the one or more upper marks that are left accessible for reference at each station.

(16.) The handing over of the stations to the local authorities has had another great advantage insomuch that an officer wanting to make use of any points in a given district can at once get the necessary information regarding their locality and has no difficulty in identifying them when assisted by the native officials who have

immediate charge of them. This is fortunate, as requests to make use of the marks, both old and new, have very much increased within the last 2 or 3 years owing to the numerous projects for new public works.

Modern stations.

(17.) While the earlier stations have been thus dealt with, all modern marks (including those of this year) have since 1865 been officially handed over to the local authorities as soon as they were established, a written receipt being taken and the Government orders for protecting them being clearly pointed out in each case. This precaution was not neglected formerly, but from being done without Government authority it was rarely attended to, and the stations were often allowed to be wilfully damaged. The modern stations should consequently be free from this danger and only liable to the ordinary accidents arising from atmospheric influences, floods, land-slips &c., which it is hoped will be reduced to a minimum by the attention of the local authorities.

(18.) The alterations as to names and boundaries referred to above may in many cases have been necessary evils, but the examination and comparison of the old and new maps, which they have rendered necessary in this case, tend to prove that there has often been undue haste in altering the ancient boundaries of the country, the local authorities having sometimes reverted to the original and sometimes having tried 2 or 3 different arrangements before they were satisfied. In a geographical point of view these changes are very objectionable, but quite apart from that, the want of fixity in the more important boundaries must be a great evil both as regards fiscal and general measures. It would be a great benefit if the Supreme Government were to insist upon these changes being limited to the very smallest amount and that they should only be permitted when the most urgent necessity for them has been proved. At present if enquiry was necessary into any question in which the districts &c., as arranged 40 years ago or later was involved, the first thing required would be a map showing the old names and boundaries in order to compare them with the new; without it any ordinary inquirer would be utterly lost. The preservation of the old names is in my opinion very important and all innovations should be very jealously watched.

(19.) An abstract of the operations of the various Survey parties and Offices is given below. Further details will be found in the Appendices which contain selected extracts from the Narrative Reports of the Executive Officers including a letter by Colonel Walker regarding the meritorious services of the late Captain J. P. Basevi, and my usual report on the Trans-Himalayan or Trans-Frontier explorations which have as before been carried on under my personal superintendence.

T. G. MONTGOMERIE, MAJOR, R.E.,
Offg. Supdt. Great Trigonometrical Survey of India.

No. I.—TRIGONOMETRICAL.

THE BRAHMAPUTRA SERIES, MERIDIAN 90°.

PERSONNEL.

W. G. Beverley, Esquire Asst. Supdt. 2nd Grade.
Mr. C. J. Neuville, Surveyor 3rd Grade.
„ G. H. Harris, Asst. Surveyor 1st Grade.

(20.) The operations in this series were, owing to the financial reductions, confined entirely to approximate operations with a view to arrange for a junction with the Assam Longitudinal Series; this was satisfactorily effected by Mr. Beverley before the close of the season, the approximate series having been extended over a direct distance of 60 miles by means of a double series consisting of a double hexagon, a pentagon and two quadrilaterals. The final rays were cleared up to the side Narsingbhanj to Peshkarbhita and were satisfactorily tested. Ten towers were constructed and the approximate series, though not complete throughout its entire length, is in such a state as to prevent any delay when the final observations are taken up. The remainder will be finished during the ensuing season.

(21.) The selection of suitable stations in such jungle-clad ground was more especially difficult because the triangulation has to span the broad expanse of the Brahmaputra.

No. II—TRIGONOMETRICAL.

THE ASSAM VALLEY TRIANGULATION(OR EASTERN FRONTIER SERIES).

(22.) The Eastern Frontier series operations in British Burmah were suspended owing to the financial reductions, and the officer in charge, Mr. Rossenrode, was directed to take charge of the operations in Assam which were more urgently required. The Assam triangulation was taken up somewhat out of its turn with a view to supply points for the Revenue Survey operations which had been commenced at a very great distance from the Trigonometrical work.

PERSONNEL.
W. C. Rossenrode, Esq. Depy. Supdt. 3rd Grade.
Mr. W. J. O'Sullivan, Asst. Surveyor 2nd Grade.
„ C. Bryson, Asst. Surveyor 3rd Grade.

(23.) The progress in Assam has been necessarily somewhat slow owing to the nature of the country and various other causes. The great breadth of the flat portion of the valley is in itself very disadvantageous to triangulation, and this is made still worse by the rivers being lined with belts of trees and by the whole country being covered with a dense jungle grass growing to a height of 12 feet and upwards. The atmosphere moreover from January to April— that is during the best part of the field season—is rendered so thick from the systematic burning of the grass that even the luminous signals used (viz. the heliotropes and lamps) are not sufficient to penetrate it except immediately after a shower of rain. The smoke for weeks at a time hangs over the valley like a pall and prevents the stations from being mutually visible. At one point the officer in charge was actually detained 6 weeks before he could get his observations. This was partly owing to the great length of the rays which in future will be somewhat diminished, bearing in mind that the length cannot be very much diminished without greatly increasing the number of stations. The triangulator in such a country has a difficult task when trying to hit off the length that is likely to allow his work to advance most rapidly.

(24.) The general want of roads or even of paths in Assam has been another great hindrance, the crossing of the great rivers moreover prevents rapid travelling and the surveyor who had finished his observations at one station at the beginning of a break of clear weather generally found that it was impossible to reach his next station before the atmosphere had got thick again. To these physical difficulties were superadded those arising from the climate, and finally from the numbers of wild animals that abound throughout the country. The whole party suffered from fever and was at times plagued with the bites of flies, ticks and leeches. The Naga fly being more especially trying, its bite inflaming the limbs and leaving an ulcerated sore that was very difficult to heal.

(25.) The numbers of elephants and tigers made the moving of small numbers of men very hazardous, and the signal parties were not even safe in their huts; over and over again the men were obliged to take refuge in a large tree which was always left standing near the station for that purpose. The elephants were more especially mischievous as they generally pulled the huts to pieces. The men had many narrow escapes but fortunately no lives were lost.

(26.) Not a little trouble was entailed by the party having to deal with the Naga tribe, through whose country part of the work was carried; special arrangements had to be made for supplying provisions.

(27.) The officer in charge and every one of the party had, owing to the difficulty of carriage, to give up their tents and take to temporary grass huts which were run up at every stage.

(28.) The party had in fact every possible difficulty to contend against, but notwithstanding this the series was advanced a direct distance of 86 miles, and this progress is, considering the above circumstances, creditable to Mr. Rossenrode who

exerted himself to the utmost. The principal triangulation covers an area of 2,111 square miles.

(29.) During the ensuing season the triangulation will be pushed still further up the valley; extra precautions have been taken as to preserving the health of the party, proper clothing and gloves having been provided so as to protect the skin as far as possible from insects &c. Muskets have been indented for to assist in driving away the wild animals, and it is hoped that the party will not be so much harassed as in the previous season.

(30.) The party will be strengthened as far as possible and arrangements have been made to secure a larger number of secondary points in the new work, and to add to the number in the old work where there is a scarcity of them.

No. III.—TRIGONOMETRICAL.

THE BIDER LONGITUDINAL SERIES, ON PARALLEL 18°.

(31.) The operations on this series were commenced by Mr. Shelverton with his usual energy. Aware of the unhealthiness of the tract he did not leave quarters till the 7th of January, he then proceeded in person to select the stations required in order to make a satisfactory junction with the Coast Series. This he succeeded in doing after a good deal of trouble. Having done this he marched to Singawaram Station and there took observations for Azimuth on the completion of which he commenced the Principal observations and had finished one station when he was seized by a violent attack of fever which unfortunately carried him off a few days afterwards.

PERSONNEL.

George Shelverton, Esq., Depy. Supdt. 3rd Grade.
H. Beverley, Esq., Asst. Surveyor 2nd Grade.
Mr. F. Bell, Assistant Surveyor 4th Grade.
„ E. P. Wrixon, Assistant Surveyor 3rd Grade.

(32.) Mr Shelverton, as noticed in the report of last year, had suffered from a very severe attack of fever from which he was supposed to have recovered; there is now however very little doubt but that his health was far from being good when the time for going into camp came round again, but no one about him seems to have known in what a very unsatisfactory state of health he was. He had only been in camp 17 days when he was again attacked with fever and from his diary it appears that from that time till his death he never shook the fever off; his death took place on the 26th February at the village of Arkur, about 40 miles from the small civil station of Doomagudiam on the Godavery River. His remains were carried to Doomagudiam and buried there.

(33.) In reporting to Government this melancholy occurrence I have already dwelt on the meritorious and efficient services of Mr. Shelverton. His devotion to his work was very great, and there is very little doubt but that it induced him to continue at his post when he ought to have taken a rest and recruited his health.

(34.) Mr. Shelverton, after serving in various parts of India, was promoted to the Senior Department in 1866; he held charge of the operations of the Gurhagarh Series and carried the triangulation across the Bikaneer, Shekhawati and Marwar deserts a direct distance of 414 miles, which he executed in the very short period of two and a half seasons. Subsequently he took up the Jubbulpore Series the whole of which he executed as well as the revision of a part of the Calcutta Longitudinal Series. In 1868 he commenced the Bider Longitudinal Series upon which he was engaged at the time of his death. In all these operations Mr. Shelverton was most successful and the progress made by him in such difficult and latterly in such unhealthy ground was highly creditable to him. His untiring devotion to his work may indeed be said to have been the cause of his untimely death by which the Great Trigonometrical Survey has suffered a very great loss.

(35.) The following extract from a despatch by His Grace the Secretary of State to the Government of India, written on the receipt of my report of his death is a testimony as to the reputation which he had established for himself beyond this department where he was held in great respect by all who had worked with him. Extract.—"Mr. Shelverton with a noble devotion to duty, remained too long

"at his post in spite of the fever which had once already prostrated himself and "had killed several of his men. I am concerned to hear that this accomplished "surveyor whose name is connected with several important operations in the "previous history of the Survey has, since the date of Colonel Walker's report, "fallen a victim to his zeal for the public service."

(36.) Colonel Walker thinking that he, Mr. Shelverton, might possibly require some additional aid, appointed Mr. H. Beverley, one of the senior Surveyors to the party with a view to assist Mr. Shelverton in the final operations should he at any time require a relief. Mr. Beverley was however employed at a distance from the Head Quarters' camp, Mr. Shelverton apparently not anticipating any probability of requiring assistance, and it was consequently impossible for Mr. Beverley to reach the Head Quarters' camp until nearly a month after Mr. Shelverton's death.

(37.) Mr. Beverley was directed by me to proceed with the Principal observations, and this he did to my entire satisfaction. The main series, owing to the necessary delay before Mr. Beverley could join, was only advanced 37 miles covering an area of 783 square miles. The preliminary operations extended over a direct distance of 144 miles involving the clearing of forest from 10 hill tops and the making of 100 miles of pathway through dense forest and jungle. The secondary work covers an area of 314 square miles by which 20 points were fixed.

(38.) Considering the critical circumstances and the way in which Mr. Beverley was suddenly called upon to take charge and the difficulty of carrying out the plans of another with which it was impossible for him to be fully acquainted, it is highly creditable to Mr. Beverley that he made such good progress.

No. IV.—TRIGONOMETRICAL.

THE BELASPUR SERIES, ON MERIDIAN 82°.

(39.) This series was extended south a direct distance of 52 miles, giving 12 new principal stations. Owing to unfavorable weather and hazy atmosphere, Mr. Keelan was unable to observe an azimuth of verification; this will be done during the ensuing season. The triangulation is rendered difficult on this series, owing to dense forest and a good deal of level ground, requiring towers on at least one flank. Stations have been selected in advance for a direct distance of 42 miles.

PERSONNEL.

H. Keelan, Esq., Offg. Depy. Supdt. 2nd Grade.
Mr. L. H. Clarke, Surveyor 3rd Grade.
„ H. E. T. Keelan, Surveyor 4th Grade.
„ H. Peychers, Assistant Surveyor 1st Grade.
„ A. Moore, Assistant Surveyor 4th Grade.

(40.) The country traversed is one of the wildest parts of India, and the difficulties of moving about being great, the progress must necessarily be slow until the series reaches the hilly ground to the south which it is hoped it may do after next field season.

(41.) Minor triangulation, covering an area of 504 square miles, was executed, by which the position of the town of Belaspur was fixed and also that of the ancient city of Ratanpur, and a junction of the Bisrampur Minor series effected with a side of the principal triangulation.

No. V.—TRIGONOMETRICAL.

THE NORTHERN SECTION OF THE BANGALORE MERIDIONAL SERIES.

(42.) Lieutenant Rogers in charge of this series has during the last season advanced the triangulation a direct distance of 160 miles with 16 new principal stations forming one double polygon, one single polygon and one hexagon, the whole covering an area of 5,649 square miles. Observations for azimuth were taken at two stations and Colonel Lambton's astronomical station at Namthabad was connected with the principal triangulation. The

PERSONNEL.

Lieutenant M. W. Rogers, R.E., Offg. Depy. Superintendent 3rd Grade.
Mr. W. C. Price, Asst. Surveyor 2nd Grade.
„ J. Bond, Asst. Surveyor 3rd Grade.
„ C. P. Torrens, Asst. Surveyor 4th Grade.

observations were carried to about 20 miles north of the Kistnah River. For about half of the season the work was carried on in the territories of His Highness the Nizam whose officials gave all assistance that was required. The approximate operations for the ensuing season have been advanced a direct distance of about 60 miles. The secondary triangulation covers an area of 1,200 square miles by which, in combination with the principal stations, 63 points were fixed with 19 heights. The hazy state of the atmosphere during the last part of the season impeded the work very much and a portion of the party suffered very severely from fever. In spite of these hindrances very satisfactory progress has been made by Lieutenant Rogers.

No. VI.—TRIGONOMETRICAL.

THE SOUTHERN SECTION OF THE BANGALORE MERIDIONAL SERIES.

(43.) This triangulation under Major Branfill was resumed as soon as the district was reported to be healthy enough to work in; the series was carried south for a direct distance of 67 miles, covering an area of 1974 square miles. The Palnei mountains which rise abruptly to 6,000 or 7,000 feet above the great plain of Coimbatore had to be crossed. During the previous season, this rugged, wild range had quite baffled the efforts of the surveyor in charge of the approximate work and he was unable to lay out a satisfactory series for crossing. At the beginning of the field season under review a practicable scheme for crossing it was however devised with the assistance of Captain Herschel who had to visit a point in these mountains. This scheme was adopted and considerable progress was made in carrying it out, but owing to bad weather and the excessive unhealthiness of the season, Major Branfill was unable to complete it, the remaining portion will however be finished during the ensuing season.

PERSONNEL.

Major B. R. Branfill, Offg. Dy. Supdt. 2nd Grade.
Mr. J. Mitchell, Assistant Surveyor 1st Grade.
„ O. V. Norris, Assistant Surveyor 2nd Grade.
„ C. D. Potter, Assistant Surveyor 3rd Grade.
E. W. Lasseron, Asst. Surveyor 4th Grade.

(44.) Though every precaution was taken not to go into camp too soon, the whole party, both the European and Native portions, suffered very severely from fever. Owing to rainy and cloudy weather there was such a large amount of sickness that Major Branfill latterly found that most of his men were physically incapable of marching, as they had become so weak with fever, and he was ultimately forced to stop the main operations earlier than usual in order to send all the sick men into recess quarters, where it was many weeks before the majority of them became convalescent—many of them being still unfit for duty, months afterwards, at the time of writing his report.

(45.) As soon as Major Branfill found it impracticable, owing to the sickness of his men, to continue the principal observations, he proceeded to set up a self-registering tide gauge at Tuticorin, where he made all the necessary arrangements for taking the observations required to determine mean sea level for the use of the Trigonometrical and Leveling operations. He then proceeded to complete some secondary triangulation in the Palnei Hills and only returned to recess quarters on the 3rd of June. The principal triangulation covers an area of 1,974 square miles over a direct distance of 67 miles. The approximate operations were extended about 100 miles further south, and complete arrangements have been made for the ensuing season. The secondary triangulation covers an additional area of 1,070 square miles by which, in combination with the principal work, 85 points with 34 heights were finally determined. Major Branfill has also worked out his aneroid observations taken during 1869-70, and from them has reduced a most valuable table of heights. Whenever it was possible, his heights as determined by the aneroid have been compared with heights determined trigonometrically or by spirit leveling, and from the close way in which his aneroid heights agree with the latter it may be concluded that the system adopted secures very good approximate results which will be useful both geographically and for general purposes; giving as they do a much better idea of the height of the country in that part than we have ever had before. Some of the mountains moreover, fixed by the triangulation, were found to rise from 5,000 to 7,550 feet above the sea; many of these are not even indicated on

the existing maps, and the triangulation now executed will consequently be of great service hereafter in enabling the ranges in that direction to be properly delineated.

No. VII.—TRIGO-TOPOGRAPHICAL.

THE SURVEY OF GUZERAT.

(46.) Lieut.-Colonel Nasmyth held charge of this party during the recess but owing to ill health he was forced to take furlough on sick certificate and Lieutenant Mc'Cullagh was placed in temporary charge at the commencement of the field season.

PERSONNEL.

Lieut.-Colonel D. J. Nasmyth, R.E., Offg. Deputy Superintendent 1st Grade.
Lieutenant J. R. McCullagh, Offg. Assistant Superintendent 1st Grade.
Mr. A. D'Souza, Surveyor 3rd Grade.
„ A. Christie, Asst. Surveyor 2nd Grade.
„ C. McA'Fee, Asst. Surveyor 2nd Grade.
„ J. Hickie, Asst. Surveyor 4th Grade.
„ G. Cusson Do. Do.
„ C. Goslin Do. Do.
„ A. H. Bryson Do. Do.

(47.) The triangulation in Guzerat was continued and a portion of the topography was commenced on the points fixed the previous year, supplemented by fresh points fixed during the current season which were computed out in the field.

(48.) During the season, 534 square miles of the country were surveyed and mapped on a scale of 2 inches to the mile. The work of each assistant was carefully examined by Lieutenant McCullagh who scrutinized on the ground a large portion of each plane table sheet. The Surveyors were made to interchange their plane tables from time to time. The margins of the contiguous work executed independently were found to agree very closely and the sketching generally was good and accurate.

(49.) The triangulation, executed for the ensuing season's topographical work, covers and area of 841 square miles by which 310 points were fixed of 97 of which the heights have also been determined; of boundary and check lines 47 miles were traversed with theodolites and chains. The work of each of the Assistant Surveyors engaged on the triangulation was twice inspected during the season.

(50.) A large portion of the members of this party being new to the work, much of the time of the officer in charge was necessarily devoted to instructing them; as they have now gained considerable experience in every kind of ground, and as a large amount of triangulation has been prepared, a good out-turn of topographical work may be anticipated next year, but the nature of the country is such that very rapid progress cannot be expected as yet.

(51.) Guzerat is one of the richest and most fertile provinces of Western India; the roads are narrow, tortuous and bounded by high hedges; rich crops cover the fields and in parts the orchards of fruit trees almost form forests. Every available piece of land is cultivated; cotton is extensively grown; bajra, barley, wheat and jowari are the chief productions with sugarcane, castor oil and tobacco in smaller proportions, rice being only grown in a few places.

(52.) Some further evidence as to the encroachment of the sea has been gathered; in one part the tide is said to flow 1½ miles further inland than it did 20 years ago, and a light mast had to be removed in consequence as it had been repeatedly washed down. The spring tide moreover washes over land demarcated by the Revenue Survey as arable land so lately as 1866. Though not altogether conclusive, these latter tend to prove that the Gulf of Cambay is encroaching on the land in this direction as well as farther north. The extent of this encroachment will hereafter be carefully ascertained by means of the tidal observations in connection with the heights of the Trigonometrical Survey which are to be carried on in this part of the coast and to the north near the Runn of Cutch &c., where it is supposed that there has been an actual subsidence of the land going on for some time,—a very possible thing, but necessarily difficult to determine decisively without accurate observations.

(53.) A farther attempt has been made to utilise the topographical details of the Guzerat Revenue Survey maps, but the result has been as disappointing as

in former years, and I am afraid the only conclusion that can be arrived at is that though these maps have been executed on the large scale of 16 inches to the mile, they are only adapted for the Revenue purposes for which they were primarily undertaken, and cannot be utilised for combined topographical maps, even of the smallest scale. This is greatly to be regretted as the maps do contain a large amount of detail and there is evidence that had the necessity for attending to the topography been impressed more strongly upon the Surveyors a very little farther work would have secured most valuable results of a general nature. On comparing the details of the Guzerat Revenue Survey maps with the Trigonometrical maps I have noticed close agreement as to minor streams &c., while the larger streams, formed by the combination of these minor streams, were not even indicated. This I understand arises from the fact that a large watercourse is generally a village or other boundary, and that the Survey merely indicated it as a boundary taking no note as to whether it was a watercourse or not. The same applies to other details, topography in fact having been treated as a minor consideration. This no doubt has arisen from a wish to reduce the cost of the Survey as much as possible, but it appears to me that greater attention to these details and to means for determining them accurately would have been amply repaid by increased accuracy even in what is required for revenue purposes quite apart from what might then have been obtained for topographical maps and general purposes: as it is, one cannot help doubting whether something has not been sacrificed even as regards Revenue purposes, the utility of an accurate connection between boundaries and the main topographical features would at any rate be great in many cases, as in that of a dispute when boundary marks have disappeared accidentally or wilfully. I intend to have a farther experiment made with these maps in another part of the country as I am exceedingly loath to think that there is no portion that cannot be utilised.

No. VIII.—TRIGO-TOPOGRAPHICAL.

THE SURVEY OF KATTYWAR.

(54.) This survey has made very satisfactory progress under Lieutenant Trotter, and may now be said to be in full operation. The country surveyed was of a very varied character, the northern portion being mostly flat and fertile while to the south low stony ridges occurred with flat spaces in between, gradually breaking into a raviny tract towards the slopes of the mountains of the Gir. A portion of the Gir mountains was surveyed at the best time of the year, and as the country thereabouts is very unhealthy at other times a portion of it will be done season by season during the healthiest period until the whole area is surveyed. Though portions of the country in this part of Kattywar are very fertile and well populated, other portions are still in such a wild state as to form the haunt of the lion,—Kattywar being one of the few places in India where that animal is now to be found.

PERSONNEL.

Lieutenant H. Trotter, R.E., Offg. Deputy Superintendent 2nd Grade.
J. McGill, Esqr. Assistant Superintendent 2nd Grade.
Mr. W. Todd, Surveyor 3rd Grade.
„ G. Anding, Assistant Surveyor 1st Grade.
„ N. Gwynne, Assistant Surveyor 2nd Grade.
„ T. Rendell, Assistant Surveyor 2nd Grade.
„ E. J. Connor, Assistant Surveyor 3rd Grade.
„ E. N. Wyatt, Assistant Surveyor 3rd Grade.
„ W. Fielding, Assistant Surveyor 4th Grade.

(55.) The out-turn of the field season has been 1,757 miles of topographical survey on the scale 2 inches to the mile, and 301 square miles on the scale of 1-inch to the mile. Lieutenant Trotter inspected the work of every plane table repeatedly during the season, and found that it was accurately and satisfactorily done; the work was checked in the usual way and by means of 681 miles of traversing for boundaries, check lines &c. The new triangulation covers an area of 2,204 square miles and with what remains of the former season's work will provide ample points for the topography of the ensuing season.

(56.) Of the final maps, 11 sheets on the scale of 2 inches to the mile were prepared for publication and also a portion of one on the 1-inch scale, and the whole of the 8 sheets forming a square degree have been redrawn for reduction to the ½-inch scale for the Atlas of India and general purposes and have since been photozincographed at Dehra. The hill shading and general execution of the maps show considerable improvement.

(57). In order to make the maps more generally useful to the natives of the country, I have authorized an experiment to be made by publishing 2 or 3 of the 1-inch maps with the names in the Guzeratee character printed under those in English. Should there be a demand for these maps, arrangements will be made to do the same for all maps turned out hereafter, and also to introduce it into new editions of the earlier maps when they are issued.

No. IX.—TRIGO-TOPOGRAPHICAL.

HIMALAYAN SURVEYS IN KUMAON AND BRITISH GURHWAL.

(58.) During the recess these operations were under my own personal charge, but just before the commencement of the field season they were transferred to Captain Thuillier preparatory to my officiating for Colonel Walker as Superintendent.

PERSONNEL.

Major T. G. Montgomerie, R..E, Deputy Superintendent 1st Grade.
Captain H. R. Thuillier, R.E., Offg. Deputy Superintendent 1st Grade.
Lieutenant J. Hill, R.E., Offg. Deputy Superintendent 3rd Grade.
Mr. E. C. Ryall, Surveyor 1st Grade.
„ J. Peyton, Do. 2nd „
„ J. Low, Do. 3rd „
„ L. Pocock, Asst. Surveyor 1st Grade.
„ H. Todd, Do. 2nd „
„ T. Kinney, Do. 3rd „
„ E. Litchfield, Do. 4th „

(59.) Captain Thuillier started the party in the field, but his health unfortunately was not such as to enable him to stand the climate of the Terai which is at most times very malarious, and where the party was working is alternately liable to dense fogs and strong winds. Finding that he was not able to carry on, Captain Thuillier applied for furlough under sick certificate and Lieutenant J. Hill was placed in the officiating charge.

(60.) The operations of the season were confined to the Kosi Valley in order to carry out a survey which the Government of India required "to facilitate the investigation into the practicability of the construction of a Railway up the Valley." As the scale ordered, viz. 6 inches to the mile, was much greater than usual and as the survey was required for special purposes, it was necessary to make special arrangements as in the Ranikhet Survey. In anticipation of this I had caused the whole of the triangulation to be prepared during the previous season, the topographers were therefore able to commence operations at once, and with the addition of some extra points in the lower portion they were able to carry on their work without interruption.

(61.) The triangulation covers an area of 93,440 acres with 735 points and 551 heights, the latter being supplemented by 815 theodolite traverse heights and 302 other heights determined by approximate methods in the field, making a total of 1,668 heights. This extra number of heights was necessary as the Government had directed that the levels should be shown at various parts of the valley and the nature of the cliffs noted,—objects which could only be attained by means of a large number of heights. These heights were invaluable guides to the topographers in laying down their eye contour-lines in the field.

(62.) In the maps of the Kosi Valley Survey, as in those of Ranikhet, certain contour-lines vertically 300 feet apart are shown by dotted lines, and the shading is effected by other interpolated contour-lines according to a scale of shade which gives a vertical interval of about 15 feet between them; from these hachures an engineer can at once obtain a very good idea of the slopes from a mere inspection of the maps.

(63.) The slope of the Kosi Valley along the banks of the Kosilla river is no doubt well within the maximum gradient which can be economically worked by Railway locomotives. Ramnuggur, the proposed commencement of the hill Railway above referred to, being 1,200 feet while Bujan the proposed terminus is 2,885 feet above the sea and the course of the river between those points being about 46 miles the average slope is less than one per 100 and there is consequently no difficulty as regards gradient and it would not even be necessary to adhere very closely to the river. Though the bed of the river is at such a moderate slope, the valley itself is bounded by lofty mountains and the river has every here and there to pass through narrow gorges with great cliffs often rising to a thousand feet and upwards above the bed.

(64.) The upper part of the valley under survey is generally free from trees and in the winter it has a desolate appearance about it, but the lower portion is densely wooded and the scenery is always very picturesque, though, as in the Himalayas generally, the river is so deep set that it is seldom to be seen as forming a portion of the landscape, the valley rarely opening to an extreme width of two miles. Only those who have struggled from the plains up the first part of the course of one of the larger Himalayan rivers can have any idea of the formidable obstacles which their banks present just above the points where they debouch into the plains. Some faint idea can perhaps be gained by those who have looked down from above into the gorges of the Sutlej and other large rivers as to what room there is likely to be for a roadway, but the fact that not one of the larger rivers has a good road along the lower part of its course is in itself a proof that the banks are not generally such as to be selected for the purpose; had they been so there is very little doubt but they would have been taken advantage of for the purpose as they obviously supply the easiest slope for a road into the heart of the mountains.

(65.) The Kosi Valley is in fact deep-cut like all the lower valleys of the Himalayas which afford an exit for the rivers to the plains; the mountains on either side rise very suddenly and abruptly from the river, those to the south to the great altitude of 8,500 feet at a distance of only three miles from the river, while those to the north rise to 6500 feet at a proportionate distance, the bed of the river thereabouts being only about 2,300 feet; hence the banks of the river are rugged in the extreme and in places the river may be said to run through a chasm in the mountains formed by the most gigantic precipices on either side; and throughout the valley is cut up by the side drainage which in the rains pours down cataracts of water through an infinity of deep-cut ravines. Fortunately the banks are not generally equally formidable on both sides and by repeated bridging of the river it may be possible to avoid a portion of the worst obstacles; there will however still remain a large amount of rock work along precipices, and a very heavy amount of bridging for the cross-drainage. These however could no doubt be provided for as far as a narrow-gauge railway is concerned, but in my opinion the side ravines which deeply indent the slopes of the mountains will prove the most difficult to deal with as they would necessarily involve such a number of very sharp short curves as to be almost unfit for a railway unless they are greatly diminished and straightened by using viaducts extensively. Ample material for doing this cheaply no doubt exists in the timber forests around, and I am hopeful that a judicious combination of timber with masonry and iron may be devised suited for the purpose and at the same time such as to be safe from white ants which continue their ravages up to altitudes above that of Bujan, for though these pests have not been noticed by me above 4,000 feet in these latitudes they are very destructive at all altitudes up to 3,500 feet and will consequently have to be very carefully guarded against.

(66.) A single line of narrow-gauge railway I understand only requires a roadway of about 12 feet in width and if that be correct I am hopeful that it may be possible to construct such a line along the Kosi at a cost which the objects in view may justify.

(67.) The fact that all roads and most pathways into the mountains have hitherto avoided the beds of the rivers and taken more or less to the ridges suggests the question as to whether a similar line might not be advisable for a railway, and before coming to a conclusion it would be as well to examine the ground between Ramnuggur and Ranikhet with a view to see whether such a line would be preferable. The survey under review does not extend beyond the banks of the Kosi, but judging from our general maps and the line of the new cart road to Ranikhet as noted thereon which at once leaves the river and takes to the ridge, it appears that even the ruling gradient for cart traffic has necessitated a very circuitous line and it is obvious that the gradient for a railway would demand still sharper curves and and a longer line and I am consequently very doubtful whether much would be gained by adhering close to the ridge or even by any intermediate line between it and the river. I have never examined the mountains thereabouts with this special object in view and consequently only offer the above remarks from general observation, but one thing is obvious, viz., that a special line leaving the river and running along or near the ridge to Ranikhet will only serve as a line to

Ranikhet itself, whereas a line running along the river to Bujan will thereby arrive at a point which will serve not only Ranikhet, but Nyneetall and Almorah; an extension rail tolerably close to the latter town and a branch to the Ramgarh iron works would moreover then be quite feasible projects and the railway would really tap whatever produce the province of Kumaon and the higher mountains beyond have to send to the plains. Himalayan borax for instance might perhaps be thereby sufficiently cheapened and stimulated to take an important place in the English market, where it has hitherto been unable to contend with the Tuscan borax in spite of the great and increasing demand for the English potteries which have to depend practically on that one source of supply which is a monopoly. In the great Tibetan plateaux above Kumaon, borax exists to an unlimited extent and is to be had for the digging; at present a small amount finds its way to the Ramnuggur borax pans; a very slight stimulus might develope a large trade there and supply not only England but Europe generally as well as India which no doubt will require more year by year for native manufacture, for as the demand for pottery increases among the lower classes it is hardly likely to be supplied by any thing but that which is made in the country itself.

(68.) At my request, Lieut. J. Hill R.E., has made careful notes as to what he thought would be the best line for a railway along the Kosi, and his conclusions will be found in the Appendix. Notes as to the nature of the various cliffs met with, as well as of the ground generally have been recorded and I think that with the aid of the maps an engineer will have little difficulty in coming to a decision as to the best line.

(69.) The topographical surveying on the 6-inch to the mile scale covers an area of 60,027 acres in the course of which 5,882 points were fixed either by the plane-table or by prismatic compass traverse being about 1 point to every 10 acres or 64 per square mile, which are ample to define all the incidents of the ground that could be shown on the scale. The work of each assistant was carefully examined by Lieutenant Hill, the details being tested in the usual way and in addition a rigorous theodolite traverse being carried through the entire length of the Survey which served not only to bind the whole work together and give a great number of valuable heights but acted also as an efficient check on the accuracy of the work of the surveyors. The topographical work was in all cases found to be well done. The drawing of the fair sheets is all that can be desired both as to the hill shading and general finish. The execution of the Survey does great credit to Lieutenant Hill and the surveyors employed in carrying it out and it is hoped that the whole of the sheets will be ready for publication by the end of this year.

(70.) The Ranikhet and Kosi Valley Surveys form complete specimens of what can be done on the 12-inch and 6-inch scales to the mile respectively when maps are required showing all the incidents of the ground.

(71.) The sheets include the Kuch Gadh ravine between Ranikhet and the Kosi river at Bujan, partly from the Kosi Valley Survey and partly from the Ranikhet sheets which were reduced to the same scale. The additon of this portion will enable a decision to be come to as to approaching Ranikhet either by extending the railway from Bujan to Belesur and thence making a road, or by making a road throughout.

No. X.—ASTRONOMICAL.

LATITUDE OBSERVATIONS ON THE MERIDIAN OF 78°.

PERSONNEL.

Captain J. Herschel, R.E., Offg. Deputy Superintendent 1st Grade.
Mr. G. Belcham, Assistant Surveyor 1st Grade.

(72.) Captain Herschel has continued to take observations with the new Zenith Sector, and in spite of unfavorable weather was able to complete 15 stations. The increased progress made fully justifies Captain Herschel's estimate as to the much larger amount of work of the same order that can be turned out by this new instrument, as compared with the old astronomical circles. Captain Herschel's further experience with this Zenith Sector has on the whole confirmed his first impressions as to its excellence.

(73.) The 15 stations form 3 groups, two of these being to the south and one to the north of the previous year's work, and are at intervals of latitude from 1° 18′ to 1° 48′ from the neighbouring groups. The groups consists of 4, 5, and 6 stations; the latter being at Cape Comorin where Captain Herschel thought it desirable to have more stations and more observations, as being the most important station to geodesists in India and one which must always be the extreme southern limit of our meridional arc.

(74.) The results deduced from the stations of two of these groups show only slight local deflection but the third group shows a startling inequality of the disturbing attraction; two of its stations which are only 8½ miles apart are separated by an apparent arc of amplitude as much as 3″·1 less than is actually the case, there being no visible cause of attraction which would be likely to alter it more than a fraction of a second. The locality of this group, as well as of the other two, having been selected in a position where the irregularities of the general surface appeared to be the smallest and where the chances of local deflection were consequently supposed to be the least.

(75.) The results give much additional evidence as to the great uncertainty of local attraction within even such short distances as 4 or 5 miles, confirming the evidence of the well known instances observed near St. Petersburg, in the north of Scotland and elsewhere: and the results here referred to may be well worthy of the attention of those who study questions into which the variations of density in the crust of the earth enter.

No. XI.—ASTRONOMICAL.

LATITUDE OBSERVATIONS ON THE MERIDIAN OF 75°.

(76.) These operations were confined to a small amount of computing and other office work carried on under Lieutenant Trotter in addition to his other duties. The observations were suspended pending the arrival of a new Zenith Sector and also partly in consequence of the absence of officers on furlough and of certain financial considerations which rendered it advisable. The observations will be resumed next field season by Captain Campbell, the expected Zenith Sector having already been safely landed at Bombay and conveyed to Poonah where the necessary preparations for bringing it into use are now in progress.

PERSONNEL.

Lieutenant H. Trotter, R.E., Offg. Deputy Superintendent 2nd Grade.
Mr. J. Wood, Asst. Surveyor 1st Grade.

(77.) The early completion of this new Zenith Sector was a matter of great importance in order that another field season might not be lost; Colonel Walker consequently obtained permission to place the services of Captain W. M. Campbell R.E., at the disposal of Colonel Strange to assist him in the final testing and examination of the new Zenith Sector and other instruments intended for the G. T. Survey. Captain Campbell was appointed to do duty at Lambeth from the expiration of his furlough and in the Appendix a detailed account will be found of the various matters in which he assisted, showing how well and fully occupied he was whilst employed in England.

(78.) The new Zenith Sector was the first instrument to which attention was directed as it was urgently required. This instrument had been constructed by Messrs. Troughton and Simms after designs by Colonel Strange, and is a sister instrument to the one which Captain Herschel is using. Profiting by the experience with the latter while in actual use, some alterations and additions have been made which are likely to add to the efficiency of this 2nd Zenith Sector. The difficulty in putting the 1st one together, owing to the great weight of the telescope and sector which had to be put on in one piece, has been obviated in the 2nd by Colonel Strange's plan of taking the telescope off for travelling, a change which has been carried out with very great advantage. The heaviest travelling case was thereby dispensed with, the process of putting together and taking down was rendered easy and safe, having formerly been dangerous. The packing cases were at the same time made as light as they could well be. Whilst the above alterations in packing &c., were being made,

the opportunity was taken to add to the instrument the means of changing zero to the extent of 15°, an arrangement suggested by Captain Herschel which is likely to add to the value of the instrument; a more convenient and reliable method was also devised for taking the runs of the levels, and besides these various other minor alterations were made which are likely to be improvements. The instrument is now it is hoped as nearly perfect as it well can be and with its sister probably forms a pair far superior to any similar instruments owned by other Governments.

(79.) Besides the Zenith Sector, the following fine instruments have been constructed, viz:—

2 Five-foot Transit Instruments,
2 Chronographs,
6 Relays with batteries &c.,
3 Astronomical Clocks,

composing the double equipment for the Electro-Longitude observations which are to be carried out under the orders of the Government for the purpose of finally determining the difference of longitude between Madras and Greenwich as well as the difference between various points in India, whereby it will be possible to measure large arcs of longitude and to compare the results with the same as measured by the geodetical operations of this Survey. The arc between Calcutta and Karachi, about 1,250 miles in length, has been already measured by our operations and in itself affords first-rate means for determining the figure of the earth in that parallel of latitude. As no such arc of longitude has yet been or is likely hereafter to be measured so near the equator, it ought to be peculiarly valuable in helping to solve this interesting question.

(80.) The whole of these instruments were carefully examined and fully tested by Colonel Strange and Captain Campbell under whose instructions such slight alterations as seemed necessary were carried out. The five-foot Transit instruments possess several novel features, the most striking and important being the new system of levels which is fully described in Captain Campbell's report appended hereto, in which farther details will be found regarding them and the other instruments, and it is only necessary here to state that it is thought that the efficie ncy of the relays has been satisfactorily established—an important matter as the relays are the electrical instruments by means of which a weak electrical current arriving from a distant station is made to call into action another strong current supplied by a local battery in order to make the mark on the chronograph. Had there been any appreciable retardation caused by the relays in communicating from the weak to the strong current they would have been comparatively useless; fortunately the retardation has been found to be inappreciable, and their sensitiveness has been proved to be such that they acted when a current was too weak to work the printing instrument in regular use in the London office of the Indo-European Telegraph. If in actual practice the above proves to be correct, it is obvious how very greatly these instruments will facilitate the accurate measurement of long arcs of longitude, as a current may by their means be carried on from point to point without any appreciable retardation. Colonel Walker has already tried the Electro-Longitude instruments in direct connection with Teheran and found them to work satisfactorily, and I am sanguine that they will be found to work equally well hereafter when brought into full operation, and that the much discussed difference of longitude between Greenwich and Madras will be finally determined in a way to be beyond all dispute.

(81.) While the above instruments were being tested, two Transit Instruments of the Russian Pattern were also carefully examined, and I need hardly say that every endeavour was made to perfect them as far as the experience gained with the instruments for India suggested. The Russian Government has always been most anxious to co-operate with the Government of India in geodetical matters. There has for many years been a free interchange of instruments between the Governments; I may instance the case of our Standard Bar B which was in Russia during the Crimean campaign, and still later the Russian pendulums which were lent to Captain Basevi and are now in our hands. I hope this interchange will continue, as its object, viz., to have the Russian and Indian geodetical operations in the same terms, is a most important one and should

be forwarded to the utmost, even if the dream of Everest the father of Indian geodesy cannot be carried out by completing an arc from Cape Comorin to Nova Zembla by one unbroken chain of triangles,—a dream which however I hope may still be accomplished; for already my operations in Ladak (Tibet) have provided two stations on the range north of the Changchenmo in Latitude 34½° which are connected directly with Cape Comorin, and if the Russians do their part by carrying their triangles down to the Tianshan range, now under their dominion, there will only remain between us the broad valley of Eastern Turkistan, some 400 miles, a comparatively easy task physically, which may hereafter be perhaps crossed without any great difficulty if the present or any future ruler of Kashgar and Yarkund proves to be sufficiently enlightened to permit it.

(82.) The Government of India has always been most ready to allow its officers to adopt all real improvements in scientific instruments for the use of its Trigonometrical Survey and has, owing to this liberal spirit, been in this respect in advance of even the most enlightened Governments of Europe. Such was the case with the great theodolites as well as in many other instances, and I think it may now be fairly congratulated on the acquisition of these splendid instruments which show that the Government of India, whilst making material progress, is by no means indifferent to higher claims, and is still careful to maintain the reputation which it has established as one of the chief patrons and promoters of science. The officers of the Great Trigonometrical Survey have every reason to be grateful for the liberality with which these noble instruments have been given to this Department, and I feel certain they fully appreciate the compliment that has thereby been paid to their exertions, in as much as they have been deemed worthy of still farther encouragement by placing at their disposal the best instruments which European science can produce; a compliment which cannot fail to induce the officers to strain themselves if possible still farther in order to fully merit the confidence which has been placed in them.

No. XII.—LEVELING OPERATIONS.

DETERMINATIONS OF ALTITUDE BY THE SPIRIT LEVEL.

(83.) The leveling operations commenced at the point where those of last year terminated in the station of Goruckpore, and from thence were carried by the north-eastern road by Pipraitch, Parraona &c. to Bettiah. From Bettiah the operations were continued past the military out-post station of Soogowlee to Motecharee, Mozufferpoor and Darbhanga. *En route* various branch lines were levelled so as to include more stations of the N. E. Longitudinal, the Hurilaong Meridional and Chendwar Meridional Series of triangles. From Darbhanga the main line was continued towards Purneah with several branches to include tower stations of the North Parasnath Meridional Series; subsequently the main line was closed for the season on a G. T. S. bench-mark embedded about half a mile beyond the village of Parsarman in mauza Parsoni, where a Hindoo temple afforded a good permanent testing point for future extension.

PERSONNEL.
C. Lane, Esq., Depy. Supdt. 2nd Grade.
Mr. A. W. Donnelly, Surveyor 2nd Grade.

(84.) During the field season 308 miles of double leveling were completed independently by Mr. Lane and his assistant, by means of which 9 Principal Stations of this Survey were connected, also 4 Irrigation bench-marks and 153 permanent marks of reference, whose heights will thereby be finally determined and become available for general purposes. One great river, the Gandak or Naraini, and 19 smaller rivers had to be crossed in the course of the operations which added considerably to the labour. The party moreover suffered from the effects of the late cessation of the rains owing to which the country was covered with sheets of water till late in the season, adding a great deal to their difficulty in carrying on the work and at the same time causing a considerable amount of sickness.

(85.) During the ensuing season the main line will be carried down to close a circuit on a bench-mark near Bhagalpore; it will also be carried to the Sonakhoda base-line which it is an object of great importance to connect; subsequently the line will be carried south as far as the time available permits.

No. XIII.—GEODETIC.

THE PENDULUM OBSERVATIONS.

(86.) During the recess Captain Basevi was employed in calculating out his previous field season's observations and preparing the results for the press. He was in addition much occupied in experimenting as to the best means for determining the temperature and pressure co-efficients for his Pendulum operations generally. Whilst arrangements for this were in progress, he compared his thermometers with a G. T. S. standard thermometer, and determined their zero errors. He then compared the scale for the Russian Pendulums with certain portions of the G. T. Survey standard steel foot.

PERSONNEL.

Capt. J. P. Basevi, R.E. Depy. Supdt. 1st Grade.
Mr. J. W. Macdougall, Asst. Surveyor 2nd Grade.

(87.) In order to determine the corrections necessary to be made to his Pendulum observations for pressure and temperature, the first object was to devise the most efficient method of sustaining the temperature of the comparing room steadily at any required degree up to 100°. After a great deal of labour and many ingenious experiments this object was most thoroughly carried out; and finally at temperatures differing greatly from the natural temperature, the range during 24 hours did not exceed 2° Fahrenheit. Having made this satisfactory arrangement Captain Basevi commenced the necessary observations and carried them on with such unremitting energy that in 4½ months he had done sufficient observing to have completed 7 Pendulum stations or as much as he latterly did in one season. It is difficult to give an adequate idea of the great amount of labour which this involved even at natural temperatures, but when it is borne in mind that this work was carried on day after day in a temperature artificially heated up to 100° while the outside temperature was but 50° Fahrenheit it may give some faint idea as to the hard strain that was put upon Captain Basevi's constitution by his constant observing. The necessary number of observations having been taken and the experiments completed, Captain Basevi at once proceeded to make arrangements to take the required observations in Ladak and Tibet. He left Dehra on the 27th March and marched through the Punjab to Mian Meer where he took the usual amount of Pendulum observations. From Mian Meer he marched through the mountains to Kashmir where he made his final arrangements for observing in the lofty plateaux of Tibet.

(88.) He left Kashmir towards the end of May and crossing the main ridge of the Himalayas by the Zojji-La pass reached Leh, the capital of Ladak on the 9th of June. From Leh he sent his assistant to the north-east in order to reconnoitre for a suitable observing station in that direction, whilst he himself went south to select a station on the lofty plateaux of Rukshu. Rukshu is a very elevated district lying immediately north of the great Himalayan watershed; as a general rule its lowest ground may be said to be 15,000 feet above the sea, the remainder rising from that altitude to more than 20,000 feet above the sea, being in fact one of the most elevated countries in the world, absolutely without inhabitants in the winter, owing to the great cold, and only occupied during the summer months by a few camps of nomadic Tartars chiefly employed in grazing the shawl goat and yaks. These Tartars with their flocks retire early to lower ground on the Indus, and Zanskar rivers. The plains and mountains round them form the most barren, desolate-looking tracts that it is possible to conceive; at a distance even the lower ground appears to be destitute of vegetation, and it is only on a close examination that any sign is visible of the scanty coarse grass on which the goats and yaks feed. The slopes of the mountains are generally composed of shingle without a sign of soil, and the whole forms a most dreary monotonous landscape.

(89.) This desolate tract can only be approached from Leh by the Takalung pass 18,060 feet in height, and over this Captain Basevi had to march with the whole of his camp, pendulums, &c. This pass which I have crossed myself is I know a particularly trying one to most people, perhaps partly from its coming on a traveller from Leh rather suddenly,—that is the transition from moderately high ground to very high ground being rapid, and partly from the openness of the country which exposes every one to the cutting winds that prevail throughout Ladak; the sudden transition probably being the most active cause, as there is no doubt that those who have been gradually inured to higher and higher altitudes feel the latter less than those who

come up to them suddenly. Whatever may be the cause, most people suffer very much, and there is no doubt that Captain Basevi and all his men including those of the country who were with him did so suffer; he particularly noted their suffering from shortness of breath and headache as well as a difficulty in walking more than a hundred yards at a time,—the usual effects of these high altitudes. Captain Basevi does not dwell much on these sufferings in his diary but the mere fact of his referring to them is sufficient proof of their intensity, for he was a man who never complained of any thing, bearing exposure and hard work of every kind with the most unflinching endurance whether in the deadly, malarious tracts of Central India, the steamy atmosphere of Cape Comorin and Minicoy, or the snows of the Himalayas. Personally I have no doubt as to the stress that was put upon him, for though in crossing this very pass I comparatively suffered but little except from a sort of dull oppression, I well remember the drawn, care-worn faces that every one round about me had for days after we got into Rukshu,—numbers of the men vowing they could not breathe and that they were going to die; this alone adding very considerably to the strain even when feeling well enough one's self, would be likely to affect any one much more who was himself suffering acutely. In addition to these results from the great altitude, Captain Basevi had for 6 days and nights to carry on observations for 22½ hours out of the 24, so that practically he was observing day and night at intervals which may be nominally stated as 3 hours but which in reality could not have afforded him a respite of 2 hours between his visits to the observatory tent. Carried on for so many days, this would be a strain on any one, but bearing in mind where and under what circumstances Captain Basevi was working, I think there will now be little difficulty in understanding what a really severe strain was put upon him. In his letters to me and others he refers specially to the difficulty of breathing when lying down, as he if he could not get sufficient air and so on, but in spite of it all he was able to select a capital station on the Moré plain of Rukshu at 15,500 feet above the sea, and to take a complete set of observations. From Moré he made his way back to the upper Indus, and by the time he reached Lukum at the northern end of the Pangong lake, he had apparently in some measure recovered from the ill effects of his hard work in Rukshu; for Major Macintyre whom he met there reports him as looking better than he had been at Dehra, though his assistant, who had seen him a few days before, states that he was then looking pulled down and worn, and his subsequent sad death seems to prove that the latter view was the correct one, and I am inclined to think that his originally good constitution had been gradually undermined by the hard work and constant exposure to so many sudden changes of climate and altitude.

(90.) It is usual to look upon British India as one country, and to take but little heed as to moving officers from one end of it to the other; but when it is borne in mind that India presents every variety of climate due to latitudes varying from 8° to 34°, it is obvious that but few constitutions are likely to be able to stand rapid changes from south to north. It is only requisite to bear in mind that Captain Basevi was necessarily exposed to many such changes and indeed to all the extremes that are to be met with in India in rapid succession—having been one season employed in the steamy atmosphere of Cape Comorin and the very next on the Himalayan snows in latitude 34°—and it is easy to understand that he was likely to be readily affected by the extreme cold; in my opinion it was due to this and the gradual weakening of his constitution that a cold he caught, just after parting with his friend Major Macintyre, took such a hold of him as to cause his death a few days afterwards. The weather from the time Captain Basevi left Rukshu till he reached the Pangong lake had been cloudy and stormy, and more rain and snow had fallen than is usual in Ladak at that season; at the Pangong he came in for a snow storm during which he caught a cold, but evidently thinking nothing of it he pushed on to the north crossing the Marsimik pass 18,629 feet above the sea and was for 7 miles exposed to a continued fall of either rain, hail or sleet, and I agree with Mr. Hennessey in thinking that this coming on whilst Captain Basevi was still suffering from his cold was what really caused his death. After such a march as that, a man suffering from bronchitis might have a chance of recovering if he had a warm house to go into at the end of it, but there was small chance for poor Captain Basevi who probably had to wait hours, wet and chilled in the cutting Tibetan wind, before his tents could arrive. His diary gives us no idea as to what he really underwent, he merely notes that when crossing this very lofty pass "difficulty of

breathing was experienced." After this including the last entry made in his diary there is not a word of complaint, and I can only conjecture that he was feeling unwell from the fact that the last words of his last letter to me, dated 13th July, from the Changchenmo conclude thus "the weather has been very bad since leaving Gya; "nothing but clouds, a good deal of rain and snow on the Chang-La (pass), and "a heavy snow storm just below the Marsimik-La (pass). I shall be glad to get "out of this country"—a wish alas! never to be realised, for marching on the next day, the 14th, his servant noticed that he was suffering considerably, though on the 15th he was able to make another march of 10 miles and actually to walk the last 3 miles being then at an altitude of over 17,000 feet; on arrival his servant said his cough was so violent that he was obliged to lie down immediately after writing the last entry in his diary. From this we also gather that he had reached the Lanak Plains and was encamped at 17,104 feet above the sea as deduced by him from his own observations before lying down. From his short description, it is easy to make out that he was in ground similar to those elevated plains of Rukshu already described only probably still more desolate owing to the extra 1,500 feet of altitude, a place trying to any one in the best of health but doubly so to a sick man, and there is little wonder that poor Captain Basevi, suffering from bronchitis in such a place, got worse and worse having nothing but a thin canvas tent to keep out the night-cold which at those altitudes sinks far below zero. During the night of the 15th he got worse; on the 16th he ordered preparations for observing to be made, but suffering more and more he was unable to rise from his bed all that day and though he seems to have passed a quiet night, the next morning, the 17th of July, he was worse and whilst once more gallantly trying to get up and go on with his work he breathed his last, owing probably to some sudden increase to the violence of his chest complaint, due to the excessive cold of the morning air. To the last he seems to have been in full possession of his faculties and quite unaware of his danger; he appears to have done every thing for himself that a non-medical man could do on such an occasion, and his servants generally seem to have been attentive, and to have assisted in every possible way that they could. His personal attendant Paraoti was by all accounts most devoted, tending him carefully to the last, and then following his body by day and night continuously till he handed it over to Captain Basevi's assistant, who unfortunately had been left several marches behind in order to reduce the size of the camp as much as practicable,—it being a great object in those desolate regions to travel as lightly as possible. This assistant, Mr. Macdougall, did what he could under these painful circumstances; the body was first buried at Tanksi, and subsequently was carried to Kashmir and laid there in the European burial ground.

(91.) I have elsewhere dwelt on the very great loss that this sad, untimely death of Captain Basevi has been, both to the Government of India and to the Trigonometrical Survey, the former losing a most talented and devoted officer and the latter one of its brightest ornaments, who had contributed greatly to advance its various practical and scientific objects, and was engaged at the time of his death in an important investigation which he had so conducted as already to have secured the very favorable notice of the highest scientific authorities in England, and had in fact laid the foundation of a European reputation. It is very sad to think that he should thus have been carried off just as he had all but finished his labours and would have been likely to reap the reward due to them.

(92.) I have already reported upon the many valuable services this talented officer has rendered to Government and his exertions have, I am glad to say, been appreciated.

(93.) In previous reports it had been noted that gravity at the coast stations had always been found to be in excess of gravity at the inland stations, and as observations at moderate altitudes tended to prove that gravity was invariably in defect as compared with that at lower altitudes, it was supposed that observations in the lofty plains of Ladak would settle this question decisively. Captain Basevi's observations give the following approximate results, viz :—

At Mian Meer (700 feet above the sea), observed vibrations in defect of computed vibrations, in terms of Punnæ near Cape Comorin, and ellipticity $= \frac{1}{300}$ ... ... $4\frac{1}{4}$ vibrations.

At Moré 15,500 feet Do. do. . . . $16\frac{1}{4}$ „

the latter at once showing the great defect of density in the Himalayas. This result may be said to have been the crowning result of Captain Basevi's investigations, and with it and his previous deductions he held the means of deciding this important problem.

(94.) It only remains for me to note that the whole of the Pendulum apparatus has been brought back in good order, and that all Captain Basevi's papers have been carefully arranged and safely lodged in the Dehra Office. I have to thank Mr. Hennessey for the great skill and labour with which he applied himself to the difficult task of rescuing every thing that was likely to be valuable, and then of arranging it so to make the whole readily available whenever it may be required. An officer is being trained to take up what little work Captain Basevi had left undone, so as to complete the observations for the whole of India, and every endeavour will be made to reduce and publish the results in such a form that they may form a lasting memorial worthy of the memory of Captain Basevi.

No. XIV.

THE COMPUTING OFFICE.

PERSONNEL.

J. B. N. Hennessey, Esq., Dy. Supdt., 1st Grade.
W. H. Cole, Esq., Asst. Supdt., 2nd Grade.

COMPUTING BRANCH.

Mr. C. Wood, Surveyor, 4th Grade.
Baboo Gunga Pershad.
" Cally Mohun Ghose.
" Gopal Chunder Sircar, and 6 other native Computers.

PRINTING BRANCH.

Mr. M. J. O'Connor.

(95.) The chief duty of the Computing Office under Mr. Hennessey has, as heretofore, been the continuation of the difficult calculations for the final reduction of the whole of the operations of the survey. With these Mr. Hennessey and his staff have made very great progress, and he has had the gratification of having brought to a most successful conclusion the computations known as the "Reduction of the North West Quadrilateral" embracing the greater part of Upper and Western India; this in itself forms one great step in the general reduction and the completion of it shows the feasibility of treating other portions of this great work in a similar, complete manner, and at the same time clears the way for them. Mathematicians will understand the difficulty of this task when it is stated that it was essential that a great triangulation 3,780 miles in length should be made consistent so that the circuits should all re-enter in every respect, and that in fulfilling these requirements it became necessary to find simultaneously 1,098 unknown quantities or angular corrections which would satisfy 23 equations of condition, the minimum number to which these could possibly be reduced, the co-efficients in the latter having been themselves determined by extensive calculation.

(96.) Mr. Hennessey I think deserves very great credit for the skill and untiring energy with which he has prosecuted these intricate and very extensive computations. It would be impossible to enter into any particulars here with reference to the above, but those who study such matters will find much interesting detail in Mr. Hennessey's Narrative Report.

(97.) The principle of reduction adopted is due to Colonel Walker, and Mr. Hennessey has most ably carried out the very difficult task of putting it into practice. In order to show that the reduction has been exceedingly satisfactory it is only necessary to state that the dispersion of the errors was attained by the aid of angular corrections of which the greatest is only $0''{\cdot}46$ and the average $0''{\cdot}13$, and the checks were so thoroughly efficient that in the whole of this very extensive calculation, not a single arithmetical mistake escaped detection. The calculations thus completed are unsurpassed, if indeed equalled in magnitude, by any other similar work on record, and Mr. Hennessey is to be congratulated on the complete success of his labours. The progress made is most encouraging and the

experience gained will no doubt facilitate the dealing with the other portions, and will at the same time give great confidence in undertaking a work of such extent, which is necessarily a most anxious task whilst there is any doubt as to the result of months of toil.

(98.) Without entering into a purely technical description, it is impossible to give an adequate idea of the difficulties of carrying out such mathematical processes practically, and the amount of ingenuity that is necessary to effect them, even when the principles to be applied have been decided on; but it will be easily understood that the difficulties were much enhanced by the fact that a large part of the computing staff is necessarily composed of natives of the country who have to be trained to the work from the very beginning. The thoroughness with which this training has been effected reflects great credit on Mr. Hennessey's arrangements: some have long been proficient computers and others who have more recently joined have made good progress. In addition to the more purely scientific work, Mr. Hennessey has as usual had much of his time occupied in supplying data to the Survey Department generally, to officers of the Department Public Works, &c.: the demand for data having increased very much during the last 2 years, owing to the increasing number of fresh surveys that are being taken up for the various new projects designed for the developement of the resources of this great country. It is gratifying to find that the results of the Great Trigonometrical Survey are being more and more brought into practical use, and it is an encouragement to continue our exertions towards ensuring the efficient protection of the principal stations which are likely to be useful as long as India is a civilized country. In this important work, Mr. Hennessey has been very busily engaged and already great progress has been made.

(99.) The 1st Volume of the record of the operations of this survey which has been published, is a very solid proof of Mr. Hennessey's exertions in the way of calculation and compilation for the press and the general superintendence of the passing of proofs. Great progress has moreover been made with the printing of the North-West Quadrilateral. The amount of work extracted out of the small press is most satisfactory, and the same may be said of the Photozincographic Office which continues to be most useful: without it indeed it would have been impossible to make the G. T. Survey results generally available even to the extent they now are.

No. XV.

CARTOGRAPHY &ca.

PERSONNEL.

Drawing Office.

W. H. Scott, Esq., Surveyor 1st Grade, and Chief Draftsman.
3 Native Drafts men and 12 Apprentices.

Photozincographic Office.

Mr. C. G. Ollenbach.
„ C. Dyson.

(100.) The Drawing Office has been chiefly employed in the compilation of the Preliminary Charts of triangulation, and of the Charts of Levels. During the year 15 Preliminary Charts of triangulation have been prepared for photozincography of which 13 have already been published; various other triangulation charts have been prepared in manuscript for Government officials. With the charts of Levels great progress has been made, 5 sheets having been compiled and published by photozincography and 7 more being in course of preparation. Numerous maps and reductions have been prepared for incorporation with the level sheets and others for the use of the Irrigation Department &c.

(101.) A few original maps and compilations of general interest have been prepared and published; others are in course of preparation. Altogether the small Drawing Office has been very fully occupied and the quality and amount of work turned out under the supervision of Mr. W. H. Scott has been very satisfactory. By the photozincographic process 20,509 copies of charts, maps and diagrams have been printed of which 2,994 have been colored by hand for issue to Government officials and sale to the public, and 10,482 copies of forms for calculation and office work have been printed by zincography for the use of the department,—being a great increase in every item except that of forms.

(102.) The duties of Personal assistant have been very efficiently carried on by Mr. G. W. E. Atkinson who has acted during the absence on furlough of Mr. H. Duhan.

No. XVI. GEOGRAPHICAL.

TRANS-HIMALAYAN OR TRANS-FRONTIER EXPLORATIONS.

(103.) These explorations have as before remained under my own personal direction. In continuation of my original design for carrying out systematised explorations beyond the frontiers of British India, I have from time to time pushed the exploring parties wherever there has appeared to be a feasible opening; amongst other places I have long had my eye on the triangular space, lying between the Indus and its great Caubul tributary, which is bounded on the north by the Hindoo-Koosh and Mustagh ranges. Heretofore I have been unable to make much progress except in the Swat and Indus direction, but I have now to report that my efforts to penetrate this difficult country have been successful through the agency of a very intelligent Pathan Havildar of our Sappers.

(104.) Hitherto this very interesting tract of mountain land, though close to our borders, has really been sealed to all attempts at exploration, and except with reference to the mere border we have been forced to base its geography on the hearsay account of inhabitants of the country, who were hardly capable of telling whether a valley ran east or west, north or south, and who were consequently very apt to mislead even when willing to give information. This being the state of the case, it appeared to me that very solid geographical results would be gained if I could get a route survey carried right through the heart of the country from Peshawur to Badukshan, and I consequently decided to send an exploring party in that direction. As a first step towards this, I, as usual, instituted a search for a frontier man and a co-religionist of the people of the country to be explored. A suitable agent for the purpose was found after much trouble in the Havildar of one of the Pathan companies of the Sappers; he was regularly trained for the work and then started from Peshawur. He crossed over from Yusufzai into Swat and from thence into Bajaur. From Bajaur he crossed over into Dir on the Punjkora river and then crossed by the Lahori pass into Kashkar, and onwards through a part of Kafiristan to Chitral. From Chitral he made his way by the lofty and difficult Nuksan pass to Zebak, on the upper Kokcha river, descending which he finally reached Faizabad the capital of Badakshan. The season and state of the country not admitting of the Havildar's making any further advance, he returned to Chitral by the Dora pass road, thus completing the survey of the head-waters of the Kokcha, a large tributary of the Oxus. From Chitral to Peshawur his return route was, with some slight variations, the same as that by which he advanced. The route, as will be seen from a glance at the map in the Appendix, was admirably calculated to open out the country, and besides fixing the positions of several important places such as Aladand in Swat, Miankilai and Jundul in Barawul, Dir on the Punjkora, and Chitral on the Koonur river. It has undoubtedly given the means of solving a great many doubtful points in connection with those districts and neighbouring countries. It has moreover determined the Lahori pass and given us, in the Nuksan and Dora passes, two more determinations of points in the ridge of the Hindoo-Koosh which are very valuable, coming as they do immediately between the Khawak pass, determined by Wood, and the Pamir Kul (lake) of the Mirza near which what is called the Hindoo-Koosh range is joined by a comparatively low watershed to the Pamir Steppe; the general run of the Hindoo-Koosh range may consequently now be said to have been definitely determined by explorations from British India. The determination of a portion of the Koonur river gives moreover considerable certainty in defining the general course of that large river to which a close approximation can now be made.

(105.) The Havildar is the first trained explorer that has passed through these regions. He was constantly in great peril, at first from ordinary robbers, and for some time from the Kafirs who infest the whole of the road from Dir to Chitral and a

times commit great ravages. In Chitral itself, though under a more solid rule, he was perhaps in still greater danger, and it is much to the credit of both the Havildar's pluck and discretion that he was able to pass through so many dangerous places not only without loss or injury to himself or party, but actually without getting into a disturbance of any kind.

(106.) This route survey, with the peaks which were determined trigonometrically last season, may be said to have put into my hands the key of the geography of the whole of the unknown region which it was desirable to explore, with the exception of Kafiristan proper. Other attempts will be made to more fully explore this interesting territory; something may be done to farther elucidate the geography of Kafiristan, but I am not sanguine as yet of being able to make much advance in that direction, the risk being still too great to authorise my sending an exploring party through the heart of the country as I should like to do. Various other explorations are in progress and will be reported on in due course.

(107.) The Havildar took Latitude Observations at 5 points, and determined the heights of 4; his route survey 286 miles in length, mostly over new ground, may be said to have opened out the geography of 13,000 square miles of *terra incognita*. The results of this his first attempt at exploration are very satisfactory, and I think promise well for the future when more extended operations are attempted.

T. G. MONTGOMERIE, MAJOR, R.E.,
Offg. Supdt. Great Trigonometrical Survey of India.

DEHRA DOON,
December 1st 1871.

Abstract of the out-turn of work executed by the Great Trigonometrical Survey parties, during the Official year 1870-71.

Description of Details.	1 Brahmaputra Series. 24-inch Theodolite.	2 Eastern Frontier Series. 14-inch Theodolite.	3 Bider Longl. Series. 36-inch Theodolite.	4 Belaspur Mdl. Series. 24-inch Theodolite.	5 Bombay Party. 24-inch Theodolite.	6 Madras Party. 24-inch Theodolite.	7 Guzerat Survey. (Topographical.)	8 Kattywar Survey. (Topographical.)	9 Kumaon and Gurhwal Survey. (Topographical.)	Total.
Number of Principal Stations, newly fixed,	...	8	4	12	16	7	...	...	...	47
Number of Principal Triangles, completed,	...	12	5	12	20	10	...	...	...	59
Area of Principal Triangulation, in square miles, ...	...	2,111	783	686	5,649	1,974	...	...	...	11,203
Lengths of Principal Series, in miles, ...	...	86	37	52	161	67	...	...	...	403
Average Triangular error, in seconds, ...	...	2·00	0·05	0·32	0·44	0·54	...	...	...	...
Average Probable errors of Angles, in seconds, ±	...	0·85	0·26	0·26	0·18	0·18	...	...	...	...
Azimuths of verification, ...	...	...	1	...	2	...	...	...	...	3
Number of Secondary Stations whose positions and heights have been fixed, ...	...	...	1	6	19	34	97	212	98	467
Number of Secondary Stations whose positions only have been fixed, ...	...	...	...	3	...	10	...	744	27	784
Number of Secondary Triangles of which all 3 angles have been observed,	...	...	3	8	14	3	343	207	24	602
Area of Secondary and Minor Triangulation, in square miles, ...	...	*3,931	314	504	1,200	1,070	841	2,204	12	10,076
Number of points fixed by intersection but not visited, ...	...	...	20	3	44	41	213	...	104	425
Length of boundary lines and check lines Surveyed, in miles	...	...	...	...	...	...	47	681	52	780
Area Topographically Surveyed on scale of 6 inch = 1 mile, in acres,... ...	...	...	...	...	...	...	...	...	60,027	60,027
Area Topographically Surveyed on scale of 2 inch = 1 mile, in miles,... ...	...	...	...	...	...	...	534	1,757	...	2,291
Area Topographically Surveyed on scale of 1 inch = 1 mile, in miles, ...	...	...	...	...	...	...	...	301	...	301
Number of Revenue Survey Stations and boundary pillars fixed, ...	...	...	...	1	...	...	...	...	...	1
Number of Principal Stations selected in advance, ...	11	7	18	8	8	7	...	...	...	59
Lengths of Approximate Series, Principal, in miles, ...	60	48	144	42	59	100	...	...	...	453
Number of Towers, constructed, ...	10	...	...	7	...	...	...	...	...	17
Do. Platforms constructed for Principal Stations, ...	...	7	13	3	16	11	...	...	...	50
Do. Platforms constructed for Secondary Stations, ...	...	...	...	4	7	...	...	109	?	...
Do. Miles of Rays cleared, ...	475	30	...	135	15	32	...	...	...	687
Do. Miles of path-way made, ...	...	592	100	...	15	...	...	...	...	707
Do. Hill tops cleared of forest and jungle,	4	20	10	6	8	4	...	...	...	52
Do. Principal Stations whose elements were computed, ...	...	?	?	?	7	14	...	...	...	...
Do. Secondary Stations whose elements were computed, ...	...	?	?	?	66	47	175	?	340	...
Do. Preliminary Charts of Triangulation,	...	1	...	...	2	1	...	...	...	4
Do. Principal Stations placed under official protection, ...	...	...	...	10	14	7	...	...	...	31
Do. Stations protected and closed, ...	...	...	5	10	9	14	...	...	...	38
Length of Line by double leveling in miles,	...	...	...	...	...	...	...	...	...	308
Number of points whose heights have been determined by spirit levels, ...	...	...	...	...	...	...	...	...	...	166
Number of points whose Latitudes have been determined Astronomically, ...	...	...	...	...	...	...	...	...	...	15
Length of Route Survey for exploration, in miles, ...	...	...	...	...	...	...	...	...	...	289
Area of unknown territory explored, in square miles, ...	...	...	...	...	...	...	...	...	...	13,000

* These secondary points consist only of snow peaks.

APPENDIX.

EXTRACTS FROM THE NARRATIVE REPORTS

OF THE

EXECUTIVE OFFICERS IN CHARGE

OF THE

SURVEY PARTIES AND OPERATIONS.

Extract from the Narrative Report—dated 16th July 1871—of W. G. BEVERLEY, ESQ., Assistant Superintendent 2nd Grade, in charge Brahmaputra Series.

(2.) Shortly after receiving charge of the party from Captain Thuillier, I left Head Quarters accompanied by Mr. Neuville and arrived at Calcutta on the 25th October. As soon as all the arrangements for organising the Native Establishment &c. were completed, the party again took the field and assembled at Kooshtia on the 12th November. The country being still under water from the late inundations, the main camp proceeded by boat up the river and arrived on the 4th December at Kallygunge on the Brahmaputra, close to the stations where work was to be resumed.

(3.) The operations of the season were confined to 1st, extending the approximate work and effecting a junction with the Assam Longitudinal Series, taken up by myself; 2nd, the clearing and testing of the final rays between stations fixed the previous season allotted to Mr. Neuville, and 3rd, the construction of masonry pillars to which Mr. Harris was deputed.

(4.) In conducting the approximate work I had been directed to adhere as close as possible to the Meridian of the Series, and at the same time to avail myself of spurs from the Kurribari Hills for stations on the Eastern flank so as to reduce the number of tower stations and the heavy attendant expenses.

(5.) Before laying out the triangulation, I thought it advisable to reconnoitre the low hills with a view to selecting such sites as would involve the least outlay for clearing the summits to render them visible from each other as well as from the plains, and which would be made accessible for a large Theodolite at a small expense.

(6.) The spurs from the higher ranges generally run parallel to each other down to the Brahmaputra, are of nearly the same altitude for a considerable distance towa rds the interior, and densely wooded to their summits with heavy interlaced bamboo and other jungle, and tall elephant grass. The selection of stations in ground of this nature, to fulfil the requisite conditions, was not an easy matter; however by the end of December I had selected and fixed the sites of 3 stations which being situated near the ends of spurs required no clearing of forest rays and very little at the summits. These are easily approached from the plains below and have water at an easy distance. Roads for the large Theodolite can be laid out at a trifling cost.

(7.) The side Alangjani T. S. to Samding H. S. of the Assam Longitudinal Series has been selected as the side of junction. Both these stations as also Dhobri were visied; the platforms and upper markstones at Dhobri and Samding were found in good preservation, but the tower at Alangjani had fallen down about 12 or 14 feet, and the rest was rapidly crumbling to pieces. The archway being closed up, the markstone is likely to be still in existence.

(8.) The tower of Alangjani in 1856-57 was 0·7 miles from the river bank, and only 1100 feet distant at the beginning of this year; as the river was cutting its banks in the direction of the tower it is not unlikely that the site will have been washed away before next season. I propose if the station should not be in existence that a new site be selected on the ray to Samding on the left bank of the Dokooar river at a sufficient distance from it, and the rays be cleared to Dhobri, and so to close the series on the side Dhobri to Samding by a single triangle; or by revisiting Pertabganj T. S. the Dhobri pentagon may be recomputed, though it would involve the rebuilding of the Pertabganj tower.

(9.) By the end of February all the trial rays had been carried, and sites fixed for the remaining stations in the plains, which with one exception are all selected at such a distance from the Brahmaputra as is likely to ensure permanency. In the exceptional case of Gobindpoor, a safer site can be had about a mile further east, and which could be selected as soon as the existence of Alangjani had been ascertained and its position finally determined.

(10.) The approximate series was carried up to the side Halkachar to Janakipur during seasons 1868-69; in 1870-71 it was carried over a direct distance of 60 miles and arranged as a double series, consisting of a double hexagon, a pentagon and two quadrilaterals. I had intended to continue the work with regular hexagons similar to those employed from the origin, but on ariving at Amkhoa the proposed site of the centre of the first hexagon I found the nearest hills only six miles distant, which from their proximity could not be overlooked, and so was obliged to abandon that arrangement.

(11.) The combination of figures adopted is the only one which requires the fewest towers to be erected and the least number of rays to be cleared and paid for. The two quadrilaterals however can be modified into a single hexagon by the introduction of another station

farther east, viz. Rangira H. S. This point has been selected as a station by the Topographical Survey and will therefore be useful, as one of the points of junction between the two surveys. The introduction of this point will obviate a vast amount of delay and vexation likely to occur in observing the two long diagonal rays from Gobindpoor to the hills, but it will also slightly alter the general meridional direction of the series. This deviation at the terminus is however of no consequence.

(12.) The final rays have been cleared up to the side Narsingbhanj to Peshkarbhita, and with few exceptions have all been tested satisfactorily. It was not considered advisable to clear the rays of the last two figures until the sites of Alangjani and Gobindpoor had been definitely fixed and the quadrilaterals retained, or the hexagon in lieu, adopted. In either case there will be very little final ray clearing for the ensuing season.

(13.) The whole of the country traversed by the approximate series during 1869-70 and 1870-71 is (excepting the hilly tract on the Eastern flank for about 35 miles) cut up by numerous large and small rivers. The soil is of so loose and sandy a nature that even the small streams have been known to shift their channels as much as $\frac{3}{4}$ of a mile in one season, while the excursions of the Brahmaputra have a far wider range. There are traces of this river having once flowed 18 miles from its present bed. Most of the numberless swamps which are dotted over the country are depressions formed in the beds of large streams which at some time previously had flowed in that direction. In consequence of these changes, there was much difficulty in tracing on the ground the sites of streams and villages as shown on the one-inch map of the districts compiled 13 years back. For the same reason it is impossible to ensure the existence of any of the towers for any period, although every precaution has been taken to select sites sufficiently removed from the river, and which are likely to exist until at least the final work has been completed. The station of Parkoksa up to which final observations were taken in 1869-70, was situated $1\frac{1}{2}$ miles from the river, but last season it was scarcely $\frac{1}{4}$ of a mile distant, and unless the river shifts its channel to the opposite side, is almost certain to be washed away.

(14.) From the end of November to the middle of February there are very heavy fogs all over the country and especially over the rivers and marshes; they set in early in the evening and do not clear off sometimes till 10 or 11 in the morning. From the middle of February until the rains set in, dust and sand storms are prevalent, and it is sometimes impossible to see across the river until the haze is dissipated by rain. Considerable delay may therefore be expected in taking observations to both day and night signals after the middle of December. The country is however pretty healthy from the beginning of November to the end of April. There is a good deal of malaria at all times in the neighborhood of large swamps and marshes, but it is salubrious along the banks of the large rivers.

(15.) Mr. Neuville was employed in clearing and testing the final rays between stations selected the previous year. He commenced work about the end of November, and by the end of March had selected the site of one station by three trial rays, and carried 276 miles of final clearing on 25 rays. Mr. Neuville was very careful in carrying and testing his rays, and although suffering from ill health he was enabled to complete all the work allotted to him. His progress was very satisfactory.

(16.) Mr. Harris was employed in building the towers. He took the field early in October and made all the requisite arrangements for providing men and materials. Mr. Harris completed 10 perforated masonry pillars 37 feet each in height and had bricks moulded and burnt at 3 other stations. Mr. Harris' arrangements have always been excellent, as well in procuring labor as in taking every necessary precaution in securing stability in the pillars he has had to erect in the loose sandy soil of the district. Mr. Harris has worked very well and successfully and has had a hard field season's work, having had to remain in camp to the end of May when the country gets very unhealthy.

Memo of work executed during Field Season 1870-71.

Description of details.	
Number of stations selected	11
Ditto of miles of rays cleared	475
Length of approximate series (Plain) in miles	60
Number of hill tops cleared of jungle	4
Ditto of towers constructed	10
Ditto of stations at which building works have been commenced	3

Extract from the Narrative Report—dated 1st July 1871—of W. C. ROSSENRODE, ESQ., Deputy Superintendent 3rd Grade, in charge of the Eastern Frontier Series (Assam Valley triangulation).

(2.) I left Calcutta on the 25th October 1870, accompanied by Messrs. O'Sullivan and Bryson by the river steamer Burma and reached Gowhatty on the 8th November.

(3.) The party took the field on the 30th November 1870; the earliest date on which I could safely venture out on field duty into the forest clad, and marshy province of Assam. I was told however that its malarious and pestilential jungles, its bogs and marshes, should not be entered before the 1st January. The field operations had hitherto been so very short for the last two or three seasons, that I ventured out a month earlier than is usually done in this province; by doing so I secured a longer interval of fine weather. Mr. O'Sullivan preceded me by a few days having left Gowhatty on the 21st November.

(4.) I arrived at my first station Khola on the 5th December and completed work on the 10th of the same month and proceeded to Singri H.S. on the right bank of the Brahmaputra river. For want of boats at the ferry two days delay occurred in crossing the river—five days more were occupied in marching. It took me therefore 7 days from Khola to Singri a distance of 35·4 miles. The cause of this great delay is the want of roads in Assam. There are only two principal kacha made roads, one on each bank of the Brahmaputra river. The road on the left bank has been made from Gwalpara to Debrugurh; and the other on the opposite side of the river goes through the whole length of the country. I had to use the road on the left bank as far as Nowgong, from thence I proceeded to Lakwa ghat ferry. The ferry took me to Tezpore, a distance of three miles; and the road on the right bank to Dharang *vel* Mangaldi the subdivision of Tezpore, was used from Tezpore to Gobroo ghat a distance of 14 miles, and a path was cut to the station branching off from this road. The route was a most circuitous one. Much time was lost this season in marching from station to station for the want of roads and paths in this province. The great scarcity of labor, and the time required to collect a band of coolies causes considerable delay in cutting rough paths; and however circuitous the Government made roads may be, they must be used.

(5.) The plains for the most part are covered with long dense grass fever breeding jungle 8, 10 and 12 feet high in Assam. As far as the eye can reach nothing else is seen in the plains but grass. The hills are clothed with dense forests, and the rivers and streams are lined with narrow belts of tree jungle. Both in the plains and hills game abounds, Tigers, Rhinoceros, Bears, Buffaloes, Deer and wild Elephants are to be found every where. The signalmen were frequently in very great peril of being destroyed by the first and last of the above animals. They used to pay nightly visits at four stations and the Elephants indulged in their usual mischievous propensities by pulling away the grass and bamboos from the huts and in some cases hurling them to the ground. There were three men at each station quite unprotected, a raised hut with a large tree of good girth and height stood conveniently contiguous to it and was the only safe retreat for them when menaced by the approach of either a Tiger or Elephant.

(6.) The lampmen begged and implored of me to supply them with fire-arms; but I had none to give. It will be necessary to provide each signalman with a musket and few rounds of ammunition to scare away the wild animals. The wild Elephants are so very numerous and so bold that they have come to the station within a few yards of Mr. O'Sullivan's tent and only retired after a few shots were fired. On another occasion two messengers were returning after having communicated my orders to the detached signalmen. They were stopped by a herd of elephants at about 4 o'clock in the afternoon a short distance from my camp. The men perceiving their danger climbed the highest trees and shouted for assistance, they were not heard in camp until 8 o'clock at night, when stillness prevailed at the station, almost every man in camp hurriedly arming himself with a club, went to their assistance shouting and yelling at the top of their voices, the herd of elephants hearing the din advanced towards the new comers trumpeting, tearing up the earth and throwing dust into the air, my men retired, armed themselves with my guns and ammunition and returned to the rescue; on nearing the herd shot after shot was fired until the elephants made a headlong rush down the hill side into the forest. The two men on the trees descended and came into camp with the men who went to their assistance. Many very narrow escapes occurred last season.

(7.) The jungles are fired from January to April and the spectacle from our hill stations is magnificent during the night. The dense grass jungle extending for miles is by this time ready for burning and the villagers commence firing it. The spectator from the summit of a hill sees himself encircled by walls of fire. In an incredibly short time driven at race horse speed by the wind the fire leaps and crackles on its destructive course consuming every thing it

comes across. The volumes of dense black smoke from this mass of burning grass literally darkens the sky and forms an intermediate canopy. The atmosphere becomes impregnated with smoke and the most powerful luminous signals cannot penetrate it. The jungles once set on fire burn continuously driven hither and thither by the wind. To avoid total destruction to the observatory tent, public and private property of the party at each station great precaution is necessary to have the hill cleared and burnt before visiting it. This is absolutely necessary at all times; for fires in Assam advance so rapidly that unless these precautions are taken the safety of the party as well as of the property is endangered. To save any thing or to escape without injury is impossible when the fire is advancing up the hill propelled by the wind. Although these fires cause considerable delay to our operations, they do a great deal of good to the country in purifying the air by consuming the decomposed vegetable matter under the grass jungle. The noxious miasmatic exhalation from the numerous marshes, bogs and streams causes much sickness in the early part of the field season, shortly after the rains. During the burning of the jungles the country becomes much healthier and continues healthy until the rains set in when again sickness breaks out.

(8.) I was detained at Kamakia H.S. for a month and a half, the ray to Khola H.S. was 50 miles in length; even in fine weather so long a ray causes delay sometimes, but in such weather as I then had the signals were not once seen during the whole of the above period. A good shower of rain fell, extinguished the fires, cleared the atmosphere of haze and smoke and enabled me to complete the two angles dependent upon Khola H.S. Although I pushed on as rapidly as I could to Kandali the next station to take advantage of the clear weather after the recent fall of rain I found on arriving there that the haze was as bad as ever and the jungle ablaze in all directions. Fortunately after a short stay some more rain fell and I was able to complete at Kandali H.S. I next visited Mehekengthu H.S., much delay occurred here from the weather and from the signals from Chengheheshon not being visible. The cause soon became known on the return of my messengers. I was informed by them that the 3 men forming the signal party were completely prostrated and incapacitated from stings of the Naga poka or Naga fly. These flies from there diminutive size can scarcely be seen, they are very numerous and spare no one; every nude part of the body is stung, inflammation with great irritation follows, swelling succeeds and a crop of foul ulcers make their appearance; these become very painful and increase in size and spread all over. Three different parties of signalmen were disabled at the above station and one man died from the effects of the poison from these flies after great and protracted suffering. On my reaching the station the men were so enfeebled from their sufferings and from the ulcerated state of their bodies that they had the appearance of living skeletons; one man could only crawl on all fours. These men were at once removed and sent to the Native Doctor and I am glad to say they all recovered.

(9.) I and the men who accompanied me to Chengheheshon were also stung but from taking the precaution of having as little of the body bare as we possibly could, from frequent use of carbolic acid soap and carbolic acid ointment to the ulcers our sufferings were less and as I was able to leave the station on the fourth day after my arrival there, we soon recovered from the stings of these Naga flies. Strange as it may appear, it is however a known fact that the Naga hills alone are infested by these poisonous flies—a few are to be met with here and there on the hills inhabited by the other tribes but myriads exist in the hills occupied by the Nagas. Mr. O'Sullivan who suffered very much from the stings of these flies informs me that they were numerous on the three Naga hills which he subsequently visited and fixed after Chengheheshon H.S. From their being confined mostly to the portion of country inhabited by the Nagas they have derived their name from that tribe and are known as the Naga fly.

(10.) After completing the first quadrilateral and taking up the Tetragon we entered the hills and the delay was considerable in collecting coolies and procuring the greatest number obtainable. I was obliged to abandon tents altogether for want of coolies, huts were erected at the different stages and a hut was constructed in lieu of the observatory tent. Had I taken the tents and depended upon the country for coolies to convey them I could not have moved at all.

(11.) My former experience in Assam was of great use. I knew that labor was scarce and was obtainable with difficulty. In starting Mr. O'Sullivan I entertained a body of Cachari coolies on monthly pay and these men proved very useful to him during the whole season, and as a few were disposed to serve I have placed them in the regular native establishment in lieu of the recruits from the North-West Provinces who were from frequent attacks of fever, early in the season disabled, and did not rally during the whole of the field operations. Most of the men from Upper India were useless and were all discharged on coming into quarters. It is my intention to introduce the people of the country into the native establishment roll. By gradually doing so I hope to have men inured to the climate and acquainted with the country and its people.

(12.) Two of the Government elephants were employed in bringing in provisions from the Hauts, (weekly markets held at large villages far removed from one another in central and upper

Assam) and Golas (depôts for grain and other articles) and for conveying them on the march from station to station. The 3rd elephant was used for the baggage of the native establishment. The 4th for the observatory and baggage tents and the 5th and last for the medicine and office boxes, treasure chest, tools and office table.

(13.) Owing to the dense jungle partially inhabited, with very few and difficult paths and the utter impossibility of obtaining correct information regarding the names of hills or routes by which they can be reached the approximate operations could not be carried on with the same rapidity as in more favored hilly localities. Much time was lost in marching and searching for the hill which was to be selected and when found the highest tree was chosen and a bamboo ladder constructed from the bottom to the the top. On the completion of the ladder, the upper branches were cut away to obtain a good view of the surrounding country. If all the back stations were visible and the forward rays open, the clearing of the rays was commenced with at once. By this method stations were fixed in hill Tippera, Chittagong, Arracan and Burma and the same system was adopted in Assam. In this forest clad, hilly country to attempt to clear a hill without being certain as to whether it will answer or not would be most imprudent, money would be uselessly expended and time lost. Some idea of the height of the forest can be formed when on measuring one of these ladders the height was found to be 120 feet. The branches of the tree were some feet higher.

(14.) The Mekir tribe inhabited the country through which the operations were carried on during the greater part of the field season. The last four stations are situated in the ranges inhabited by Nagas. The difference between this tribe and the former is very great. The Mekirs are cheerful, willing and hardworking. The Nagas on the other hand are mulish, sullen and obstructive. They are the warrior tribe on these mountains and go about armed with spears, in the use of which they are very expert. They are lazy and indolent and shew very great unwillingness to act as porters or cutters. They are often very insolent and overbearing. This tribe has very frequently committed raids in the province and are much feared by the Mekirs, and other hill tribes; as also by the people in the plains. These savages cannot be depended upon. I beg to suggest that I may be allowed to give the Nagas presents of beads, broadcloth chudders and other trinkets which they would value and which would in a great measure conciliate them. The chief men only will receive the chudders. The beads and other trinkets will be distributed to the others who render assistance.

(15.) To avoid the hills inhabited by these savages and to carry the triangulation through the plains will be very expensive and tedious and it is my intention to take advantage of the Naga hills to save time and expense; for it is my conviction that what I can execute in one season on the hills will occupy me three or even four seasons to accomplish in the plains.

(16.) The party remained out this season much longer in the field than in previous years. The rains set in as usual in the beginning of April with violent storms, thunder and lightning and continued so during the whole month. There were fewer storms and less thunder and lightning in May but the rain was more frequent and severe. I held my ground until the 15th of the month, but I could do so no longer, the rains actually set in, the men were falling sick, and the country was daily becoming more difficult for marching owing to the rapid rise of the hill streams, I closed work and marched to Shillong where the whole of the party was concentrated by the 5th June. Shortly after the rains set in, the plains in Assam gradually become submerged. Swarms of leeches make their appearance, they are to be met with every where, on the hills and in the plains. Every one in camp suffered from them, there was no avoiding or escaping from these pests; with garments soiled and bloody we came to the end of each stage. A poisonous kind of tick is also very numerous. These ticks are to be found among clumps of bamboos. They like the leeches cannot be avoided; a sudden pain is felt about some part of the body and on examining it a tick is found with his head and claws buried in the flesh. In removing them force is used and the claws and head with proboscis remain buried. This causes much irritation and pain for months and subsides only after being cauterized with nitrate of silver.

(17.) Mr. W. J. O'Sullivan, Assistant Surveyor 2nd Grade was indefatigable in his exertions to provide me with stations and to advance the work as rapidly as he could. In the early part of the season he suffered in health and latterly from the stings of the Naga pokas. Notwithstanding the ulcerated state of his body and bad health he kept his ground and prosecuted his arduous labors walking every inch of ground traversed by him during the entire field season. Horses were useless in the country through which he carried on the triangulation. He succeeded in selecting a Tetragon and a Pentagon advancing the approximate work 47·6 miles during the season. Considering the difficulties of marching in a country without roads and paths, the dense jungles sparsely inhabited and great scarcity of labor Mr. O'Sullivan has done very well.

(18.) Mr. C. Bryson, Assistant Surveyor 3rd Grade assisted me in the Observatory until the 17th February. He fell ill the next day; I left him at Silghat for medical treatment with the Native Doctor. Mr. Bryson was very useful in the observatory and understands his work

thoroughly. The 14-inch Theodolite had very coarse and uneven wires and I got Mr. Bryson to put on new ones and to adjust the collimation. I found he understood all the adjustments of the Theodolite and its manipulation and during an attack of fever I had at Kamakia H.S., Mr. Bryson observed the Snowy Peaks at my request and obtained very good results. On recovering from the attack of fever above mentioned Mr. Bryson joined Mr. O'Sullivan and assisted him in the approximate operations. He constructed 3 Platforms and determined and cleared the ray between Khelebenshon and Kankochan. Mr. Bryson has worked well.

Extract from the Narrative Report—dated 1st July 1871—of H. BEVERLEY, ESQ., Surveyor 2nd Grade, Officiating in charge of the Bider Longitudinal Series.

Consequent on the death of Mr. G. Shelverton, I was, by D. O. No. 2 dated 10th March 1871, placed temporarily in charge of the Bider Longitudinal Series, it has therefore devolved on me to submit the narrative of the operations of the late field season and recess.

(2.) Before proceeding further, I would beg to submit the following short statement of Mr. Shelverton's illness and death. In the second para of his narrative report for season 1869-70, Mr. Shelverton referred to his own illness during the months of January and February 1870, which resulted in a very severe attack of brain fever, from the effects of which he nearly died. I regret to state that he appears never to have quite shaken off this illness; during the recess he several times mentioned he had suffered from attacks of fever, which seem to have lasted only for the day as far as we are aware and which appeared to have come on periodically. I believe the comparatively favorable climate of Waltair kept the fever in check, and it required him but to expose himself again to the malarious tract, for the disease to take a firmer hold of his constitution. Mr. Shelverton left Waltair on the 7th January, and only seventeen days after, he experienced his first attack of fever, which continued off and on till it terminated fatally on the night of the 26th February. In his official diary he noted the dates he had fever viz., from the 25th to 28th of January inclusive, again from 7th to 10th and 19th to 24th February inclusive, on this last day he remarked in the diary "unable to go up to Rápák as I was laid up with fever till midday, very much weakened by this lengthened attack of illness," the next day he was too ill to make further entries, and the following day was his last. The Native Doctor states he suffered from remittent fever, and that inflammatory symptoms set in on the 25th when he became delirious and eventually unconscious—he remained in that state till his death the following night. I have been told that this fever was of the same type as the brain fever of the previous season. His remains were removed for interment by Mr. Wrixon to Doomagudiam, a small station about 40 miles by the village paths from Arkur village where he died.

(3.) Mr. Shelverton was in the habit of treating himself for his complaints, and he rarely called in any professional aid. He was also very reticent in alluding to his ailments; hence it was that all in camp were unaware of the seriousness of his malady till the alarming symptoms set in, when it was too late either for the Native Doctor to do any thing for him, or for Mr. Wrixon to urge him to go, or even to remove him, to the nearest civil station for medical aid.

(4.) Owing to the unhealthiness of the tract of country this party had been working in the previous year, most of the men of the Native Establishment who were from the N. W. Provinces took their discharge, and many of those who had obtained leave to visit their homes remained away. Mr. Shelverton consequently found about the middle of November, that he had neither instrument carriers, nor men for an extra Burkandaze guard. He then on the 15th November, applied to the Collector of Ganjam to entertain 80 men for the Establishment from that district who joined him at Waltair on the 21st December. On the 14th December, Mr. Shelverton applied for a Police guard from the Superintendent of Police here, in lieu of the extra Burkandazes who had not returned from leave; as that Officer had no orders to supply the guard, reference was made to yourself in the matter, and eventually it was furnished on the 2nd January.

(5.) Under these circumstances, and as the country was notoriously unhealthy for about a month and a half after the termination of the rains, Mr. Shelverton with Mr. Wrixon and the main camp did not leave Waltair till the 7th January. Myself, Mr. Bell and the signal parties however started by the 29th December 1870.

(6.) Owing to instructions conveyed in letter No. $\frac{16}{970}$, dated 20th September 1870, from the Superintendent G. T. Survey, Mr. Shelverton resolved, if practicable, to have a symmetrical double connection with the Coast Series on the side Kap-Dhar, (which had last year been reported impracticable) either by the quadrilateral Dhar-Kap-Khairabiding-Cheru, if the ray Dhar-Cheru was likely to be visible, or by a Pentagon, including the above stations and new central and southern flank stations. For the former he proceeded himself with the main Camp to the foot of Dhar, sending Mr. Wrixon to the hill top to report whether the ray Dhar-Cheru was visible, or whether it could be altered for a more suitable point: Mr. Wrixon reported the quadrilateral impracticable. Meanwhile I was instruct to select the centre station, which I succeeded in doing, but about 9 miles south of the proposed position; and Mr. Bell was requested at the same time to fix the southern station to complete the Pentagon: he succeeded in getting a point on the spot indicated. Mr. Shelverton however found that this station was too close to the centre, he therefore with Mr. Wrixon proceeded to select a new southern station: two hills were ascended, one by himself, and the other by Mr. Wrixon, the latter was found to suit exactly for the purpose. Mr. Shelverton next marched to Singawaram H.S., the 2nd centre of the double Polygon of last year, where he completed a set of circumpolar star observations to Polaris and 4165 Ursæ Minoris, after which he began the Principal Observations for the season at Narakonda. Completing this station on the 18th February 1871 he marched to Arkur village below Rapak, his next station, where his lamented death took place.

(7.) Under instructions from Mr. Shelverton, I selected Kalingkonda H.S., the centre station of the last figure of the Bider Series, then inspected Kap H.S., one of the stations of the Coast Series. Finding that the station was in good preservation, I prepared it for final observations and then prepared Khairabiding H.S., after which, I selected Balidongor H.S., making the Pancha pentagon into a compound figure in order to get a suitable base (Munas-Balidongor) for the series along the meridian of 82°. On this base I had thrown out the Tulsi-Saikarpan double figure, and was on my way to Y station, when the melancholy intelligence reached me at Jugdulpore (Bustar), 13 days after its occurrence, I immediately retraced my steps and joined the Head Quarters camp on the 20th March. Prior to this Mr. Shelverton intimated to me in a letter which reached me on the 8th March—in supercession of his previous instructions—that he wished me to start the Meridional Series on the side Khairabiding-Munas. This new base I have since retained, and have laid out two figures on the meridian of 82°; the two last points have not been visited. The two stations completing the Balidongor figure were selected by Mr. Bell, at my request. On taking over charge, I telegraphed to yourself and received permission to resume final observations suspended by Mr. Shelverton's death, and was enabled to complete observations at the five remaining stations of the Kaler pentagon (one station having been observed by Mr. Shelverton) from the 28th March to the 30th April inclusive. The "chota barsat" having set in, and the country becoming too unhealthy to work in any longer, I closed work, the party returning to recess quarters by the 18th May.

(8.) As desired by Mr. Shelverton, Mr. Bell selected a southern flank station of the Kalingkonda pentagon, which as stated before was rejected and Pandawala selected in its stead. He next visited Cheru and tested the ray to Pedakonda. Below this hill, at Guddum village he halted 12 days, awaiting instructions, at Mr. Shelverton's request. On the 18th and again on the 24th January, further instructions were sent to him, in accordance with which he first built the pillars and platforms and cut the roads to the hill stations of Cheru and Pancha, then observed secondary angles at Kaler, Kanslur, Pancha and Katamraj, and lastly prepared the stations of Kalingkonda and Pandawala and cut the roads to these stations. At Kalingkonda he received instructions from me to complete the Balidongor figure, when he visited and prepared the station of Yendrika and selected Silongdongor: the rays to this last station could not be tested owing to rain and cloudy weather. Mr. Bell closed work on the 3rd May and returned to recess quarters on the 18th idem. Besides the above, he had 30 hills poled for secondary work. I regret Mr. Bell has been unable to do a satisfactory season's work: it was from causes over which he had no control. For 12 days he was encamped at Guddum awaiting instructions, and again the instructions he received involved the loss of several days in travelling backwards and forwards through a wild and uninhabited tract of country to the stations he had either to prepare for Mr. Shelverton, or visit for secondary observations. He has suffered considerably from repeated attacks of fever throughout the season.

(9.) Mr. Wrixon was throughout the season with the main camp. As stated previously, he was sent to Dhar H. S. to report whether a quadrilateral was practicable, again he was sent to Pandawala, and this station was retained on his report as the southern flank station of the Kalingkonda figure. Under Mr. Shelverton he recorded in the observatory and was engaged in current office duties. I consider he did his best for Mr. Shelverton in the peculiar and trying circumstances he was placed in at the time of his death. Subsequently he remained with the party at Kaler village till my arrival, and assisted me during the remainder of the season in current office duties, and in recording in the observatory. A plane-table was set up which was used by Mr.

Wrixon for laying down villages round the principal stations and encampments, chiefly on the banks of the Sevaru R: the country round Papikonda and Pedakonda being too rugged and wooded for the table to be of much use. Mr. Wrixon has also suffered from repeated attacks of fever throughout the season. I beg to state that during the time he has been with me, I have been quite satisfied with the way in which he performed his duties.

(10.) Of the four stations of the Kaler figure finally determined this year, Singanama is in the Jeypore state, Kaler in the Upper Godavery district, Papikonda and Pedakonda in Rajamundry. The country throughout this tract is wild, more especially round Papikonda and Pedakonda, which are on the Eastern Ghats. The last named station is situated on a block of hills about 4,000 feet high, and was first visited by Captain Glassford the Deputy Commissioner of Sironcha in 1866. There are several villages round this station. Papikonda is quite uninhabited for several miles round. The other two stations have some small hamlets round them, consisting of but a few huts each. The inhabitants of these places, as soon as they hear of the approach of a party desert their villages and hide in the dense jungles round them, and no inducement will bring them back till the camp has left their vicinity. This was the case throughout the S.W. portion of the Jeypore district. Under these circumstances, it was impossible to get any assistance from the villagers whatever, either for procuring provisions or labor. On the banks of the Sevaru a rather large stream which passes close to Kaler and Rapak and falls into the Godavery, the villagers were not so timid, and our supply of provisions and labor were chiefly obtained from there.

(11.) The two figures remaining to complete the Bider Series are entirely on the Eastern Ghats,—a high table land about 3,000 feet above sea level—our stations ranging from 3,500 to 5,000 feet. The three stations Balidongor, Yendrika and Silongdongor of the Meridional Series, are also on the same range, the remaining points are on hills overhanging the plains of Bustar and Jeypore.

(12.) About the parallel of 18° 15′ the change in the language is a very marked feature of the country, the villagers to the north speaking different dialects of Ooriah, and those to the south Telegu. It is so peculiar that any one crossing from the one village to the other, is struck with the difference at once. Having Hindoostanies, Ooriahs and Telegus it was curious to notice the effect of this change in my camp.

(13.) There has been considerable sickness among the Native Establishment throughout the season, but only two deaths occured; one a classie from fever, and the other the camp Bunniah from Rheumatism after he had taken his discharge and left the party.

Extract from the Narrative Report—dated 16th August 1871—of H. KEELAN, ESQ., Offg. Deputy Superintendent 2nd Grade, in charge Belaspur Meridional Series.

(2.) The party left Head Quarters on the 4th and arrived at Chunar on the 7th November, and proceeded from thence to resume operations on the Bilaspur Meridional Series, in the Central Provinces, where, on the arrival of the camp, on the 11th December, at the tower station of Bodri, I commenced operations.

(5.) After giving full instructions to the detached parties, I proceeded southward to reconnoitre the nature of the country across the Mahanaddi. The course of this stream, where the series crosses it, is S. South West and N. North East and is bounded on its right bank by low, densely wooded hills running parallel to its course, and is by no means a large stream in this locality, though lower down, where the Seonath river, a deep stream, falls into it, the Mahanaddi assumes formidable proportions and becomes navigable from this point all the way down to the sea. The course of the hills, as I have noticed above, is very unfavorable for the triangulation, as at present; the west flank of the approximate series, lies on the level plain, requiring towers, whilst the stations on the east flank are situated on the hills. I expect that 20 or 30 miles lower down, the ground will be entirely hilly, when artificial elevations will be no longer required.

(6.) I returned north to inspect the progress the towers were making and by the 1st of February I was glad to find 2 or 3 of the new towers nearly ready for principal observations, for which I am indebted to the exertions of Mr. Surveyor H. E. T. Keelan. Finding the approximate work in so forward a state, I proceeded to the hill station of Sonti, the eastern point of the side at which the previous season's work closed, and there commenced obervations, and by the close of the month, observations were completed at the hill stations of Sonti, and Dalea, and at the tower stations of Bodri, Gathaora, Konargarh and Kotgarh P. station.

(7.) During the month of March final observations were completed at the tower stations of Kaneri, Bhitkuli, Pathaidi, Donga-Kharaod, and at Berdha, and Latua platform stations—thus completing 2 hexagons. There now being no prospect of advancing farther with final work, as the approximate series was progressing tardily, I proceeded on the 26th March to Pathaidi T.S., the centre station of the second hexagon, to observe a verificatory Azimuth, this point being situated very favorably and free from local attraction.

(8.) For these verificatory observations I selected *a* Ursæ Minoris, but the weather became unfortunately, from the very commencement, cloudy, and the same unfavorable aspect extended over a fortnight; so that I could never even complete a single zero. As the next pair of stars would not be available before the first week in May, and having a long march back to Chunar to recess the establishment, or that portion of it, for the protection of the instruments and stores, I gave up all hopes of completing this part of the season's programme and, on the 10th April, quitted the district with the intention of resuming these observations the first thing next field season, in the meanwhile having taken care to protect the tower from injury during the monsoons.

(9.) Mr. Surveyor L. H. Clarke was detached on the 11th December, first of all to rebuild the fallen tower at the station of Bhitkuli and then two new ones at two other stations at the lower extremities of the series, as well as to clear all the rays from those points: at the same time he was to ascertain, whilst building materials were being got ready, by means of scaffolding, the necessary heights the new towers should be, and in order, that he might carry on his duties more expeditiously, I detached Mr. Assistant Surveyor, Moore, after his return from medical treatment from Bilaspur, to assist him, and the following is the amount of work done during the field season under review viz. Built 1 small tower, 2 platforms, cleared 3 or 4 rays of his old work, selected 8 stations on the approximate series extending 42 miles in a direct distance, cleared 3 rays on it and removed jungle on 2 hill tops.

* Berdha, Latua.

(7.) Mr. Surveyor, H. E. T. Keelan received instructions on the same day to take up the upper portion of Mr. Clarke's previous season's unfinished work, to prepare materials in the first instance, to rebuild 3 towers that had come down, and clear all the rays from them, with instructions to co-operate with Messrs. Clarke and Peychers with the view of ascertaining the proper heights their respective towers should be. This Assistant's towers were situated at the head of the triangulation, just below the hills and were required sooner than those rebuilding lower down. He cleared all the rays in one of which he had to remove several huts in a village for which compensation was duly made, and had his towers ready in good time to commence the principal observations. I next sent him to finish the construction of the towers entrusted to Mr. Assistant Surveyor H. W. Peychers, in consequence of that assistant being required to record in the observatory. After the completion of the building of these towers he was next directed to lay down the position of Belaspur, the town and civil station that gives the district its name, also to lay down the position of the old and decaying town of Ratanpur. After this work was completed he next proceeded to connect the Bisrampur Minor Triangulation with a side of the Principal Series, as this work was left unfinished the previous season owing to Mr. Peychers, who was employed on it, having been recalled to build the rectangular pillars over the Principal Stations and transfer them to the village officials. The tract of country in which this Minor Triangulation lies is notoriously unhealthy and Mr. Keelan had just finished when himself and nearly all his men including private servants were prostrated with jungle fever. The out-turn of work done by this assistant was very satisfactory, notwithstanding that the very hazy and cloudy weather during the latter end of March and nearly the half of April delayed his completing the work sooner.

* Bodri, Gathaora, Kaneri.

(11.) Mr. Assistant Surveyor H. W. Peychers received instruction on the 11th December to take up a third portion of the previous seasons unfinished work and to prepare materials at 3 tower stations. The debris of the old tower at Konargarh had to be removed and a new one built over the station. He had also to clear all the rays from his 3 stations, and to co-operate with Messrs. Clarke and Keelan to determine the heights his towers should be. Mr. Peychers cleared all the rays, finished the new tower at Konargarh and built a portion of the second very expeditiously when he was recalled to take Mr. Moore's place in the observatory.

(12.) Mr. Assistant Surveyor A. Moore was employed during the greater part of the season under Mr. Clarke's orders, that is, from the end of January to the end of April, on the approximate series, as I was apprehensive that his malady for which he had been sent to the Civil Surgeon of Bilaspur might at any moment return, and retard the principal operations to a greater extent than they already had been. It does not, however, appear that his assistance on the approximate series was properly directed or of much use as the out-turn of work on it exhibits.

(17.) In conclusion, I am glad to be able to speak of Messrs. Keelan and Peychers in terms of commendation for their zealous and hearty assistance during the past field season.

Extract from the Narrative Report—dated 6th July 1871—of Lieutenant M. W. ROGERS, R.E., Offg. Deputy Superintendent 3rd Grade, in charge Bombay Party.

Messrs. Price and Bond left Bangalore on the 5th November, the former to carry on the approximate Series, the latter to select and build a group of Zenith Distance Stations for Captain Herschel. The Main party took the field on the 18th November and commenced observations at Pangurh H.S., on the 1st December. From this date the observations were carried on continuously without any occurrence worthy of remark.

Circumpolar observations for Azimuth were taken at Honur H.S. and Darrur H.S., the former is, and the latter is intended to be, the center of a group of Zenith Distance Stations

The weather was very favourable until the end of February, by which time the series had reached the Tongabudra river. After this date the heat increased greatly and the atmosphere became so hazy that it was seldom that the hills on which the Stations were, could be seen, except, perhaps, for an hour towards evening. This caused some delay in the observations, and still more in the approximate series; this latter had been stopped last season by order of the Superintendent, and was therefore already not so far in advance as it should have been: and the further delay caused by the weather brought the principal observations still nearer to the approximate work; I therefore decided on closing observations a fortnight earlier than I had intended. The observations were carried to about 20 miles north of the River Kistna and were closed at Janikalu H.S., on the 5th April.

The series has been advanced 160 miles, 65 angles having been observed at 18 principal Stations forming one double polygon, one single polygon and one Hexagon, the southern portion of a double figure; the whole covering an area of 5649 square miles. I hope during the next season to complete the series to Bider and also to connect the towers of Hyderabad, Kurnool and Cuddapah.

After closing the principal observations, I marched to Gooty and observed at three stations in the vicinity, in order to connect Colonel Lambton's Astronomical station of Namthabad with the principal triangulation. This being finished, I closed the stations in the neighbourhood and marched towards Bangalore, which was reached on the 4th May.

For the last 2½ months of the season the work was chiefly in the territories of His Highness the Nizam. At the instance of the Resident, a Tehsildar and Sepoy guard was attached to the camp and rendered great assistance. Arrangements were made to supply Mr. Price and myself with officials, permanently attached to the camps, and this will, I understand, be done next season. I am greatly obliged for the assistance rendered to me by the Nizam's Government. The health of the party was generally good, I lost two men from fever, but with that exception the season has been fairly healthy.

Mr. Price was employed in selecting and building stations in advance of the main series. He completed 15 stations besides selecting 4 zenith distance stations for Captain Herschel and placing marks on all important and conspicuous points. I have already mentioned the difficulties caused by the hazy weather: it reflects great credit on Mr. Price that he got on at all during the last month, so dense was the haze. On his homeward march he closed 9 stations and connected a new zenith distance station with the triangulation. Owing to the requirements of the series I was obliged to throw the whole labor of the station building on him; and although the heat and hard work caused his health to suffer towards the end of the season, he persevered and accomplished his work to my entire satisfaction and in a manner and with a good will which does him great credit.

Mr. Bond was employed in selecting and building four zenith distance stations for Captain Herschel. This was the first example of this kind of station and Mr. Bond completed his work satisfactorily. He next selected two stations for connecting Namthabad with the main triangulation. After this he proceeded to carry out a minor series to connect the town of Cuddapah. In this, I am sorry to say, the progress has not been satisfactory. The heat was very great and Mr. Bond and his party suffered severely from fever: for some time he had but two men fit for work.

Cuddapah is surrounded by trees and it was a matter of difficulty to see the principal buildings without going to greater expense and trouble in clearing rays than the importance of the work would justify. The inhabitants were very unwilling to render assistance which also caused delay and trouble; under these difficulties, Mr. Bond chose his points with judgement. Having selected and built the stations along a distance of 90 miles he commenced observations,

but at his first station was taken ill and had to go into Cuddapah for medical treatment; he was ordered by the Surgeon there not to attempt to go into camp again that season, he therefore returned with his party to Bangalore which he reached in the end of April. This was his first season at independent work. I was very well satisfied with the first portion, and that the amount done was small was, I consider, his misfortune and not his fault.

Mr. Torrens joined the party in November and accompanied me as recorder during the season; he works well and willingly and a little more experience and neatness will make him a very useful Assistant.

During the Recess of 1870 the computation of the first double polygon of the Northern Section of the Bangalore Meridional Series was completed and the two azimuths, observed at the ends of the Bangalore Base-line, computed. The Secondary triangulation on the west coast from Bombay to Goa, was then computed. This involved constructing a preliminary chart of the South Konkan series which was a work of considerable labor.

Extract from the Narrative Report—dated 14th July 1871—of Major B. R. BRANFILL, Deputy Superintendent 3rd Grade, in charge of the Madras Party.

The party took the field in the Coimbatore District as early in November as the weather permitted, and as soon as the district to be triangulated was reported to be healthy enough to work in.

The season has been an unfortunate one, and according to the statements of both Native and European inhabitants, a very unusual and exceedingly unhealthy one, on account of the rainy and cloudy weather.

The work to be done was the continuation of the Bangalore Meridional Series, Southern Section, to the South of the parallel of 11°, carrying it over the great mountain range of the Palnei Hills, which here rises abruptly 6000 to 7000 feet from the great plain of Coimbatore, extending from the Western Ghats as far as the meridian of 77° 45′. (The meridian of the Great Arc being 77° 41′).

The country was very difficult, and had baffled several very promising plans of the Officer in charge of the approximate series during the previous season; so much so, that he despaired of being able to carry on the approximate series in advance without assistance. I therefore determined to take ground to the east flank, and so to avoid the most difficult part of the country and to take up the approximate series in advance myself, and, with the help of existing charts, I laid a plan which seemed almost certainly feasible. It so happened that Captain Herschel was going to the station of Kutiaparei (or Mallapatti) and its neighbourhood for his Zenith Distance observations, and would be for some weeks on the spot where the best plan for the triangulation could be decided on, before I could arrive there. I therefore asked him to look out for me and give me the benefit of his observations, which he was good enough to do, sending me a plan which I have no hesitation in saying appeared to be the best for the triangulation which the country admitted. He suggested the introduction of two or three quadrilateral figures in place of the regular polygons I had arranged for, getting over the country with fewer stations, and avoiding the most difficult and inaccessible places. I immediately adopted the plan, and nothing but an unusually bad season prevented my completing the observations at all the stations proposed. But long spells of cloudy and rainy weather continually stopped my observations and caused such an amount of sickness as to delay me most seriously, until the hazy and hot weather of March and April set in and put an end to further observing.

Even had it been otherwise and the air clear enough, most of the men of the party were ill with fever and quite unable to march. I therefore on the 20th of April sent off all the sick men into Recess Quarters at Bangalore, where it was many weeks before the majority of them became convalescent; many of them are still unfit for duty.

The station of Kutiaparei (or Mallapatti) having been used for Pendulum and Z. D. observations was fixed upon for Azimuth observations, but as this station was not reached no Azimuth was observed this season.

As soon as I found it impracticable to continue the principal observations, I proceeded with Mr. Laseron by dâk to Tuticorin according to my instructions, and set up the self registering Tide Gauge which had been sent to me for the purpose.

It was necessary to build a house for its protection and for this purpose the materials of an old house, previously set up at the Oyster Nursery, were placed at my disposal by Captain Phipps Master Attendant, who was kind enough to give me every assistance in his power.

For a platform an old iron tank (5 feet cube) was purchased and half sunk and filled with sand; and for a well for the float to rise and fall in, some empty hogsheads were sunk a foot or two below the lowest low water mark, communication with the Sea being maintained through an iron pipe introduced into the bottom of the well, and carried into deep water.

In order to set the drum to correspond nearly with mean sea level, observations were made at every high and low water for nearly a semi-lunation before fixing the float on the self registering Tide Gauge, and thereafter observations were continued at the temporary gauge as a check upon the times and heights registered on the drum until it was ascertained to be working satisfactorily.

The difference of level of the permanent Bench-Marks, fixed in December 1869, was repeatedly observed and the zero points of the scales of the temporary and permanent Tide Gauges frequently determined. An anemometer was set up and a good 3-inch Aneroid Barometer (No. 280. T. Cooke and Sons) set to correspond with a mercurial Barometer left in the Master Attendant's office, to be registered daily in a Tide Journal to be kept for the purpose, to accompany the sheets taken off the cylinder or drum of the Instrument.

This occupied a month. On the 20th May I left Tuticorin, and after completing some secondary observations which remained to be done on the Palnei Hills, proceeded to Bangalore by dâk and rail, arriving there on the 3rd June. Mr. Laseron remained at Tuticorin 10 days after my departure to watch the self registering Tide Gauge and to keep the accompanying Tide Journal. It has now been registering the tides for more than 3 semi-lunations continuously and is reported by Captain Phipps to be working very well.

Principal observations were completed at 7 principal stations (26 angles) forming one Hexagon and one Quadrilateral figure, advancing the series 67 miles southwards. Six of the stations were on rugged hills or mountains averaging 3500 feet high (between 1200 feet and 7550 feet).

The approximate series has been carried 100 miles in advance of the last stations observed at and has closed upon the triangulation about the Cape Comorin Base-Line. All the stations in advance are built and all in rear finally closed.

My Assistants suffered from sickness severely throughout the season as well as the natives of the party.

Mr. J. W. Mitchell, Assistant Surveyor 1st Grade, was engaged on the approximate series in advance, but like the rest of the party, was much hindered by the unusually rainy and cloudy weather of the season as well as by sickness. He however visited 15 points and finally selected 6 for principal stations, built 4 platform stations, and erected 7 pole and brush signals and cleared 32 miles of rays; carrying the approximate series 100 miles to the south and closing upon the triangulation around the Cape Comorin Base-Line.

Mr. O. V. Norris, Assistant Surveyor 3rd Grade, and some of his party caught fever at the first station they visited. As no one of the signal, observing and closing parties was ill afterwards at the same place, it seems that he was a week or so too early, and it is fortunate that the main party was no earlier. Mr. Norris selected 2 and built 5 platform stations, one of which he also finally closed. He was obliged to go into Madura with his party for medical treatment for a fortnight, and was several times incapacitated by sickness from carrying on his field duties. I directed him to join my camp and assist in the observatory and office for about a month whilst on the Palnei Hills, in the hope of his deriving benefit from the change, after which he executed some secondary triangulation I gave him near Madura. I regret to add that his health has not yet been completely restored. Considering his state of health, I think he has done a very fair amount of work.

Mr. C. D. Potter, Assistant Surveyor 3rd Grade, selected and built two principal stations on lofty and difficult mountains. He then acted for one month as observatory recorder and office Assistant, after which he finally closed 7 principal and 4 minor stations, and from what I saw of his work and arrangements, I have reason to be well satisfied with him and to report favorably of his zeal and ability.

Mr. E. W. Laseron, Assistant Surveyor 4th Grade, has accompanied me as observatory and office Assistant throughout the season, in which capacity he has given satisfaction. During one month of the field season, he was obliged to seek medical treatment in Madura. He practised observing with the 7-inch theodolite, in the use of which he acquired some facility and accuracy.

He gave me much assistance and took a large share of the Tidal observations day and night at Tuticorin, and suffered severely from the consequent exposure to the sun.

A list of the mean barometric heights of the stages of my camp and of the stations visited during the field season is attached.

Barometric heights of stations and halting stages of the Madras party, Great Trigonometrical Survey visited during the field season 1869-70, *determined by daily Aneroid observations and compared with the leveled or Trigonometrical values above sea level.*

No.	STATION	Barometric height	Leveled height	REMARK
		Feet	Feet	
1	No. 2 Residency Road, (Bangalore)	2973		
2	Bangalore Railway Station, (the highest point of the journey) ...	datum	3034	
3	Kadgudi, Railway Station ...	2859	2856	In Eastern Mysore above the Ghats.
4	Malur „ ...	2962	2970	
5	Kolar Road „ ...	2670	2666	
6	Kuppam „ ...	2248	2245	
7	Jalarapet „ (Junction station below the Ghats) ...	1357	1322	
8	Tripatur Railway Station, ...	1310	1272	
9	Samalpatti „ ...	1285	1264	
10	Morapur „ ...	1328	1306	
11	Mallapuram „ ...	1394	1391	In the Salem District.
12	Top of Mallapuram ghat, ...	1526		
13	Shervarai hills Railway Station, ...	1261	1241	
14	Salem (Selam) „ ...	941	922	
15	Mac Donald's Choultry, „ ...	811	785	
16	Sankari Drug, „ ...	898	872	
17	Kaveri Bridge (the lowest point of the journey) ...	525	502	
18	Erode, Railway Station, ...	562	541	
19	Perundurei „ ...	866	844	
20	Wutkali „ ...	983	976	
21	Avenashi Road „ (or Tirupur Railway Station,) ...	990	988	In the Coimbatore District.
22	Somanur, „ ...	1106	1115	
23	Coimbatore (about the lowest point of the Palghat gap,) ...	1285	1303	
		Barometric height	Trigonometrical height	
24	Salem Railway Station, ...		930	
25	Fischer's knoll or Bear's hill (Yerkad settlement) ...	4834	4828	
26	Yerkad Church floor, ...	4670		
27	„ hill top above church, ...	4820		
28	Alexandra Hotel, ...	4668		
29	Fair Lawns Hotel, about (by a single observation) ...	4600		
30	Yerkad lake, ...	4420		
31	Duff's hill (Sanasi Karradu H.S.,) ...	5213	5231	The Shervarai hills, 10 miles N.N.E. of Salem.
32	Taylor's saddle, (top of Atur ghat)	4650		
33	Shervarayan hill top, ...	5345	5342	
34	Sholei Karradu, (forested summit of green hills) ...		5371	
35	Muttunad (green hills, highest point). This is believed to be the highest point of the Shervarai hills.		5410	
36	South of Twin Hills, ...		4855	
37	Salem, Fischer's compound, ...	847		S.E. of Salem town.
38	Periur Chattar, on high road to W.	784		
39	Kanjamallei H.S., ...	3260	3238	6 or 7 miles S.W. W. from Salem.
40	Sankari Drug T.B., ...	1016		1285 feet below the top of Drug and 25 feet above the adjacent plains.

NOTE.—The foregoing Nos. 1 to 23 were obtained from Aneroid observations made whilst travelling by rail from Bangalore to Coimbatore and shew a maximum error of 35 feet after falling 1700 feet, and a closing error of 18 feet for, which they are uncorrected.

List of Barometric and Trigonometrical Heights.

No.	Station and Stage.	Barometric value.	Trigonometrical height.	Remark
		Feet	Feet	
41	Narainpaliam village, ...	800		Camp at foot of Merur hill ¼ mile S. of village on road between Sankari Drug and Trichengodu.
42	Morur H.S., ...	1617	1643	
43	Bavani kudal, ...	493		At junction of Bavani and Kaveri Rivers.
44	Narinjipet, ...	578		Right bank of Kaveri, at base of Palamallei.
45	Palamallei H.S., ...	4848	4924	About 4200 feet above the plains at its base.
46	Andiur, ...	668		Camp S.W. of village.
47	Kempanaikem pm. and Chellipaliam	790		Camp W. of village.
48	Urugamallei H.S., ...	4911	4879	N. end of Malleiamma Drug range 4200 feet above the plain at S. foot.
49	Attani left bank of Bavani, ...	550		Camp N. of village & near high road.
50	Komal kerradu S., ...	756	757	About 60 feet above plain around.
51	Nallagawendenpaliam, ...	712		Camp N.W. of village.
52	Thittamallei H.S., ...	1255	1218	About 200 feet above the plain.
53	Kunatur, ...	1015		Camp N.N.E. of village.
54	Perundurei Traveller's Bangalow, ...	936		W. of Town.
55	Chennimallei H.S., ...	1713	1749	800 to 900 feet above the plain.
56	Chennimallei village at N.E. foot of do.,	858		Camp S.W. of village.
57	Arrasellur, ...	804		Camp at S.E. foot of hill.
58	Yettimallei S., ...	623	618	About 50 feet above base of mount.
59	Ichipaliam, ...	568		Camp S. of road.
60	Tennellei, (Camp N. of high road near old temple) ...	631		S. of Noyel River, Kangayam Divn.
61	Katpaliam (or Kachmarrei) S.E. end of Pachapaliam base-line of 1806,	883	879	
62	Minachivallasei, ...	967		
63	Kanapollei S., (N.W. end of Pachapaliam base-line of 1806) ...	1038	1017	
64	Manthamarrei S., (Pachapaliam station), ...	958	971	
65	Tiruman Kerradu S., ...	980	970	
66	Kangayam, ...	1000		Camp near Kacheri, S. of village.
67	Hallagamallei H.S., ...	1320	1353	S.E. front of hill temple.
68	Hallagamallei village, ...	1098		Camp N. of village S. foot of hill.
69	Avenasipaliam, ...	1050		Camp opposite Chattram.
70	Udiur H.S., ...	1310	1275	S. central summit of group, not the highest point which is about 400 feet above the plain.
71	Udiur village at milestone (Kangyam 10 Darapuram 11), ...	900		Camp W. of village E. foot of hill.
72	Darapuram, ...	805		Camp N. of town, 46 feet above Amravati river, and 16 feet below the Muttam or highest part of town.
73	Kollupaliam S., ...	1220		A mile north of Salarmaddam on old road.
74	Chenjeri vill., camp E. foot of hill,	1230		In the Tamarind Tope.
75	Chenjeri H.T. roof, ...	1375		An isolated rock about 150 feet high.
76	Palladam Traveller's Bangalow ...	1159		S.W. of town.
77	Kundudam, ...	949		On road Palladam to Daropuram.
78	Kallimedu S., ...	1306		Between Mantaripaliam and Vayalrashi.
79	Chavadipaliam (or Kethanur), ...	1329		Camp W. of village.
80	Perumangutta Kadu S., ...	1431		Minor station, on high ground W.N.W. of village.
81	Chengodampaliam, ...	1508		About the highest part of the plain country opposite (E.) of Palghat gap.
82	Veddiapaliam S., ...	1480		Prominent point of the water-shed.
83	Shamichettipaliam S., ...	1261		On the central ridge of the Palghat gap, between the Noyel and Palar rivers.

List of Barometric and Trigonometrical Heights—(Continued.)

No.	Station and Stage.	Barometric height	Leveled height	REMARK.
		Feet.	Feet.	
84	Arrakolam S., ...	1411		
85	Sholur village. ...	1478		On high road, 14 miles E. of Coimbatore, camp N.W. of village.
86	Coimbatore (jail), ...	1400		High ground N. of town & cantonment.
87	Ditto low ground, ...	1315		House near long tank.
23	Coimbatore Rail station, ...	datum	1303	
88	Mettapaliam hotel, ...	1055		High road to Nilgiri hills.
89	Do. Bridge over Bavani river ...	1000		
90	Kalar Bridge, ...	1200		} Cooly stages on the Kunur ghat.
91	Barliar, ...	2520		
92	Kunur (Coonoor) Bridge, ...	5600		At top of ghat.
93	Grey's Hotel, ...	5920		Higher part of Kunur.
	Lamb's Rock, about ...	5750		By a single observation. Above a precipice at S.E. edge of Nilgiri mountains.
94	Arravankadu, ...	6080		Village near Honeywells brewery (old Uty road.)
95	Yellanhalli Chattar, ...	6850		Stage 5 miles from Uty, and 7 from Kunur on new road.
96	Uty, 1st cutting, ...	7510		Highest point of Kunur and Uty road
97	The Union Hotel (Sylk's), ...	7410		Near Utakamand club.
98	Utakamand (Ooty) lake, ...	7250		By a single observation.
99	Do. Church, St. Stephen's, ...	7480		Near Utakamand Library and Post Office.
100	Government Botanical Gardens, ...	7275		Gateway at bottom.
101	Ditto, ...	7680		Gateway at top.
102	Ditto, ...	7970		Pond at top of Chinchara ravine.
103	Dodabetta summit, ...	8655	8690	Considered the highest point in south of India.
104	Snowdon (Devarsholeibetta), ...	8343		Top of hill.
105	Saddle at Dr. Pope's school, ...	7630		

NOTE.—The barometric heights No. 88 to 105 were obtained from Aneroid observations made during a visit to the Nilgiri hills of a few days in May 1870, compared with the published leveled heights given opposite Nos. 23 and 103. Half the closing error between these has been applied as a correction.

Extract from the Narrative Report—dated 22nd August 1871—of Lieutenant J. R McCULLAGH, R.E., Offg. Assistant Superintendent 1st Grade, Offg. in charge Guzerat Survey.

The Party takes the field.

(2.) On the 2nd November 1870, all the computations connected with the previous Season's Triangulation having been completed, the Party took the Field. The Assistants had orders to rendezvous at Surat for the purpose of obtaining the necessary instruments and stores, but as the distribution took up some little time, the last of them did not fairly get to his work till the middle of the month.

Considerations influencing the plan of operations.

(3.) The previous season, each Assistant Surveyor had been assigned a width of 15 minutes of Latitude with orders to cover as far as he could, eastward of the Meridian of 72° 30′ 0″, with a network triangulation; but in no case had it extended over half a degree. Owing therefore to an insufficiency of triangulation having been accomplished to afford the points required for all the plane tables of any single sheet, it became a matter for consideration whether it would be better to postpone the topography altogether for another season, or by executing a portion of the computations in the field to endeavour to turn out one or more sheets.

The latter plan was decided on as being the better, since enough triangulation had been done, in one sheet at least, to warrant a hope that it would be possible to finish the remainder, as well as the computations, in time to admit of the sketching being also completed during the season.

Plan of operations.

(4.) Whereas in the previous season, excepting a very small amount (about 15 square miles) of sketching, arrangements for carrying on triangulation only, had been made; this season for the reasons assigned in the last paragraph provision had not only to be made for its continuance, but also for the execution of a certain amount of topography as well, and under these circumstances it was found necessary to slightly alter the plan of operations of the preceding year; as far as was possible however, it was still adhered to. In the first place it was desired to carry on the Myhi River Minor Series which had been started the previous year by Lieutenant A. Baird R.E. and Mr. Christie, and this duty was assigned to me. Each of the Assistant Surveyors with the exception of Mr. McAfee received orders to continue his own section of net work triangulation, Mr. Bryson being given the one vacated by Mr. McA'Fee in addition to his own.

Messrs. D'Souza and McA'Fee were told off to perform the Topographical portion of the work. They had also to train some newly appointed Sub-Surveyors, in addition, and of these various operations I will now speak in detail.

Myhi River Minor Series.

(5.) Commencing from the side Sarod-Duharan of the Guzerat Coast Series, the minor series was planned to run along the general course of the Myhi river, and to join on to the side Ghorarao-Poeda of the Guzerat Longitudinal Series, and in the previous season Mr. Christie had selected four stations. Having examined the ground I decided to adopt three of these stations, and I then proceeded to select others. Owing to the densely wooded nature of the country on both banks of the river this was a task of some difficulty, it was impossible to see flashing signals, and the direction of each ray had to be taken from the glare of a large fire at night. These fires at times had to be made of huge dimensions before they could be seen, and rarely did it happen that the first attempt proved successful.

The ground being very flat, it was not easy to fix upon good sites for the Stations, consequently the progress made was not rapid, I had however selected four Stations (the sides of the triangles averaging about 7 miles) when I was obliged to discontinue further selection owing to my being appointed to the charge (officiating) of the Party, consequent on Colonel Nasmyth's departure on sick leave to the Colonies. The trees in this part of the country are nearly all mangoes of large size; and being valuable property, it was only natural that the proprietors should object to their being cut down in the process of ray clearing. Before commencing to clear therefore, I thought it advisable to try and make some arrangement with the Resident at Baroda, concerning this matter, but though I twice went to Baroda, and had interviews with him and his First Assistant, and wrote several letters on the subject, up to the present moment I have not been able to obtain the sanction of His Highness the Guickwar's Durbar for the clearing of the rays which have been laid out.

Network Triangulation.

(6.) The Assistant Surveyors detailed for network triangulation were, Mr. Cusson (sheet No. 8) Mr. Bryson (sheets No. 9 and 10), north of the River Myhi; and Mr. Christie (sheet No. 11) Mr. Hickie, (sheet No. 12) and Mr. Goslin (sheet No. 13), south of the River. A general description of the country, through which the operations have been carried, will be found further on, from which it will be easy to gather that the difficulties of the work were very great, owing to the extremely flat nature of the ground, and the presence of high standing crops in most cases, with the addition of large plantations of fruit trees, and lofty hedges in others.

The districts in which the work of Messrs. Cusson and Bryson lay, were the most difficult, and in parts densely wooded tracts were met with, which had to be avoided as much as possible, owing to the trees being for the most part fruit bearing, and the very great expense which would be entailed (in compensation awards) by their being cut down. The people of these Districts are extremely obstructive and troublesome, and though no serious resistance was shown to the progress of the Survey, a great deal of delay and annoyance were often experienced.

Messrs. Christie, Hickie, and Goslin had for the most part somewhat easier country to work in, but being such a dead level it was often impossible to see the signals, until they were raised many feet above the ground. Occasionally mounds were met with, and wherever possible banks of tanks were made use of, but being as a rule close up to villages they were not always suitable sites for stations. In this District also, much trouble was occasioned by the unwillingness of the people to render assistance, and constant representations had to be made to the civil officers, of the inconvenience and delay arising from this cause.

(7.) The Assistant Surveyors received orders to take observations sufficient to insure at least the prescribed number of one height per 10 square miles being forthcoming not only in the past, but also in the previous season's work. To effect this it was necessary that a certain extent of ground should be gone over again, I trust however you will consider the somewhat diminished out-turn of triangulation consequent thereon, has been more than counterbalanced by the advantage of the heights of a large number of stations having been ascertained.

Vertical Observations.

(8.) It was decided to commence sketching in sheet No. 12 and afterwards to go on with sheet No. 11 if time permitted. At starting there were points for only two full plane tables, and for portions of four others, and as the data required for the remaining portions, and for the other plane tables had to be computed in the field, some little management was necessary to prevent delay and embarrassment arising; this I am glad to be able to say was satisfactorily accomplished. A small portion in the N. W. corner was taken up and triangulated by Mr. Christie, and on its completion the angle sheets were sent in to Mr. D'Souza who with Mr. McA'Fee reduced the computations. Mr. Hickie in the meantime had finished the approximate work in the Eastern part of the sheet, and he in the South-East, assisted by Mr. Christie in North-East, completed the observations. The computations of this portion of the triangulation were taken in hand by Messrs. D'Souza and Hickie, and were happily got through in time to allow of the topography of sheet No. 12 being completed. A small portion of sheet No. 11 was also sketched.

Topography.

(9.) Towards the end of the season Mr. Christie having got into densely wooded country, in the East of sheet No. 11, and permission to cut trees being still withheld by His Highness the Guikwar it was found necessary to resort to traversing, I therefore called in Mr. Hickie who had just finished vertical observations and set him, along with Mr. Christie, to work on the circuits. I may here observe that at starting, these two Surveyors knew very little of this description of work, I therefore had to take them in hand, and having carefully explained the principles and method of carrying on traverses, I commenced the work, and continued with them for some time until they were thoroughly conversant with the practice. I beg leave to state with reference to this method of surveying that though resorted to in this case it is ill adapted to the greater part of the country. The work was carried on under most favourable circumstances, because being at the end of the season the crops were altogether, or very nearly cleared off the ground, and long lines could be taken across fields where in the early part of the season it would have been impossible to see a hundred yards. At the commencement of the season the damage tos tanding crops by chaining through them would be very great, it would therefore I imagine be necessary to keep altogether to the roads, but they are almost invariably hedge-lined, very tortuous, and moreover so narrow that two carts very often cannot pass. Where carts meet under these circumstances, which I have constantly seen happen, they are obliged to wait until a gap is made in the hedge to allow of one set turning off. Traversing under these conditions, it is perhaps hardly necessary to observe, must be very slow and tedious.

Traverses

(11.) On taking charge of the party I proceeded to make a careful inspection of the manner in which the operations were being carried on, and it was also desirable that I should have a knowledge of the country other than what was derived from hearsay. During the season I twice visited the Assistant Surveyors engaged on triangulation, remaining some time with each, giving them instruction and advice how to act in cases of difficulty.

Supervision and Examination of the work.

A considerable portion of my time was occupied with the Surveyors engaged on topography. Two of the Sub-Surveyors were placed immediately under Mr. D'Souza and one under Mr. McA'Fee, and their work was carefully examined at short intervals by these Surveyors, anything wrong or badly delineated being done over again; they thus got a thorough insight into the necessity of being accurate. The practice existing in other parties of interchanging, and interexamining plane tables was here also adopted, and in addition to this system of check, I personally scrutinized on the ground a large portion of each plane table section, and invariably found the work very good and accurate, and the features carefully delineated. The margins of the contiguous plane tables, executed independently, were found to agree almost exactly, and though the out-turn for the season has not been large, I have every confidence in its quality.

(14.) The following is an account of the work performed by each of the Assistants of the Party.

Detail of work performed by the Assistants.

Mr. A. D'Souza has been untiring in his exertions during the season; the country he has had to work in is flat and uninteresting, but there is nevertheless a fair amount of detail. He has thoroughly instructed two Sub-Surveyors, and the manner in which they have independently executed portions of the plane table sections, reflects credit not only on themselves, but on

their instructor. Mr. D'Souza has turned out 167 square miles of topography, the whole of which has been well and carefully done, and as in addition to a month and a half spent in reducing computations, a great portion of his time was occupied in training the new Sub-Surveyors, and in examining their work, I think this may be considered very creditable. Since the return of the Party to Poona, Mr. D'Souza has taken great pains in giving extra training to the Sub-Surveyors, and has devoted a considerable amount of time out of office hours to this object: the zeal and energy he has displayed is very praiseworthy.

Mr. A. D. Christie has executed a network triangulation covering 212 square miles. The number of triangles is 105 in addition to 102 intersected points, and he has determined by vertical observations the heights of 12 points. He likewise took the observations at 22 stations in sheet No. 12 and completed nearly 16 miles of traverses. Hardworking and painstaking in the Field, he has proved himself to be a quick and careful computor in office, and he has throughout given me every satisfaction.

Mr. McA'Fee was given the portion of the sheet (No. 12) lying nearest the Sea. Inland, the country resembles that on which Mr. D'Souza was engaged, but on the Coast the work was of a most disagreeable nature; for some distance from the shore line the ground is cut up into innumerable Nullas and water courses, the crossing of which is attended with considerable trouble. Mr. McA'Fee to save loss of time by going long detours, and regardless of his personal comfort, used to wade across these places, constantly up to his middle in mud and water. During the last two months of the Season, dust-storms were experienced almost every day, which, added to the intense glare from the wet mud, rendered working along the shore extremely trying. Mr. McA'Fee has completed 221 square miles very neatly and accurately, besides which about a fortnight of his time in the Field, was occupied in reducing computations, and he has further instructed a Sub-Surveyor in a manner nowise inferior to the teaching given the other two men. I have reason to be satisfied with his active and zealous conduct at all times since he has been under my personal observation.

Mr. Hickie was employed on net work triangulation, he worked with great energy to complete the triangulation of sheet No. 12, to the extent of 120 square miles. He laid out 26 triangles, and fixed the positions of 21 intersected points, he also took vertical observations for the determination of the heights of 59 stations, and likewise executed 31 miles of traverses. He was further occupied nearly a month in the Field in reducing computations. I have only to add that he has fully borne out all I have previously written in his favor.

Mr. Cusson's network triangulation extended over an area of 237 square miles, his triangles are 78 in number, and he has determined the positions of 38 intersected points, and has fixed the heights of 25 stations. I had instructed him to carry out a series of traverses, but just as he had commenced, and had laid out about 15 miles in length, I was obliged to call him down to the assistance of Mr. Bryson and he relieved the latter of the observations at 12 stations, in Sheet No. 9. Mr. Cusson continues to merit the good opinion I have expressed of his services.

Mr. Goslin selected and laid out triangles covering an area of 200 square miles, but only observed at stations extending over 110 square miles, at 6 of which vertical observations were taken. He has also observed to a fair number of trees and brush signals; but as these latter observations have only been taken on one face it is doubtful how the results will turn out.

Mr. Bryson laid out 75 triangles covering an area of nearly 162 square miles, and he also took observations for the determination of the heights of about the prescribed number of stations; as the computations however have not as yet been worked out, the result will be given hereafter. I regret to say that owing to some misunderstanding between Messrs. Cusson and Bryson, when the former observed at the stations of the latter, a portion of the computations for heights cannot be undertaken this year, as the stations from which the initial heights are obtained have not been observed at. This can however be easily set right next season as a few days only will be required, in which to rectify matters. Mr. Bryson worked hard and zealously during the season and has succeeded in giving every satisfaction.

The three Sub-Surveyors, Shaik Kassim Meea, Luxumon Ghorparay and Balwant Govind Gokhalay, worked on the whole very well; they executed respectively 59, 48 and 36 square miles of topography. Since their return, they have been instructed in traversing with compass and chain, and have been taught to work out the computations connected therewith, as well as other office duties.

The Native Establishment was, at the commencement of the season, for the most part composed of recruits, not more than about one-third knew the duties of khallasies at all, and of that number little more than half only, might be called really trained men. Under these circumstances the establishment may be said to have worked satisfactorily.

Health of the Party.

(15.) In the early part of the season there was some sickness among Europeans and Natives, but not of a serious nature, and during the whole time there was not a single death, and only one man was invalided. I think, considering the amount of disease which prevailed at times in some parts of the districts, the Party is to be congratulated on being so fortunate.

Adaptation of the Revenue Survey Details to the Trigonometrical Survey Triangulation.

(17.) It remains now for me to endeavour to analyze the possibility, or otherwise, of adapting the details afforded by the Revenue Survey Maps to our system of triangulation, with the view of turning out a map useful for Geographical purposes.

In the appendix to the Report of season 1869-70, Lieutenant-Colonel Nasmyth R.E. states the result of the tests applied over a limited area, to be "so unsatisfactory," that he "had abandoned any idea of utilizing the Revenue Survey Maps"; the Superintendent, however, considered these tests were "scarcely sufficiently numerous to enable a final decision to be arrived at", "and thought" it not improbable that "in other portions of the Districts the Revenue Surveys might have been made with greater accuracy." The District (Broach) under survey last season, being altogether distinct from that of the previous season (Khaira) affords a good opportunity for ascertaining whether such is really the case, or not. In carrying on the sketching, the village maps were made use of as a guide to the amount of detail existing on the grounds of each village, and to the position of the different boundary marks, trijunctions &c.; in the course of the work however, numerous and large discrepancies were discovered, not only in the positions of certain objects as determined by us, compared with the positions assigned to the same by the Revenue Survey Maps; but also in the positions given to these objects by contiguous village maps. The margins of adjoining maps in very few cases we found to agree even moderately well, and in many cases details admissible on a scale of 2" to the mile have been left out altogether on the maps drawn on a scale of 16" to the mile. The distances between two trijunction marks as taken off the maps of single villages have been found in several cases to differ from our values, to the extent of $\frac{1}{8}$ of a mile. I had hoped notwithstanding this, that on getting into Quarters I might by means of the points common to both surveys be able to mark out the village boundaries on our sheets, but I find that so much "forcing" and "screwing" is necessary to make them fit in, that I have thought it advisable to omit them for fear of misleading.

I am now preparing charts shewing the discrepancies existing between our work and that of the Revenue Survey, which will be forwarded as soon as ready. It is not to be supposed that all portions are equally inaccurate, but as far as I am at present able to judge, the process of "filling in details" from the Revenue Survey Maps will be always attended with a great deal of trouble, and will then be unsatisfactory, as since reliance cannot be placed on any portions being thoroughly accurate, it will be necessary to have every portion minutely examined on the ground. An examination of this sort would take nearly as long as would be required for the actual sketching.

(18.) GENERAL DESCRIPTION OF THE COUNTRY THROUGH WHICH THE OPERATIONS HAVE BEEN CARRIED.

Appearance.

(1.) The country of Guzerat though presenting very different aspects in different parts, is taken all in all perhaps one of the richest and most fertile provinces in India. The great contrast which exists between various places is very striking, in some extensive fields different kinds of grain are alone met with, further on cotton appears to be the only thing grown, and then from a vast expanse on which there is scarcely anything to be found bigger than a shrub to afford protection from the scorching rays of the sun, one suddenly enters into a forest of magnificent fruit trees, of almost every description, under the shade of which the crops appear to have as luxuriant a growth as in the open. In places the roads and fields are closely hedge-bound, in others there is nothing to hinder the numerous herds of deer from roaming where they will.

Soil.

(2.) The soil is for the most part of two kinds, one black and of a rich nature, the other light and sandy, but whatever the description, every available spot appears to be cultivated, the only exception being along the Sea shore where there are large tracts of salt waste, utterly unfit for anything, being washed by the spring tides. With regard to the encroachment of the Sea, Mr. McA'Fee observes in his Narrative Report that "from information gathered from the oldest "inhabitants on the Coast, it would seem that the Gulf of Cambay is encroaching on its "Eastern as well as on its Western shore, changing the cultivated land into a salt waste, where "only a stunted description of grass can grow. At Paniadra and Kadodra of the Wagra "Talooka, and at Nara and Deojagan of the Jamboosar Talooka, I was told that the spring "tides flow 1½ miles further in than they did 20 years ago. This is possible as the spring tide "washes over ground demarcated by the Revenue Survey in 1866, as arable land. Another in-

"cident worthy of note is that the Deojagan lightmast, which was put up on the right bank "of the Dhadhar, some distance from the reach of the tides, had to be moved in March "last to a ridge 1¼ miles to the S.E., as it had been repeatedly washed down.

Productions.

(3.) The following are the chief productions of the district, bajree, barley, wheat, jowarey, and rice in a few places. Cotton is extensively grown, also sugar-cane, castor-oil and tobacco, in smaller quantities.

Roads.

(4.) The roads are invariably bad, in fact they are nothing more than cart tracks as a rule, and as each cart keeps in the track of the one before it, in time deep wheel marks get cut which renders riding at a quick pace dangerous. I have only seen, outside the Cantonments, two fair roads one from Khaira to Mehmoodabad, about 9 miles in length, the other fromBaro da to Mukarpoor, communicating between two palaces of His Highness the Guickwar, about 5 miles apart. In some places they are so deep in sand that progression along them is very slow and tiresome.

Water supply.

(5.) The principal Rivers are the Saburmuttee, Myhi and Nurbudda, and some smaller ones are the Dhadhar, Watruck, Meyswah and Seyree. The four first are tidal, the Nurbudda being navigable as far as Broach (about 30 miles from its mouth) for small steamers. The other three can only be ascended for short distances by country boats. There are numerous ferries and fords, but within the influence of the tide the latter can very often only be crossed at low water. Irrigation is not so much resorted to as in other parts of India, and the water is mostly obtained from wells and tanks.

Villages.

(6.) The villages are generally speaking well built and compact, but I don't think it has ever been my fate to see anything to equal their squalid condition. Sanitation is utterly ignored, and cleanliness is not even dreamed of. Every village has one or more tanks close by, from which water is taken for household purposes, yet it is an every day sight to see cattle wallowing, and men, women and children bathing, and washing their clothes in the same water they drink from. In the hot weather these ponds gradually dry up, and the stench emitted from them is almost unbearable. The streets are the receptacle of the carcases of dead animals, as well as the evacuations of man and beast, and it is simply disgusting and sickening to pass through them. It is not to be wondered at under these circumstances that every year numbers of villages are scourged with cholera, fever, or other diseases.

Population.

(7.) The great bulk of the population belongs to the different Hindoo Castes, but there is a considerable sprinkling of Mahomedans, and people of other religions. I am not able to give numbers, but in the British Districts the villages are close together and thickly populated. The people are nearly altogether engaged in agricultural pursuits, and the more respectable classes are wealthy. The language spoken derives its name from that of the Province, and though at present the mass of the people are no doubt ignorant and uneducated, great efforts are being made to instil a certain amount of education into them, and every village of any pretensions, has its school.

Climate.

(8.) The seasons are three, the cold, hot and rainy. The first is very pleasant, and for about a month, or so, it is really cold at nights. The hot season on the other hand is rather trying, it gets decidedly warm about the beginning of March, and the heat increases till the rain falls in the early part of July, though sometimes it rains for few days in June. In April and May, hot winds are prevalent, but near the coast the great heat is tempered by the sea breeze. The thermometer readings taken in the afternoon were generally above 100°, occasionally up to 110° during the last two months of the Field Season.

The monsoon is supposed to be over by the end of September, but the Districts are considered to be very unhealthy, in some places fatal to be entered, till towards the beginning of December.

OMETRICAL SURVEY OF INDIA.

AR TOPOGRAPHICAL SURVEY

Extract from the Narrative Report—dated 8th September 1871—of Lieutenant TROTTER, R.E., Deputy Superintendent 3rd Grade, in charge of the Kattywar Survey.

(2.) During the recess of 1870 fair copies of sheets XVII, XVIII and XIX were prepared, on the 2″ scale, for reduction and publication on the 1″ scale. The mapping of sheet XIV also, which had been left incomplete the previous year (owing to a portion of it having to be re-surveyed) was finished, and the whole of the four sheets were sent to Head Quarters at the close of the recess. Besides this the eight sheets composing degree sheet No. III were almost entirely re-drawn. The whole of these maps viz., degree sheet No. III (21° 22° N. Lat. and 72° 73° E. Long.) on the $\frac{1}{4}$″ scale, and survey sheets on the 1″ scale XIV, XVII, XVIII and XIX have been photozincographed at Dehra Doon during the present year, and as far as I am able to judge, show considerable improvement on former years. The Hill shading in sheet XVII was the work of Mr. N. Gwynne and I think does him great credit.

(3.) The out-turn of work during the past field season has been very satisfactory; no less than 2058 square miles having been topographically surveyed whilst about 2200 square miles have been prepared by triangulation for next season's operations. Of the ground topographically surveyed, about 280 square miles of wild mountainous country forming the W. half of sheet XXVIII, were on the 1″ scale. The remainder on our usual scale of 2″ to the mile.

(4.) The party took the field at the usual time and reached Gogo, on the 20th and 21st November.

(5.) After arrival at Gogo, the Assistants were detained till the 26th preparing the graticules and projecting the points for the season's work. When complete they marched for the scene of field operations, the nearest point of which was distant only about sixty miles from the Sea coast. The whole of the Assistants were on their ground at work early in the 1st week in December.

(6.) My Senior Assistant, Mr. J. Mc'Gill was directed to start the minor triangulation near the line of junction of sheets XXIV and XXV. Mr. T. Rendell who had never had any experience in triangulating was directed to accompany him at starting, to learn the *modus operandi*. After a week's stay with Mr. Mc'Gill, Mr. Rendell was considered to be able to take up independent work and had the triangulation of sheet XXV allotted to him. Mr. Mc'Gill worked northwards starting from the side Itria H.S., to Omat H.S., (of the Kattywar Minor Meridional Series No. III). He completed the minor triangulation over sheets XXIV, XXIII and XXII working without intermission until the 6th April on which date he closed work by my orders.

(7.) Mr. Mc'Gill had worked with his usual energy and zeal and was rewarded by an out-turn of about 1650 square miles, the details connected with which will be found in the table appended to this Report.

(8.) The work completed by Mr. Mc'Gill together with about 550 square miles triangulated over by Mr. T. Rendell, will give ample employment to our detail Surveyors during the next field season. Mr. Mc'Gill reports that the ground on which he was working is generally hilly, stony, bare and cut up by small streams. The crops consist chiefly of sugar-cane, jawaree, bajree and gram &c., but barely enough of these articles are grown to suffice for the wants of the district. In the Southern portion, the hills are generally covered with grass, but in the Northern districts it is scarce, its place being occupied with Cactus and Palas (Butea frondosa) bushes. In some places as much as one Rupee per diem had to be paid for grass for one horse. The country had suffered severely during the two previous seasons from drought and locusts, two very common scourges in Kattywar. The country was not densely populated, villages being generally few, small and far apart. This is chiefly due to the large number of petty independent states into which it is divided. The triangulation of sheet XXV (550 square miles) was commenced by Mr. Rendell on the 7th December and completed on the 2nd February, when he proceeded South to take up a plane table in sheet XXVIII. It was Mr. Rendell's first attempt at triangulation and the results on the whole are good, although from want of experience he has had some difficulty in identifying trees &c., from different points of view and hence a good many of his intersected points have (in computation) had to be rejected.

(9.) Mr. Rendell however worked hard and I am very well satisfied with his results, an abstract of which is shewn in the appendix.

(10.) The ground in sheet XXV with the exception of the North East corner (which is hilly) is flat with small isolated hills springing up here and there. The ground is mostly covered with cotton but a certain quantity of the usual grain crops are also grown.

(11.) To save time in the field, but also chiefly to save time in office hereafter, I gave a (Native) recorder to each of the Triangulating Parties, and at the same time gave instructions that both original and duplicate angle books should be kept up and completed in the field. This was done and instead of the time of some of the Senior Assistants being occupied during the recess (as was the case last year) in the almost mechanical preparation of duplicates, Mr. Mc'Gill was immediately on arrival in quarters, able to take in hand the regular computations and I trust all arrears will be brought up during the present recess.

(12.) Krishnaji Govind accompanied Mr. Mc'Gill as recorder, and Balkrishnaji the Printer was attached to Mr. T. Rendell. Both of them have been reported on favorably.

TOPOGRAPHICAL PARTIES.

(13.) All the other European Assistants of the Party were employed throughout the season in plane tabling.

(14.) I had hoped at the beginning of the season that the topography of sheets XXVI, XXVII, XXVIII and XXIX, and the very small area comprising sheet XXX would be completed, but owing to the great amount of detail in sheet XXVII which occupied the Assistants a great deal longer than I had anticipated and owing to the illness of Messrs. Todd, Anding, Gwynne and Connor I was compelled to leave sheets XXIX and XXX unfinished. One active Surveyor at least will be occupied the whole of next season completing those sheets.

(15.) With the exception of the left half of sheet XXVIII consisting of the hilly and mountainous district of the Gir, the work was carried on on our usual scale, 2″ to the mile; I had previously sought and obtained the sanction of the Superintendent to have this exceptional piece of country surveyed on the 1″ scale. My chief object in this was to get over the work in these very unhealthy districts, as quickly as possible compatible with a correct representation of the features of the ground, but as my Assistants had had no prior practice on that scale, it is doubtful whether much time was saved, although the experience obtained will be very useful when surveying other portions of the Gir in future years.

(16.) Owing to the mapping of sheet XXVIII having been executed on two different scales viz. 1″=1 mile for the left and 2″=1 mile for the right half, it has been necessary to make some alteration in our method of preparing the fair copy for publication and to save labour, time, and consequently money, I have had the four 2″ plane tables reduced by Photography from the original maps to the 1″ scale, and then transferred by Zincography and printed in faint blue on to the right half of a sheet of drawing paper, on the left half of which the four original 1″ maps have since been traced through. The whole sheet is now being drawn in this office on the 1″ scale and will have to be reproduced by Photography on the same scale. This has necessitated very great care and very careful drawing, but the results will I trust prove satisfactory.

(17.) The reductions from the originals by Photography were done in the Poona Photo-zincographic Office to save delay in sending them to Dehra, and what is still more important, the risk that would have been incurred in transmitting across country the original maps (of which no duplicates exist).

(18.) It should be pointed out that if 2″ maps of this sheet are ever required, it will have to be redrawn for the purpose, but as far as I can judge there is not, nor ever will be any demand or necessity for the publication of that sheet on the 2″ scale.

(19.) I would here advert to a proposal I have made to show on all our future 1″ maps the names of Talookas and villages in the Vernacular. This will make the maps really useful to the people of the country where I suppose not 100 Natives in the whole province can even *read* the Roman Character. Owing to this there is at present no demand for our maps, but under the proposed arrangement, which you have assented to in principle, I have no doubt but that a very considerable demand will spring up.

Names on the Maps to be given in native characters as well as in Roman character.

(21.) Mr. W. Todd commenced work on easy ground in sheet XXVI, but before he had finished it I required his services to project and prepare some plane tables for some of the Native Surveyors. This, and the completion of his own board, occupied him until the middle of February when he proceeded to take up one of the 1″ boards in the Gir. The four Gir boards (each containing about 79 square miles) I had allotted to Messrs. W. Todd, T. Rendell, Wyatt and Fielding. The ground being exceedingly unhealthy after the monsoons and early in the year, I could not venture to send the Assistants in before February. The heat during that month and March was intense, the thermometer in my tent in the plains to the North, under the shade of a large tree often rising to 96° and 97° without a breath of wind stirring. Mr. Todd, anxious to

finish his board as rapidly as possible, had been working very hard during this trying heat, having to climb up steep, bare hills where it may be supposed the radiated heat was very great, was struck down with a very severe illness. He had completed his work on the 12th March and marched next day down South to join Mr. Wyatt, but on the evening of the 14th I received a note from Mr. Wyatt stating that Mr. Todd was very ill and I found him on arrival next morning suffering apparently from a sort of combination of fever and sunstroke, pulse nearly all day at 125, accompanied during the heat of the day by violent fever and delirium. The Native Doctor who had also been summoned the day before had fortunately arrived and under his treatment Mr. Todd partially though slowly recovered. The place where he was taken ill, Gedardi, was in the middle of the Gir, and as the camping ground was fearfully hot and the water bad, as soon as I could venture to do so (on the night of the 17th) I extemporized a dhooly, and started him off, carried by Khlassies, towards the coast. By marching the greater part of two nights, accompanied by Mr. Wyatt, I succeeded in getting him down to Samteir, a cool and shady camping ground, about 8 miles from the coast (in sheet XXIX.) Here Mr. Todd remained till the close of the season. As soon as he was able to do a little light work, he was employed in preparing plane tables &c., in sheet XXIX and continued doing office work till the middle of April, when he, Mr. Rendell and Mr. Connor all started together to return to recess quarters.

(22.) Mr. Todd's total out-turn of work was 146 square miles; early in the season he was working in easy ground, but his last plane table was in a hilly and intricate country the features of which were ably and truthfully delineated. I very much regret that he has suffered so severely in the performance of his duties.

(23.) Mr. G. Anding was transfered at Colonel Nasmyth's request from the Guzerat Party at the commencement of the Field Season and joined my Head Quarters in Kattywar at about the middle of December. He commenced his first piece of independent work on the 6th February and by the end of the season had completed 66 square miles of topography, by no means a satisfactory season's work. He was suffering from ill health and by neglecting to inform me of the same, caused great inconvenience and prevented the completion of the survey of the Island of Diu and its vicinity, which I had been particularly anxious to accomplish. Since his return to Head Quarters, he has been obliged to take six months leave, on medical certificate.

(24.) Mr. Gwynne commenced working in sheet XXVI on the 5th December. He was accompanied by Mr. Connor whom he was directed to instruct in the practical use of the plane table. On the 12th when he thought Mr. Connor sufficiently up in the work he left and took up a fresh board to the South. Mr. Gwynne continued uninterruptedly at work up to the 25th April, when, although in a comparatively cool climate, viz., the Island of Diu, he got a slight sunstroke, and as it was so late in the season I sent him off at once by sea to Bombay. He rapidly recovered and arrived at Poona on the 1st May.

(25.) Mr Gwynne worked as usual, hard and zealously; most of his ground was easy and flat but he had one hilly half board in sheet XXVIII which he executed in excellent style. In his last half board he had to fix a few points by triangulation prior to commencing the detail survey. Mr. Gwynne is a capital draftsman and very useful in office.

(26.) Mr. Rendell after finishing his triangulation in sheet XXV, took up one of the Gir boards, a very hilly and difficult piece of ground, which considering that it was almost the first piece of hilly ground he had been called on to survey, he did to my entire satisfaction.

(27.) The climate of the Gir however had its effect, and an attack of fever compelled him to leave his ground, for a while, but a stay of a few days near the sea enabled him to pick up his strength and return to his work which he completed on the 20th April.

(28.) Mr. E. J. Connor was transferred to this Party at the close of the last recess. He had never had any experience in topographical work. He accompanied Mr. Gwynne early in the season to learn the use of the plane table and commenced independent work on the 13th December and continued at work till the middle of March by which time he had surveyed 100 square miles of easy ground. As his eyes were suffering very much from the combined effects of glare and dust, he was employed for the remainder of the season in assisting in the projection of plane tables and in current office work.

(29.) Mr. E. N. Wyatt reached Gogo with the other assistants, but on their leaving to take up the field work, he was suffering from low fever and inflamed throat and on the recommendation of Dr. George, Honorary Assistant Surgeon, I left him behind in Gogo for medical treatment. By the 9th of December he was able to start and, accompanied by Mr. G. Anding, who had arrived at Gogo the previous day, marched to his plane table on the extreme N.W. corner of sheet XXVI where he commenced work on the 26th December.

(30.) In spite of this late beginning, by working diligently and steadily throughout the season, Mr. Wyatt had on the 12th May completed 274 miles of detail survey (the largest out-

turn this season) of which 70 miles were on the 1″ and the remainder on the 2″ scale; a portion of his time also had been taken up in examining the work of some of the Native Assistants.

(31.) The Gir board allotted to Mr. Wyatt was the most hilly and difficult of the four, but the manner in which he executed the work proved that I was justified in giving it to him. It occupied him from the 11th February to the 22nd March.

(32.) The establishments of both Messrs. Rendell and Wyatt suffered severely from fever. At one time all Mr. Wyatt's servants were laid up and he was fortunate in being able to secure the services of a Musulman Khlassie as cook and servant of all work. I used to supply him and Mr. Rendell with healthy Khlassies in exchange for sick ones and consequently the progress of the work was never interrupted. Mr. Wyatt himself fortunately escaped fever.

(34.) Mr. W. Fielding has worked steadily and well throughout the season. He completed (including one of the Gir boards) 257 square miles of topography, the whole of which is accurately and neatly executed.

(35.) A great feature in this year's operations, is the marked advance that has been shewn by the Native Surveyors in plane-tabling, both as regards quality and quantity of work.

Native Surveyors, Topographers.

Vissajee Ragoonath. | Gunesh Bapoojee.
Govindjee Mahalay. | Raojee Narayen.
Vishnu Moreshwar | Shridhar Saccaram.

(36.) Vissajee Ragoonath was only employed for a very short period in plane tabling as his time was fully occupied in plotting the field traverses as they came in from the surveyors, and in assisting in the projections of plane tables and other miscellaneous work, which he has generally done to my satisfaction.

(37.) Govindjee Mahalay and Vishnu Moreshwar are old hands and did 208 and 206 miles of good work respectively. Gunesh Bapoojee and Raojee Narayen surveyed 132 and 192 miles accurately and carefully, and Shridhar Saccaram, who although he has been sometime in the Department has never done any independent plane table work, executed 150 square miles in very creditable style.

(38.) The strength of my Field Establishment having been reduced to the Financial requirements of the Government, I was unable to employ more than three traverse parties, for measuring the Talooka boundaries. The latter fortunately were not so numerous and intricate as in the districts surveyed the previous year, and their measurement proceeded *pari passu* with the topographical work.

Traverse Surveyors.

Gopal Vishnoo.
Narsu Dinker.
Boloojee Bhoseker.
Tukaram Chowdry.

(39.) Gopal Vishnu surveyed 146 miles, Narsu Dinker 240·5, Boloojee Bhoseker 33·5 and Tukaram 121·8 miles of boundary in addition to which Boloojee Bhosekar traversed 139 miles for the purpose of checking the topography.

(40.) I am not altogether satisfied with the system (which was adopted on my suggestion) of trusting generally to plot the traverses by protraction (*i.e.* only computing those that appeared on protraction to have a large error).

(41.) Our Native Surveyors are not good hands at the work and I almost think that on the whole, time would be saved by computing all the traverses in the first instance, and I purpose doing so in future.

(42.) One very important boundary in sheet XXIX is that in the Gir between the Junagarh and Baroda states. It has been disputed for very many years and more than one Boundary Commissioner has been employed in the settlement, constant appeals and references on both sides have been made, and it was only late in the present year that the boundary stones were laid down. It would have been quite impossible to have traversed this boundary, as it runs across high mountains and over deep precipitous ravines where it would have been quite impossible to chain and the boundary stones were laid down so late in the season (after we had surveyed the ground) that it would hardly have been possible even if it had been considered worth the labour, to have fixed the stones by triangulation. I accordingly directed Messrs. Wyatt and Rendell through whose boards the boundary passed to go carefully over it and fix it on their plane tables. This was done, and 19·5 miles of boundary were thus laid down. This was the only course to pursue. Our boundaries next season will be very numerous and many of them pass over undulating

and hilly ground, and I cannot help thinking that the Subtense Instrument would be an invaluable adjunct to the Survey. I recently sent in an indent for a couple but have been informed that none will be out in the country for another two years.

(43.) The tidal and leveling observations which it was proposed should be carried out by this party in connection with the change of the relative level of land and sea in the neighbourhood of the Gulf of Cutch, have not yet been commenced. I have however during the past field season examined that portion of the coast in, and adjacent to the ground we have been surveying, but I have not yet been able to discover any suitable place for the proposed tidal observations.

(46.) Shortly after returning to Kattywar, I went to Rajkote the Head Quarters of the Province; where the whole of the officials, and nearly every Chief in Kattywar (some hundreds in number) were assembled to meet H. E. the Governor of Bombay. While there I had an opportunity of showing His Excellency our maps and explaining the progress of the survey, and I also made the acquaintance of all the officials with whom I am likely to be thrown in contact during the future progress of the survey.

(47.) On returning from Rajkote, I inspected the two triangulating parties under Messrs. Mc'Gill and Rendell and then rejoined my Head Quarters in the vicinity of the Plane Table and Traverse Surveyors. With so many Native Surveyors and young hands at work it is no doubt indispensably necessary, if one wishes to be absolutely certain of the accuracy of the work, to be constantly on the move and I accordingly inspected the work of every plane table repeatedly throughout the season.

(48.) The country under survey is of very varied character. The Northern portion where the Surveyors commenced work consists of a flat and fertile plain. The soil is generally black and yields rich crops of cotton, bajra and jowar, which are the staple products of the country. Besides these however sugar-cane, wheat, gram til and other crops are grown in smaller quantities.

(49.) Over portions of this district, more especially to the south of the River Shetruji which flows through it in an easterly direction, there is a quantity of saline matter in the soil which makes the water in the wells generally brackish and of very disagreeable colour and taste. I did not find however that it was unhealthy. In some few villages however the well water was only used for purposes of irrigation, and rain water from tanks was used for drinking. The water of the Shetruji and other small rivers flowing into it is generally drunk in preference to any other. Where it is very brackish the ground in the vicinity generally consists of waste and low jungle on which there is pretty fair grazing ground for cattle which are plentiful in nearly all parts of Kattywar.

(50.) As the Surveyors proceeded South, the character of the country gradually changed, low stony ridges covered with short stunted grass, Cactus and Khyr bushes occupy large portions of the ground, but the flat spaces between them are generally under cultivation, either cotton or bajra, the crops however not being so rich as in the more favoured lands to the North. Water is more frequently found in the Nallahs, but the country is not nearly so thickly populated.

(51.) Further South again towards the slopes of the mountains of the Gir, the ground is cut up into large ravines 40 and 50 feet deep and 100 yards or more in breadth their sloping banks generally covered with a species of prickly pear.

(52.) The Gir is the name given to a district containing the most extensive range of mountains (though not the highest) and the widest parts of Kattywar. It was long celebrated as the constant retreat of Bharwatias (outlaws) who in the former disorganized state of the country were constantly wandering about, coming down unawares on the open towns, levying black mail and then returning to their mountain fastnesses. The usual rule with these marauders was only to plunder the villages belonging to the state from which they were originally outlawed and as the neighbouring states were generally at feud, one with the other, these outlaws often found protection where they ought to have met with extermination.

(53.) In 1868, two officers were killed in attacking one of these bands in the Burda Hills near Rajkote since which they have been broken up and I trust permanently dispersed, though a few months ago I heard of one or two parties who were committing depredations not far off from the ground where we shall be working next season.

(54.) A famous retreat of these outlaws was at a very strong natural position called Vejalkot in the neighbourhood of the Rawul River, situated in our last season's work. It is now an old ruin on an elevated piece of ground completely surrounded either by the Rawul River with its deep precipitous banks or Nullahs as deep and with almost perpendicular sides.

(55.) These hills are traversed by rivers rising in the Northern portion of them and running nearly due south, the principal of them (in the past season's work) being the Machundra, the Rawul, the Nalia and the Malan rivers; these all flow southwards, but a portion only of their waters flow into the Indian Ocean, as what is perhaps a large stream in the Gir almost entirely loses itself in sands and flats before reaching the Sea.

(56.) Between the beds of these rivers rise lofty hills with precipitous sides, many approaching but none exceeding a height of 2000 feet. The tops of the hills are generally bare of trees but are nearly always covered with long grass which is burnt in the hot weather. In the ravines and valleys towards the Eastern portion of the Gir there is not very dense foliage, what there is consisting chiefly of Dhak (Palas) and Khyr. In the central Gir, in the large water courses there are large Banyan trees as well as dense masses of Coranda, in the shade of which a lion may occasionally be found during the heat of the day. In parts also, the sides of the hills are more or less covered with stunted teak, with Nalida, Gangra, Jamoon, Dhowrab, Temburwah (a kind of ebony) and other jungle trees. Large timber trees such as are found in other parts of India are conspicuous only by their absence.

(57.) The country is very thinly inhabited. In a district of about 100 square miles, there is but one so called village Temburwar consisting of a few huts only and the average population of the W. half of sheet XXVIII is only about 10 per square mile. Besides the permanent villages however there are migratory bodies of herdsmen, who take their flocks about in search of pasture during the hot weather, stopping in some place (where they perhaps find water and a few huts) until the grass about is consumed. They then proceed to another spot. These collections of *huts* go by the local name of *Neyses* and are only tenanted during the hot months. The dreadful fevers and bowel complaints for which the Gir is famous prevent these people from taking up their residence except for the few hot months of the year. During the rest of the year they reside in villages outside the Gir.

(58.) Most of the Gir villages are inhabited by "Kolis". The herdsmen are generally termed Rubaries or Charans. Around the villages are small patches of cultivation affording barely sufficient produce for the miserable and fever stricken inhabitants.

(59.) The Rubaries get provisions from the villages outside the Gir in exchange for ghi, butter and milk the produce of their numerous herds. A very curious fact about the district is the use there (as well as in the country to the south of it) of Spanish Dollars (called Raals) and these wretched men who perhaps hardly know an English Rupee by sight are quite familiar with the Raal which is worth about two and quarter Rupees of our money. I believe it was introduced through the neighbouring Portuguese settlement of Diu and the once piratical harbour of Jaffrabad.

(60.) There is but one road through this portion of the Gir. I have taken carts along it from Dhari to Oona viâ Temburwar, but it would be quite impracticable for heavily laden carts.

(61.) Every Rubari owns a buffalo which he uses for taking his produce to, and bringing back his food from the plains and these are the only baggage animals to be found in the Gir.

(62.) South of this range of hills the country is again almost a dead flat, well cultivated, with cotton and bajra; parts near the south coast are densly covered with mango and other trees forming camping grounds far superior to any I have seen in other parts of Kattywar where a tree of sufficient size to pitch a large tent under, is the exception and not the rule. There is good grazing ground all along the south coast, as heavy dews fall at night even in the hot weather and keep up a supply of a short green grass which supports large flocks of sheep and cattle.

(63.) A very curious feature in the southern District is the large limestone masses, generally old stone quarries, which rise abruptly from the surrounding flats and have very curious and fantastic forms. In parts whole masses of the hill have been quarried away leaving upright pillars of stone standing generally covered with green creepers, and resembling in the distance the most picturesque looking ruined castles, a deception which is kept up until a near approach reveals the truth.

(64.) The country has once upon a time been much richer than at present. Near Oona in sheet XXX are the remains of a very large tank about 200 yards in diameter which reminds me very forcibly, from its general internal appearance, of the old Roman amphitheatres in the South of Europe. Its walls in one portion are composed of solid rock but in the greater part consist of stone terraces going down to the bottom of the tank, which when I saw it was nearly dry.

(65.) There is a fair sprinkling of game over the whole of the ground we have been surveying, Nil-Gae (called Roz in Gujerati), antelope and ravine deer being generally common in the flat country. In the Gir itself there are lions, panthers, hyenas, sambur, cheetal, wild hog and Nil-Gae; but none of these are common, except perhaps the two last, and it cannot be said to be thickly stocked with game. There is not a tiger in the whole of Kattywar. The lion is popularly supposed to be maneless; but this is a fallacy, and one that I saw had a very fine mane, the lioness had none but had a strong resemblance to a tiger in shape, though not in colour.

(66.) The Talooka Boundary Demarkations which are intended to be carried on in advance of our survey operations (by native boundary committees appointed by the Durbars and working under the Political Agent) are progressing favourably. In the ground to be surveyed next year there will I trust be but few unsettled boundaries, of which I am sorry to say there are a good number in the ground we have just surveyed.

(67.) The Baroda Durbar, a portion of whose territories situated in the Amreli Mahals we have just been working on, is most obstructive in the matter of boundary disputes and I fully expect that when we have completed the survey of Kattywar there will yet remain a number of disputed Baroda boundaries. The great Gir dispute with Junagarh before alluded to (and which has just been settled and the boundary demarkated by Colonel Lester of the Bombay Staff corps) has occupied the time of a special Boundary Commissioner for very many years and the Bombay Government has finally confirmed Colonel Lester's decision.

(68.) The amount of topographical survey completed is 2058 square miles against 1138 of the previous year.

(71.) In conclusion I beg to acknowledge the cordial assistance which is always rendered to myself and the assistants of this Party by Colonel Anderson the Political Agent and all his assistants in Kattywar with whom we have come in contact.

Extract from the Narrative Report—dated 14th July 1871—of Captain J. HERSCHEL R.E., Offg. Deputy Superintendent 1st Grade, in charge No. 1 Extra Party.

(1.) In a postscript to my report for 1869-70, I was able to add some results of th at season's work, which confirmed the belief under which the distribution of the stations of observation had been decided on. As this subject will gradually occupy more attention, and as it enters largely into what will now have to be narrated concerning the following season's work, now in course of reduction, some explanation of the matter must be ventured upon.

(2.) It is so well known that the astronomical latitude of a place—that is, the altitude of the pole as derived from the *Observed Zenith Distance* of a star of *known N. Polar Distance*—is affected by the displacement of the vanishing point of a plumb line from the true Zenith by local attraction, that it is only necessary to allude to it for the sake of making more distinctly obvious that, if this displacement is not only great, but also greatly capricious, it becomes desirable to take fully into consideration the bearing of this fact on the value which any such determination of latitude can have. The distribution of stations in season 1869-70 was made with a view to ascertaining whether this seemingly capricious variation was to be *expected* in India, as it had been recognized in Europe. No difficulty has been experienced in accepting as real the varying amount of displacement at stations so far apart as 50 miles or more. The large number of results at stations *so distributed* over large portions of Northern India had proved beyond question that an *a priori* estimate of its amount at any one point (not within that distance of another at which it might be known) would be little better than a guess. But evidence was wanting that the displacement ascertained at one point would not hold good for a considerable area round it. For this purpose stations of observations were grouped; and before proceeding with a description of the next season's work it is needful to show what the actual results were, as well as the immediate inferences to be drawn from them.

(3.) When comparing astronomic latitudes with geodetic it must always be remembered that the latter are to some extent hypothetical, in as much as they always depend on an assumed origin. In this case the origin is the astronomical latitude of Calcutta where the deflection of the plumb line is assumed *nil*. Were this assumption correct the difference between geodetic and astronomic latitudes at any other point would correctly represent the deflection at that point: and notwithstanding that it is necessarily otherwise, yet since the error, whatever it may be, affects all the geodetic latitudes alike the comparison of deflections *inter se* will be unaffected. I now give the reduced results of the field season 1869-70 (see Table appended).

(4.) The first three stations, it will be remembered, form a group at and near the Bangalore base forming a triangle (whose sides are 6·8, 6·1 and 3·1 miles) in an undulating but not hilly portion of Mysore at an average height of 3,100 feet above sea. The last three form a triangle whose sides are 15·8, 5·2 and 14·0 miles, situated in the extensive plain East of the Neilghiris, about 800 feet above sea, and 140 miles South of Bangalore.

(5.) The change of average deflection at the 2nd group as compared with the 1st is not remarkable, considering their distance apart; but the variable character of the individual deflections at either group is very significant. It is clear that the uncertainty—which cannot possibly be due to error of observation to the extent required to explain it—is such that, just an as estimate of the gross deflection at a distant point would be hazardous, so the presumption that it would be nearly the same at two distant contiguous points would likewise be unwarrantable. The strictly local character of the attraction which causes these deflections is betrayed; and, to put the logical conclusion roughly before us, the minute accuracy aimed at in this kind of determination ceases to have a practical value. For it has been conclusively proved in the English Ordnance Survey that local attractions are to be accounted for only very slightly by attention to the local surface, and they cannot be accounted for practically by what is below that surface without a more intimate knowledge of the geological conditions than we seem likely to obtain within any period now contemplated.

(6.) On the strength of this confirmatory evidence, and with this conclusion forcing itself upon me, I proposed to the Superintendent to modify still further the practice hitherto pursued and to increase the number of local determinations at the expense of their individual accuracy. The proposal was met with some hesitation but permission was given to act as maturer consideration should dictate. I resolved eventually to endeavour to secure further evidence without materially sacrificing accuracy, by observing at 5 points of a group, of which the central one should have a set of observations of the usual character (*i.e.* of pairs of stars evenly distributed and observed on 3 nights each) while 2 nights only should be devoted at each of the others to getting as many stars as possible, with a view to linking each subsidiary station to the central one and to the others by amplitude alone.

This is not a fitting place to argue the question of amplitude *versus* absolute latitudes. I need only say that where the differences of latitudes are very small, and the same instrument can be used at all the points successively in but few days, it simplifies matters greatly to ignore latitude altogether until the reductions are complete. It is anticipated that by distributing the observations in the way described, over an area of 10 or 12 miles square the *accidental* features of the local attraction of the locality will be betrayed and eliminated while the resulting astronomic latitude of the central point, so modified, will be not less accurate, numerically, and far more correct in the wider sense of being more representative, than if the whole labour had been confined to one spot.

(7.) I now proceed to describe the localities and to narrate the chief incidents of the past season. At the time my party left Bangalore, early in November 1870, the principal triangulation on the meridian of 78° extended only a few miles south of the 2nd of the above mentioned groups, where it had got into difficulties caused by the obstinate refusal of the approximate triangulation ahead to adapt itself to the features of the country. I was therefore in some uncertainty where to chose a suitable district for the group which must lie between Pachapaliam and Cape Comorin—the only obligatory point being a pendulum station of Captain Basevi's. To this point I marched in the first instance, and soon saw that it was not only suitable in itself but would almost certainly be selected as a principal station of the coming triangulation. But before the subsidiary stations could be chosen it was necessary to learn the probable course of the former; and this required me to project and suggest to Major Branfill a configuration which as the event proved was much easier to propose than to execute; the fact being that the difficulties in the way of the principal triangulation at this part are greatly enhanced by peculiar climatic conditions which could not well be foreseen.

(8.) Observations of Zenith Distance were commenced at the station of Kutiapare* on the 29th November in favorable weather, which unfortunately did not last. A great deal of rain had fallen before my arrival, and but little more at any time was sufficient to make the black soil country nearly impracticable for carts. Thus it happened that 2 only out of the 4 intended subsidiary stations were decided upon before the central station was quitted—a 3rd was afterwards chosen almost at hazard, and observed at, without a single view of the distant hills while a 4th, a most promising hillock, turned out on my arrival to be a smooth inaccessible mass of gneiss, about 40 feet high, in a black, soil plain. The top only had been visible, and it had been reported practicable by the mason who built the observatory pillar. As he had gone up and down by a series of notches cut in the face of the solid rock his faith in my power of overcoming such a trifling difficulty as that of sending up the instrument and observatory by the same route must have been unbounded.

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* Captain Basevi's "Malapatti" Station is in an adjacent field.

(9.) Up to this point delays had been most vexatious and progress slow. I therefore decided to get out of the wet black soil country and hasten down by the high road to Cape Comorin. I did so by forced marches in good weather but when within one march of the station for which I was making, being now again off the road, bad weather set in and detained the Camp for 6 days, drenched and idle, and unable to obtain supplies, in a district reported to be one of the richest in India.

(10.) Kudankolam Observatory—the most southern of the Principal G. T. S. Stations was reached on the 16th January 1871. This station is on the prolongation of the Cape Comorin Base—of which it was originally intended to be one extremity. It is situated about 1500 yards from the sea, and may for the present purpose be considered the principal, rather than the central, of 6 Stations of observation, of which two lie also on the coast, N. E. and S. W; another—the intended North End of the base—due North 7 miles; and 2 more on the East and West flanks of the base. That on the coast S. W. of Kudankolam is Punnæ (Pannei) one of Col. Lambton's early astronomical stations, which formed the southern extremity of his Indian Arc of Meridian.

(11.) The observations of Zenith Distance at this point cost but 3 days and will obviate the necessity of depending on results which can only be rendered available by recomputation from meagre data.

(12.) The number of subsidiary stations of this group is therefore 5, a larger number than I have introduced anywhere else as yet. It seemed desirable to venture as far in this direction as I might, at this particular place, on account of its being the most important station to Geodesists in India, and one which must ever be the extreme southern limit of this meridional arc. For the same reason the number of observations was slightly increased. These were completed at Rathapuram, the 6th station of the group on the night of the 15th February—*i. e.* in less than one month after reaching Kudankolam.

(13.) We had now to make the best of our way to Bellary 470 miles due north. This was accomplished by road and rail by the 7th March, and on the 13th observations were again commenced at one of the outlying stations of the *Honur* group 25 miles S. E of Bellary. By this time it was no longer a question of rainy weather and cloudy skies but of intensely hot days and sultry nights. During the whole of another 3 weeks spent on this group the thermometer stood for a great part of every day at 102°—105° in my tent and as that country is bare of trees and very dry, there was never any shelter or water within a mile or two of the observing points. But as the nights were always fine the work was quickly got over, and on the 6th of April the return march to Bangalore was commenced. We entered Bangalore on the 20th rather more than 5 months after leaving it.

(14.) Although only 3 groups of stations were accomplished during the season—which as far as Geodesy is concerned, can furnish but so many distinct determinations of latitude—I am satisfied that that science is considerably richer than if twice the number of points a degree or more apart had been observed at with equal or greater accuracy. But this can only be proved by the computed results. Should it appear that, unlike those of last year, the minor amplitudes accord closely with those shown by trigonometrical operations, it will indeed be strong evidence in favor of isolated determinations—evidence which is much wanted to rescue all such from a suspicion of pretending to greater worth than they can now be believed to possess. But, should it be found otherwise—a line of cogent argument will have been opened against the utility of continuing the system of seeking to determine the astronomic latitudes at isolated points with minute accuracy, and in favor of abandoning certain methods of observation which involve a useless expenditure of time and labor.

(15.) I annex tabular statements showing the ground gone over, the particulars as to numbers of stars used, of observations, and of observing nights &c. The first is given for the sake of showing how small a proportion of the whole season has been really devoted to Zenith Distance observations—not because of the system of grouping, so much as from unfavorable weather, and the long distances which had to be traversed. Perhaps this is the best place to say that should the programme for next season be what I now anticipate viz., a regular and more rapid progress northward, terminating within reach of Mhow, Ellichpore, or some such place—there will be no such disproportion between the work done and the distance gone over; and I may hope then to shew quite double as much.

(16.) No change of any great consequence has been made in the routine of observing. The only point worth mentioning is that in consequence of an appreciable error of "run"—which cannot be mechanically corrected—having been proved to exist strict attention has been paid to the fact and a correction has been applied in reducing. To do this it is necessary to be *certain* what graduation has been used in any given reading—and that involves a rigid adherence to a rule in reading. It is sufficient to mention this, without going further into the matter here, to explain why, in the absence of such an *invariable* rule, no run correction may safely be applied,

retrospectively; and why therefore I am unable to correct the observations taken in 1869-70 and in December 1871 for run. Kudankolam was the first station where the readings were taken according to a fixed rule in this respect.

(17.) I am sorry to say that a closer acquaintance with the instrument has modified but very slightly, my first impressions of its excellence. A peculiar and very perplexing instability is evidenced by the different indications of the levels, which I have not yet been able to trace satisfactorily to its source.

(18.) There is also a peculiar tendency in the "zero error"—*i.e.* the reading of the microscopes when the line of collimation is parallel to the axis of azimuthal rotation—to be greater (by about one fifth of a second) when the first intersection has been made in the position "telescope west" and the second in the position "telescope east," than when the two intersections have been made in the reverse order. As the "direction of the axis" has no real existence except what is founded on the *two* positions, being in fact an imaginary bisection of the angle defined by the directions of any fixed line in the instrument before and after reversal, the "zero error" also is equally dependent on both, and ought to be found the same in whatever *order* the positions occur. But this is on the assumption that the instrument as a whole is rigid. That the "zero error" *is* dependent on the order of the two positions is an indication of a want of rigidity. And this probably is also at the bottom of the defect indicated by the level readings last referred to.

(19.) I may also mention, not as a defect so much as an interesting optical peculiarity of the Telescope—that it gives with stars of the 2nd and under favorable conditions 3rd magnitudes a small crimson "ghost" which when first remarked was mistaken for a companion of the star under observation. So exact is the resemblance that it was only by accident that the true explanation presented itself. In general the attention is fully occupied in making the necessary intersection, but on one occasion it was arrested by my noticing that the red companion which was on the right (*i.e.* North) at the first intersection was also on the right (*i. e.* South) at the 2nd (after reversal) proving that the cause lay in the telescope and not in the sky. But for the reversal I should have had no reason to doubt the evidence of my eye sight and might unhesitatingly have affirmed the existence of a red companion until the too frequent recurrence of the phenomenon should have raised a doubt.

(20.) In the foregoing narrative I have endeavoured to keep in view the importance which should attach to the purpose for which, as well as to the means by which, determinations of latitude are required. Until the arrival of the Zenith Sector instruments had been used for these determinations, of a kind and in a manner which did not permit more than 5 or 6 being obtained in one season. At one time two such were in use but during the 7 years from 1863 to 1870 the total number was only 44. In earlier years about 10 had been taken, on special occasions. I apprehend that on the arrival of the second Sector, now expected, the Astronomical Circles will be consigned to a well earned repose—at any rate until a method of using them with less expenditure of time shall have been devised, and an increase of the strength of the Department shall have made available the requisite number of observers. The Sectors are competent to turn out at least double the amount of work, *of the same order*, and were trigonometrical stations available without difficulty, fully 25 or 30 determinations might be made annually by the two, with a degree of accuracy quite on a par with the average of those made by the Circles; while, if the standard were lowered, of course a still larger number might be looked for.*

(21.) I am strongly of opinion that the standard should and will be lowered, and I will therefore assume an average of 30 stations per annum for the out-turn of the two instruments. At this rate two or three year's work would equal in amount the whole results up to the date of the arrival of the Sectors, and ten years—a comparatively short period for which to arrange a system of observation on a matter of this magnitude—will see us in a position to look back on the arrival of the Sectors as on the commencement of a new era.

(22.) The main, if not the only, difficulty in carrying out this principle is, that suitable Trigonometrical Stations are not available where they are wanted. This difficulty however, though a real one, is not so great as it seems. For not only is there no occasion for requiring that principal stations alone shall be used, even with the present pretensions of latitude determinations, but if, as I propose, the standard of the latter be materially lowered a comparatively rude geodetic determination will suffice; provided the connection is *based* on first class triangulation; and provided there is no loop hole for suspicion as to the identity of the station. If for example the standard of $\pm 0''.10$ is fixed as the "probable error" of the latitude determination—which is equivalent to saying that the chances are to be enormously (500 to 1) against

* In the table which I give at the end of this report it appears that in a season of 5 months which cannot be considered exceptionally favorable, 15 stations 53 miles apart might have been observed at for 3½ nights each; with an average of 3 nights per station besides, to cover contingencies and adjustments.

the actual error being a quarter of a second since this would correspond, at the well known rate of 1″ of latitude to 100 feet of meridional displacement, to 10 feet of error in the position of the station, it is clear that 3 or 4 feet even of error due to the trigonometrical connection would be comparatively unimportant. And this it must be admitted would be a very rude error to make in a trigonometrical connection even with inferior instruments. Practically, so great an error would be impossible, and it is therefore not essential that recourse be had to first class theodolites for the connection of Astronomical Stations.

(23.) There *is* another difficulty in the way of greatly increasing the number of astronomical points; but it is removed at once if first class theodolites are relieved from the onus of fixing these trigonometrically; and indeed the necessity of finding such points is a strong argument for relaxation in this respect. I allude to the selection of points free from obvious disadvantages of position.

(24.) I have been led to make these remarks because the question is one which presses for solution. So long as Astronomical and Trigonometrical parties are so circumstanced as to be able to concert measures, a moderate exercise of discretionary power will no doubt suffice; but where this is not the case the one party may hamper, or be inadequately accommodated by the other, to an extent which will produce complication and waste of labour. Hitherto I have only experienced this in a small degree; but I anticipate serious inconvenience and loss of time next season, unless I may count on the subsequent aid of a surveyor, or unless I am made independent of one by being instructed to execute for myself such triangulation as may be necessary.

(25.) Up to the present time the calculations, though well advanced, do not yet enable me to judge of the character of the past season's work; but I hope to be in a position to do so shortly. The ultimate comparison of the resulting astronomic latitudes with those produced by the triangulation must however remain to some extent incomplete. Although the stations in the neighbourhood of the Cape have been trigonometrically connected with each other no connection with the triangulation to the north has yet been effected except such as may be deducible from Colonel Lambton's Surveying Operations. This will no doubt be practically accurate enough, but will involve calculation of which I do not at present know the amount, and which I cannot therefore formally undertake to execute. Again, the principal triangulation to which I have before alluded could not be extended by Major Branfill during the last season quite so far as to give final values of the geodetical positions of the stations of the Mallapatti group, and the comparison here will be only approximate. The Honur group however, near Bellary, has been fully connected, and the comparison there will be complete.

(26.) I have only to add, in conclusion, that I have been ably seconded throughout the past year both in office and in the field by Mr. G. Belcham who has by unfailing attention to his duties well earned the promotion which he lately received. He has now acted as observatory assistant for 8 years and is well acquainted with the duties of such an office, as well as with the special nature of the computations which occupy us in the recess; and this particular kind of training must always make his services valuable where such work has to be done. At the same time I cannot but regret that it is so unavoidably of a special and limited character, and could wish that I had the opportunity to require the exercise of his faculties in a less confined sphere of action.

(27.) The health of the party during the past season has been good.

Abstract of Results of Zenith Distance Observations 1869-70.

	I Bangalore Base S. End.			II Bangalore Base N. End.			III Dodagunta Station.		
Bangalore group.	° ′ ″	″		° ′ ″	″		° ′ ″	″	
Astronomic Lat. by N. Stars; probable error; No. of stars	13 0 36·00	± ·053	58	13 4 52·96	± ·081	22	12 59 52·17	±0·071	23
Do. by S. Stars; Do. do.	35 90	·078	28	52·82	·082	22	51·88	·071	23
	+0·10			+0 14			+0·29		
Difference (N—S)									
Mean Astronomic Latitude; probable error: No. of stars	13 0 35·95	± ·047	86	13 4 52·89	± ·058	44	12 59 52·02	± ·050	46
Geodetic Latitude (Origin Calcutta)	13 0 43·59			13 4 58 74			12 59 58·42		
Apparent effect of local attraction ($\lambda_o - \lambda_c$)	−7·64			−5·85			−6·40		
Probable error of an observation* and number of Ditto		±0·42	304		±0·41	142		±0·36	148

	IV Yettimallei Station.			V Pachapaliam Station.			VI Katpaliam Station.		
Pachapaliam group.	° ′ ″	″		° ′ ″	″		° ′ ″	″	
Astronomic Lat. by N. Stars; probable error; No. of Stars	11 3 52·22	±0·073	28	10 59 40·75	± ·040	25	10 56 36·45	±0·044	26
Do. by S. Stars; Do. do.	51·91	·076	28	40·87	·075	23	36·65	·071	24
	+0·31			−0·12			−0·20		
Difference (N—S)									
Mean Astronomic Latitude; probable error; No. of stars	11 3 52·06	± ·052	56	10 59 40·81	± ·043	48	10 56 36·55	± ·042	50
Geodetic Latitude (Origin Calcutta)	11 3 52 68			10 59 42·56			10 56 38·65		
Apparent effect of local attraction ($\lambda_o - \lambda_c$)	−0·62			−1·75			−2·10		
Probable error of an observation* and number of Ditto		±0·41	172		±0·24	143		±0·26	133

NOTE.—The probable error of an observation has been obtained from a consideration of the apparent errors of individual observations wherever there have been two or more of the same star. This quantity therefore is free from such errors as are due to constant causes; e. g. error of N. P. Distance, error of graduation, and such like. It represents the combined effect of imperfect observation and reading, and of erroneous level reductions; as well as of some instrumental defects which vary from day to day.

Route &c.	Days.	Marches.	Working nights.	Miles by Rail	Miles by road or track.
Bangalore to Trichinopoly, by rail	2	...	...	281	...
Trichinopoly to Kutiapare, by road	13	11	...		122
At and about Kutiapare	37	6	19		63
Kutiapare to Kundankolam, by road	14	6	...		91
Cape Comorin group	31	5	19		38
Ditto to Caroor R Station, by road	16	15	...		218
Caroor Railway Station to Bellary, by rail	3	...	...	505	...
At Bellary and to Honur, by road	5	2	...		20
Honur group	25	5	15		56
Ditto to Bangalore, by road	14	14	...		186
Total, ...	160	64	53	786	794
Average per observing station (15) ...		4·3	3·5		53

Distribution of observations 1870-71.

No. of group.	No. of Station.	Name of group and station.	Working nights.	Stars.	Observations.	Average per night.
3		*Mallapatti*	19	72	384	
	VII	Kutiapare Station, ...	10	57	182	18·2
	VIII	Black Station, ...	3	38	60	20·
	IX	Shulakare Station, ...	4	40	77	19·3
	X	Pandalagudi, ...	2	38	65	32·5
4		*Cape Comorin*	19	68	560	
	XI	Kudankolam Observatory, ...	8	54	192	24·0
	XII	Visiapathi Station, ...	2	42	77	38·5
	XIII	Alakaneri Station, ...	2	41	75	37·5
	XIV	Pannei Observatory, ...	2	42	78	39·
	XV	Tanakarakolam Station, ...	2	37	57	28·5
	XVI	Rathapuram, ...	3	37	81	27·
5		*Honur*	15	66	409	
	XVII	Yerragunta, ...	2	37	72	36·
	XVIII	Honur, ...	6	58	155	25·8
	XIX	Nimbagal, ...	2	38	58	29·
	XX	Chikalgurki, ...	2	38	54	27·
	XXI	Bandur, ...	3	38	70	23·3
		Totals ...	53	138	1,353	

Postscript.

The observations described above have since been provisionally reduced, and the results are shown below. They cannot be accepted as perfectly trustworthy, for several reasons—but, as the errors to which they are liable are to a great extent, if not wholly, constant for all the individuals of the groups severally; and moreover actually small as compared with the conclusions to which attention will be directed, it is unnecessary (for present purposes) to discuss their inaccuracy. It will be sufficient to say that the errors referred to are due to—1st an instrumental failing, (which must be closely investigated) and 2nd inaccuracy in the calculated places of several stars, arising probably from erroneous proper motions. From their nature these errors are eliminated in comparing the results *inter se,* as I now wish to do.

The annexed Table shows, side by side, the geodetic and astronomic co-latitudes of the 15 Stations (forming 3 groups) at which observations were taken during the season reported on above, as well as similar results for the previous season, and the apparent disturbance caused by local attraction. Bearing in mind that the geodetic latitude is derived *from the astronomic latitude of Calcutta,* and that a comparison of precisely the same kind *at Madras* indicated a

very small disturbance there, the close agreement noticeable in this Table between the computed and observed results *at Cape Comorin* is first to be remarked. The conclusion is that the disturbance, if any, is nearly identical at these three sea side stations. But it should by no means be inferred that the disturbance, because relatively, is absolutely small.

Reverting now to the subject which as explained in the body of this report, occupied my attention when considering the plan of distribution of the season's work it will be apparent that in the 1st of the 3 present groups there is comparatively slight indication of a *varying* disturbing force. Still less is any such traceable in the Cape Comorin group. In the third on the contrary the inequality of the disturbing attraction is so great as to be really startling. Stations XIX and XX for instance which are only $8\frac{1}{2}$ miles apart are separated by an apparent arc of amplitude no less than 3″·1 less than is actually the case! This may be in part attributable to a small hill North of XX; the attraction of which can hardly however be more than a fraction of a second, as it is a mile distant and not 300 feet high and by no means extensive.

I find it impossible to avoid the conclusion that we have here an instance of local attraction so irregular as to completely justify the presumption on which the system of observing *in groups* was first based, and to remove all doubts as to the desirability of persevering in that system. The last column of the Table shows approximately the uncertainty of local attraction within such short distances as 4 or 5 miles.

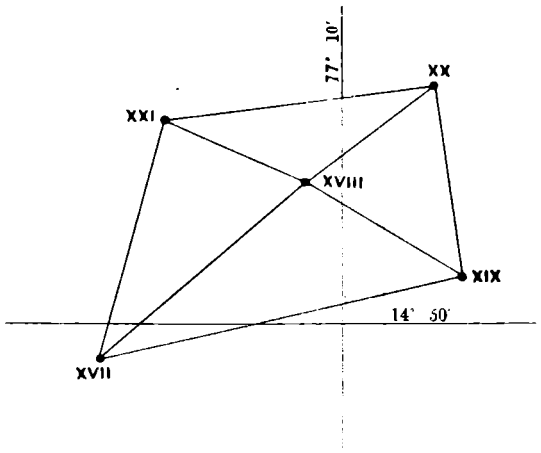
The geodetic elements of the Cape Comorin group have been kindly computed for me by Lieutenant Rogers, by means of Colonel Lambton's triangulation; the calculations being based upon the elements of the modern survey operations at the most southern identified stations common to both—near the Pachapaliam group. The assistance has been invaluable, as I could not otherwise have made any use of that portion of the results.

Comparison of Astronomic with Geodetic results—1869-70, 70-71.

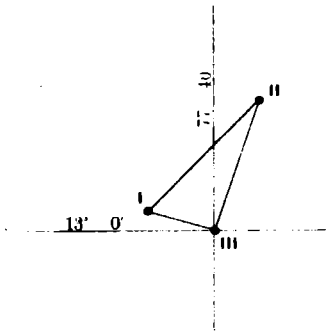
Station No.	Name of Station.	Geodetic.		Co-latitude.		Difference. $\lambda_o - \lambda_c$	Difference from mean.
		Latitude.	Longitude.	Geodetic $90° - \lambda_c$	Astro. $90° - \lambda_o$		
I	Bangalore base S. End	12°60′43″·59	77°37′28″·02	76°59′16″·41	24″·03	− 7″·62	− 1″·00
II	Bangalore base N. End	64 58·74	41 44·06	55 1·26	7·11	− 5·85	+ 0·77
III	Dodagunta ...	59 58·42	40 1·10	60 1·58	7·98	− 6·40	+ 0·22
					Mean	− 6·62	
IV	Yettimallei ...	10 63 52·68	77 53 15·10	78 56 7·32	7·93	− 0·61	+ 0·88
V	Pachapaliam ...	59 42·56	39 53·80	60 17·44	19·20	− 1·76	− 0·27
VI	Katpaliam ...	56 38·65	43 18·65	63 21·35	23·45	− 2·10	− 0·61
					Mean	− 1·49	
VII	Kutiapare ...	9 28 47·59	78 3 5·85	80 31 12·41	13·07	− 0·66	− 0·24
VIII	Black S. ...	31 4·03	5 26·88	28 55·97	55·93	+ 0·04	+ 0·46
IX	Shulakare ...	32 16·01	77 59 19·35	27 43·99	44·63	− 0·64	− 0·22
X	Pandalagudi ...			36	29·57		
					Mean	− 0·42	
XI	Kudankolam ...	8 10 23·77	77 43 54·	81 49 36·23	36·77	− 0·54	− 0·41
XII	Visiapathi ...	12 10·57	49 3·	47 49·43	49·36	+ 0·07	+ 0·20
XIII	Alakaneri ...	13 41·74	46 58·	46 18·26	18·08	+ 0·18	+ 0·31
XIV	Pannei ...	9 30·04	40 2·	50 29·96	30·40	− 0·44	− 0·31
XV	Tanakarkolam ...	13 57·60	41 21·	46 2·40	2·51	− 0·11	+ 0·02
XVI	Rathapuram ...	17 1·65	44 35·	42 58·35	58·31	+ 0·04	+ 0·17
					Mean	− 0·13	
XVII	Bekurtipa ...	14 48 25·89	77 0 45·26	75 11 34·11	32·84	+ 1·27	+ 1·37
XVIII	Honur ...	55 21·61	8 30·29	4 38·39	37·94	+ 0·45	+ 0·55
XIX	Nimbagal ...	51 55·10	14 19·47	8 4·90	4·05	+ 0·85	+ 0·95
XX	Chikalgurki ...	59 7·18	13 34·07	0 52·82	55·09	− 2·27	− 2·17
XXI	Bandur ..	57 44·97	3 4·60	2 15·03	15·81	− 0·78	− 0·68
					Mean	− 0·10	

Rough chart to illustrate positions of Zenith Distance Stations.

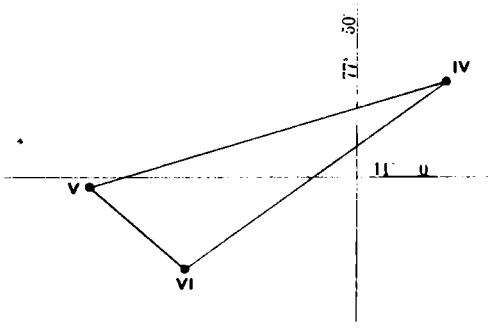
Honur group (South of Bellary)



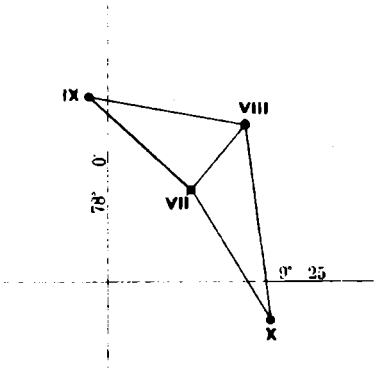
Bangalore group



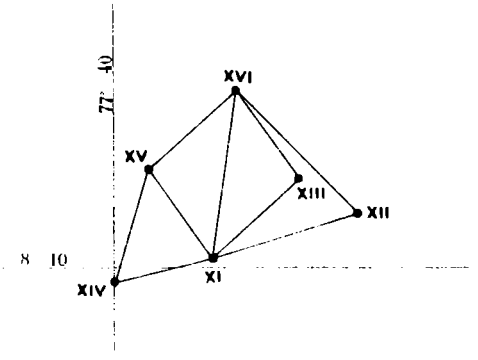
Pachapalam group (East of Coimbatore)



Malapatti group (South of Madura)



C. Cochin group



Photozincographed at the Office of the Superintendent Great Trigonometrical Survey, Dehra Doon September 1871.

Extract from the Narrative Report—dated 10th July 1871—of C. LANE, ESQ., Deputy Superintendent 2nd Grade, in charge No. 3. Extra Party.

(2.) The Party was engaged throughout the preceding recess, from the 2nd May 1870 to 17th October, in reduction of the observations and preparation of the ordinary abstracts, as well as the abstract for publication of the leveling operations of season 1869-70, and afterwards in computation of sundry Secondary Latitudes, Longitudes and Heights of the Guzerat Series, received from the Computing Office at Head Quarters.

(3.) In consequence of heavy rain having set in on the 22nd October, which continued till the 29th inclusive, the Party was delayed at Benares, as well as the camels *en route* for some eight days, so that the Party did not form Camp out of Benares till the 1st November; the camels arriving on the 2nd, the Party marched on the 3rd idem *en route* to Goruckpore, reaching the place on the 18th, where, after testing the collimation of the two Levels and the values of paka points in the vicinity, and comparing staves with the portable iron standard, the leveling operations were resumed on the 21st November from the G. T. S. Bench mark on the paved step of the Station church, and carried by the North Eastern road to Pipraitch, Captainganj, Parraona, Bagha and Bettiah. From Bettiah the operations proceeded along the road, passing about $\frac{3}{4}$ of a mile South of the military outpost station of Soogowlee, to Motecharee, Mozufferpoor and Darbhanga.

(4.) The following branch lines were leveled on the way. From Bahadur Sing's paka well at Bagha to Jankiram's temple in Maoza Bankatwa. From Bhawanibax's old paka well in Maoza Chandarpur, on the road, about 6 miles E.S.E. of Bagha, to Bakwa Tower Station common to both the Hurilaong Meridional and the N.E. Longitudinal Series. From a large peg in Maoza Rampur, about 26 miles on the road, S.E.E. of Bagha, to Patjirwa Tower Station of the Hurilaong Meridional Series. From a large peg on the same road, in Maoza Soogowlee, to Raja Rajendar Kissore Sing's temple at Soogowlee. From Motecharee, from a road culvert at branching of roads to Dhakaram-Chander and Mozufferpoor, to Rupdi Tower Station of the N.E. Longitudinal Series. From a large peg in Maoza Lashkaripur, on the same road, about $4\frac{1}{2}$ miles N.W. of Mozufferpoor, to Harpur Tower Station of the Chendwar Meridional Series. From Chowdri Nathu Lal's gateway in the city of Mozufferpoor to the Station church. From the same gateway to Sawajpur Tower Station of the Chendwar Meridional Series. From the N. flight of stone steps of Seosahai's paka tank in the same city to Paladpur Tower Station, also of the Chendwar Meridional Series.

(5.) From Darbhanga the main line was continued, on the same road marked with milestones leading towards Purneah. On the way, from M.S. 40 from Mozufferpoor, about 7 miles nearly E.N.E. of Darbhanga, a branch line was carried to Chotapati Tower Station, of the North Parasnath Meridional Series: returning to M.S. 38 from Mozufferpoor, a branch line was taken to Basatpur Tower Station, and another afterwards from M.S. 50 from Mozufferpoor to Harpur Tower Station, both of the same North Parasnath Meridional Series. Subsequently the main line was finally closed on a G. T. S. Bench mark embedded about half a mile beyond the village of Parsarman, in Maoza Parsoni, where a Hindoo Temple at the former afforded a good, permanent testing point for future extension, no other being within several miles ahead, for the commencement of next season's operations, and the weather having become exceedingly dusty, hot and trying to continue the work to Bhagulpore, which station was still about 80 miles distant, and said to be, at the season of the year, across arid waste land, destitute of tree, shade and even water for a considerable portion of the distance; and, with the river Ganges eventually to cross near the end.

(6.) Owing to the unusually late cessation of the rainy season, on taking the field the country was found excessively wet and damp, throughout November and the greater portion of December, and was covered with extensive sheets of water. The military road to Bettiah and Soogowlee, along which the operations were carried, was much out of repair and cut across by water in a great number of places, many of which parts were perfect bogs. As a natural consequence there was much sickness in camp, from fever and dysentery in November, influenza of a very obstinate type in December, as well as throughout January, and till about the middle of February. The tract between Bagha, on the left bank of the Gandak or Naraini river, and Motecharee, proved to be the most unhealthy, owing to an extremely damp atmosphere from dense fogs, and owing to the deleterious nature of the water, which latter was so bad that the majority of the inhabitants (not excepting even cats, dogs and sheep,) were found to be troubled with large goitres, especially in the vicinity of Soogowlee, a military outpost station, where more than one body of some twenty sick native soldiers at a time, were seen passing on the road. One entire village on this road is said to be so bad with the disease that the people cannot articulate or converse with one another, save by strange noises accompanied

by signs and gestures. Three or four acute cases of the disease occurred in camp, but being treated at the commencement were speedily cured.

(7.) Field work having been closed on the G.T.S.B.M. embedded as described near the large village of Parsarman, the party marched for Benares to quarter for the recess arriving at the station on the 3rd May.

(8.) Mr. A.W. Donnelly, Surveyor 2nd grade, has been, throughout the past year, unremitting in the zealous performance of his duties, and I have great pleasure in stating, in continuation of last year's narrative report, that he has afforded the greatest satisfaction.

(9.) Sub-Surveyor Amjad Ali assisted in recording observations, in transcribing the duplicate of No. 2 Level, as well as in attending to the current office work and preparation of the monthly papers. Sub-Surveyor Narsing Dass assisted in recording observations, and during my temporary illness in observing with No. 2 Level, and also in keeping up the duplicate of No. 3 Level. Both the Sub-Surveyors worked hard and gave satisfaction.

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

308 miles 40·92 chains of double leveling, including branch lines, embracing determination of

9 Tower Stations, viz: Bakwa, Patjirwa, Rupdi, Harpur, Sawajpur, Paladpur, Chotaipati, Basatpur and Harpur of the N.E. Longitudinal Series, and the Hurilaong, Chendwar and North Parasnath Meridional Series, as described in paras: (4) and (5).

4 Gandak river Irrigation Department Bench marks.

1 Trijunction pillar.

151 Paka points.

1 G.T.S. Bench mark (embedded).

1 river and 19 streams were crossed, viz. the Gandak or Naraini, the little Gandak, Bansi, and two other branches of the Gandak, Harrah, Chandrawati, Hardho, Buri Gandak twice, Berwa Man, Bakya, Lakhendei, Bagmatti, Kamla twice, Jiwaitch, Puran Dhar, Ballan, Tilguja, Patalia and Dhamra.

Extract from the Narrative Report—dated 27th September 1871—of Lieutenant J. HILL, R.E., Offg. Deputy Superintendent 3rd Grade, Offg. in charge Kumaon and Gurhwal Party.

The Recess of 1870.

(1.) During the recess of 1870, while Major Montgomerie was in charge of this party, 231 trigonometrical heights of the Ranikhet Survey were computed; all the calculations connected with the previous season's triangulation of the Kosi valley were commenced and completed; all the fair maps of the Ranikhet Survey were drawn on a scale of 12 inches to a mile; the last original sheet of the Mussoorie and Landour Survey which remained unfinished was shaded and the settlement boundary running through that sheet was laid down upon it.

Ranikhet maps.

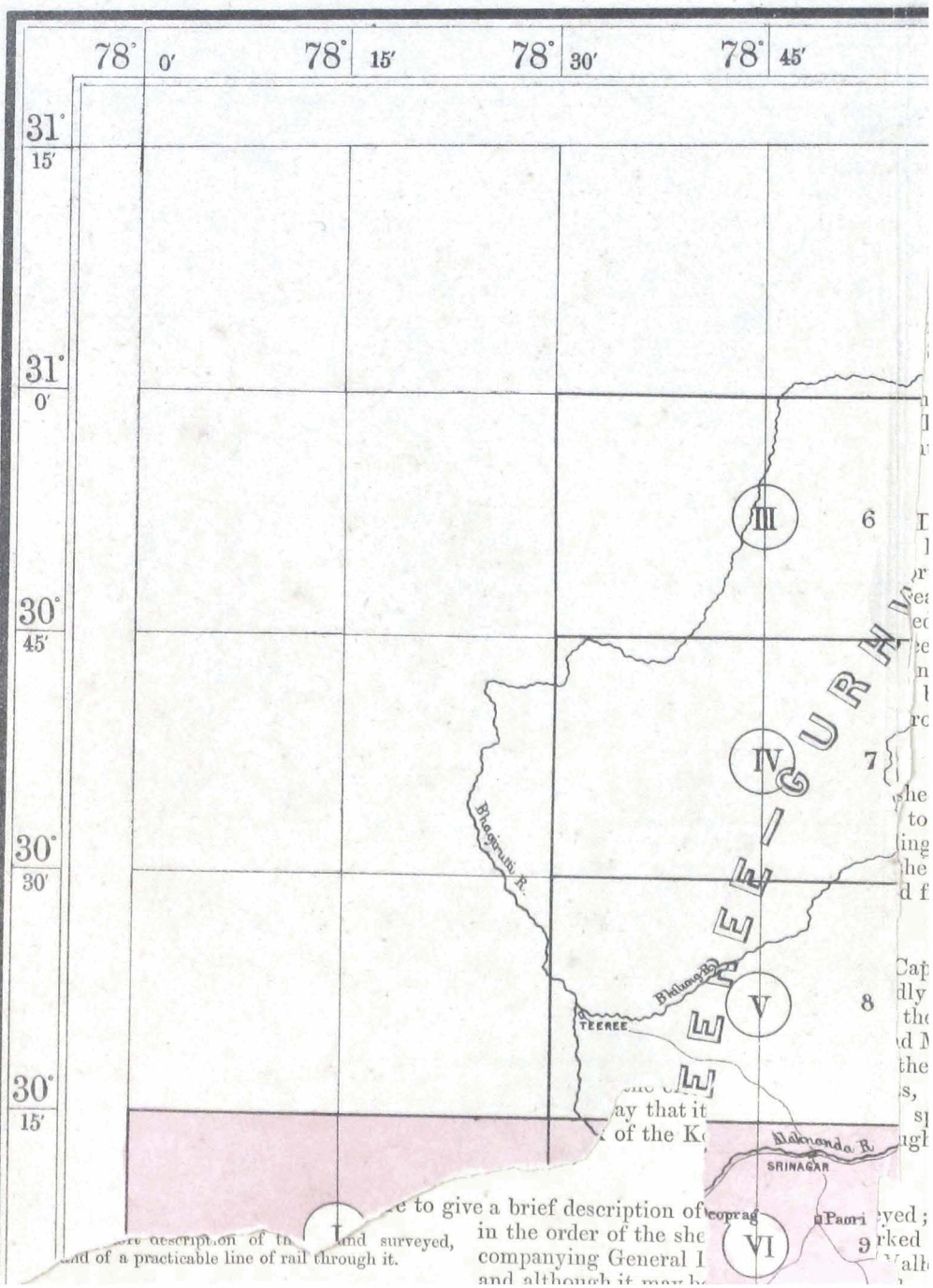
(2.) The Ranikhet maps comprised 11 large shaded sheets, each measuring 24 × 21 inches, and the same number of unshaded Skeleton Charts of an equal size. On the former sheets the features of the ground were delineated by the method of horizontal line shading; the true directions of the lines, and the depths of shade being determined from approximate eye contours derived from the trigonometrical heights.

(3.) The approximate eye contours at the levels of 5000, 5500, 5800, 6000, 6500, 6700, 6800 and 6900 feet above the sea were those chosen to be the chief guide-lines for the shading, and a scale of shade was adopted which gave a vertical height of about 6 feet between the *hachures*. Thus, a general uniformity of style was obtained, and although owing to the necessity for the early publication of the maps, six different draftsmen had to be employed, it was found that when all their work was joined together it formed a satisfactory and accordant whole.

(4.) The chief guide-lines, already mentioned, were entered in the Skeleton Charts in order to give a series of general, approximate levels through Ranikhet, and thus assist the engineers whose duty it was to plan the Sanitarium.

(5.) The Ranikhet maps were all printed by the Photozincographic process, and published by the beginning of November.

INDEX TO THE S



...e to give a brief description of ... in the order of the she... companying General I... and although it may b...

...re description of th... land surveyed, ...nd of a practicable line of rail through it.

(6.) On the 1st October 1870 Captain Thuillier received charge of this party from Major Montgomerie, who was called to undertake the duties of Superintendent of the Department. At this time the Ranikhet map work was approaching its completion: Captain Thuillier, accordingly, commenced his preparations for making the topographical survey, on a scale of 6 inches to a mile, of the Kosi Valley, and Kuch Gadh, which was required by the Government* "to facilitate the investigation into the practicability of the construction of a railway up the valley."

Captain H. R. Thuillier R.E.

Kosi Valley Survey on scale of 6 inches to a mile.

* No. 1197 B.M, dated 25th November 1869 P.W. Department.

(7.) It was laid down by the Government that the Survey might be confined to the ground near the river over which a line of railway would be likely to pass; and the Superintendent considered that such ground would lie within a width of about one mile on each side of the river. Captain Thuillier, therefore, was directed to survey within this limit as to breadth, from Ramnuggur to Bujan by the Kosi Valley, (see the accompanying General Index to the Kosi Valley Survey) and thence to the nearest point in Ranikhet by the Kuch Gadh.

(8.) He commenced his preparations by dividing the area to be surveyed into 10 plane table sections which he apportioned, with full instructions, to the following officers viz: myself, and Messrs E. C. Ryall, J. Peyton, J. Low, L. Pocock, H. Todd and T. Kinney; while Mr. F. Ryall, who joined this party during the recess from the Brahmaputra Series, and who had had no experience of topographical surveying, was directed to carry a rigorous theodolite and chain traverse, with vertical observations, through the whole length of the Survey.

(9.) Each of these officers as soon as his recess work was finished was sent into camp to take up his Kosi work, and Captain Thuillier was able to complete all his own arrangements, and take the field by the end of November.

The Field Season of 1870-71.

(10.) His intention was to have marched to Ramnuggur (which from Dehra is the nearest point of the Kosi Survey) by the way of Rurki, Bijnour and Kashipur, for he had business to transact at Rurki connected with the equipment of the party; but, unfortunately, an illness from which he had been suffering from some months before this time increased to such an extent that he found himself unable to advance beyond Kashipur. He reached that city, which lies about 16 miles to the south-west of Ramnuggur, on the 20th December; but, after remaining there a week he had to be taken to Moradabad, where he was under medical treatment until the second week in January. He then returned to Kashipur; but, finding that his health did not improve, he was obliged to apply for medical leave to Europe, and resign his charge of this party.

(12.) Upon the official announcement by Captain Thuillier that he wished to resign his charge, and proceed on sick leave to Europe, I was directed to take his place: I accordingly left my work in the Kosi Valley, and marched to Kashipur, where I took over charge of the party from him on the afternoon of the 10th February 1871, and on the next day I returned from Kashipur to Ramnuggur to resume work in the Kosi Valley.

Lieutenant J. Hill, R.E.

(13.) The party was now very short-handed: it had lost the direction of Captain Thuillier, and I very soon found that it was impossible for me to carry on uninterruptedly my former work, and at the same time fill his place: it had moreover, during the last recess, lost the services of Mr. W.G. Beverley, who was advanced to the charge of the Brahmaputra Series, and Mr. G.W.E. Atkinson had been transferred from it to the Superintendent's Office. Under these circumstances I was obliged to make an exceptional call upon the energy of the Assistants, which they most cheerfully responded to. It is due to them to say that it was through their special exertions alone that the whole of the topographical work of the Kosi Survey was brought to a conclusion in the short period of a single field season.

(14.) It may be well here to give a brief description of the ground surveyed; noticing it in the order of the sheets which are marked on the accompanying General Index of the Kosi Valley Survey: and although it may be considered beyond my province to give an opinion as to the advisability of constructing a railway up the valley of the Kosi, I may be permitted, as I have carefully inspected the ground, to give a general idea of one line over which I believe, if its construction were sanctioned, a railway might be carried.

A short description of the ground surveyed, and of a practicable line of rail through it.

(15.) At the southernmost point of the Survey, where the Kosi leaves the outer ranges of the Bhabar hills for the plains, is the town of Ramnuggur. Fifteen years ago its site was a mere encamping ground; but since then district and forest roads have been made; and little by

Sheet No. 1. Ramnuggur.

little Ramnuggur has grown, first superseding the old town of Chilkia which now lies in ruins three miles to the South, and becoming at last the chief market-town in Kumaon.

(16.) Commanded by densely wooded heights, the town of Ramnuggur stands at an elevation of 1200 feet above the sea level, and about 70 feet above the river, on an alluvial plateau, a description of which is given further on by Mr. E. C. Ryall, who surveyed it. On this plateau, and a little to the north of the town is the position already chosen for the terminus of the proposed extention of the Rohilcund Railway. From this point a line of rail up the Kosi Valley might conveniently start; following a line (shown by chain dots on the Index) which for some miles keeps more or less closely to the line of the present cart road, and passing through the slightly higher plain of Amdanda, which is the site of an ancient city whose remains occur continuously all along the road to the village of Dikoli.

(17.) Thus far the ground presents few engineering difficulties: it is in general flat, and, being crossed by only unimportant streams, the cost of constructing this portion of a line of railway up the valley would be small. But at Dikoli difficulties commence and continue at intervals along the route which, although far from insurmountable, would cause the construction of a railway to be a very costly undertaking.

Sheet No. 2. Dikoli.

(18.) The alluvial plain of Dikoli is situated about 6 miles north of Ramnuggur, where the low Bhabar hills begin to mingle with the spurs which descend from the higher ranges of the Sub-Himalayas.

(19.) The geological formation which prevails over all this part of the Survey, from Ramnuggur upwards to Kumeria, is sandstone underlying beds of clay and boulders, and forming plateaux, called *chaors*, which, although sometimes almost level, have generally a gentle downward slope towards the North, and a scarped face to the South.

(20.) In one of these chaors, called Bazar ka Chaor, to the west of the plain of Dikoli, and overlooking it, are some relics of ancient temples which were probably connected with the ruined city already mentioned in para (16). Mr. Peyton, who surveyed this locality, gives, further on, a discription of these interesting remains.

(21.) The valley narrows rapidly above Dikoli until, at the spot where the iron suspension bridge spans the river, there is not a greater distance than 200 yards from cliff to cliff, and the stream at this point is not more than 50 yards wide. Here the line of railway would pass in a northerly slanting direction across the river, avoiding the cliffs on the right bank, and the numerous streams, or *sotes*, which a little further on empty themselves during the rainy season into the river on that side.

(22.) In this neighbourhood a spongy limestone is found, which is said to answer well for building purposes. Its quality, I believe, has already been tested by engineers of the Public Works Department, in the construction of the piers of the iron suspension bridge, and in the building of the P. W. D. Road Inspection House; in which latter work, moreover, the carved stones of the Bazar ka chaor were freely made use of. Mr. Peyton gives, further on an account of the limestone he noticed in this part of the valley.

(23.) On the left bank of the river, and about 700 yards above the iron suspension bridge, the line of railway, after traversing a rather narrow flat, would reach a perpendicular wall of rock which has already been cut away sufficiently to allow the Ranikhet cart road to pass. Here, where the Suki Rao and Kali Gadh (after joining together a few hundred yards to the N. E.) run into the Kosi, the line of rail would be carried over a bridge. Thence it would continue its course along the foot of the hills to Chokhamb No. 6 flag.

(24.) A little beyond this latter spot it might be deemed necessary to divert the waters of the river slightly to the west, so that they might no longer strike against the angle at Chokhamb No. 6 flag and indeed, all through this part of the valley it would be needful to guard against damage from the river, which is constantly changing its bed.

Sheet No. 3. Mohan.

(25.) The line of rail would now cross the Chokhamb Flat, and turn to the east at Chokhamb No. 2 H.S. Here it might be thought well to make a cutting, so as to avoid too sharp a curve. At this point, which is opposite Mohan, the line would slightly rise, keeping to the small narrow flats which, in this vicinity, terminate the lower slopes of the hill-sides.

(26.) The appearance of the opposite side of the valley is here very striking. Extensive plateaux, densely wooded with *sal*, which is the prevalent tree in this part of the valley, rise one above the other with a strange regularity which, were their formation not understood, would almost suggest the idea that they were the result of man's labour. Remains of ancient

inhabitation are found in the plateau nearest to Mohan. This part of the valley is more fully described hereafter by Mr. E. C. Ryall who surveyed it.

(27.) The line of rail on reaching the eastern margin of the flat below Khairali H.S. would pass over to the Belgeda and Kumeria plateaux on the right bank of the river, cross the Ranikhet cart road on that side, and return to the left bank at the Khania Dhang flat.

(28.) From this point the line would keep to the left bank, cutting through the rock at the base of the hill in one or two places, until it reached the flats at Okhaldunga, where the river takes a sharp turn round the Singiagarhi hill. Here the line would sweep round the north-west and north slopes of Singiagarhi, and again cross, where the stream is narrow, to the right bank.

Sheet No. 4. Okhaldunga.

(29.) Hereabouts the formation near the bed of the Kosi changes from the rather soft sandstone which prevails throughout the Bhabar hills of Dikoli and Ramnuggur, to a much harder variety of the same rock which, lower down the valley, is only found at a considerable height above the river. So hard, indeed, is the rock that it is quarried with difficulty, and it is apt to turn the edges of the tools which are used to cut it.

(30.) The line would now remain on the right bank of the river for about 1,600 yards, and return to the left bank at the Bhaitla fields. Thence, after crossing the Bawas Gadhera, it would pass, by a cutting, through the Tanguri rock, and continue on the same side of the river to Talla Seti. Throughout this part of the valley the mountain-sides are precipitous and thickly wooded.

(31.) About half a mile above the Tanguri rock a serious obstacle to a line of rail occurs. Here, for a distance of about half a mile, the hills rise very steeply from the river on both sides, and loose stones and rocks are continually falling into it. Hereabouts, owing to the frequent land slips which take place during the rainy season, the district road is constantly giving way, and much expense is said to be incurred in keeping it in even tolerable repair.

(32) After overcoming this obstacle the line would reach the upper slopes of Talla Seti, and cut through the adjacent ridge near the pass over which the district road has been taken.

(33.) From this point I think it would be well still to keep to the left bank as far as the iron suspension bridge at Puntpipal. On this side of the river, a few hundred yards beyond the village of Seti, the line would reach troublesome, rocky ground, and for nearly a mile below the Puntpipal suspension bridge the difficulties to be overcome would, no doubt, be great, especially where a crumbling felspathic rock occurs, which is continually slipping: but I believe it would be better to face these obstacles than to cross the river, pass over the Amel fields, cut through the slopes at Thorna, or round their declivities, and arrive after all at the Pant ki gadh, which would have to be crossed before Puntpipal could be reached.

Sheet No. 5. Seti, Amel.

(34.) At Puntpipal the small spur which descends to the eastern pier of the present bridge would be cut through, and the line would cross in a north-easterly direction to the right bank of the Kosi.

(35.) The present iron suspension bridge at Puntpipal was erected by Mr. Lawder the District Engineer of Kumaon at the point where the branch road to Ranikhet leaves the district road. He told me that before commencing that work he made a search through the immediate neighbourhood for lime, and was fortunate enough to find, close to the site of the bridge, and just above the water line, a bed of good limestone. This limestone, being on the spot, could be used with advantage in the construction of the railway bridge. Limestone is also found in one or two other places in this vicinity.

(36.) A little below Seti the appearance of the country changes. The sandstone gives place to crystalline rocks of various compositions; and the valley loses more and more its wooded character until, near Puntpipal, the mountain-sides are bare.

(37.) The railway would continue on the right bank of the river through the extent of this sheet, following pretty closely the line of the present district road.

Sheet No. 6. Uchakot, Simalkha.

(38.) The country hereabouts is not of an interesting character. It is bare, and the hills are steep. They are composed of a dull, buff-coloured schist whose tint is diffused over all this part of the valley, except where an occasional land-slip, white as chalk but really

felspathic, shines out from among the surrounding rocks. Here by the river-side, as in the other parts of the valley, are low alluvial flats, which are irrigated by channels brought from the main stream, and which yield two crops in the year. Every here and there also, interspersed among the steep mountain-spurs, and at various heights above the river, are gentle slopes which are terraced and cultivated by the villagers. Where it is possible, these fields, or *khets*, are irrigated from the nearest ravine in which there is water; and their little irrigation canals may often be seen winding round the faces of the hills, and in many instances crossing what seem to be sheer precipices.

(39.) A hard, porous limestone of a whitish colour is quarried from the foot of the hill under the village of Pahonkot, whence it is carried across the river, and burnt near the road-side, below the village of Chadula. About 4½ miles further up the valley, before reaching the village of Simalkha, good limestone is again found in a rocky promontory close to, and to the north of, the Jaman Ger ravine. Also, on the right bank of the river, opposite Simalkha the road passes by the foot of a limestone rock from which the stone is constantly being removed. The rock here breaks away in small cubical fragments, which form a debris at the base of the hill. The lime of this neighbourhood required for the works at Ranikhet is burnt, about three quarters of a mile beyond this spot, in a kiln which stands by the road-side below the rocks at Khairni No. 3 H.S. just within the limits of the next sheet.

(40.) The line of rail would pass the limekiln mentioned in the last paragraph, and rise, by means of a small cutting, to a spot, close to Dhari No. 3 H.S., in the sloping fields below the village of Khairni. Here the line would cross, at a height of about 50 feet above the river, to Dhaniakot No. 4 H.S., and, continuing its direction, would almost immediately recross the stream, and cut through the narrow rocky spur which descends to the river on the right bank.

Sheet No. 7. Bujan.

(41.) On reaching the part of the valley which enters this sheet the scenery becomes at once more varied. The ground about the village of Dhaniakot, with its curious mixture of knife-edge ridges, and wide, gentle slopes, contrasts with the solid-looking, lofty hills on the opposite bank of the river. At the turn of the river round Dhaniakot No. 4 H. S., the district road winds under steep rocks of varied colours until it reaches the point marked with a cross on the Index. The villagers say that here a portion of the road is carried away every year in the rainy season, and that land-slips from above take place at the same time, choking up the road here and there in the vicinity; so that travellers are then obliged to make a detour by the village road which ascends from Dhari No. 3 H. S., passes by the village of Dhari, and returns to the district road at the commencement of the descent to Bujan. The place in question, which would thus appear to be impracticable during the rainy season, is not quite safe even at other periods of the year. I have myself frequently seen stones of various sizes dropping from above at this spot; and on one occasion when I was passing by it in the evening, returning from my work, one of my carriers, who was following a few paces behind me, narrowly escaped destruction from a large fragment which fell from the rock overhead.

(42.) In this part of the valley I did not notice the existence of limestone; but other necessary building materials are plentiful here, as elsewhere along the line of survey. In the spur on which the village of Khairni is situated, at the spot marked by Khairni H.S., a flag-stone useful for roofing purposes is found. Some of the slabs I saw were a yard square, and from an inch to an inch and a half thick: in most cases, however, they were smaller, and many of the small specimens could be split to a thickness of about a quarter of an inch.

(43.) Having cut through the narrow, rocky spur mentioned in para: (40) the line of rail would again cross to the left bank of the river, and having passed over the gentle ground at Patana, and skirted the steep, wooded hill-side a little further on, would recross to the right bank at the angle of the river where the district road has its sharp rise and fall before it reaches Bujan. From this point the line would keep to the right bank, and arrive finally after crossing the Kuch Gadh, at its terminus in the low fields of Bujan, opposite the village of Majera.

(44.) Were it thought advisable, the railway could be extended up the Kuch Gadh to a point, a little more than half a mile above the Belesar Temple, near where the direct road to Ranikhet commences its steep ascent. The Kuch Gadh calls for little description. It is an ordinary mountain valley, such as is often met with in this part of the country, formed by bare-looking hills, which though rounded and gentle towards their higher slopes descend steeply on each side into a shingly bed, through which, during the winter months a stream of water trickles, just sufficient to irrigate the few small fields that line the bottom of the valley.

(45.) It will be seen that the route, thus generally described, in addition to the numerous small bridges, and masonry platforms required for crossing the frequent ravines, and torrent-beds it would meet with along its course, would involve the construction of 10 bridges across the main stream of the Kosi.

(46.) In designing these bridges, and, in fact, in planning the whole line, care should be taken to keep well above the highest flood-line of the river. Where the valley is wide the variations in the level of the water are, of course, small. In the vicinity of Mohan, Dikoli, and Ramnuggur, for example, such variations, according to the common report of the inhabitants of those places, are confined within a vertical limit of 10 feet above the river-bed, or less: but, where the valley contracts, as it does above Dikoli, and at Singiagarhi, Tanguri, and Pantpipal, and the water-way is narrow, a sudden flood-rise of thirty or forty feet might be apprehended. It was thus that, many years ago, an iron suspension bridge which crossed the Kosi near the village of Majera was carried away by a great flood.

Sheet No. 8. Ranikhet.

(47.) Sheet No. 8, with the exception of a small portion at the South, the extent of which may be seen by referring to the Index, is a reduction from the large scale survey of Ranikhet. This reduction has been made so that the present series of maps may be complete in itself, and show the whole line of country along the route from Ramnuggur to the cantonments of Ranikhet. A full description of Ranikhet, and the Ranikhet Survey is given by Major Montgomerie in his last year's Narrative Report.

(48.) The triangulation of the Kosi Valley was also noticed by Major Montgomerie in that Report; it will, therefore, here suffice to say that Messrs. W. G. Beverley, E. C. Ryall, and G. W. E. Atkinson were the triangulators, and that their work, of which the following is a statement, was found to be accurate when tested by the topographers.

Area triangulated in square miles	1st class Secondary Triangles	2nd class Secondary Triangles	Stations visited	Intersected points	Heights	Area in acres to each point	Area in acres to each height
146	171	1,070	117	618	444	128	205

On the general execution of the Kosi Valley Survey.

(49.) Any topographical survey, which is on a scale large enough to admit of every feature of the country being delineated, and in which the ground is expressed by the method of horizontal line shading, requires, in addition to numerous trigonometrical points, a large number of accurately determined heights: but the Kosi Valley Survey, which fulfils the above conditions, is required for a special object (see para: (6)) to attain which it becomes necessary to employ a far greater number of heights than would be considered sufficient in ordinary cases. In order to be able to decide as to the practicability of the ground for a line of railway, it was laid down by Government that the various slopes of the hill-sides should be noted: but the slopes of the ground vary from the gentlest gradients to vertical precipices, and are seldom uniform for more than a few yards consecutively. To measure even the chief variations of slope would have been an endless task, and would probably have given but very imperfect information after all. Therefore it seemed well, following the spirit more than the letter of the order, to determine such a number of heights as would enable one, with the help of the shading, to judge of the slopes by examining the maps.

Heights, and approximate Contour-lines.

(50.) The number of heights which have been determined is as follows:—551 ordinary Trigonometrical Heights, 815 Theodolite Traverse Heights, and 302 heights by approximate methods in the field: in all 1668. These heights were invaluable guides to the topographers in laying down their eye contour-lines in the field; and the fair maps, which are now in preparation, are also shaded on the principle of approximate contour-lines. In these maps certain contours, which are vertically 300 feet apart, are shown by dotted lines, and the shading is effected by other interpolated horizontal lines according to a scale of shade which gives a vertical interval of about 15 feet between the *hachures*. Thus, instead of being obliged to search, and perhaps without success, for a note specifying the slope of the ground at any particular place, an engineer would arrive at once at a very good idea of that slope by means of direct horizontal measurement from the map, and by taking into account the relative heights of the contours at the place in question.

(51.) A rigorous theodolite traverse with back and forward vertical observations was carried through the entire length of the Survey, and served not only to bind the whole work together, and give a great number of valuable heights, but acted also as an efficient check on the accuracy of the work of the Surveyors. The increase of recorded traversing in topographical work seems a desideratum. Even simple compass and chain traversing, with back as well as forward bearings, has, in large scale surveys, an advantage over similar work done with the plane table and chain. In certain ground it is far the quicker method of surveying, and it has the great merit of preserving an independent record of the work done, which work can be plotted from the field books on whatever scale may happen to be required.

Theodolite Traverse.

(52.) I carefully inspected the work of all the assistants, visiting some parts of the Survey several times, and found the topographical work in all cases well done. The triangulation of the Kuch Gadh, and upper parts of the Kosi Valley, except perhaps in the high ground along the margin of the Survey where the points fixed were few, was ample, and close to the river almost excessive: but in certain densely wooded portions of the lower part of the valley, included in the first three sheets, the triangulation was meagre. In these portions, which are near Dikoli and Ramnuggur, it became necessary to fix a number of additional points; and this duty was quickly and efficiently performed by Mr. E. C. Ryall.

Inspection of work.

(53.) In such tracts of country it is almost impossible to give topographers too many points: but much trouble would have been saved if even such staves as had been fixed trigonometrically during the previous field-season had been firmly erected. In several cases no traces of them were to be found. The necessity of firmly erecting trigonometrical signals has been constantly insisted upon; but unfortunately in some instances, such as the present, without success. The marking of the trees on which flags had been placed was also in some cases, neglected; and the flags, as usual, had been stolen. Under these circumstances, and in a dense forest where it would appear the trees had too often been chosen by the stavers not on account of their size or remarkable appearance, but rather with reference to the ease with which they could be climbed, the difficulty, and in some instances the impossibility, of recognising them can be imagined.

(54.) Before returning into recess quarters I visited Ranikhet, and inspected the permanent masonry pillars which are being built there by the Executive Engineer on the sites of the trigonometrical stations of the Ranikhet Survey. He is using mud, not lime, as a cement in the construction of these pillars, and says that this plan has been found to answer well. In order to ensure great solidity he has formed the circular top of each pillar out of three heavy, flat stones of similar shape (sectors of 120°). I cannot state the exact number of pillars already completed, for although I have asked for this information I have not yet received it; but when I visited Ranikhet a considerable number had been built within the cantonments.

Ranikhet Survey Pillars.

(55.) Ranikhet has now been connected with Ramnuggur by a large scale survey, and it will be seen, by referring to the Index, that a short survey of about 7 miles in length is all that is required to connect it with Nynee Tal. The topographical work of such a survey could be done by one assistant in a single field season.

(56.) The weather was unusually fine during the greater part of the past field season, and the health of the party was, on the whole, good. A few cases of dysentery and fever occurred, and towards the end of the season, when the heat became great, there were one or two cases of sun-stroke; but none of these cases terminated fatally.

The health of the party.

(57.) Supplies and carriage were not procured without considerable expense and difficulty. There is, no doubt, every autumn an exodus of large numbers of the people from the Kosi Valley, who then go to cultivate their fields in the Bhabar: but a sufficient number of them remained behind in their villages, during the past field season, to furnish without hardship to themselves, both carriage and such supplies as coarse wheaten flour, rice, and milk to the small camps of the Surveyors. It was ordered, however, in consequence of representations made by the Commissioner of Kumaon, that instead of depending on the villages for carriage and supplies, permanent coolies should be entertained for transporting baggage, and bringing provisions from the nearest place where there was a buniah. In my own case when I was encamped opposite the village of Dhaniakot, before I received charge of the party, I found that after I had complied with the order, and had gone to the expense of hiring men, the villagers of the neighbourhood began, of their own accord, to bring supplies to my camp; doubtless thinking that it was better to get a full price for their produce at their own doors, than to send it to be sold to buniahs at a distance.

Supplies and Carriage.

Topographical Details of the Kosi Valley Survey—Season 1870-71.

	Area surveyed in acres.	Heights & stations fixed by theodolite traverses.	Number of approximate heights fixed.	Plane table & prismatic compass stations.	Area in acres to each plane table point.	REMARKS.
Lieut. J. Hill, R.E., ...	1850	34	36	360	5	Precipitous but generally open ground.
Mr. E. C. Ryall, ...	10220		180	1024	10	Densely wooded and intricate ground.
„ J. Peyton, ...	8760			927	9·5	Densely wooded and intricate ground.
„ J. Low, ...	12020			1112	10·8	Open precipitous ground.
„ F. W. Ryall, ...		528				
„ L. Pocock, ...	9363		45	1058	8·9	One half densely wooded, the rest precipitous and comparatively open ground.
„ H. F. Todd, ...	6400	253	7	560	11·4	Precipitous and comparatively open ground.
„ T. Kinney, ...	11409		34	785	14·6	One-fourth densely wooded, the rest precipitous, open ground.
TOTAL, ...	60027	815	302	5822	10·0	

Triangulation &c.,

	Area in sq. miles	1st class secondary triangles	2nd class secondary triangles	Stations visited	Intersected points	Heights	Points whose elements have been computed	Area in acres to each point	Area in acres to each height
Kumaon & Gurhwal one-inch Survey							215		
Kosi Valley Survey—Additional triangulation by Mr. E.C. Ryall,	11·5	24	223	21	104	107	125	52	70
TOTAL, ...	11·5	24	223	21	104	107	340	52	70

(58.) On the preceding page is a tabular statement of the work done by each assistant. My own work, before I received charge of the party, is also there detailed.

(59.) On the 1st July of the present recess Lieutenant H. M. Chambers R. E. joined this party from the Computing Office. Since that date he has been employed in helping me to prepare the fair maps of the Kosi Valley Survey. His knowledge of his duties, and skill in drawing have already proved of great assistance to me.

(60.) Mr. E. C. Ryall took the field about the middle of November, and proceeded to sketch the portions of ground which had been assigned to him. These tracts cover an area of over 10,000 acres, and lie in the vicinities of Mohan, and Ramnuggur, being separated from each other by the ground in the neighbourhood of Dikoli. They are, for the most part, covered with dense forest; a circumstance which obliged Mr. Ryall to adopt a system of traverses by which, with the assistance of numerous trigonometrical stations, he was able to obtain minute accuracy, and show in the clearest manner every feature of the ground.

(61.) Mr. Ryall, besides doing his topographical work, carried some additional triangulation [see para: (52)] over part of his own, and the neighbouring ground, and computed out in the field the points he determined. This triangulation and its computation represent about six weeks' hard work. He has done an admirable season's work; and since his return to recess quarters he has given me great assistance in the preparation of the Kosi Valley Survey maps, and in some computations connected with the general triangulation of Kumaon and Gurhwal.

(62.) Mr. Ryall gives the following description of the ground he surveyed.

"The formation of the hills all the way from Ramnuggur to Okhaldunga, and up to 4000 feet above sea level, is principally of sandstone, conglomerates, clay and layers of loose boulders imbedded in clay and sand. These formations alternate one with the other in the order stated. The last named does not extend much over 300 feet above the level of the river. The sandstone is seldom reddish in color and never purely red. The different shades of gray and greenish gray predominate. The hardness of the sandstone varies directly in the order of the depth of its stratum, that met with a few hundred feet above the river is soft and friable, all the rest is harder in proportion to its height, but none can be said to be so compact as not to be broken up with an ordinary blow from a hammer. The conglomerates also are easily separable.

The larger plateaux chiefly consist of horizontal layers of sandstone, boulders, clay and loam—the loam covers them from 1 to 10 feet in thickness.

About 200 feet above the plain on which Ramnuggur is situated, there lies another and a very extensive flat, known as the Amdanda ka chaor. This chaor extends almost all the way to Dikoli village. On it and principally to the eastern side of it might be seen numerous mounds, the sites of the ruins of ancient buildings. It does not appear that these mounds have ever excited the curiosity of archæologists, but they have been worked up here and there for the purpose of extracting the carved stones and bricks employed in building the town of Rumnuggur. Similar remains of an ancient town might also be seen on the Kua ka chaor above Mohan.

Owing to the steep gradient (1 to 100) of the bed of the Kosi from Okhaldunga to Ramnuggur, the surface of the channels is rough and strewn with boulders.

The country lying on the right bank of the Kosi river from Kumeria to Dikoli is very much cut up by large ravines, the inclination of whose courses to the Kosi is very great. During the rains the water, draining the country through these ravines, must come down with great velocity. A still greater peculiarity with these ravines is, that after leaving what might be called relatively the foot of the hills, their waters seldom keep to one bed but at times are distributed into numerous channels and at others confine themselves to few— in the latter case their course might be seen marked with great destruction.

From Okhaldunga to Bujan the principal rock (or rocks as it might be more appropriate to term it) is difficult to define, beyond stating that it is a hard quartzose sandstone running unto metamorphic quartz. The quartzose sandstone however only retains its distinctive form up to about 3 miles above Okhaldunga. This metamorphic quartz is so very hard that the operation of blasting is rendered very difficult.

During the winter months I found the average discharge of the Kosi opposite Mohan, or Chokhamb No. 2 H.S., to be about 310 cubic feet in one second of time. The width of the stream being 60 feet at an average depth of 1·4 feet the velocity being nearly 2·5 miles an hour. At this point, about 25 years ago, the river is said by the villagers of Chokhamb to have risen to the height of 10 feet from the absolute bed of the river—the channel way being nearly 800 feet. I would suggest that this statement be received with caution. I myself remarked the flood height during the rainy season of 1870 (which I believe was unusually severe) to be a little over 6 feet. Even during the extraordinary flood alluded to by the villagers the waters did not cover the Chokhamb flats.

Many of the islands of the Kosi river are about 8 feet above the winter level of the waters. These islands are overgrown with Catechu, and Sissoo trees, and from the appearance of these trees and the thickness of the loam deposit on the islands it appears that the latter have stood the ravages of years.

Among the trees to be met with on either side of the Kosi, and up to 3000 feet above sea level, the Sal is by far the most numerous. There are very few fine specimens of this tree left, the forest authorities having cut most of them down. Among the other trees might be mentioned the Catechu, Simul (*Bombax Heptaphyllum*) the Haldu, the Bail, the Sissoo and the Toon."

(63.) Mr. J. Peyton started about the middle of November to take up his work in the Kosi Valley. The ground he surveyed extends for a little more than 6 miles in a southerly direction from the large chaors which lie to the north of the Debi Rock, and it embraces an area of nearly 9000 acres.

(64.) An accident, unfortunately, happened to Mr. Peyton while he was out surveying one day in the beginning of January which laid him up for 3 weeks: he was also short of

trigonometrical points until Mr. Ryall completed the triangulation already mentioned in paras: (52) and (60). In spite of these drawbacks Mr. Peyton did a large amount of work, and his delineation of ground is as artistically performed as usual. He is now engaged in shading one of the forthcoming maps of the Kosi Valley Survey.

(65.) The following are some extracts from Mr. Peyton's notes on the ground in the vicinity of Dikoli.

"Of limestone there are two varieties. A whitish coarse—grained limestone formed in fresh water, is found in the hills west of the Ramnuggur road, its southern limit being the platform above Chandalghati, and extending north as far as the cliffs near Debi Rock. This calcareous tufa, or stalagmitic incrustation of lime, caused by water holding lime in solution, is abundant in the hills west of the fields of Dikoli, and is quarried for use within a few feet of the Ramnuggur road. The other limestone is a compact fine—grained stone of a dark gray color, and is found in the form of nodules, in beds of clay and gravel, often traversed by veins of carbonate of lime. It is not a local rock; but numerous fragments are found at the base of the cliffs on both sides of the river, indicating that it is not far distant.

From Dikoli four roads branch off to the higher mountains, two viâ Okhaldunga which unite in one there, one viâ Mohan, and the cart road to Ranikhet, which last is the most circuitous.

On the western limit of the cultivated fields of Dikoli, and in many places overhanging the main road, is a ledge of hard conglomerate rock, or pudding-stone, surmounted by extensive "chaors" intersected by a few transverse ravines. These plateaux contain the debris of the various rocks of which the Himalayas are composed. The mica and felspar of the higher regions may be recognized even in the finest sand.

On one of these chaors several remains of ancient temples have been found a few feet from the surface. A great many fine specimens of capitals of pillars, medallions, figures of lions and other animals, and Budhistic designs, carved on sandstone, have been dug out under the superintendence of an official of the D. P. W. who has used them in a public building near the suspension bridge, chiefly as ornaments for mantelpieces, archways, and pillars, some of the pillars are foliated, interspersed with birds, dragons and other figures; and amongst the animal forms the most prominent is the lion, which was probably at a remote period, a denizen of the neighbouring forests.

On a plateau above that which contains these remains is an ancient well, about which there is nothing remarkable except that the blocks of sandstone with which the sides are built up are very neatly joined together."

(66.) Mr. J. Low went into camp in the beginning of November to take up the sketching of the Kuch Gadh. By the middle of February he had made such progress that I selected him to sketch the portion of my own ground which remained unfinished when I received charge of the party. That portion, roughly speaking, extends from Dhaniakot eastwards to Bujan, and thence in a northerly direction for about a mile and half up the Kuch Gadh; the total portion, therefore, assigned to Mr. Low extends from Dhaniakot to the limits of the Ranikhet survey, and its area just exceeds 12000 acres. Mr. Low by unremitting exertions was enabled to finish his work on the 15th April: he has been steadily improving in his hill sketching, and this last season's work is very creditable to him. On returning to quarters Mr. Low made a series of measurements with a perambulator, to enable me to prepare a table of distances for the new edition of the guide map for Mussoorie and Landour; he also took up some computations connected with the survey of the northern parts of Gurhwal, and on their completion he started, and is now on his way, to resume his triangulation in the higher ranges of the Himalayas.

(67.) Mr. F. Ryall remained with the Head Quarters camp until the beginning of February. He was then ordered to proceed to Ramnuggur, and carry a rigorous theodolite traverse, with changes of face of the instrument, and back as well as forward vertical observations, from that place up the valley. His traverse, except through the part of the valley between Dikoli and Okhaldunga, was carried along the district road. In many places the turns in that road, where it winds along the sides of steep slopes and precipices, are so short and sharp that Mr. F. Ryall often found it impossible to measure even for 100 feet in one direction, and the road itself was generally in a dilapidated condition: the rigorous method of observing, also, which he was obliged to follow, took up so much time that he found it impossible to put up his instrument more than 15 or 16 times in a day. These circumstances combined to make the aggregate of his work less than could have been desired; for, although he worked steadily, he was only able to accomplish an average traversed distance of a little less than half a mile a day; and I was therefore obliged, towards the end of March, to direct Mr. H. Todd to help him to finish his work. Mr. F. Ryall since his return to quarters has been employed in computing out his traverse, and in assisting Messrs. Low and Pocock with their triangulation computations.

(68.) Mr. L. Pocock took the field in the middle of November. His work lay in the part of the Kosi Valley between Kumeria and Talla Seti. Many parts of the ground surveyed by him which lie at some distance from the river are very steep and densely wooded. In these parts it happened that far fewer trigonometrical points had been fixed, area for area, than in the ground within half a mile of the river: Mr. Pocock had, consequently, much harder work to do than if he had been liberally supplied with points. The dandy allowance moreover hitherto given by Government to the assistants, had been discontinued, and he had, therefore (riding being out of the question in such ground) to walk all day in the heat of the sun.

The exertion thus entailed, combined with the heat, brought on an illness, about the end of February, from which he suffered, more or less, for the rest of the field season.

(70.) In spite of medical certificate to the effect that he was unfit to undergo the exposure to the sun his duties entailed, and that complete rest from all mental labour was desirable for his recovery, Mr. Pocock managed, by working in the mornings and evenings when the sun was not at its full strength, to turn out an excellent season's work; and his sketching, which was always thoughtfully and accurately done, is now becoming very much improved in style. He closed work on the 26th April, and on his return to quarters took up the computation of those points in the northern parts of Garhwal which remained uncomputed. He has completed this work, and has just started to continue his former triangulation in the higher Himalayan ranges.

(71.) Mr. H. Todd went into camp in the middle of November to undertake the sketching of the part of the Kosi Valley which lies between Talla Seti and Thorna. He has delineated this ground, which is 6,400 acres in extent with great accuracy, and has produced a very perfect topographical drawing. He concluded his sketching about the last week in March, and then took up part of the theodolite traverse which had been originally assigned to Mr. F. Ryall. Mr. H. Todd traversed from a point about half a mile above the Puntpipal suspension bridge to the southern limit of the Ranikhet Survey at the village of Pilkholi. He was able to finish a good season's work on the 7th April; and since his return to quarters he has been employed in computing out his traverse and in assisting in the preparation of the Kosi Valley Survey maps.

(72.) Mr. T. Kinney, about the middle of November, was employed in laying down the part of the settlement boundary of Mussoorie and Landour which includes Rajpore. That work over, he shaded the final sheet of the Mussoorie and Landour Survey. This work occupied him until the 9th December, on which day he left Dehra to take up his work in the Kosi Valley. The bulk of his work lay in the part of the valley between Thorna and the village of Simalkha. The ground is there bare and precipitous, and, but for the physical labour required in walking over it, gave him little trouble; but he had another portion between Khairali and Kumeria, adjoining Mr. Pocock's work, which is densely wooded, steep, and difficult; and in addition to sketching it, he had to carry a plane-table and chain traverse along that part of the Ranikhet cart road which lies between Kumeria and the ground sketched by Mr. Peyton. In spite of the lateness of his arrival on his ground Mr. Kinney succeeded in finishing all the work allotted to him by the last week in April. The extent of country surveyed by him just exceeds 11,400 acres. This large area has been thoroughly well surveyed, every feature of the ground being faithfully delineated, and altogether Mr. Kinney's field work has been most excellent and satisfactory. Since his return to recess quarters he has been employed on the new edition of the guide Map for Mussoorie and Landour, and in assisting in the preparation of the forthcoming maps of the Kosi Valley Survey.

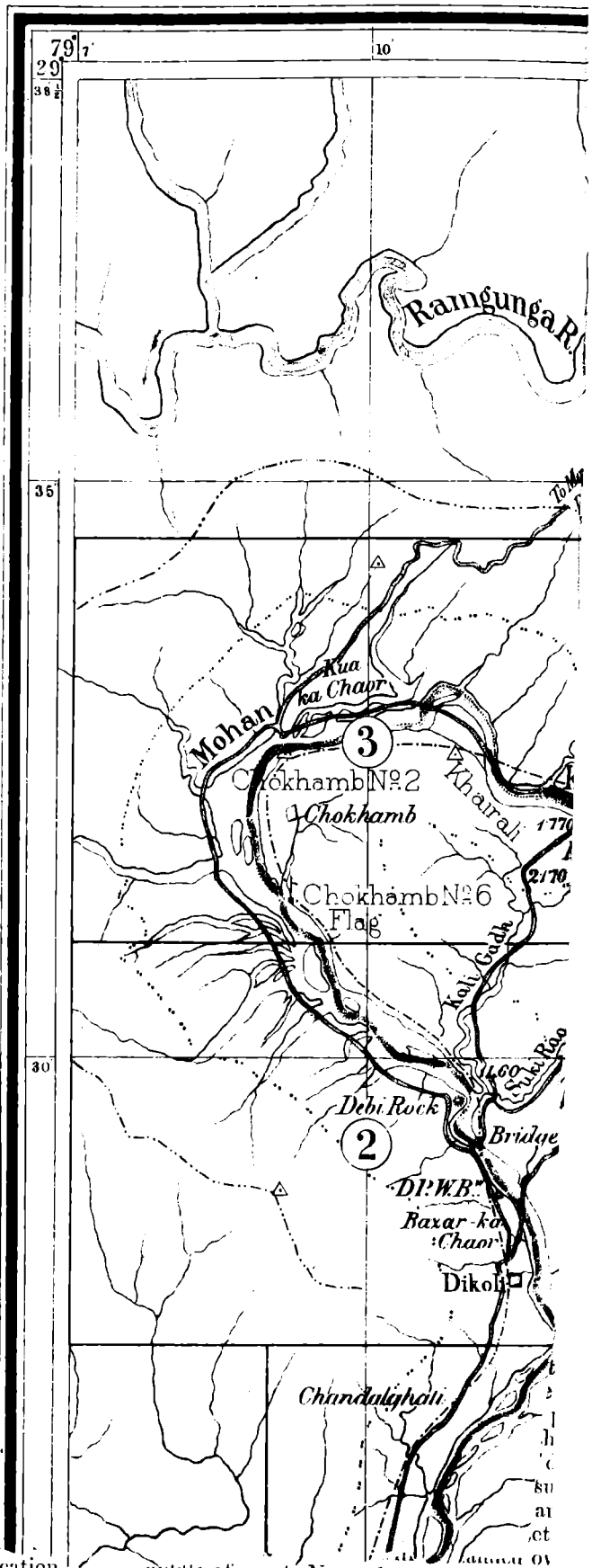
(73.) Mr. E. Litchfield has been employed in the office on computations, and the general current work of the party. During the field season he also practised plane tabling for a few days under Messrs. Ryall and Peyton, and was favourably reported on by them.

(74.) The men of the Native Establishment worked well and cheerfully in the field: and the work of the native draughtsmen has given satisfaction, being neat, and carefully executed.

(75.) While the party was working in the field 3 native draughtsmen belonging to it were employed at Dehra on the final sheets of the large scale survey of Mussoorie and Landour, which are now all published. That survey being now completed, a reduction by photography was made from it at the Head Quarters' Office to serve as a guide map for Mussoorie and Landour.

The present recess of 1871.

(76.) On returning to quarters, a new edition of the guide map, with an index and table of distances was prepared, on the basis of the reduction mentioned in the preceding paragraph, and sent to Dehra for publication: its table of distances was drawn up chiefly from the measurements made by Mr. Low [see para: (66)]; but much help was also given by a table of distances, kindly lent me by Mr. J. B. N. Hennessey, the distances in which had been measured by himself several years ago. The assistants of the party, and the native draughtsmen are now engaged on the fair maps of the Kosi Valley Survey, which number 8 large shaded sheets, and a corresponding number of skeleton charts, all of which, it is hoped, will be handed over to the Head Quarters' Office for publication by the middle of next November. The details of this work, however, belong properly to next year's report, and need not, therefore, be further noticed in this place.



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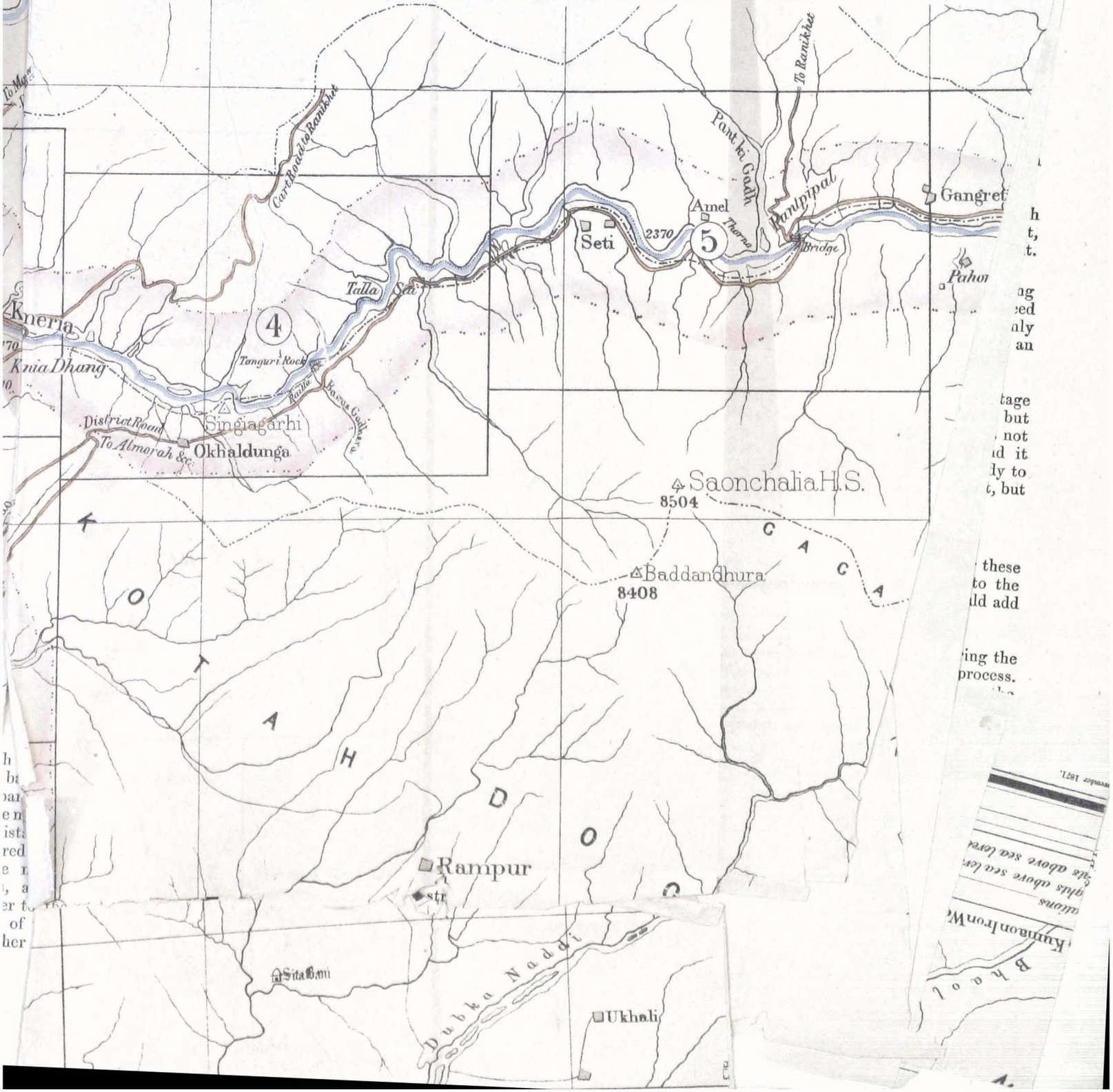
GREAT TRIGONOMETRICAL SURVEY OF INDIA.

GENERAL INDEX TO THE KOSI VALLEY SURVEY

Scale = $\frac{1}{105600}$ or 0·6 Inches to a Mile

8 Furlongs 0 1 2 3 4 5 6 Miles



Extract from the Narrative Report—dated 21st September 1871—of Captain W. M. CAMPBELL, R.E., Deputy Superintendent 3rd Grade.

As you are aware, at the expiration of my furlough on 11th December 1870, my services were placed at the disposal of Colonel Strange, to assist him in the final examination and testing of the new Zenith Sector, and other instruments intended for the G. T. Survey, then approaching completion; on this duty I was employed up to the date of my leaving England, early in August.

The Zenith Sector is a sister instrument, to the one which Captain Herschel has now had in use for 3 field seasons.

Shortly before I joined Colonel Strange, Captain Herschel had writen to him regarding the performance of the zenith sector, of which he wrote generally in terms of high praise. In that letter Captain Herschel remarked on the difficulty of putting his instrument together, owing to the great weight of the telescope and sector, which had to be put on in one piece, and that also in a very awkward position: this part of the instrument also involved a very heavy and large case for travelling. Colonel Strange hit on the plan of taking the telescope off the sector for travelling, a change which was immediately carried out with very great advantage in many respects.

(1.) The heaviest case was dispensed with and the new case containing the sector (with the transit axis which is inseparable from it) is now the only large case of the whole instrument, which requires extreme care in carriage, and it is very portable, both as regards size and weight.

(2.) The process of putting together and taking down, was very greatly simplified, being rendered easy and safe, where as before, with unpractised hands it was just the reverse indeed as Captain Herschel remarked, (if I remember his words aright) with native assistance only and without mechanical aids, it was a process too dangerous to be carried on long without an accident being the probable consequence.

(3.) While this change of packing was being effected, the delay was taken advantage of to carry out several minor alterations and additions, which seemed to be improvements, but before describing these, I would remark on the use of the word "delay" above, that it was not in reality delay, for when the sister instrument arrived in India, Captain Herschel found it necessary to construct new travelling cases, those in which it arrived being too unwieldy to carry about in the Field. The same process would have been necessary for this instrument, but now the new cases are as light as could well be used under any circumstances.

(4.) The following are some of the additions referred to above:

The telescope is fixed on to the sector by powerful steel bolts, and the holes for these were slotted so as to give a range of $7\frac{1}{2}°$ on each side, thus allowing a change of zero to the extent of 15°. I believe Captain Herschel had remarked, that such an arrangement would add to the value of the instrument, which I think cannot be disputed.

(5.) The only method originally for taking the runs of the levels, was by altering the general level of the instrument, a most cumbersome, and in my own opinion, unreliable process. Brackets have now been made, which can be bolted on to the flanges of the telescope, in the centre of its length, and these brackets have Ys, in which the levels can be placed without being removed from their mountings. The telescope being turned into the horizon, the runs of the levels can be obtained with great ease and rapidity, by using a collimator, and either the microscopes, or the telescope micrometer, as most convenient.

(6.) The levels were cased in cylindrical glasses and this was altered, because of the difficulty (even in England) of procuring such glasses in case of breakage, and they are now covered with pent roofs of plane glass. The plane glass has I think also the advantage over the cylindrical, as regards accuracy in reading the levels.

(7.) The mounting of the levels was also changed in the adjustment for zero, which was at first effected by two opposing nuts on a common screw in the ordinary way, for which was substituted a strong bow spring acting with gravity, against a nut and screw.

Nicety of adjustment is certainly increased by the alteration, and as far as I can yet judge, the stability of the adjustment was not impaired. The original opposing nuts are still kept at hand, in case of the adjustment failing.

(8.) The insertion of the horizontal axis into its bearings without jarring was a difficult matter, to facilitate which collars carrying guiding wedges were designed and applied.

(9.) When the instrument was returned from the maker (Troughton and Simms) one of the two spiral springs, which worked the eye-piece micrometer, was found to be broken. Instead of having a new spring made, the action was changed, so as to be independent of springs, and the screw of the micrometer now works in a collar, so as to have a fixed bearing with either motion—an arrangement which I think will be found better than a dependence on springs.

(10.) When the instrument was supposed to be completely finished a troublesome difficulty occurred. The adjustment of the microscopes when altered was found deficient in stability, to such a degree, that no confidence whatever could have been placed in the work done.

This fault puzzled us very much, and among other attempted remedies, the spring which keeps the sector up against its bearings, and thus regulates the distance of the graduated limb from the microscopes, was strengthened. In the end the fault was found to be in the fitting of the collars holding the microscopes, which were so tight, that when the thumb-screws for moving the microscopes were used, the effect was not to move them, but to bend the arms of the framework, thereby of course setting up all sorts of strains, utterly fatal to stability. The fittings were eased, and bars introduced parallel to the microscopes, joining together the arms of the framework carrying them.

These bars are I think a great improvement, giving additional strength to the frame.

(11.) Colonel Strange and I took a sufficient quantity of observations with the instrument at Lambeth to satisfy ourselves that every thing worked smoothly, and I trust that when it comes into use in this country, no grave faults will be found with it.

(12.) The only point about which I have misgivings is the trustworthiness of the levels, which are I believe about as good as can be obtained in England, but still very far from satisfactory.

It is most unfortunate in an instrument of this kind, in which every thing is ultimately referred to the levels, that these latter are by far the most imperfect and untrustworthy part of the whole.

The distrust of levels as at present made, where great accuracy is required, is I think very general among those who have studied the subject. Captain Herschel particularly enlarged on this point as regards his Zenith Sector, and Colonel Strange was well aware of the shortcoming of these parts, and has for some time been engaged in experiments, with a view to improve the manufacture. The fact is, that the demand for really good, and therefore expensive levels is not sufficient to encourage makers to expend money in an endeavour to improve the quality.

(13.) Though as I have remarked above, levels are much distrusted by those who know them well, yet on the other hand, I fear there is a great deal too much faith put in them generally, by those who use them, and their short-comings cannot be too strongly enlarged upon.

(14.) I spent a great deal of time and labour on the examination of a number of levels, supplied by Troughton and Simms and by Cooke, using for the purpose a most convenient instrument constructed by Messrs. Cooke, on the design I believe of Colonel Strange, and I compared them with two levels, the private property of Colonel Strange, one made by Repsold and the other purchased from Secreton of Paris.

(15.) The irregularities in the degree of curvature, of all the English levels, were most startling and they were also as a rule slow and sluggish, as compared with the French and German. They were all sealed bubbles, *i. e.* the ends of the glass were closed by the blowpipe.

(16.) The Repsold level was a stoppered bubble and gave far better results, both as to regularity of curvature and style of action, than the average of the English bubbles: but then its cost was I believe about three times as great.

(17.) The level by Secreton excelled that by Repsold, as much as the latter was better than the average English, indeed if levels of such a standard of excellence were procurable, one would have little more to wish for, for in every respect it was nearly perfect—great regularity of curvature, combined with remarkable liveliness of motion, and rapidity in coming to rest.

This bubble was a sealed one, which proves, that it is possible to perform that act without distorting the tube, and I believe also that it did not cost more than half the Repsold's price.

It is possible that this level may have been an exceptionably good one, but Colonel Strange told me, that it was simply selected in his presence from a number in store, which he believes were all made by a German in Secreton's employ.

There was great grief at Lambeth when this pet level was broken by an accident.

(18.) The conclusion I came to after making these experiments was, that in my own practice I should adopt the following rule. First to test the level and fix upon the best portion of its curve, allowing a range of about 20 divisions at a mean temperature within which the bubble should always be kept during observations. Then by repeated runs to find the mean value of a division of the portion used. And lastly, as far as possible, to eliminate the effect of irregularity of curvature, by introducing a systematic change of zero, so to speak, *i. e.* to set the level after each night's observing for use the next night, so that the instrument being level, if the bubble ends read 40 *r* and 40 *l* the first night, (the range being from 30 *r*—50 *l* to 50 *r*—30 *l*) they should read 35 *r* and 45 *l* next night, 45 *r* 35 *l* the night after, and so on.

The changes of temperature would assist this system, by constantly altering the length of the bubble and therefore bringing different portions of the tube into use.

The level of the instrument must always be carefully attended to, and kept as nearly perfect as possible.

By this means I should hope to approximate, in a series of nights' observations, to the equal use of every division in that portion of the tube, from which the mean value of the division had been obtained, and thus as far as possible, cancel the effect of irregularities in the value of the divisions *inter se*.

(19.) Colonel Strange's experiments in levels, referred to above, are chiefly directed to a means of stoppering so effectually, as to allow of the use of chloroform in the bubble.

Chloroform is considered the best fluid, but it is so volatile that it escapes through all stoppering.

Also to devise a way of sealing without distorting the tube.

(20.) The instruments in hand besides the Zenith Sector, and all more or less ready for final inspection, were those composing the double equipment for Electro-Longitude observations, *viz.*

2, 5-foot Transit instruments.
2, Chronographs.
6, Relays, with batteries &c.
2, Astronomical clocks.

And also 2 Russian Transit instruments, and a third Astronomical clock. Of these, all except one of the 5-foot Transit and the 2 Russian Transit instruments, were packed and ready for shipment on 1st August.

(21.) The second 5-foot Transit was sent back to the makers (Messrs. Cooke and Son of York) several months ago, after careful examination, for a number of slight alterations.

(22.) The reflection of the rays, in the Russian Transit instruments, was obtained by using a prism, the half of a cube of about 2¼ inches side, and on examination, this prism was found to be so faulty in both instruments, that good definition of an object could not be obtained, and the focus changed appreciably according to the portion of the prism used.

This fault necessitated the return of the instruments to the maker. And in consequence of the difficulty of procuring prisms of the required excellence, Colonel Strange directed, that reflectors of speculum metal should be substituted.

The drawings for the mountings of these were submitted and approved of some time ago.

(23.) These instruments, the 5-foot and 2 Russian Transits, should have been returned to Lambeth some time before I left England, when there would probably have been no difficulty in getting them ready to be sent with the others. In consequence, however, of the makers delays they had not been received at Lambeth when I left.

(24.) I shall now proceed to describe shortly the instruments of the Longitude Equipment and the nature of the inspection and experiments applied to them.

(25.) The 5-foot Transits are sister instruments, with slight differences, they are very light and portable, and of simple construction.

They possess several novel features, the most striking and important being the system of levels, which is quite new, the design I believe of the late Mr. Cooke, senior.

(26.) The levels are four in number, suspended on arms projecting from the telescope tube, close to its junction with the transit axis, so that as the telescope revolves the levels also revolve on their pivots, always maintaining a position (if in adjustment) at right angles to the plane of revolution of the telescope.

These levels can therefore be read, in any position of the telescope, and in this respect are very superior to the usual striding level.

(27.) From the position of the levels, they are necessarily affected, in exactly the same degree as the plane of the telescope is affected, (1) by any inequality of the transit axis pivots, (2) by flexure of the transit axis. A striding level, on the contrary, might shew an effect of inequality of pivots axactly the opposite to the effect on the telescope: while no amount of flexure of the transit axis, could affect it at all.

(28.) There was considerable discussion on the subject of these levels, in consequence of which I put the instruments through an elaborate series of tests, 1st as to the figure of the pivots, 2nd (one instrument only) to arrive at some idea of the amount and effect of flexure of the transit axis.

(29.) The first series I performed by putting the axis alone on its bearings, and weighting it with lead, to represent the weight of the telescope. A wooden striding frame, with brass Ys, for feet, was then placed on the pivots, and was high enough to allow the weighted axis to be rotated underneath it.

On this striding frame, two levels were fixed, and their readings taken, several times over, at every 30° of revolution of the axis, and for several positions (longitudinally) of the frame on the pivots.

The result was, that in neither instruments was any error discovered which amounted to $\frac{1}{4}''$.

(30.) The experiments to detect flexure of axis were more intricate and their results cannot be considered so reliable as the above.

The method employed was, to put up the axis alone, and alternately apply and remove without delay, a weight representing the telescope, and I managed by a system of levers to do this without the least jerk or disturbance, in about 2 seconds for each operation.

(31.) The behaviour of the axis was watched in more ways than one. Firstly placing a lens in the aperture of one pivot, with a cross of spider lines in its focus, in the centre of the axis (*i.e.* at the intersection of the telescope and transit axis) and watching the movements of the latter by a collimator placed opposite the pivot lens. This plan was tried in several ways, without satisfactory results, owing to the rough nature of the appliances available..

(32.) The method I finally adopted was as follows. I inserted a rod into the aperture of the pivot, and on this rod suspended a level, and I took the difference of readings of this level with and without the weight on the axis, as a measure of the flexure of that end of the axis due to the weight of the telescope.

Then changing the rod to the other pivot I repeated the process, and if the result was the same as before, I concluded that the flexure of the axis was uniform, and therefore could have no effect on the plane of the telescope.

(33.) I do not of course claim any degree of accuracy for this experiment, involving as it does several hypotheses which may be false, for instance that each half of the axis bends with the flexure in a degree proportioned to the tilt of the extreme end thereof, and uniformly from that end to the centre. But I do think, that the experiments were calculated to throw some light on the subject, and I believe that no axis was ever tested in a similar manner before, nor, as far as I know, has the effect of this flexure on the telescope ever been taken into account. In justification of the assumption that each half of the axis should be affected uniformly by flexure, I may mention, that they were most carefully turned, both inside and out, so as to be as symmetrical as possible.

(34.) When I obtained a difference between the indications of the level in the two pivots, I considered half the amount as the effect on the plane of the telescope.

(35.) The average tilt I found was 11″·02 for one and 10″·93 for the other pivot, the mean effect on the telescope 0″·08, and the maximum 0″·14.

The absolute droop of the centre of the axis, due to weight of telescope = 92lbs, was 0·0009, inches, axis being 36 inches in length.

(36.) I regret that I had the opportunity of applying this process only to one instrument, because as the axes are made of different material, one being gun metal and the other aluminium bronze, a comparison would have been of interest.

(37.) Although the levels give the means of taking a level reading in any position of the instrument, this would be a troublesome process because the adjustments, are somewhat complicated, and the effect of residual error thereof, varies with the position of the telescope, in proportion to the sines and cosines of the altitude.

If we may consider the form of the pivots appreciably perfect, and the flexure of the axis symmetrical, there is no great object in obtaining a level reading at any particular altitude, but the level of the instrument found in one convenient position may be applied to all.

This I consider may be best done by level readings, with reversion of ends, telescope pointed first to zenith and then to nadir, by which process all errors of adjustment are eliminated, or if considered preferable, it may be done by using the mercury trough which is supplied with the instrument.

(39.) The Chronographs are intended for the record, by electricity, of the observed tansits of stars, and clock signals. They consist of a metal drum, covered with prepared paper, and made to revolve at a very uniform rate, by means of clock work, supplied with very nice regulating appliances.

(40.) The Relays are the electrical instruments, by which the current for recording on the chronograph is obtained, and may be described as a means for making a weak electrical current, arriving from a distant station, call into action a strong current, supplied by a local battery, which makes the mark on the chronograph.

(41.) Considerable discussion arose as to the use of these relays, doubts being entertained (1) as to their sensibility to weak currents (2) as to the time lost by their interposition between the signal from the distant station, and its effect on the chronograph.

I am glad to say, that both these points may be considered as settled, in favour of the relays.

(42.) (1) As regards sensitiveness: I tested them at Lambeth, with a resistance coil, and found no difficulty in passing a current through them from a very weak battery, with 1,000,000 ohms of resistance interposed.

I also took them to the office of the Indo-European Telegraph Company, and by the courtesy of the officials there, I was allowed to attach them to the wire with which they were working at the time.

The result showed, that what was considered a weak current from a station 400 miles distant with an additional resistance of 40,000 ohms interposed by means of resistance coils, was sufficient to work them, and also that they acted when the current was too weak to work the printing instrument in regular use at the office.

(43.) (2) As regards the second point, of retardation caused by the relay, I hit on a method of measuring automatically, by means of the chronograph, the amount of this retardation, which I found to be unappreciable.

The test moreover is very simple and may be applied by an observer, in possession of one of the chronographs, at any time to any individual relay.

(44.) The chronograph also gives the means of obtaining an absolute value of an observer's personal equation, in a very simple manner, which was tested at Lambeth and could with ease be acted on, if considered advisable, by each observer, every night.

(45.) These processes though perfectly simple, are not easy to describe in writing, indeed throughout this report I have labored under the difficulty, of either writing at very great length, endeavoring to make every thing clear to a person unacquainted with the instruments under description, or on the other hand (as I have tried) simply to give a sketch of my work, which a person having general knowledge of the subject may be able to follow.

(46.) The Astronomical clocks are by Frodsham and exactly similar to each other.

They are provided with a contrivance for breaking an electrical circuit, at each second, by means of a wheel with 60 teeth, and at each break a mark is made on the chronograph with which the clock is in connection.

(47.) In order to identify these marks, one tooth of the break contact wheel is cut out, so that every 60th mark on the chronograph is wanting, and the wheel is so adjusted, that this missing mark corresponds to the first second of each minute on the clock's dial.

(48.) All signals on the chronograph are made by breaking circuit, being much more instantaneous than the reverse method of completing circuit.

The observer makes his signals by means of a key held in his hand.

Extract from the Narrative Report—dated 1st May 1871—of J. B. N. HENNESSEY, ESQ., Deputy Superintendent 1st Grade, G. T. Survey, In charge Computing Office.

Calculating Branch.

(1.) I have much pleasure in reporting the successful conclusion of the computations known as "Reduction of the N.W. Quadrilateral" (*i. e.* Sironj-Chach). This intricate and very extensive calculation is mentioned in my last report, where allusion is made to it at no greater length than the progress then accomplished seemed to require; but though the work now stands performed, I am still precluded from entering into any details of the process adopted, because my description would necessarily be purely technical in nature and hence hardly suited for the purposes of this report. I therefore confine myself to the following facts in this place.

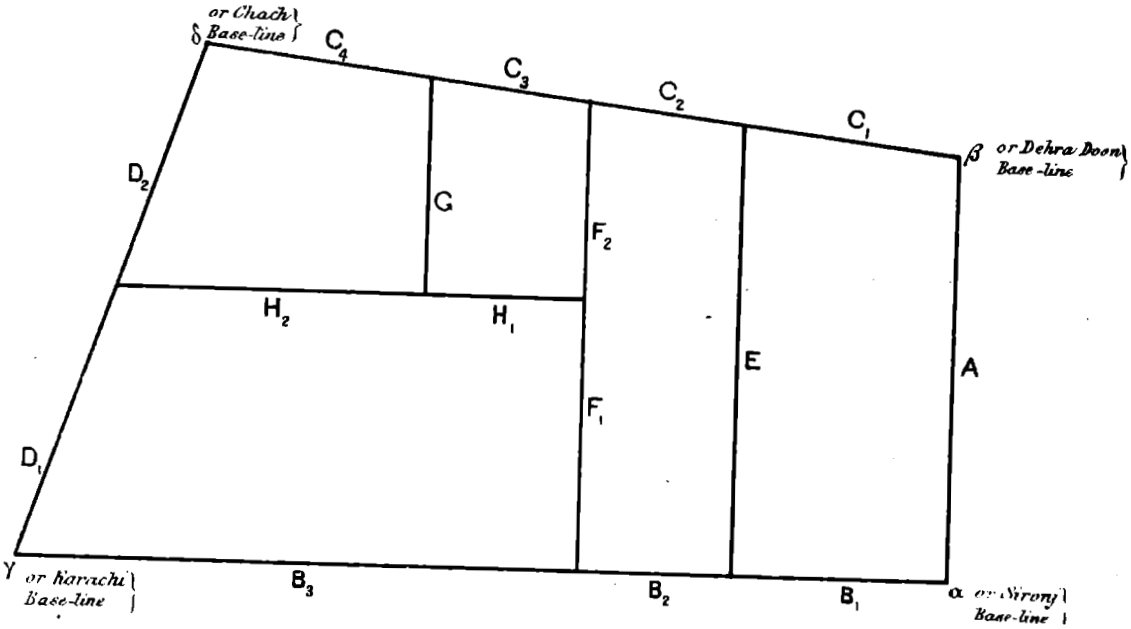
Reduction of Triangulation included in quadrilateral Sironj-Chach.

(2.) Continued.—The triangulation in question is made up of 8 different series of triangles, which constitute a figure including five mutually dependent circuits: [see diagram appended] the outer boundary of the diagram represents a four-sided figure of which each corner is occupied by a base-line. It was essential that this triangulation should be made consistent, so that the circuits should all re-enter in side, latitude, longitude and azimuth, and also that the values of the base-lines by triangulation should be identical with those by measurement. In fulfilling these requirements it became necessary to find simultaneously 1647 unknown quantities or angular corrections, which should satisfy 572 equations of condition and the well-known equation, that the weights of the uncorrected angles into the squares of the corresponding corrections should be a minimum; conditions, which I need hardly add, would in general defy the arithmetical accuracy attainable. Owing however to the fact that 549 rigorous equations were all of the form $x + y + z = 0$, it became easy to eliminate a third of the unknown quantities before differentiation, and to make a large reduction in the number of equations of condition, so that the former stood reduced to 1098, and the latter to only 23; the co-efficients in the last named however, being determined after considerable calculation.

(3.) Continued.—The following table contains the facts of computation:—

No. of Equation		Triangulation involved (see Diagram)	Value of e: Before reduction — Nat. No.	Before reduction — Log.	By substitution of "indeterminate factors" — Nat. No.	By substitution of "indeterminate factors" — Log.	By substitution of y, z in terms $(by + cz)$ — As computed to 5 decimals.	By substitution of y, z in terms $(by + cz)$ — On contraction to 3 decimals.	Residual; after correcting the angles.	
1	in side	A	+2·08975	0·3200935	+2·08975	0·3200935	+2·08983	+2·08973	+·00000001	logarithms
2	in side	$B_1 + E + C_1$	+3·23911	0·5104252	+3·23911	0·5104252	+3·23915	+3·23911	−·00000001	logarithms
3	in side	$C_1 + C_2 + C_3 + C_4$	+3·41483	0·5333697	+3·41483	0·5333698	+3·41486	+3·41483	·00000000	logarithms
4	in side	$B_1 + B_2 + B_3 + B_4$	−3·78054	0·5775539	−3·78054	0·5775540	−3·78045	−3·78053	+·00000003	logarithms
5	in side	$D_1 + D_2$	+7·77955	0·8909517	+7·77955	0·8909516	+7·77974	+7·77958	−·00000006	logarithms
6	in side	$(E + C_3) - (B_2 + F_1 + F_2)$	−5·91778	0·7721588	−5·91778	0·7721590	−5·91779	−5·91781	−·00000001	logarithms
7	in side	$(F_2 + C_3) - (H_1 + G)$	+7·16688	0·8553300	+7·16688	0·8553300	+7·16687	+7·16690	+·00000004	logarithms
8	in side	$(G + C_4) - (H_2 + D_2)$	−0·25172	$\bar{1}$·4009167	−0·25172	$\bar{1}$·4009198	−·25181	−·25178	+·00000003	logarithms
9	in λ	$(A + C_1) - (B + E)$	+·391	$\bar{1}$·5921768	+·3909998	$\bar{1}$·5921766	+·39038	+·39114	+·002	
10	in L	Ditto	+·168	$\bar{1}$·2253093	+·1680001	$\bar{1}$·2253095	+·16785	+·16794	·000	
11	in A	Ditto	+5·906	0·7712934	+5·9060014	0·7712935	+5·90556	+5·90565	+·001	
12	in λ	$(E + C_3) - (B_2 + F_1 + F_2)$	−·390	$\bar{1}$·5910646	−·3899997	$\bar{1}$·5910643	−·38998	−·38995	+·005	
13	in L	Ditto	+·214	$\bar{1}$·3304138	+·2140018	$\bar{1}$·3301174	+·21402	+·21113	−·006	
14	in A	Ditto	+1·550	0·1903317	+1·5499986	0·1903313	+1·55023	+1·54989	−·004	
15	in λ	$(F_1 + H_1 + H_2) - (B_3 + D_1)$	+·387	$\bar{1}$·5877110	+·3870006	$\bar{1}$·5877116	+·38697	+·38710	−·004	
16	in L	Ditto	+·293	$\bar{1}$·1668676	+·2929990	$\bar{1}$·1668662	+·29293	+·29305	+·001	
17	in A	Ditto	−3·254	0·5124175	−3·2510011	0·5124177	−3·25131	−3·25395	+·007	
18	in λ	$(F_2 + C_3) - (H_1 + G)$	+·036	$\bar{2}$·5563025	+·0360000	2·5563027	+·03594	+·03598	+·004	
19	in L	Ditto	−·287	$\bar{1}$·4578819	−·2870001	$\bar{1}$·4578820	−·28700	−·28701	−·001	
20	in A	Ditto	−4·232	0·6265157	−4·2320020	0·6265160	−4·23190	−4·23160	−·001	
21	in λ	$(G + C_4) - (H_2 + D_2)$	−·005	$\bar{3}$·6989700	−·0050002	$\bar{3}$·6989891	−·00488	−·00485	−·004	
22	in L	Ditto	−·290	$\bar{1}$·4623980	−·2900000	$\bar{1}$·4623980	−·28999	−·28994	+·008	
23	in A	Ditto	−3·000	0·4771213	−2·9999982	0·4771210	−2·99980	−3·00028	·000	

In equations 1 to 5, to find the error, the *measured* value of the base-line is subtracted from the value by computation brought up in the order the letters are named above, *i e* from *a*. Also, λ stands for Latitude, L for Longitude and A for Azimuth.


δ or Chach Base-line
C4
C3
C2
C1
β or Dehra Doon Base-line
D2
G
F2
H2
H1
E
A
F1
D1
γ or Karachi Base-line
B3
B2
B1
α or Sirony Base-line

Calculating Branch—(Continued).

In explanation of the above, I may premise, that the equations of condition were of the form,

$$*[b\,y + c\,z]_1^p = e:$$

in these, the total errors to be dispersed between base-lines or in circuits are denoted by the absolute terms e_1, e_2, e_3 . . . . e_{23}; their numerical values will be found in column 1 of the table. As however the elimination was most conveniently performed by the aid of Zech's accurate tables for finding Log. $(a \pm b)$ from Log. a and Log. b, the function of e actually employed in the elimination was Log. e which is given in column 2. On finding the indeterminate factors and substituting them in their own equations, check values of e were obtained; these are given in columns 3 and 4, and a comparison between columns 1 and 3 will shew the accuracy with which this step was performed. Subsequently, the unknown quantities y and z being found, their numerical values were entered in the equations of condition and the values of e again checked, as may be seen by comparing 1 and 5: as however the angular corrections were required to only 3 places of decimals, the remaining places were rejected subject to minute arbitrary variations, after which the final values of e were determined as given in column 6. The angles were now corrected and the usual circuit calculations for side, latitude, longitude and azimuth completed, when the residual errors, *i. e.* those which the process had failed to disperse, § appeared: these are given in column 7. Considering that only 7-place logarithm tables are employed in all our calculations, and that the latitude, longitude and azimuth were intended to be kept only to 2 places of decimals, it will be seen that the dispersion required has been completely effected. It is also not without interest to remark, that this result has been attained by the aid of angular corrections of which the greatest is only 0″·460, and the average about 0″·13; and it is a matter of satisfaction to add, that the checks established were so thoroughly efficient, that not a single arithmetical mistake escaped detection. The calculations thus completed are I believe, unsurpassed, if indeed equalled, in magnitude by any other similar work on record; and though the process, as first applied to geodetical figures by Galloway in the Memoirs of the Astronomical Society, is easily followed when the equations of condition and unknown quantities are only moderately numerous; this is by no means the case when the triangulation to be reduced is as extensive as that under notice. The principle of reduction adopted is due to Colonel J. T. Walker R.E., Superintendent G. T. Survey.

Calculation and Compilation for the press and passing of proofs.

(4.) The first modern printed record of the operations of the Great Trigonometrical Survey, Vol. I on Standards of Measure and Base-lines, has been printed and published. The book consists of 533 pages besides 33 plates; and 200 copies of the volume have been forwarded for distribution and deposit to His Grace the Secretary of State for India. Further notice here of this work appears unnecessary since the book is published and generally accessible.

(5.) Continued.—I have also to notice the publication, to meet local wants, of the Spirit Leveled Heights from Lucknow viâ Goruckpore &c., to Dildernugger Bench-mark; the pamphlet consists of 27 pages besides an illustrating chart and provides descriptions and numerical heights of 275 points. The following have been compiled and passed through the press: Calcutta Meridional Series 42 pages; and Numerical data for 13 charts of Indus and Northern Bombay Triangulation. Copy for the press has also been prepared of 59 simple and 20 compound figures and of 16 quadrilaterals.

Protection of Great Trigonometrical Survey Principal Stations.

(6.) The lists, correspondence and enquiry which this duty involves have been continued with the care and despatch which the great importance of the subject demands; 49 *new* lists including 211 stations have been prepared and distributed to district officers, and check lists of 900 stations in 125 districts compiled for reference.

Instrumental work and sundries.

(7.) Meteorological observations were taken at 9·30 A. M. and 3·30 P. M. on every day of the year and a copy supplied monthly to the Reporter to Government for the N. W. Provinces; a table of monthly results for 1871 and of the annual rainfall since 1861 is appended. 17 sets of observations for local mean time were made and computed by Mr. W. H. Cole, M.A. and Mr. C. Wood. Numerical and other data called for, comprising 38 pages of compilation, were supplied to 29 officers. A list of observed latitude, azimuth and mean sea level was prepared for the Index Chart. Instruction to Lieutenant Chambers R.E., in the calculations of the department was commenced, &c. &c.

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* The left hand member of this equation, written at length will be understood by

$$b_1 y_1 + c_1 z_1 + b_2 y_2 + c_2 z_2 + \ldots\ldots + b_p y_p + c_p z_p -$$

§ The residuals in λ, L and A do not arise from want of rigour in "the reduction," for columns 1 and 6 are identical to at least 3 places: they are due to want of logarithm tables to more places than 7, and may have been slightly enhanced by the necessary simplification of treating λ as a constant in the primary differentiation.

Photo-zincographic Branch.

Progress. (8.)—The work performed by this office is given in the following table under the heads of Maps, Numerical Charts, Plates and Diagrams; the last named include drawings of Bench-marks for the level sheets.

Maps.

Subject	When published	No. of parts.	No. of copies printed.
Prints of maps published in former years, ...		7	626
Spirit leveling operations No. 10, ...	May, 1870.	1	130
„ „ 17, ...	„ „	1	105
Index to Mussoorie and Landour Survey, ...	„ „	1	102
A settlement officer's map, ...	„ „	1	10
Bhawulpore map sheet No. 1 *(for Political Agent, Bhawulpore)*,	June, „	1	75
„ „ 2, *Do. do. do.* ..	„ „	1	75
Index to Kattywar Survey, ...	July, „	1	384
Bhawulpore map sheet No. 3, *(for Political Agent, Bhawulpore)*,	August, „	1	87
„ addns. to foregoing sheets, *Do. do.* ..	„ „	3	75
Map of Ranikhet sheet No. 2 skeleton, ...	„ „	1	55
„ „ 2 contoured, ...	Sept., „	1	54
„ „ 7 skeleton, ...	„ „	1	56
„ „ 8 „	„ „	1	55
„ „ 3 „	Octr., „	1	55
„ „ 4 „	„ „	1	55
„ „ 6 „	„ „	1	55
„ „ 9 „	„ „	1	54
„ „ 10 „	„ „	1	55
„ „ 11 „	„ „	1	55
„ „ 8 contoured, ...	„ „	1	52
„ „ 1 „	Novr., „	1	53
„ „ 3 „	„ „	1	53
„ „ 4 „	„ „	1	54
„ „ 5 „	„ „	1	52
„ „ 6 „	„ „	1	54
„ „ 7 „	„ „	1	57
„ „ 9 „	„ „	1	54
„ „ 10 „	„ „	1	54
„ „ 11 „	„ „	1	54
„ „ 5 skeleton, ...	„ „	1	55
Minicoy Island, ...	„ „	1	276
Spirit leveling operations No. 19, ...	„ „	1	64
„ „ 7, ...	Dec. „	1	105
Kattywar Degree sheet No. III, ...	„ „	1	100
Index to Ranikhet Survey, ...	Jany. 1871	1	340
Kumaon and Gurhwal sheet No. 17 contoured, ...	„ „	1	100
Dussun Canal, *(for Ganges Canal Department)*, ...	„ „	4	33
Map of Ranikhet sheet No. 1 skeleton, ...	„ „	1	53
Kattywar No. 19, ...	„ „	1	140
„ „ 14, ...	Feby. „	1	145
„ „ 17, ...	„ „	1	145
„ „ 18, ...	„ „	1	152
Mirza's route map, ...	„ „	1	385
Spirit leveling operations No. 5 (2nd edition), ...	Mar. „	1	106
„ „ 12 do.	„ „	1	102
Mussoorie and Landour sheet No. 15 contoured, ..	„ „	1	101
„ „ 15 skeleton, ...	„ „	1	108
„ „ 16 contoured, ..	„ „	1	105
„ „ 16 skeleton, ...	„ „	1	100
„ „ 17 contoured, ..	„ „	1	105
„ „ 17 skeleton, ...	April „	1	105
„ „ 19 contoured, ..	„ „	1	105
„ „ 19 skeleton, ...	„ „	1	105
„ „ 20 „ ..	„ „	1	34
Index to Kumaon and Gurhwal Survey, ...	„ „	1	511
Index to leveling operations, ...	„ „	1	30
	Total, ..	68	6465

Photo-zincographic Branch—(Continued.)

Numerical Charts.

Subject	When published	No. of parts	No. of copies printed
Mangalore Meridional Series 1865-67, ...	May 1870	2	65
Northern portions of Bombay No. 1, ...	June ,,	1	68
,, ,, 2, ...	,, ,,	1	66
Bider Longitudinal Series 1868-69, ...	Sept. ,,	1	65
Brahmaputra Series 1869-70, ...	Nov. ,,	1	65
Belaspur Meridional Series, ...	Jany. 1871	3	64
Great Indus Series No. 6, ...	,, ,,	1	64
Northern portions of Bombay No. 2, ...	Feby. ,,	1	63
Great Indus Series No. 5, ...	,, ,,	1	65
,, ,, 7, ...	,, ,,	1	62
Northern portions of Bombay No. 7, ...	Mar. ,,	1	64
Great Indus Series No. 8, ...	,, ,,	1	63
,, ,, 9, ...	,, ,,	1	65
	Total, ..	16	839

Plates and diagrams.

Subject	When published	No. of copies printed
Forms, Bench-marks &c., &c., ...	May 1870,	741
	August ,,	498
	Sept. ,,	1398
	Octr. ,,	3962
	Novr. ,,	6110
	Decr. ,,	250
	Jany. 1871,	246
	Total, ..	13205

of the preceding prints, the forms alone are not Photo-zincographed but zincographed; 4242 copies of maps and 575 of numerical charts were issued during the year. An abstract of the work executed since 1866-67 is as follows:—

Subject.	1866-67 No. of prints.	1867-68 No. of prints.	1868-69 No. of prints.	1869-70 No. of prints.	1870-71 No. of prints.
Maps, charts and diagrams,	7,118	7,376	5,538	12,315	20,509
Forms, ...	5,152	10,531	10,800	13,571	10,482

A glance at the annually increasing numbers of copies printed will shew the augmenting demands made on this process: it may however be added that an unusually large number of maps were required last year, but even after making every allowance on this score, the amount of work called for is found to be rapidly on the increase.

Typographic Branch.

Progress.

(9.) The work of this office since 1865-66 is included in the table which follows :—

	1865-66	1866-67	1867-68	1868-69	1869-70	1870-71
Pages composed	377	756	641	697	693	819
„ printed	53,329	93,411	126,696	155,025	106,231	234,828

Here also the increasing demand and supply are apparent.

(10.) In conclusion, I have to express my obligation to Mr. W. H. Cole, M. A. for much, varied and valuable assistance afforded in helping me to conduct the duties of the Computing Office. My thanks are also due to Mr. C. Wood, and Baboo Gungapershad who continue to render me valuable and ready aid. I have reason to be satisfied with Baboos Kally Mohan Ghose, Gopal Chunder, Tarapodo and Kally Coomar, and I would also notice Baboo Lollit Mohan Dhur as a promising computer and as one who is anxious to become generally useful. The remaining computers have worked earnestly.

(11.) Messrs. Ollenbach and Dyson in the Photozincographic office continue to work satisfactorily; and Mr. O'Connor, Printer, deserves commendation for the efficient discharge of his duties.

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

YEAR & MONTH.	BAROMETER. At 9 30 A.M. Highest.	Lowest.	Monthly Mean.	At 3 30 P.M. Highest.	Lowest.	Monthly Mean.	HYGROMETER. At 9 30 A.M. Monthly Mean Temperature of Dew Point.	Monthly Mean Humidity.	At 3 30 P.M. Monthly Mean Temperature of Dew point.	Monthly Mean Humidity.	THERMOMETER. Dry Bulb. Max: in Sun's rays.	Min: in Grass.	Max: in Air.	Min: in Air.	Mean in Air.	Wet Bulb. Max: Wet.	Min: Wet.	Mean Wet.	RAIN. No. of days it fell.	Fall in inches.	WIND. Average direction.	Mean force in lbs per sq. foot.	CLOUD. 0—10 At 9 30 A.M.	At 3 30 P.M.
1870.																								
January	27·839	27·614	27·739	27·724	27·461	27·645	42·6	·587	42·3	·381	81·7	31·4	73·8	36·9	55·6	60·2	34·2	47·3	2	·04	S.	0·01	2	2
February	·824	·582	·704	·714	·480	·612	46·4	·552	47·0	·402	87·5	37·3	78·3	39·7	60·4	61·5	38·5	51·0	4	1·39	„	·01	2	3
March	·766	·546	·662	·692	·448	·582	52·0	·601	48·8	·435	93·4	38·0	81·5	44·9	64·5	66·7	42·7	55·0	11	4·13	S. W.	·01	4	5
April	·784	·520	·613	·695	·402	·519	53·2	·435	51·1	·326	107·4	47·1	92·6	51·7	72·6	72·2	48·4	60·2	4	1·84	„	·01	2	2
May	·670	·321	·454	·555	·214	·362	55·5	·317	52·0	·226	115·3	55·7	101·2	63·4	83·9	76·8	51·8	66·6	2	·31	„	·01	0	2
June	·544	·318	·414	·478	·213	·319	67·7	·576	65·2	·485	118·5	66·3	104·8	71·9	84·5	79·4	58·0	71·4	13	7·04	„	·01	5	5
July	·471	·224	·349	·412	·200	·277	76·2	·858	76·7	·826	105·5	71·0	90·1	71·3	79·6	82·2	70·1	76·2	28	33·05	„	·00	8	8
August	·559	·262	·424	·489	·189	·346	75·3	·838	75·7	·852	102·7	69·1	87·2	70·1	78·5	81·1	63·1	74·9	25	28·45	„	·00	7	8
September	·704	·391	·555	·618	·373	·463	71·7	·798	72·0	·756	101·1	61·2	85·4	62·1	75·8	79·6	61·3	71·7	18	13·78	W.	·00	5	6
October	·787	·555	·679	·705	·450	·579	63·1	·636	63·7	·540	100·9	52·1	87·2	55·9	72·5	77·3	52·8	65·1	1	1·39	S. W.	·00	1	2
November	·864	·663	·779	·782	·577	·684	50·0	·578	50·7	·446	93·0	39·3	80·8	43·2	63·2	68·4	41·0	54·8	0	·00	W., S. & S. E.	·00	1	2
December	·917	·613	·817	·824	·517	·722	42·8	·582	43·7	·429	81·1	36·0	72·5	40·3	56·5	58·5	36·5	48·5	1	·01	W.	·00	2	3

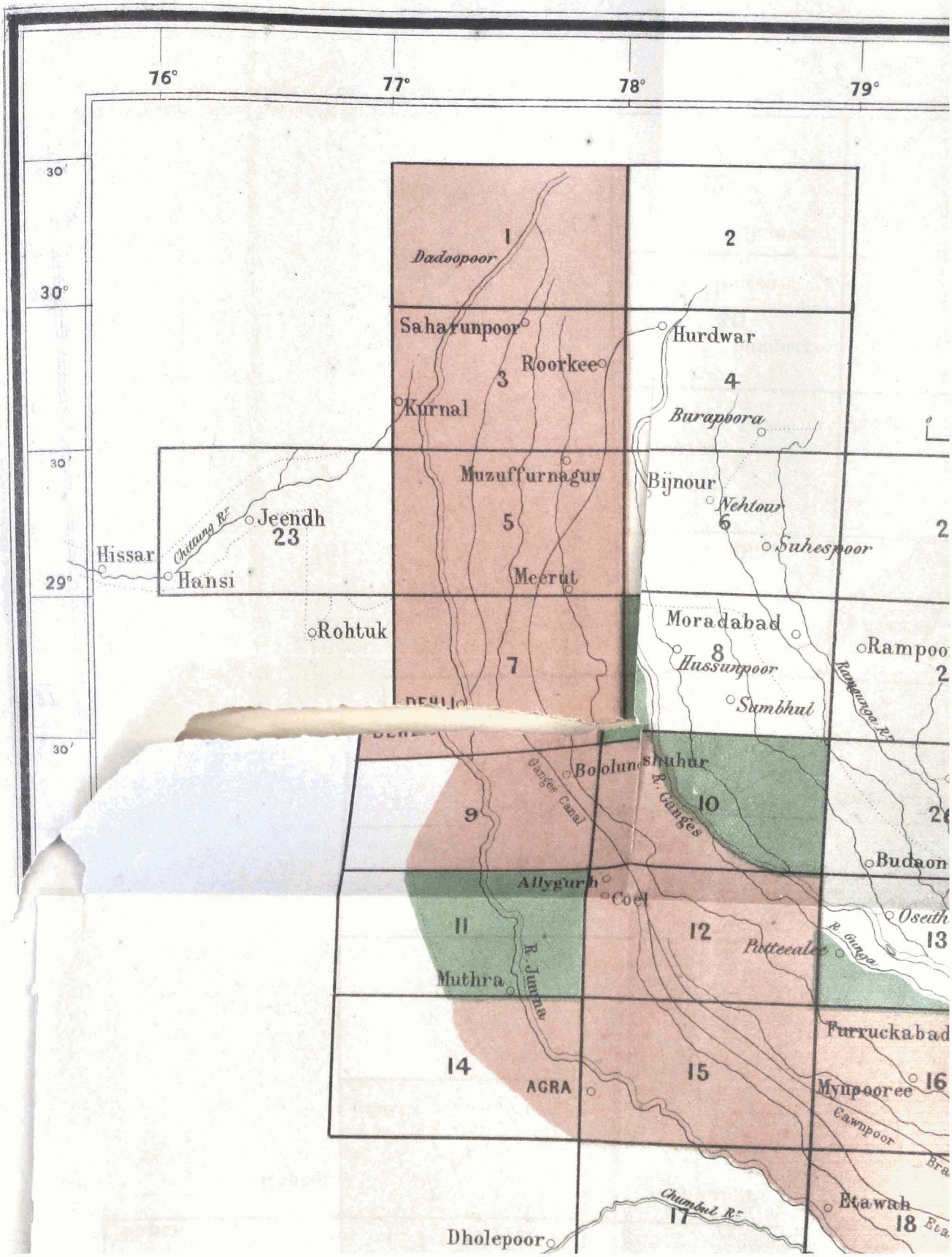
ABSTRACT OF RAIN-FALL AT DEHRA DOON G. T. SURVEY OFFICE FROM 1861 TO 1870.

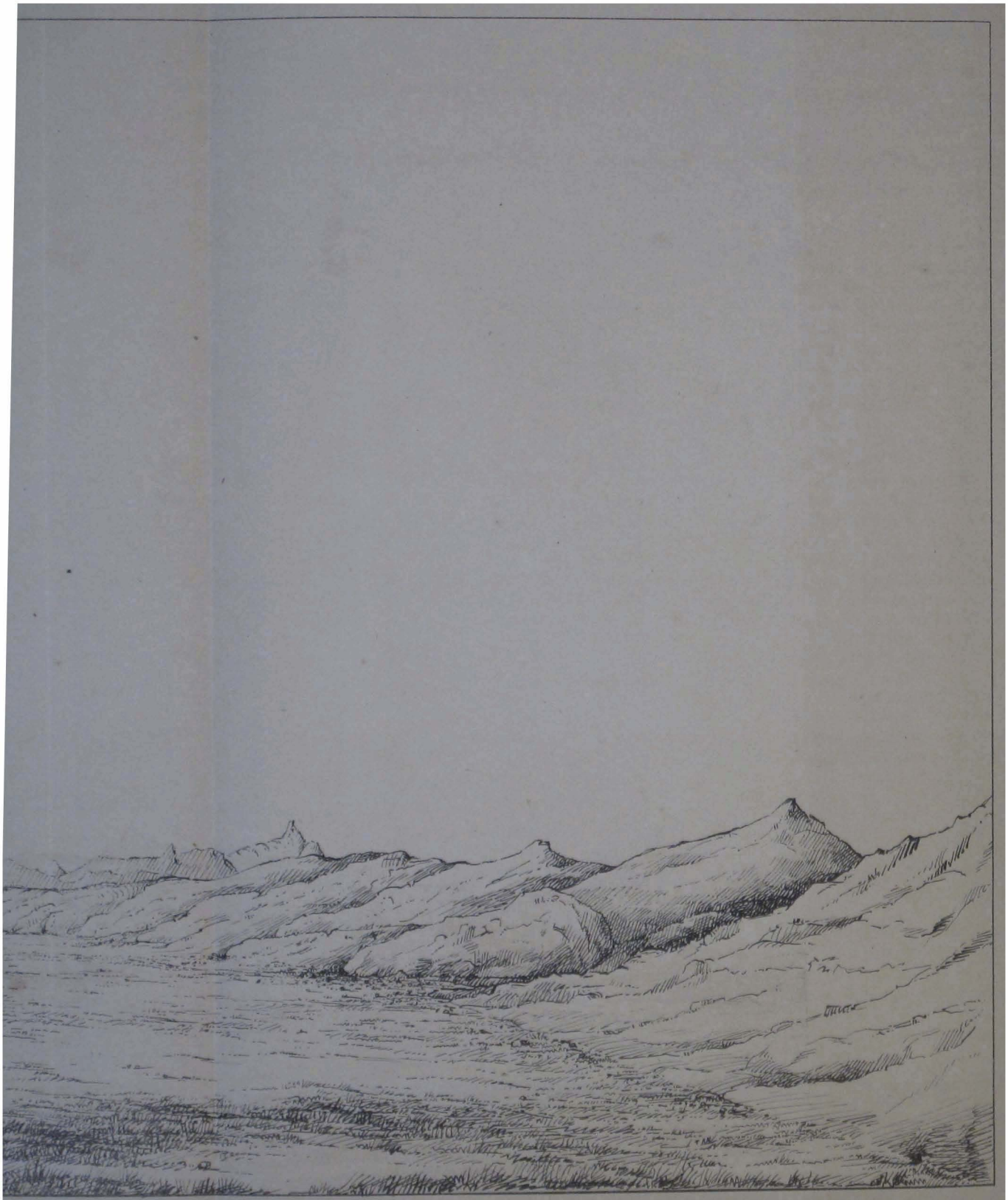
MONTH.	1861. Inches.	1862. Inches.	1863. Inches.	1864. Inches.	1865. Inches.	1866. Inches.	1867. Inches.	1868. Inches.	1869. Inches.	1870. Inches.
January, ...	———	———	3·31	·36	1·93	———	1·25	2·69	1·67	·04
February, ...	———	———	·00	2·18	6·48	———	1·46	7·28	1·43	1·39
March, ...	———	———	1·69	·52	4·67	———	1·43	1·74	7·25	4·13
April, ...	———	———	·33	·21	1·35	2·50	·74	·84	·11	1·84
May, ...	———	———	·34	2·53	6·45	———	3·21	·82	·00	·31
June, ...	12·19	———	12·19	·29	2·10	8·21	9·94	6·83	2·96	7·04
July, ...	24·53	28·66	36·96	37·60	19·12	34·75	28·69	21·26	20·66	33·05
August, ...	54·75	45·22	24·78	22·59	29·10	23·70	23·63	12·85	16·79	28·45
September, ...	9·31	20·20	2·19	7·21	10·06	5·60	3·81	3·02	22·56	13·78
October, ...	·02	5·52	·60	1·68	·00	·20	·93	·05	2·39	1·39
November, ...	·01	·00	·92	·17	.00	———	·00	·00	·00	·00
December, ...	·00	·00	·60	·03	4·02	———	·00	·18	1·22	·01
Total, ...	100·81	99·60	83·91	75·37	85·58	74·96	75·09	57·56	77·04	91·43

NOTE.—Where blanks occur no record is forthcoming. Height of Barometer Cistern above Mean Sea Level, 2232·41 feet.

Annual Return of amount of Work executed in the Drawing Branch of the Office of Superintendent G. T. Survey, from 1st May 1870 to 30th April 1871.

DESCRIPTION OF WORK.	REMARKS.
Sheet No. 3 Levels in the N.W. P., 3rd Edition (Compilation), ...	For Photozincography.
Do. No. 5 ditto ditto 2nd ditto ditto, ...	Ditto.
Do. No. 7 ditto ditto (Comp.) *Vide Al. Retn. for* 69-70, ...	Ditto.
Do. No. 8 ditto ditto ditto ditto For Photozinco....	In course of preparation.
Do. No. 9 ditto ditto ditto ...	Ditto.
Do. No. 10 ditto ditto 2nd Edition (Compilation), ditto ...	Ditto.
Do. No. 11 ditto ditto (Comp.) *Vide Al. Retn. for* 69-70, ditto ...	Ditto.
Do. No. 12 ditto ditto 2nd Edition (Compilation), ...	For Photozincography.
Do. No. 13 ditto ditto (Comp.) *Vide Al. Retn. for* 69-70, ditto ...	In course of preparation.
Do. No. 14 ditto ditto ditto ditto ...	Ditto.
Do. No. 15 ditto ditto ditto ditto ditto ...	Ditto.
Do. No. 19 ditto ditto ditto ditto ...	For Photozincography.
Map of N.W. Himalaya and Kashmir Survey (Compilation) *Vide Al. Retn. for* 69-70 ...	For reduction by Photo.
Sheet No. 2 Preliminary Charts of Triangulation in the Northern Portions of the Bombay Presidency *Vide Annual Return for* 69-70,	For Photozincography.
Do. No. 3 ditto ditto ditto ditto ...	Ditto.
Do. No. 5 ditto ditto ditto For Photozincography,...	Remaining to be examined.
Do. No. 6 ditto ditto ditto ditto ...	In course of examination.
Do. No. 7 ditto ditto ditto *Vide Al. Return for* 69-70...	For Photozincography.
Do. No. 10 ditto ditto ditto	Ditto.
Do. No. 4 ditto of the Great Indus Series, ...	Ditto.
Do. No. 5 ditto ditto	Ditto.
Do. No. 6 ditto ditto	Ditto.
Do. No. 7 ditto ditto	Ditto.
Do. No. 8 ditto ditto	Ditto.
Do. No. 9 ditto ditto	Ditto.
Do. No. 10 ditto ditto	Ditto.
Route Survey from Badakshan across the Pamir Steppe, ...	Ditto.
Plan of the Island of Minicoy, ...	Ditto.
Preliminary Chart of the South Konkan Meridional Series, Seasons 1842-43-44, 64-65-66,	Ditto.
Ditto Great Arc Series 69-70, ...	Ditto.
Map of routes between the Punjab and Eastern Turkestan, ...	Ditto.
Colored 2994 copies of maps of various kinds, and performed numerous other miscellaneous duties, ...	
Reduced and incorporated several Series of triangulation into the G. T. Survey Index Chart for its completion to 1st May 1870, ...	To be engraved.
Prepared an Index Chart of India shewing all the stations where Latitude and Azimuth have been observed Astronomically and Pendulum Observations taken, ...	Ditto.
Reduced sheets Nos. 1, 2, 3, and 4, tracing of the Jumna and Hindun Canal, right project protraction of levels, ...	For incorporation into level sheets.
Reduced sheets Nos. 1, 2, and 3, tracing of the Ramgunga Canal, Sumbhul and Amroha Branches, ...	Ditto.
Reduced tracing of map in 2 sheets of levels taken in part of Kumaon, Bhabur and Bareilly district 1865-66-67-68, ...	Ditto.
Reduced tracing of general plan shewing the Survey and reduced levels of the country proposed to be irrigated by the northern or first Division the Ramgunga Canal 1870,	Ditto.
Made a copy of the tracing of Ganges Canal, Koel branch project map and chart of levels,	For Office use.
Reduced ditto ditto ditto ...	For incorporation into level sheets.
Printed levels in the tracing of the Dussun Canal for Colonel Greathead, ...	For Photozincography.
Prepared plates I to XXXIII for Vol. I, G. T. S.	
Prepared an extract from the Great Arc Series, scale 8 miles to an inch, on linen, ...	For the Executive Engineer Agra Canal.
Made copies of Mr. Shaw's Route Survey in 3 sheets from Karakoram pass to Kashgar, ...	For Office use.
Made an extract from rough sketch shewing trade routes between purgunah Lahol and Shadula, ...	Ditto.
Do. copy of Mr. Reynold's map of the portion of Ladak surveyed in Aug. & Sept. 1870,	Ditto.
Examined sheet No. 1 Jamoo territories, ...	For return to Surveyor General's Office.
Prepared a Chart of Spirit Leveling operations Seasons 1868-69, 69-70 Scale 20 miles = 1 inch, ...	For publication.
Prepared an extract from the Prely. Chart of the Kashmir Series 1857 between Lat. 31° 30′ and 35° 30′, Long. 75° and 76°, on linen, ...	For Captain Basevi.
Prepared an extract from the Prely. Chart of the Kashmir Series 1861-62 between Lat. 33° and 34°, Long. 77° 30′ and 78° 30′, on linen, ...	Ditto.
Prepared an extract from the Prely. Chart of the Kashmir Series 1861-62 between Lat. 34° and 35°, Long. 78° 30′ and 79° 30′, on linen, ...	Ditto.


76°
77°
78°
79°
30'
30°
30'
29°
30'
1
Dadoopoor
2
Saharunpoor
Roorkee
3
Kurnal
Hurdwar
4
Burapoora
Muzuffurnagur
5
Meerut
Bijnour
Nehtour
6
Suhespoor
Jeendh
23
Hissar
Chittang R.
Hansi
Rohtuk
7
DELHI
Moradabad
8
Hussunpoor
Sumbhul
Rampoo
Ramgunga R.
Ganges Canal
Boolundshuhar
R. Ganges
9
10
Budaon
Allygurh
Coel
11
12
Putteealee
R. Ganga
Oseith
13
R. Jumna
Muthra
Furruckabad
14
AGRA
15
Mynpooree
16
Cawnpoor
Chumbul R.
17
Etawah
18
Dholepoor



ROM A SKETCH BY CAPTN J. P. BASEVI R. E.

rvey Office in Debra Doon, November 1871.

Extract from the Narrative Report—dated Dehra Doon 15th November 1871—of J. B. N. HENNESSEY, ESQ., Deputy Superintendent 1st Grade, Offg. in charge No. 4 Extra Party.

Consequent on the lamented death of Captain J. P. Basevi, R.E., Deputy Superintendent 1st Grade, I was appointed on 7th August last, to the charge of his party, in addition to my other duties, and directed to take such steps for the preservation and arrangement of his records as the nature of the case might require.

(2.) The charge which has thus devolved on me, includes the duty of describing the work, on which Captain Basevi was engaged since the date of his report of July 1870.

(3.) Besides the ordinary calculation of his previous field seasons' operations and preparation of his results for the press, Captain Basevi was engaged during the recess of 1870 in experimenting on the most suitable procedure for determining "the temperature and pressure coefficients" for his Pendulum operations. He eventually decided on heating his apparatus by means of heated air passed along a series of flues under the floor of the apartment in which his experiments were made: the transit room at Dehra 16′ × 24′ was placed at his disposal and he proceeded to construct a room within this room as hereafter briefly described. While this was in course of building, he compared his thermometers with one of the standard thermometers in the Superintendent's stores, and determined the zero errors of the former: he also compared the scale for the Russian Pendulums with certain portions of the G. T. Survey Standard steel foot.

(4.) The experiment room at Dehra being sufficiently advanced Captain Basevi proceeded to this place and set about the necessary preliminary arrangements for making his experiments. As is well known to those who have experimented on expansions, the primary difficulty encountered arises from the inability to control the temperature of the object under manipulation; this was overcome as already said by building one room within another. The inner room was warmed by the heated surface of its floor; for low temperatures the room was allowed to cool down to the natural temperature prevailing, the cooling process being expedited by open troughs containing cold water placed over head. It was anticipated, that (as happened at Kew) sensible differences between the readings of the upper and lower thermometers might be expected: this evil was overcome by raising the working floor of the inner room about 5 feet above its heated floor, the former floor being made up of wood battens. So far the precautions taken promised to act efficiently, but on commencing work it was found, that the fireplace being some 12 feet without the external walls, the process of heating up was exceedingly slow, and what was worse that the temperature could not be maintained at a constant heat from fluctuations in the fire itself. These evils were remedied thus: the flue from the fireplace to the building was covered with a mound of earth, whereby the caloric engendered was economised; and the fire was controlled by burning a given weight of fuel within each hour. After this the range of temperature of the inner room during 24 hours did not exceed 2°, while within the cylinder the similar ranges during the hot and cold experiments were respectively under $1\frac{1}{2}$ and $1\frac{3}{4}$ degrees Fahrenheit.

(5.) The sets of coincidences observed by Captain Basevi were the following:—

Pendulum No. 4.

Sets	Temp.	Pressure		Sets	Temp.	Pressure	
	°				°		
12	97·1	0·61		9	100·2	0·61	
9	99·3	1·90	Hot.	9	101·1	1·89	Hot.
9	99·4	4·30		9	100·7	4·22	
9	99·5	10·07		9	100·5	10·05	
9	98·5	17·52		9	99·9	17·44	
9	90·1	27·68		9	99·9	27·58	
6	80·4	1·90	Interme-	9	50·1	0·66	
6	78·2	4·24	diate.	9	53·0	2·02	
				9	53·2	4·21	
				9	52·8	10·16	Cold.
				9	52·4	17·47	
				9	54·2	27·87	

Pendulum No. 1821.

9	101·2	0·51	Hot.	9	51·8	0·64	Cold.
9	98·8	4·16		9	51·3	4·15	
9	99·9	27·84		9	51·2	27·78	

Each set lasted for 3 hours and consisted of 3 coincidences or groups, and as no less than 231 sets were taken, it is easily shown that the amount of observation involved in these experiments is represented by the similar work ordinarily executed at no less than 7 Pendulum stations. Even this fact however gives but a meagre idea of labor which Captain Basevi underwent: the long continued strain on his energies for nearly 4½ months is beyond all description; but the tax on his physical constitution is easily understood from the single fact, that while the external temperature was at some 50°, he worked time after time for many days together in a room heated up to just twice that temperature, viz. 100°.

(6.) As implied in para (3) the preceding experiments were intended to afford the means of determining two co-efficients, and with this view, Captain Basevi proceeded to reduce his experiments and find the variables; the process necessarily involves some assumption of the law of variation, and reductions have been made on several hypotheses.

(7.) Having concluded his experiments, Captain Basevi accompanied by Mr. Macdougall marched from Dehra on the 27th March. He arrived at Meean Meer on 1st April and left it on 17th idem, having in the interval completed 8 sets of observations, each of which lasted 9 hours and included 7 coincidences or groups. At this and his subsequent station of Moré he determined time by altitudes of known stars, measured with an 8″ Theodolite which has an 8″ complete vertical circle.

(8.) The camp next proceeded to Sreenuggur, and arrived there on 12th May. Having completed the requisite arrangements for working on the contemplated high lands, the party proceeded onwards to Leh, arriving there on the 9th June. Here Mr. Macdougall was deputed to proceed on an exploring expedition to the North-East, while Captain Basevi proceeded southwards and eventually selected his station of Moré in Rukchu, Lat. 23° 16′ Long. 77° 54′; Height above sea level 15,500 feet. At Moré he varied his procedure in observing, for a set was now made to last 22½ hours, so that practically he was observing day and night at intervals which may be nominally stated as 3 hours, but which in reality could not have afforded him a respite of 2 hours between visits to the observatory tent. This continued for 6 days and nights and these observations are the last that he made before his death. On their completion, he traced his way back northwards and met Mr. Macdougall returning from his exploration at Muglib on the 8th of July.

(9.) Meanwhile Mr. Macdougall had proceeded by Lukum at the head of the Pangong Lake and over the Marsimik pass along the Changchenmo road to Gogra near the Kiam hot springs. From the latter place he explored northwards to about 34° 42′ north Latitude and returning from thence he selected an alternative station which however he suggested might be superseded by some point on the Lanak plains. Mr. Macdougall appears to have worked earnestly and with good results. He encountered considerable hardships and his explorations lead him into difficult and very trying ground.

(10.) Having obtained all necessary information from Mr. Macdougall, Captain Basevi turned his steps generally eastward from Muglib following the course of explorations which his assistant indicated up to a point near the hot springs of Kiam: meanwhile, owing to the scarcity of provisions and fuel Mr. Macdougall was left behind at Tanksi to compute the observations taken at Moré station. Arrived at Kiam, Captain Basevi considered the northern grounds as less favorable in promise than those to the East, and so he marched on 14th July in the latter direction to a place called Lungun, 11 miles; the next day though now evidently suffering sensibly from illness he marched 10 miles to "Lanak maidan" (plain). The day following he was considerably worse in health, and the next morning, 17th July 1871, while the day was yet dawning, he breathed his last.

(11.) I now turn to notice such circumstances of his endurance and death as may be compressed in the limits of this narrative. I have read the depositions of his servants, (taken so carefully by C. Girdlestone Esq., the resident at Cashmere) on the return of these men to Sreenuggur; I have also conversed with the men who were present in his tent when he died, and Captain Basevi's official diary, the only one he kept, is now open before me. But after studying all the available information with the care due to the memory of a valued friend of many years standing, I can find but little to tell beyond the melancholy and lamented fact of his being no more.

(12.) There can be no doubt of his having suffered considerably from the effects of the rarified air: his diary contains passing allusions to pains in the head and to difficulty in breathing, and these slight allusions should be considerably strengthened to judge of what he actually experienced, for no man complained less, or had a braver, unflinching spirit than Captain Basevi. In going to Moré he crossed the Takalung La (pass) at 18,060 feet on 16th June: his diary contains the entry on this date; "I suffered as well as the men, natives "of the country, or Hindustanies, from shortness of breath also headache finding it difficult to "walk more than a hundred yards at a time." On the 30th June when returning from Moré

he went over the same pass, but either his sufferings had become an old story so that he did not care to write them down, or in reality his riding over the pass made the journey much easier. The entry in his journal on this occasion is simply this. "Rode up the pass. The "ponies appeared to feel the rarity of the air just as much as I did when coming: they "panted and stopped when near the top every 2 or 3 minutes to breathe". At the Chang La (17,531 feet) he appears to have suffered less than on the Takalung La: but despite these trials there is reason to believe, that up to the 10th July, he was in the same state of good sound health as when he left Dehra on 27th March previous. On this point there is the evidence of Major Donald Macintyre of the 2nd Goorkhas, who in company with Major Macdonald met Captain Basevi on 10th July at Lukum (head of Pangong Lake). In the written statement which Major Macintyre has obliged me with, he emphatically states as follows, with reference to this meeting. "I remarked that he (Captain Basevi) was looking at that time "so much better than when he left Dehra in the spring. In fact I had never seen him looking "better or in higher spirits".

(13.) On the same day after this meeting, Captain Basevi commenced the ascent of the Marsimik pass, and for seven long miles he was exposed to a continued fall of "either rain, hail or sleet:" my own belief is that he caught his death-cold on this occasion. The day after (11th) he crossed the pass, the highest he had been over, viz. 18,629 feet above sea level; he states briefly in his journal, "difficulty of breathing experienced." After this, including the last entry made in his diary on 15th July, there is not a sign or word, of complaint; and for the rest I necessarily base my narrative on the evidence of his servants.

(14.) Amongst these servants was a native named Paraoti who officiated as Captain Basevi's bearer and was with him more frequently than any other person in camp. The man is simple and truthful by nature and his affection for his master was so manifest, that I see every reason for relying thoroughly on his evidence: other servants have also deposed much to the same purport as Paraoti, but the deposition of the latter is more earnest and naturally includes little details which the others had no opportunities of observing.

(15.) Paraoti noticed that his master seemed to be suffering considerably on 14th July, when the camp marched 11 miles (16,341 height) to Lungun: on halting for the day Captain Basevi took a dose of some aperient medicine. The next day, 15th July, he made his last march to "Lanak maidan" (plain), gallantly walking the last 3 miles, down an incline, into camp, though he must have been seriously ill at the time. He is said to have set up his theodolite, probably with a view to identifying points around and finding his own position; but he must have failed in the endeavour to observe for his observations are not recorded. "He then went into his tent and wrote a little" says Paraoti, "but his cough was so violent "that he was obliged to abandon his writing and lie down". From the absence of any other record on the date in question, I conclude that what he wrote before lying down was his last entry in his diary. I give this at length:—

1871, July 15th Saturday. "Lanak maidan 10 miles; height 17,104 feet. Road over broad un-"dulating plains the whole way. This plain is very broad but I am a little in doubt about a hill "to the north, so do not consider it definitely fixed. There is abundance of wood, water 600 "yards off and grass within a mile or two in abundance. Wind just the same as yesterday(1). Ramu "(the guide) says that it changes from west to east about midnight."

As night approached his cough became more violent and his breathing oppressive: his chest pained and he expectorated phlegm.

(16.) Early on the morning of the 16th he gave orders to pitch the observatory tent: he would commence work presently he said, but though he still gallantly struggled to do his duty, his strength had failed so that he never again left his bed. "My master called me" says Paraoti "after the sun had risen. He coughed violently, there was a rattling in his throat and "he spoke with difficulty. I felt he was very ill but I had no idea that he was in any danger. "He wished for some gruel: the only flour to be got was of the hill grain "gerim": it looked "like barley flour. The gruel was prepared and my master weighed and added a whitish powder to "it(2); he drank a small quantity of this mixture from time to time: at about noon I helped my "master to apply a mustard plaster to his chest and shortly afterwards I immersed his feet "in a warm bath. As the day was waning he called for a spirit lamp and inhaled steam "from the spout of a small copper kettle. About 2 hours after sunset, he told me I had "been working hard all day and that he wished me to go to my tent and rest. At his request "I placed the candle, matches and spirit lamp near him and retired to my tent for the night. "My master made no remarks about his state, beyond that he had great pain in the chest."

As usual a native was on guard all night within a few feet of Captain Basevi's tent, the man being changed periodically as customery. Captain Basevi did not call for the sentry during the night.

NOTE.—(1.) Easterly wind until near 9 A. M.: soon after 10 A. M. a westerly wind set in.
(2.) Ipecacuanha powder from Bathgate and Co.

(17.) At about 4 A. M. on the 17th July, Captain Basevi called to the man on guard, Guptar by name and ordered him to send for Paraoti. "My master" says the latter "ordered me "to light the spirit lamp, warm some water and prepare gruel for him. He tried to drink it but "failed owing to his cough. He gargled with some warm water; his breathing was very quick; "his face was flushed; he was able to speak only at intervals from the choking in his throat: "seeing his sufferings I began to cry, on which my master stretched out an arm and touch- "ing me said in a weak voice, "Don't be afraid (or distressed) I shall be well shortly". Not "many minutes after the rattling in his throat became very loud and he breathed his last."

(18.) Paraoti and all the other servants made their depositions on oath, as already said in para. (11), before C. Girdlestone Esq., Resident at Sreenuggur, Dr. J. R. Johnson on special duty in Cashmere being present at the time. Dr. Johnson's deposition is as follows :—

"I have heard all the foregoing evidence which has been taken today in my presence and "I have had an opportunity of examining such witnesses as I thought it advisable to question "on various points connected with Captain Basevi's death and illness. I have been unable to "detect any circumstance which would point to a suspicion of foul play by poison or otherwise. "The chief witnesses are unanimous in stating that the deceased caught cold by exposure to a "snow storm on the 9th of July, and that from that period up to the 14th when he was taken "seriously ill, he constantly suffered from cough and other symptoms of Bronchitis. He certain- "ly did not live in circumstances tending to his recovery. On the contrary he undertook long "marches and exposed himself to conditions likely to aggravate such a disorder. In my opinion "the immediate cause of death was suffocation from Acute Bronchitis, probably complicated "with pneumonia. Dr. Adams of the Royal Artillery in Rawul Pindee, who has been present "during the examination, fully concurs in my view."

(19.) I have been at particular pains to elicit if Captain Basevi left any massages or directions, but nothing is forthcoming oral or written; and after carefully studying all the available evidence, I am of opinion that he was not aware of being in any danger. His faculties were still quite unimpaired to the very last, and he was able almost with his last breath, certainly with his last words, to try and soothe Paraoti's distress by saying "I shall be well shortly." Amid all the painful circumstances of his death, such as the absence of medical aid; complete isolation from his countrymen; his utter helplessness, in those distant wild and rock-bound regions to summon the smallest aid or even to obtain the common comforts of life; amid these and other painful reflections that suggest themselves, it is almost a consolation to think that he was spared the pain and knowledge of a protracted illness. He died, as he had lived, striving to do his duty; and those who knew and can recall his generosity, courage, kind-heartedness and rare abilities will long regret his loss.

(20.) The rest is soon told. The deceased officer was attended by a man named Kale Khan, appointed by the Maharaja of Cashmere to provide supplies for the camp. Kale Khan directly wrote off to the official at Sreenugger and started in attendance on the body, making forced marches with the view of reaching the capital of his master. Meanwhile Mr. Macdougall at Tanksi hearing of the melancholy event advanced rapidly and met the body at Lukum, the head of the Pangong Lake. The remains were carried on without stopping to Tanksi, where they were interred, decomposition having set in. Subsequently the body was removed to Sreenugger and was buried there in the cemetery for Christians, by Charles Girdlestone Esq.

(21.) I cannot close these remarks without adding a few words in recognition of Paraoti's admirable behaviour. It will be remembered that his master died on the morning of the 17th; from that time till arrival at Tanksi on the evening of the 21st, Paraoti never left the body, though he could easily have made excuses for remaining in the camp at Lanak. With insufficient food and but little rest, this man alone of all those with the deceased refused to stay behind. By day and night, for full 100 miles over rugged inclines, at considerable heights and over the Marsimik pass, Paraoti followed the remains of his dead master.

(22.) It only remains to add, that in accordance with orders received, the camp was marched back to Dehra under Mr. Macdougall's care; the party arrived at Head Quarters on 19th September. Mr. Macdougall discharged this duty to my satisfaction, and the apparatus has been brought back in good order.

(23.) In conclusion, I add the following results of Captain Basevi's observations at Mecan Meer and Moré, remarking that the numbers are only approximate.

At Mecan Meer, observed vibrations reduced, in defect of computed vibrations in terms of Punnae and ellipticity $= \frac{1}{300}$ . . . . . $4\frac{1}{4}$ vibrations.

At Moré Do. do . . . . . $16\frac{3}{4}$ "

(24.) I append a letter by Colonel J. T. Walker R.E., Superintendent Great Trigonometrical Survey, which appeared in "The Times" (London) under date September 19th 1871. The letter is so valuable a record of the late Captain J. P. Basevi's services that I hope it may be printed with this report.

TO THE EDITOR OF THE TIMES.

Sir,—The last mail from India has brought intelligence of the death of Captain James Palladio Basevi, of the Royal (late Bengal) Engineers, Deputy-Superintendent of the Great Trigonometrical Survey of India, an officer of great worth and ability, whose loss will be long felt in the department of the public service to which he belonged. He was a son of the celebrated architect, George Basevi, who designed the Fitzwilliam Museum at Cambridge and several other buildings of importance, and was attaining great eminence in his profession when he lost his life by falling from the tower of Ely Cathedral. The circumstances of his death excited the sympathies of Her Majesty the Queen, who, with the kindness of heart which so much endears her to her subjects, not only condoled with the family, but offered to assist in providing for the sons.

James Basevi was distinguished as a lad for more than ordinary talent, and particularly for his mathematical abilities. First at Rugby, then at Cheltenham College, and afterwards at Addiscombe, he won for himself a high position among his fellow students, and in December, 1851, he left Addiscombe as the first cadet of his term, obtaining the first prize in mathematics, the sword for good conduct, the Pollock medal, and a commission in the Honourable East India Company's Corps of Engineers.

The first few years of his services in India were spent in the Department of Public Works in the Bengal Presidency; but in 1856 he was appointed to the Great Trigonometrical Survey of India, in which he continued to serve up to the time of his death. His natural abilities, great powers of perseverance, and fastidiously conscientious devotion to his duties, soon indicated him to be one of the most excellent and valuable officers of the department. He took a prominent part in each of the various branches of the operations, the triangulation, topography, linear measurements, and astronomical observations, but more particularly in the principal triangulation, of which he completed two chains of an aggregate length of nearly 300 miles. In 1860 he rendered valuable assistance in a military reconnaisance of the country of the Mahsood Wuzeeris, on the Trans-Indus Frontier, which was made when an expedition was sent, under General Sir Neville Chamberlain, K.C.B., to punish that tribe for repeated raids and aggressions. In 1862, while employed on the east coast of the Peninsula, he was deputed on an operation of a similar character, though unattended by any of the pomp or circumstance of war; single-handed he completed a valuable reconnaisance of the wild mountain tracts and forests of Jeypore and Bustar, to the west of Vizagapatam, which, though bordering on districts that had long been held by the British Government, were so sparsely inhabited and so malarious and deadly that they were still little known and had never been surveyed.

But, while ever ready to throw himself into any work which he might be required to perform, his bent of mind and habits of study led him to feel a preference for the more purely scientific branches of the operation of the Trigonometrical Survey. Thus, in 1864, he was selected to undertake certain operations which had been proposed by the President and Council of the Royal Society for the determination of the force of gravity at the stations of the great meridional arc of triangles measured by Lambton and Everest, which extends from Cape Comorin to the Himalayan Mountains. The investigations were to be effected by measuring the number of vibrations which would be made in a given time by certain invariable pendulums when swung at the several stations. The pendulums were the property of the Royal Society, and they had been used by General Sabine in his celebrated operations, extending from the equator through the Atlantic to the Arctic Ocean. Similar observations had been made by various persons in other parts of the world, but in almost all instances on islands or coasts, and not in the interior of continents; thus further observations were needed in order to ascertain to what extent the results might be affected by differences in the conditions of the earth's crust under oceans and continents. By the combination of pendulum observations with the astronomical and geodesical measurements of the Indian Survey a very favourable opportunity would be presented for acquiring information of great value towards the solution of many problems of high scientific interest. These considerations induced the Indian Government to accede to the proposals of the Royal Society, and the circumstance that the Russian Government intended to have pendulum observations made at the principal stations of the Great Russian Arc was doubtless not without its influence also on the Indian authorities. Captain Basevi entered on the pendulum observations with his characteristic ardour and devotion. Fully impressed with the conviction that the utmost accuracy and precision humanly attainable would not be more than his work demanded of him, he spared no pains to attain the high standard of accuracy which he set before himself. He carried his observations of pendulum and clock coincidences over at least 12 days at each station; for 10 hours daily—from 6 A. M. to

4 P. M.—he never left his pendulums for more than a few minutes at a time, taking rounds of observations at intervals of an hour and a half a part; then at night he would devote a couple of hours to star observations for determining time. Thus he voluntarily undertook an amount of work which few men would care to perform continuously, and he carried it through without flinching or at all relaxing his programme of operation during the 5 years that the work lasted. He also made very elaborate and laborious investigations of the corrections for temperature and pressure to be used in the reduction of his observations. For this purpose it was frequently necessary to raise the experimenting room to a very high artificial temperature, 40 to 50 degrees above the temperature of the external air, and to sustain the heat at a constant point for several days together. The room was intensely stifling, and of the many visitors who went to watch the operations there was scarcely one who would remain in it for more than a few minutes or who cared to visit it a second time; but Captain Basevi carried on his observations in it just as at his ordinary stations for weeks together with a pertinacious devotion which was the surprise and admiration of all who knew what he was doing, but which, as will be seen from the sequel, may possibly have tended to undermine his constitution.

His observations of the pendulums on the Indian arc showed that the local variations of gravity which are superposed on the great law of increase from the equator to the poles, though apparently irregular when examined singly, are subject to laws which are highly interesting and curious and are well worthy of investigation. At the northern extremity of the arc the results indicate a deficiency of density as the stations approach the Himalayan Mountains, while at the southern extremity they indicate an increase of density as the stations approach the ocean; thus both groups of results point to a law of diminution of density under mountains and continents, and an increase under the bed of the ocean. To test this point still further, after the completion of the observations on the arc the pendulums were taken to an island in the latitude of Cape Comorin, but about 250 miles from the mainland, and to several stations on the east and west coasts of the Peninsula, in the same latitudes as certain of the stations in the middle of the continent. In all cases it was found that gravity at a coast station is in excess of gravity at a corresponding inland station, and that at the ocean station it is greater than at Cape Comorin, thereby corroborating the law of local variation which the previous operations had indicated.

Thus far, however, observations had not been taken at any very great altitudes, the highest station in the Himalayas being under 7,000 feet; arrangements were therefore made to swing the pendulums on some of the elevated table lands in the interior of the Himalayas, which rise to altitudes of 14,000 feet to 17,000 feet. It was expected that this would be sufficient to complete the work in India, and then the pendulums would be taken back to England to be swung at the base stations of Greenwich and Kew, and *en route* at Aden and at Ismailha on the Suez Canal, places which are in the same latitudes as some of Captain Basevi's stations. Thus gravity at Aden would be directly compared with gravity at certain of the coast and continental stations of the Indian Peninsula, and similarly the plains of Egypt would be compared with the Himalayan Mountains.

In the spring of the present year, as soon as the snows of the winter were sufficiently melted to permit of the opening of the passes over the southern ranges of the Himalayas into Kashmir and Ladak, Captain Basevi proceeded to Kashmir on his way to the high table lands in the interior. He was furnished with letters from the Secretary of State and the Government of India to insure his obtaining from the Maharajah of Kashmir the help which he needed for the successful prosecution of an arduous enterprise. Without this assistance it would have been impossible for him to carry out his operations, for before he could reach the table lands on which observations were to be taken he would have to cross some of the most difficult mountain passes in the world, and traverse highly elevated and quite uninhabited regions in which food for man is wholly unprocurable, fuel very scarce, while in many parts neither water is to be met with nor grass for the beasts of burden. He required a large number of men to carry his instruments and camp equipage, and several mules or ponies to convey sufficient food for 30 or 40 days' consumption. The Maharajah of Kashmir appears to have responded with his usual cordiality to the calls which were made upon him, and to have done all in his power to assist Captain Basevi, supplying all his requirements at the outset, and sending with him a confidential agent, with instructions to carry out his orders, and with full powers to act under any emergency.

Early in June he reached Leh, the capital of Ladak, where a stock of provisions had to be laid in and arrangements made for supplying the depôts in advance. He then proceeded to the Khiangchu table land in Rukshu, about 80 miles to the south of Leh as the crow flies, where he found a suitable station, which also afforded the necessaries of water, fuel, and fodder for an encampment. There, at a spot called Moré, in lat. 33° 16′ and long. 77° 54′, and at an altitude of 15, 500 feet, he completed a satisfactory series of observations, which show a very gross deficiency of density. After applying the usual reductions to sea level, &c., it was found that the force of gravity at Moré did not exceed the normal amount for the parallel of latitude 6° to the south, as determined by the previous observations with the same pendulums.

Wishing to have one more independent determination at a high altitude, Captain Basevi proceeded to the Changchenmo Valley, which lies due east of Leh, across the newly proposed trade route between the British province of Lahoul and the States of Eastern Turkestan. Near the

eastern extremity of that valley, on the confines of the Chinese territories, he found a suitable position in lat. 34·10 by long. 79·25, at an altitude which is not exactly known, but must probably have exceeded 16,000 feet. He hoped to complete his observations in ten days, and then commence the journey back to India. But he did not live to carry out his intentions; already the hand of death was upon him, and, all unconsciously to himself, the over-exertion to which he was subjected in a highly rarified atmosphere and under great vicissitudes of climate was rapidly undermining a constitution which, though vigorous, had already been sorely tried.

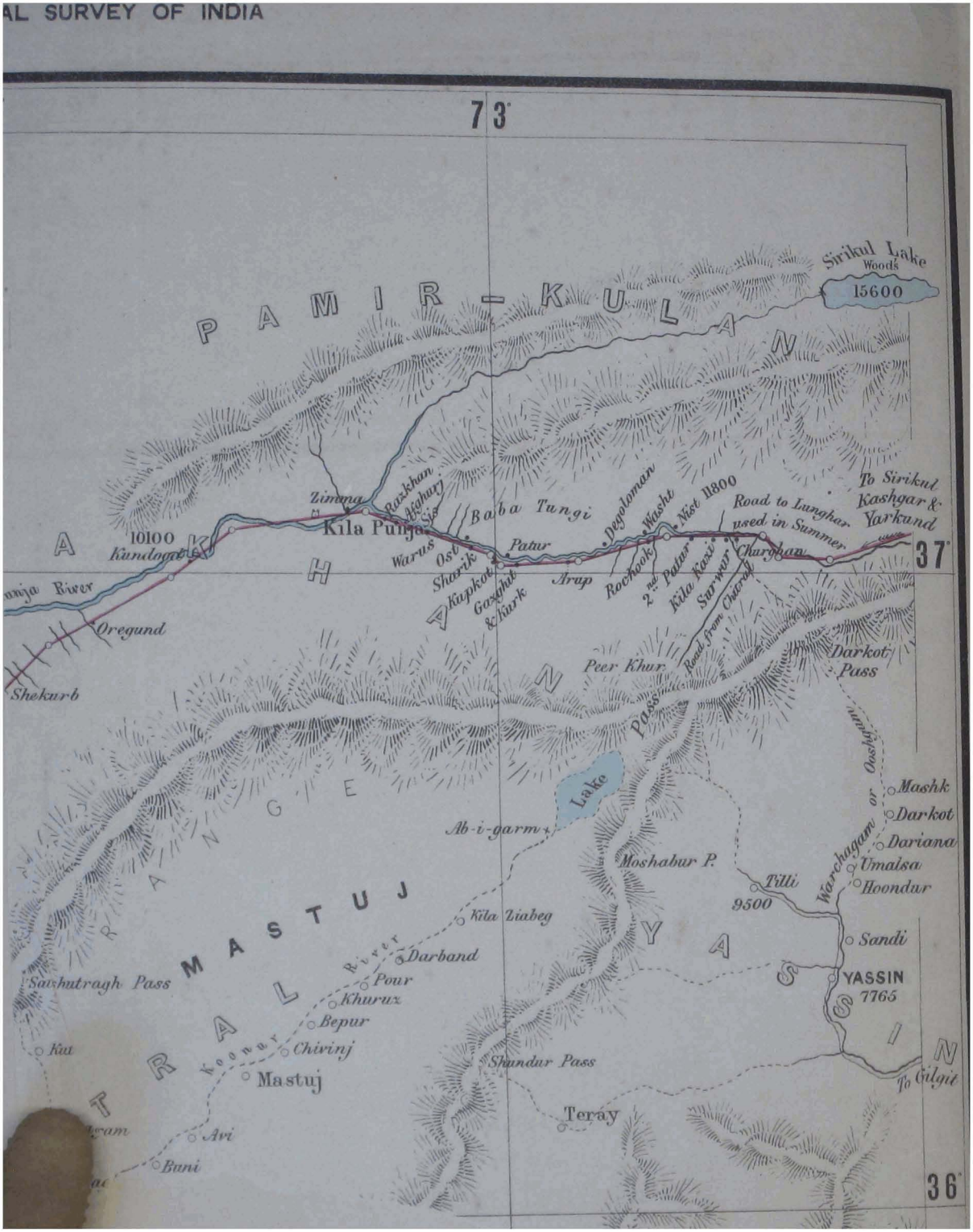
He reached his last station on the 15th of July, and on the next day—which was devoted to preliminary operations—he had a bad cough and complained of pains in the chest; no medical aid was within hundreds of miles, nor any European within some days' journey, for he had just sent away his European assistant to the nearest depôt in order to economize the expenditure of provisions in the camp. Thus no one was with him but his native servants and attendants. From their accounts it appears that he tried to relieve the pains in his chest by a mustard poultice, and afterwards by fomentation and inhaling steam through the funnel of a camp kettle. Subsequently he retired for the night with apparent composure, giving orders for every thing to be in readiness to commence work early next day. He rose at 5 o'clock on the following morning (the 17th), but while in the act of dressing became suddenly very ill, lay down on his bed, and died almost immediately; a little blood exuded from his mouth and eyes and ears, indicating that a blood vessel had probably burst in his lungs.

Some weeks previously, on crossing the Tákalung pass between Leh and his station at Moré, he had suffered much from the extreme rarity of the atmosphere, the height of the pass being nearly 18,000 feet; his pony had died a short time before, and meanwhile he had not got another, and so he walked over the pass. Writing to a friend on the 29th of June, he says, "I found crossing the Tákalung very trying; I could scarcely walk for more than a hundred yards at a time for want of breath. I had to enlarge all the air holes in the hand lamps (at Moré) before they would burn. I feel as if I had not air enough to breathe." Subsequently, on the 13th of July, in the last letter he is known to have written, after mentioning that the weather had been very bad, with a good deal of rain and heavy snow storms, he simply says, "I shall be glad to get out of this country"; but this was much for him to say who was so brave and uncomplaining, so silent about everything which concerned himself. His assistant reports that the vicissitudes of climate at the time were very great, the thermometer falling below zero (of Fahrenheit) at day break, and rising to 70 or 80 degrees in the afternoon.

It is clear that, in addition to the risk entailed by severe exertion in an exceedingly rarified atmosphere, Captain Basevi was exposed to very inclement weather, to great extremes of cold and heat, to frequent rains and heavy snow storms, which, in a bleak and highly elevated region almost wholly devoid of fuel, must have caused much privation and suffering. With the devotion of a soldier on the battlefield, he has fallen a martyr to his love of science and his earnest efforts to complete the work he had to do; in a hard struggle with the physical difficulties which he had to encounter—and nature too often opposes such difficulties to those who would investigate her secrets—he succumbed at the moment that the prize was almost within his reach and his work all but completed, and he was looking forward to a speedy return to England and to his wife and children. Thus has passed away in the prime of his life a man of sterling worth and excellent abilities, a public servant of whom it may be truly said that it would not be easy to find his equal in habitual forgetfulness of self and devotion to duty.

I am &c.,

(Sd.) J. T. WALKER, COLONEL R.E.,
Supdt. G. T. Survey of India.
17, Queensberry-place, South Kensington.


73°
PAMIR-KULAN
Sirikul Lake
Woods
15600
To Sirikul
Kashgar &
Yarkand
Road to Lunghar
used in Summer
Zimang
Ruzkhan
Hathurj
Kila Punja
Baba Tungi
Degoloman
Washt
Nist 11800
10100
Kundogate
Warus
Ost
Sharik
Patur
Kapkot
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Kurk
Arup
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2nd Patur
Kila Kazi
Sarwar
Chargbaz
Road from Chitral
37°
Oregund
Shekurb
Peer Khur
Pass
Darkot
Pass
Lake
Ab-i-garm
Moshabur P.
Tilli
9500
Warchagam or Oshkaman
Mashk
Darkot
Dariana
Umalsa
Hoondar
Sandi
YASSIN
7765
Kila Ziabeg
Darband
River
Pour
Khurux
Bepur
Chivinj
Koonay
Mastuj
Saiyhutragh Pass
Shandur Pass
Teray
To Gilgit
Avi
Buni
36°

Memorandum on the Trans-Himalayan Explorations made during 1870, by Major T. G. MONTGOMERIE, R.E., Offg. Superintendent G. T. Survey of India, in charge of the Trans-Himalayan Exploring Parties.

The Trans-Himalayan and Trans-Frontier explorations were carried on during 1870 in various directions in continuation of my general plan for systematically exploring all unknown or partially unknown countries beyond the British Frontier; one line of exploration from Peshawur direct to Faizabad, the capital of Badakshan, was brought to a successful conclusion, and will now be reported on.

I have long wished to clear up the geography of the mountainous tract lying between Caubul and Little Tibet which is bounded on the south by the Indus river and its great Caubul tributary and on the north by the Hindoo-Koosh and Mustagh ranges. Though draining into our territory and though we have several routes actually going into it near Peshawur and again near Gilgit, our progress in clearing up the geography of this very difficult tract has hitherto been very slow, reliable work indeed extending but a very little way beyond the border. This ignorance has been the more aggravating as from information derived from natives of the country we really know nearly every thing as to each separate portion though unable to put the pieces together so as to form a reliable whole; the inhabitants who constantly come down to Peshawur &c. being uneducated and consequently incapable of explaining how any except the larger tracts lie with reference to each other. This being the state of the case, it appeared to me that if a Route Survey could be carried right through the heart of the country, I should be able to get the correct positions of the larger places and should at the same time be able to string together a large amount of detailed information which I have collected as to the minor tracts, valleys &c., of the country, so as to form a fairly reliable map of the whole. With this object in view I made various attempts to get a suitable agent from near the Peshawur frontier, but failed in getting a satisfactory one until I at last applied to Lieut.-Colonel Maunsell, the Commandant of the Sappers and Miners, who placed at my disposal a very intelligent Pathan Sapper who after a good deal of labour was trained to the work and was getting on very well with a first attempt at exploration when he was killed in a quarrel with some other Pathan with reference to some old feud between their families: as this was however in no way connected with his exploring work it was determined to make another attempt: a Pathan from the frontier with the requisite amount of education was accordingly entertained, and his training nearly completed when facts came to light that rendered it necessary to remove him. This was a great disappointment, but still hoping for success I applied for the second time to the Commandant of the Sappers and was fortunate enough to have a Pathan Sapper placed at my disposal who was in every way qualified for the work; he was consequently carefully trained and after several preliminary trials was started on an exploring expedition with instructions to carry a Route Survey from Peshawur through Swat, Bajaur, Dir, Chitral &c., to Badukshan.

Starting from Peshawur on the 12th of August, the party crossed into Swat by the Malakund pass on a range which rises into peaks of 6,000 to 7,000 feet, reaching on the 15th Alladand, the capital of the present ruler of Swat, a small poorly built town of 300 houses. The next day, at a mile and a half north of Alladand, they reached the Swat river, a very large stream, which they crossed on rafts: continuing their march the same day they ascended the opposite mountains and by an easy pass crossed over the Lurrum mountains into the Talash district, and descending to the Punjkora river crossed it on the 17th; this river appeared to be even larger than the Swat river. From the Punjkora river they marched on through Jundul the largest district of Bajaur, reaching, on the 18th August, Miankilai, the chief town of Jundul, and the capital in fact of the province. Bajaur is divided into 3 districts viz., Jundul (Miankilai), Nawagai and Shahr, each of which is ruled by a separate Khan; the two latter however being in a measure subordinate to the present Khan of Jundul, Faiz Talab Khan styled Haji-Saheb-Zada in consequence of his having made the pilgrimage to Mecca, and who has owing to this and his general uprightness as a ruler, become much respected in spite of a slight weakness in the one matter of horses, which he apparently cannot resist taking at his own price for his own use,—a failing which however I understand is looked upon with a very kindly eye by all except the immediate sufferers; the Bajauries in fact, being a race of horse dealers, appreciate any sharpness in such a direction. Having a great partiality for good horses, he has collected them from all parts of the province and now boasts of a well mounted force of about 800 sowars.

Faiz Talab Khan resides in Burwa, a stronghold of some pretensions: his influence extends beyond his own province, and he is considered to be a more powerful chief than the present ruler of Swat or of any other of the neighbouring provinces; his rule seems to be exactly suited to the wild tribes he has to deal with, though he is unable to keep in check their innate thievish propensities, for even in his capital Miankilai the Sapper and his party only escaped being plundered by means of extra precautions and great vigilance,—a plot to loot them having been formed soon after they arrived. After two days halt, the party travelled north for one march more through Jundul, and then crossing the Janbattai mountains which rise to 12,000 feet, they descended gradually through Barawul, part of which is under a brother of Faiz Talab Khan; thence passing into the Dir district they arrived on the 23rd of August at Dir itself which the Sapper reports as being a small town of about 400 houses.

So far the Sapper had made his way as an ordinary traveller, but from Dir to Chitral the road is infested by Kafirs and it was consequently necessary to make some other arrangements in order to have a chance of a safe transit across this dangerous tract. Traders are in the habit of halting at Dir or Chitral until a large number collect, in order that the may all start together: sometimes as many as 200 start at the same time, but in spite of this and other precautions the travellers are frequently attacked by the Kafirs and many are killed. Those of the travellers who fall are buried by the side of the road, mounds surmounted by a flag marking their graves, these are called the tombs

of the martyrs. The Sapper saw hundreds of these, anything but reassuring, memorials on the way between Dir and Chitral.

On arrival at Dir they were much disappointed to find that all the traders for the northern route had already left, and that there was nothing for it but to make a special arrangement for their party by itself. In this dilemma the Sapper presented himself before Ramatoolah Khan, the chief of Dir and asked for assistance. Ramatoolah Khan questioned him as to the object of his journey &c., and was fortunately satisfied with the answers he got.

The Sapper then placed a handsome gold laced scarf by the chief, and pointing out that as all the traders had already started it would be simple madness for his small party to go by itself, he begged that the chief would kindly send an escort with them; after some hesitation the chief consented and gave the necessary orders. The party accordingly resumed its march and on reaching the village of Kashgarai found an escort of 25 armed men awaiting them; the next day they reached Gujor and then crossing the Lahori pass close to mountains of 14,000 feet and upwards, they after a very trying march reached the village of Ashreth, here in spite of their escort they were much troubled by the Kafirs who swarm in and about the village, the inhabitants pampering them so as to escape being more openly plundered. During the night an incessant discharge of small arms was kept up on the Sapper's party who returned the fire, but owing to the darkness there was no damage done on either side as far as was known. The next day they resumed their march being glad to get safely out of Ashreth. Their escort accomapanied them down to the Koonur river and finally parted from them at the village of Galatak, in the Chitral district, where an escort was no longer necessary. From thence they made their way up the Koonur river to Chitral, crossing one very large tributary called the Shushidurra which joins in on the left or eastern bank. On the road near Brary on the 30th August, the Sapper first heard a report of the murder of poor Mr. Hayward; the report was that a saheb by name "Hawel", who had travelled from Kashmir to Chitral and whose intention was to have gone thence into Badukshan, had been murdered at place called Ooshgoom, (distant about seven days journey north-east of Chitral), by the order of Mir Walli of Ooshgoom, son of the late Goraman of Yassin. The saheb was said to have been accompanied by eight servants, one of whom alone escaped though not without some wounds, the other 7 being all killed. After the saheb was murdered, some 700 tillahs or gold pieces, (about 6 rupees each in value,) were found and taken by the murderers along with his clothes, guns, pistols, his watch, books and a variety of other property.

On the 31st of August the party reached Chitral where their first transaction with the Chitral chief was an attempt on his part, through his Wazir, to make them exchange a portion of their goods at his valuation. The Sapper had an interview the next day with the chief, who is styled Badshah by the people thereabouts, but it was to no purpose, so there was nothing for it but to submit to the imposition.

The Sapper saw the chief Aman-i-mulk several times, and has given the following account of a very remarkable interview he had with him when Mir Walli, the murderer of Mr. Hayward was present. "On the 4th of September the Badshah of Chitral sent for me, (the Sapper,) in durbar and gave me a "seat on his right between himself and Mir Walli; after the ordinary inquiries, the Badshah then "commenced to talk with some of his durbar officials who sat opposite him, and while he was engaged "thus, I turned to Mir Walli and in a quiet way asked him what was the cause of quarrel between "Hayward saheb and himself, on which he said to me that "I was in no way inclined to quarrel with "Hayward saheb for I had seen him on a former occasion while he was travelling through our country "when we interchanged civilities and presents, and parted good friends, but on this latter occasion of "his travelling through the country he was forcibly pressing coolies and other people to carry his "baggage from stage to stage on his way into Badakshan, besides taking supplies of food for his fol-"lowers from the villagers by force, and several complaints from the zemindars reached me to this "effect. On Hayward saheb coming up to the village where I was, I remonstrated with him and advised "him not to act as he was acting towards the people, whereupon the saheb turned round on me and "abused me, telling me that this country did not belong to us but to the English, and altogether his "attitude on the occasion was very violent, so much so that I feared his using personal violence to "myself, and in consequence I kept quiet. The saheb encamped for that night near the place I was, "but towards morning I sent some sixty men to a place a little distance ahead called Ooshgoom, with "orders to wait in ambush for the saheb and his party and on their way thence to fall upon them and "kill them—which they did, killing Hayward saheb and seven of his servants."

It is generally reported in the country that on Aman-i-mulk (the Badshah of Chitral) hearing that Mir Walli had ordered Hayward saheb to be murdered, he exclaimed that "Mir Walli is my enemy, for what authority had he without any order from me to take upon himself to kill Hayward saheb, I must imprison him for the act." Report furthermore says, that Mir Walli on learning this threat of the Badshah fled into Badukshan and hid himself in that country for about 25 days, after which he returned to Chitral and presented himself to the chief, giving him a gun taken from Hayward saheb. The date on which Mir Walli returned to Chitral was the 28th August, from which date they have appeared fast friends. The Badshah always now keeps one of Mr. Hayward's guns beside him whilst in durbar.

The people of Chitral appear to be convinced that Mr. Hayward was murdered by the orders of Aman-i-mulk, the chief of Chitral, who used Mir Walli merely as an instrument in the murder; for they say that the fact of Mir Walli being away for so short a time after the murder and then returning and continuing such a fast friend of the chief tend to show that the chief's appearing to have been annoyed on learning the saheb's fate was simply a blind to throw the blame off himself, the actual offender. Moreover the people of Chitral are convinced that Mir Walli could not have, on his own

responsibility, undertaken the murder of Hayward saheb, for his authority in the country is so weak that he would not have been obeyed had not a higher authority instructed him in the act. They are all convinced that Mir Walli's flight and sudden return to Chitral were planned by Aman-i-mulk before hand. Aman-i-mulk has the reputation of being a very deceitful man, speaking to the humblest of his men in a soft hypocritical manner behind which he conceals a bad unfeeling heart. He is said to live in the constant fear that his country will be taken from him, and to avoid any good excuse for this being done his evil acts are always so planned that the blame should rest on the shoulders of others. The following illustrates this which the Havildar heard from several individuals while in Chitral.

A Subadar named Dillawar Khan and 2 Sepoys belonging to one of the Native Regiments serving under the British at a Frontier Station, were making their way into Badakshan by Chitral, and were well received by the chief and had left for Badakshan when the Badshah got notice that a Subadar and 2 Sepoys employed by the British were taking notes of the country, and was recommended on their arrival at Chitral to detain them. The description given of these men, travelling as they were in the disguise of fakirs, corresponded with the 3 men and they were pursued by the Badshah's men, overtaken and brought back to Chitral and by the chief's orders kept close prisoners. After a confinement of 20 days they were brought before the chief who told them that he had just learnt that they were employed by the British, but had he known this sooner they would certainly not have been imprisoned, so in order to compensate them and throw off all suspicion, he made them presents of chogas &c., treated them with apparent cordiality, and asked them which way they intended to travel; on learning which he ordered two of his men in their presence to escort them as far as a village which he named and to treat them well and see that they wanted for nothing on the road, but secretly he instructed the escort to murder them the moment they were out of his country; and according to several reports they did murder the Subadar, though the other two made their escape. Some however suppose that the Subadar died from cold and weakness. One choga and two note books of the Subadar's are still reported to be in the hands of the petty chief at Zebak.

The account of Hayward's murder agrees in the main with that from other sources; Ooshgoom where the murder was said to have been perpetrated is I presume the Wurchagam noted on poor Mr. Hayward's map as the name of the stream or valley, immediately north of Yassin, through the lower part of which he passed when he first visited Yassin; Darkot is according to the account received from Kashmir the name of the village near which he was murdered, it will be found on the accompanying map 20 miles due north of Yassin.

The Sapper reports that Aman-i-mulk, the Chitral chief seemed to be very friendly with Mir Walli, and most assuredly took a share of the spoils of poor Hayward's camp, for he always carried one of Hayward's rifles, taking it with him to the Eedgah or place for praying where the Sapper accompained him and saw the rifle placed alongside of him.

Chitral consists of a number of small villages and separate houses scattered over a considerable area, though according to his boiling point observation it is 7140 feet above the sea, it is very hot at times during the summer. The Government of the country seems to be only a few shades better than that of the neighbouring Kafir tribes, the chief carries on the slave trade himself, *i.e.* catching Kafirs if he can, but failing them seizing his own subjects and selling them whenever they give him an excuse for doing so by committing any real or imaginary breach of his laws. Probably no great numbers are thus sold into slavery, but as far as could be made out no family in Chitral is quite safe from that fate. The Chitral chief was, on the whole, very civil to the Sapper, and as soon as a one-sided exchange of goods had been effected, he allowed the party to march on towards Badakshan.

Starting from Chitral on the 5th of September, they continued their journey to the north, leaving the main Koonur river on their right and ascending a large side stream, they after some delay reached the base of the lofty Nuksan mountain by noon of the 15th of September, and the same afternoon accomplished about half the ascent. The climate was very trying partly on account of the steepness and partly an account of the snow. Their camp was of course a most uncomfortable one, but they were not able to enjoy long such small comfort as was to be got there, for it was necessary to be off by 3 o'clock the next morning so as to clear the pass before the Kafirs met them,—the road near the pass being dangerous owing to strong bands of those robbers who are always on the look out for the chance of plunder. After a very stiff climb the party reached the crest of the pass, crossing large beds of snow and immense masses of ice; the road for a distance of 4 or 500 paces being literally cut through the ice to a depth of from 6 to as much as 12 feet. Every here and there the ice was fissured with vast cracks which the travellers avoided with the greatest care.

The Sapper had never been on any snowy mountains before, but this account leaves no doubt in my mind that this part of the so called Hindoo-Koosh range at any rate boasts of one glacier, the vast cracks or in other words the crevasses being quite unmistakable as they never occur in an ordinary snow-bed. As the mountains on either side of the pass rise considerably above it, the probability is that there are numerous glaciers in the neighbourhood. The above is the first evidence that we have as to their being any glaciers in the Hindoo-Koosh, nothing of the kind having been noted between Bamian and Pamir Kul the most easterly point visited by the Mirza.

Having crossed the pass, they descended rapidly and after a very hard march reached Daigul the first village of Badakshan, and on the 18th September made their way to Zebak on the Kokcha river, the same group of villages that the Mirza passed through in the previous year thus completing a junction and connecting the two Route Surveys together. From Zebak they went down the Kokcha river, by much the same route that the Mirza ascended, reaching Faizabad the capital of Badukshan on the 25th of September.

The Sapper found that Jehandar Shah, the Mir or ruler who held Badakshan when the Mirza was there, had been supplanted by Mahmood Shah who was assisted by the Amir of Caubul. The party had instructions to advance still farther north across the Oxus and they tried to arrange for so doing, but could not because the road in that direction was strictly closed by the orders of the Amir Sher Ali who suspected that letters were sent by that route to Abdul Rahman Khan by his supporters in Caubul.

Whilst in Faizabad, the Havildar witnessed the fate of a man upon whom some such letters were found. The unfortunate wretch was thrown from a lofty bridge down into the rapid stream of the Kokcha, and though not killed on the spot he died a few days afterwards from injuries received by being dashed against the boulders which protrude from the water in every direction. This is a favourite mode of execution in Badakshan and was noted by Wood when he passed through the country.

Being able to devise no immediate means of advancing to the north, the Sapper according to his instructions prepared to return. Starting on the 27th of October, his party reached Zebak on the 31st of October where they witnessed a meeting between the rulers of Badakshan and Chitral. On the 3rd November they left with a party of traders accompanying Mir Walli, the murderer of Mr. Hayward, who had come into Zebak with the Chitral chief. Whilst there the scoundrel Mir Walli had his leg broken between the knee and the ankle by the kick of a horse, and when the Sapper saw him was in great pain with it, the bone never having been allowed to set.

From Zebak it was necessary for the party to take a different route from that by which they crossed the Hindoo-Koosh on their upward journey,—the lofty Nuksan pass being already closed owing to the lateness of the season. The traders said the only chance was to try the Dora pass to the west which was somewhat less difficult, though less used owing to its running through a part of Kafiristan and to its consequently being always infested by strong bands of Kafirs. The traders however, having Mir Walli's escort and being in considerable numbers themselves, thought they might risk the passage; they therefore marched on taking the more westerly of the two streams which, coming from the south, join at Zebak. The first day they reached Sanglech where the cold was so intense (though it was only the 3rd of November), that the stream which flows past that village in a steep bed was already frozen hard; the next day they advanced to another village also called Sanglech and here two of the Sapper's servants deserted, being afraid to face the intense cold expected on the Dora pass; the Sapper however, resolved to go on with his diminished party; on the 5th they encamped in a desolate place at the foot of the Dora pass, here they had to be very vigilant so as not to be surprised by the Kafirs who are thereabouts more especially troublesome. By good arrangements they escaped an attack and the next day they succeeded in crossing the Dora pass, the road appearing to the Sapper to be even worse than the Nuksan pass; this he thinks was in part due to the lateness of the season. He says he never in his life experienced such hardship as he did on those two stages. The combined effect of the intense cold, the high cutting wind that prevailed, the fact of being deserted by two servants, and the anxiety owing to threatened attacks by the Kafirs made them feel the height of misery, the more especially as from the 6th, when they passed the crest of the Dora pass, till the 7th of November, when they reached Lotko in the Chitral province, it was snowing hard. From thence they marched on to Shogoth thus joining in to their former route. The Chitral chief caught them up and passed them on the way, and thinking he had a good opportunity he ordered an extra toll to be taken from the traders; they however refused to leave Shogoth and held out there 6 days till they at last got better terms. The Sapper with them reached Chitral on the 16th of November; on the 17th he again presented himself to the Badshah who now however looked coldly on him saying that he had heard he was in the employ of the English. The Sapper however, was nothing daunted and requested that he might have a pass for his return: the chief, though convinced he had heard a true account as to the Sapper, thought it as well not to interfere with him and his party and so gave the necessary order. The Sapper said when he left, Mir Walli was still in great agony from his broken leg and as he could actually hear the bone grating when he moved, and it was then more than a month since it was fractured, there is little doubt but that this scoundrel may hereafter be recognised by his lameness which is likely to be permanent, and which may yet perhaps assist in bringing him to justice and to the fate he so richly deserves.

Having completed his arrangements, the Sapper marched back by much the same route as he had advanced, reaching Peshawur on the 13th of December, having again passed safely through the corner of Kafiristan between Chitral and Dir, and not a little glad to think that neither he nor any of his men had added another mound to the tombs of the many Mahomedan martyrs who have fallen on that road.

His Route Survey is 286 miles in length over entirely new ground which has never before been surveyed by an explorer, though no doubt other natives may have passed over the whole length. The route touches upon a great number of districts and determines with all desirable accuracy a number of important places. It accounts for the geography of about 13,000 square miles of this *terra incognita* and will aid in unravelling the geography of a still greater area. The route is checked by 20 Latitude observations at 5 places. The boiling point observations are very meagre,—the Sapper not quite appreciating their importance, this being his first expedition. He moreover says he wished to boil on the passes but was unable to do so without risk of detection, except on the Nuksan pass where unfortunately he could find no wood being far above the limits of forests. From the glacier and the amount of snow in September as well as other evidence, I conclude the Nuksan pass to be above 17,000 feet; that of Dora may be 16,000 to 16,500.

The position of Chitral has always been a great desideratum, and as it is so immediately north of Peshawur it may be concluded that it has been very satisfactorily determined, as any error in the distances could but very slightly affect its longitude while its latitude is thoroughly established by 3 astronomical

observations which agree very fairly *inter se*, the Sapper having shown by his observations for Peshawur and for Faizabad that he understands taking Latitudes,—those at the latter place agreeing very closely with Wood and the Mirza.

The heights of Miankilai and Chitral, though only approximate, assist in forming a better general idea of the height of the countries traversed than we have yet had; a glance at the accompanying map will show what has been accomplished. Amongst other things it may be said that the course of the great Koonur river has been definitely, though roughly, determined as there now exist but two gaps,—the 1st between Chitral and the Mirza's bearing from edge of the Pamir Steppe which evidently points to the source of the Koonur river, and the 2nd gap between Chitral and Chigur Serai as determined by Griffith's accurate observations. These gaps can in a measure be filled up by the aid of the numerous peaks which we have determined trigonometrically in that direction, and I think it may be said that those portions of the course of the Koonur river will not hereafter be found to differ materially from the dotted line given in the map. Should any explorer hereafter be fortunate enough to traverse its whole course his additions will be chiefly as to the side streams.

The Sapper's pacing on the whole seems to have been good. As compared with the difference of latitude between Peshawur and Chitral it appears that one of his paces was on the average 21·8 inches in length which is somewhat short.

Accepting the Mirza's value of Zebak and the Sapper's value for Chitral, the direct distance between those places should be 60·5 miles; using the value of the Sapper's pace as determined from the latitudes of Peshawur and Chitral, viz. 21·8 inches, the distance between those places would be 69·1 miles, a fair agreement considering the roughness of the ground and the fact that there is no telling exactly what points of Zebak the Mirza and the Sapper respectively refer to.

A farther check is afforded by his route between Zebak and Faizabad being the same as that by the Mirza; the Sapper gives very nearly the same average bearing and makes the distance 62·9 miles while the Mirza makes the same 59·5 of his miles, which as shown in para: (30) of my last year's memorandum were 0·02 in defect, and the 59·5 miles being consequently equal to 60·7 miles,—a close agreement bearing in mind that Faizabad is a mile in length and that there are 8 villages in Zebak and no particular place for halting in, travellers sometimes choosing one and sometimes another.

Altogether the Sapper's work has satisfactorily stood the tests applied; he has moreover fixed a number of peaks by bearings and though mostly rather close to his route they will aid in solving the geography of the surrounding mountains.

In my opinion the Sapper deserves all credit for his great pluck and endurance as well as for the discretion with which he penetrated through such a difficult country without I believe getting into a single disturbance with the people of any of the districts he traversed, though constantly bullied by requests for legal and illegal tolls which were made at most places. I am convinced moreover, that his undaunted bearing on his return journey when the chief had guessed his secret was the means of preventing himself and party from being sold into slavery or possibly from a worse fate, the wily chief probably thinking that his co-religionist who showed such a bold front did so because he was backed by some thing more than the few men he had with him.

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Narrative Report of an exploration of the route from Peshawur through Swat, Bajaur Barawul, Dir, Kafiristan and Chitral to Faizabad in Badakshan, drawn up from the original journals &c., by Major T. G. Montgomerie, R.E., in charge of the Trans-Himalayan Exploring Parties.

The Sapper left Peshawur accompanied by his assistant and servants on the 12th August and arrived towards evening at a village called Nasath, on 13th arrived at Jelala village, on 14th reached the village of Durgai which is on the frontier of Swat and not in British territory. Durgai is surrounded by a mud wall about 40 feet in height and 3 feet in thickness, it is occupied by an unscrupulous set of bandits, and consequently wholesale robberies and murders are quite common. On the morning of the 15th August they left Durgai village and after crossing the Malakund range reached the village of Alladand towards night fall. This place Alladand is the seat of the present Khan or ruler of Swat, a man not equal to govern the country properly and hence the people are dissatisfied and are always intriguing to induce his predecessor to resume the rule of the country. The village of Alladand consists of about 300 houses built of stone cemented with mud. On the morning of the 16th August, after paying the tax imposed for the goods with them, the party left Alladand village; marching on for a mile and a half they reached the Swat river, which they crossed on rafts, arriving by night at a group of four villages called Ooch, one of which belongs exclusively to the sect called Saiyuds and the other three exclusively to Pathans.

On the 17th they reached the small fort of Serai by noon, and after paying the usual toll charged there they travelled on till they arrived at Shumshi Khan village, where they had to pay another toll. Both these villages are presided over by officials styling themselves Khans and are amenable to Faiz Talab Khan the ruler of Bajaur. Continuing their march on the same day they crossed the Punjkora river and stayed for the night at Kotkai village; the tract from the village of Ooch to the Punjkora river constitutes the district called Talash. On the 18th they arrived by night at Miankilai, which is the largest and most important town in all Bajaur; it is situated in the largest of the three subdivisions of the Bajaur Province, viz. Jundul. The town of Miankilai has about one thousand houses built, as usual in these parts, of stone cemented with mud.

The present ruler of Miankilai has, owing to his popularity, the greatest amount of authority of all the Khans in the Bajaur district, and is styled by the people Haji-Sahib-Zada.

The party halted at Miankilai for 2 days in order to take star observations for the determination of its latitude. While halting for the purpose, a plot to loot the party was made by a gang of thieves; this fortunately was revealed to the Sapper by the owner of the house they occupied, and consequently by extra caution and vigilance on their part the danger thus threatened was warded off.

On the morning of the 20th August they left Miankilai town and arrived at Kanbat village situated in Jundul. This village is notorious for thieves, and they had to adopt great precautions for the the security of their baggage. On the 21st they reached the fort and village of Janbattai after crossing the mountain of the same name. The ascent to the pass of Janbattai from either side is stiff, but fortunately several springs of water exist on the way and help to allay the immoderate thirst produced by the ascent. The northern slopes of this mountain are covered with dense Pine forest while the southern slopes are only partially covered. It rained for half the day while they were on the Janbattai mountain.

Here the Sapper met Feroza-Khan (brother to Faiz Talab Khan of Jundul), who is the possessor of a small tract of country including several villages in the Barawul district. He appeared friendly though anxious to find out the real object of the Sapper's journey; fortunately the latter managed to ward off all suspicion as to the real state of affairs by giving out that he was going to Chitral in the hope of getting some presents from the Badshah, whose reputation for such was proverbial, and at the same time to obtain some falcons for which Chitral is far famed and which fetch such high prices in the Punjab. Feroza-Khan has a great partiality for fire-arms of all descriptions and showed a large number of guns of English manufacture which he had been at great pains in collecting.

On the 22nd they reached, towards evening, the village of Soorbat situated in the district of Dir. Half-way on this march they came across the fort and village of Bandai situated on the frontier of the Barawul district. On the 23rd they arrived at the village of Dir which contains about 400 houses. The present ruler of Dir is Ramatoolah Khan, son of Ghazan Khan who during his life time ruled the large tract of mountain land which at present constitutes the district of Dir. Ghazan Khan was a powerful chief and his authority was very great, for even the Badshah of Chitral was tributary to this chieftain. He left nine sons, all of whom aspired to the vacant Guddee and bloodshed among these brothers ensued, till at last Ramatoolah Khan, the eldest established himself permanently as chief. The brothers then dispersed themselves over the country but are still jealous and impatient of Ramatoolah Khan's authority, endeavouring to throw the country into a state of disaffection and anarchy by questioning their eldest brother's right to the Khanship of Dir.

Ramatoolah Khan is in person a handsome, manly young chief, six feet in height, and is mentally well fitted to rule in such a country. His administration of justice is the theme for praise with all the people.

The road from Dir to Chitral is infested with Kafir robbers, who are much dreaded by travellers. It can be said to be open for only 2½ months of the year, from the latter end of May to the middle of

August. Two reasons make the road impracticable during the remaining months of the year, viz. the snow during the winter and the dread of the Kafirs during the warmer months.

Having made arrangements the party continued its march on the 25th and reached a village called Kashgarai, from whence an escort of 25 armed men accompanied them on the 26th on the route to Chitral. On the 26th they reached the village of Gujor inhabited only during the summer months, on the 27th after crossing over the Lahori mountain they reached the village of Ashreth after a very tedious day's journey. Immense quantities of iron are found in the bed of a small stream which rises at the foot of the Lahori mountain; the process adopted to obtain this iron is similar to that in the washing of gold dust from the streams of other parts of the country. A quantity of sand from the stream is placed in a sieve and washed till the iron is left behind.

Ashreth village is the resort of scores of the Kafir robbers. It is the place most dreaded by the merchants who travel by this route. The Kafirs usually keep up an incessant fire on travellers throughout the night. The exploring party was not spared in this respect and hence passed a most anxious night returning the fire of the robbers, but with what effect the darkness prevented them from ascertaining. Leaving Ashreth on the 28th they reached the village of Darosh at night, after having dispensed with their escort at a village called Galatak situated in the Chitral district. Darosh possesses a fort which is the residence of Kokan Beg, brother to Aman-i-mulk the Badshah of Chitral. This Khan levies on all merchants and others a toll or tax, but in consequence of a letter having been sent to him by the ruler of Dir through one of his officials asking him to exempt the party from, all tolls, they were not asked to pay anything.

On the 29th they reached Shushidurra, a small village on the right bank of the Shushidurra river which throughout the year contains so large a volume of water that at no time is it fordable, and always has to be crossed by a bridge. This river flows into the Koonur river.

It is reported that in the neighbourhood of this village a silver mine exists which is said not to be worked because the chief of Chitral fears that were the fact known to the Amir of Caubul, or the Maharajah of Kashmir or the Amir of Badakshan, his country might be wrested from him. The silver, it is rumoured by the people, was accidentally discovered in a spot in this neighbourhood by a Fakir who in person reported the circumstance to the Badshah of Chitral; the latter was then conducted to the spot and after satisfying himself of the truth of its existence he is said to have imprisoned the discoverer and then to have poisoned him. The existence of silver hereabouts is not unlikely for the country is rich in copper mines, which are said not to be worked now for the same reasons as given for not working the silver. "Orpiment" or yellow arsenic, called Hurtal, which is much used for dyeing cloth is also found in large quantities in the country. On the 30th they left Shushidurra and travelled to Bruz village.

On the 31st August the party reached Chitral. On the arrival of any merchant at Chitral an official of the Durbar immediately reports the circumstance to the chief with a list of the merchandize with the merchant. The Badshah's Wazir then repairs to the merchant and in his master's name informs him that the Badshah requires to exchange goods with him to a large amount. The arrival of the party was reported in due course to the Badshah, who sent as usual his Wazir with the stereotyped request to exchange goods, but thinking that they might avoid this imposition they requested time up to the next morning to make up their mind on the matter. Consequently on the morning of the following day the Sapper went to the residence of the Badshah in the fort. The Badshah then interrogated them as to where they had come from, where they were going, and as to the object of their journey. They answered that they had come from Peshawur and were going to Bokhara where they hoped to recover money from certain of their countrymen who had amassed large fortunes and were settled in Bokhara. The chief of Chitral advised them not to attempt the journey, for the road was closed to travellers onwards from the river Hamoon (the Oxus) by the Amir of Badakshan, Mir Mahmood Shah, in compliance with orders received by the latter from Sher Ali, the Amir of Caubul who has considerable authority in Badakshan. The reason for this prohibition is that about a year and a half ago on the persons of three travellers, who were on their way to Bokhara and who were accidentally searched, were found letters of great political importance purporting to have been written by certain intriguing Sirdars of Caubul to Abdool Rahman Khan nephew of the present ruler Sher Ali of Caubul. Abdool Rahman Khan was said to be at this time in Bokhara under the protection of the Russian Government. These three men on whom the letters were found were forwarded on to Caubul and by order of the Amir were blown away from guns. All these matters were told to the Sapper direct by the Badshah of Chitral himself, in order to force him to interchange the goods he had brought with him, such as richly worked scarfs, chuddurs &c., with such articles as he would or could give in return, and seeing his intention the Sapper replied that at least he would travel up as far as the frontier (the Hamoon river) even supposing that he could proceed no further.

On the 5th September 1870, after making arrangements for the onward march and disposing of a couple of asses which were of no further use, the party left Chitral and reached the village of Shogoth towards evening. At this place they had to halt on the 6th and 7th in order to change carriers. On the 8th they left Shogoth and reached Shali village. On the 10th they marched to Hurkarri village where they stayed till the 13th September.

On the 14th they left Hurkarri and reached the village of Oweer; the road on this march for a mile is very dangerous for laden animals and so they had to unlade the ponies and convey the bag-

gage on men. On the 15th by noon they reached the foot of the mountain called Nuksan; after refreshing themselves they commenced the ascent that same day, but had to encamp about half-way up the hill in consequence of night coming on. The ascent of this hill is attended with great fatigue, being covered with snow nearly from the foot of the mountain, the slope is great and a high, cold and sharp wind always blows throughout the day, making it very disagreable for travellers. The feeling of shortness of breath is felt on this mountain and travellers eat raw onions on making the ascent in order to counteract if possible the giddy feeling which comes over every one.

On the 16th they rose at about 3 A.M. and resumed their journey reaching the crest of the mountain at day break; this was done so as to avoid any likelihood of the party meeting with the Kafir robbers who from this point again begin to be dangerous; the party continued their march till they reached the village of Daigul making altogether a very long and tedious march.

On the 17th they discharged the carriers who were with them and halted at Daigul (which is on the frontier of Badakshan), to make fresh arrangements for carriers &c. On the 18th the arrangements being completed, they started and reached Zebak which is formed of eight villages scattered within a small distance of each other. The present petty chief of Zebak, Mir Hak Nazar by name, has received his authority direct from the ruler of Faizabad. Zebak is in a valley from 2 to 3 miles in length and surrounded on all sides by mountains; three streams, one flowing from Yarkund, one from Daigul, and the third from Sanglech meet at Zebak and flow from thence in one united stream towards Faizabad.

One road leads from Zebak towards Yarkund, another leads to Daigul, a third leads to Sanglech and a fourth to Faizabad. The trade in slaves of both sexes assumes no great proportions in either Chitral or Faizabad. In the former place it is monopolised by the chief and no one besides himself dares to sell slaves, while in the latter place merchants chiefly from Bokhara deal in them, the ruler of Faizabad taking no part in the transactions.

The party was delayed at Zebak for 2 days in consequence of an attempt that was made there to induce them to surrender their goods with little or no payment, which the Sapper on the other hand was determined not to do at any rate without the payment of their full value.

On the 21st they reached Sufaid Durra village, on the 22nd Soofian village. The country about this village is very productive in fruit of all kinds; the apple grows to perfection, and is so abundant that for a single copper they bought about 50. On the 23rd they reached Yardar village; on the 24th Robat and on the 25th September they arrived at Faizabad.

On arrival at Faizabad they learnt that the road through Kolab into Bokhara was closed by the orders of the Amir of Caubul in consequence of his being suspicious that this road was the one used in the conveyance of letters to Abdool Rahman Khan from intriguing sirdars in Caubul, and that they, to avoid all suspicion, had the letters conveyed in the first instance to Peshawur and thence through Swat, Chitral, Faizabad, Rustak &c., into Bokhara.

The present ruler of Badakshan, Mir Mahmood Shah, was placed there in October 1869, by Sher Ali Khan and is tributary to the latter. He is in caste a Saiyud and is reputed to be a learned man; the people of Badakshan, however, are averse to his rule as he oppresses them by demands for extra revenue &c. which is taken from the people on the plea of the same being demanded by the Amir of Caubul, but a large portion of which they are certain is retained by Mir Mahmood Shah for his own use. No less a sum than Rs. 80,000, besides 500 horses, was paid to Sher Ali during the first year of Mir Mahmood Shah's rule in Badakshan. The former ruler of Badakshan was Jehandar Shah an intimate friend of Abdool Rahman Khan; and when the latter fled to Bokhara, Jehandar Shah also left his country and followed his friend, the country being taken from him by Mir Mahmood Shah. The chief of Badakshan up to this time never paid any tribute to the Amir of Caubul.

Jehandar Shah when chief of Badakshan is said not to have oppressed his subjects and though a drunkard and a dissolute character, was able to maintain his independence and never paid any tribute to Caubul. Traders from all parts of Turkestan, Bokhara, Caubul, Candahar &c. resort to Faizabad and the Bajauri Pathans flock thither in large numbers to barter and trade.

The contrast between the two durbars of Chitral and Faizabad is very striking in the matter of the authority of their respective chiefs, the manner in which the durbar is conducted &c. The chief of Faizabad is much respected in durbar, and the despatch of public business, the conduct of public worship, the dress of the people and other public matters betoken the prosperity of the country and the security from oppression which the people really enjoy.

It was commonly reported in Faizabad that a Saheb who had travelled a long distance and had gone to Caubul and received a letter from Amir Sher Ali had found his way into Faizabad, where he was treated in a very cordial manner by Mir Mahmood Shah who gave him a small escort to enable him to travel to Yarkund; he had left Faizabad but 10 days when the party arrived there. This Saheb carried quantities of medicines with him and gave medical aid to the inhabitants of the countries through which he passed. It is reported that he found his way to Yarkund but that he was imprisoned there, for unknown reasons, by the Khoosh Begi or the ruler of that place. During his stay in Faizabad the Sapper witnessed the fate of three men on whom letters, written by some sirdars of Caubul to Abdool Rahman Khan and Jehandar Khan, had been found. They were at first sentenced to be hanged, but their lives were interceded for by some people and the sentence was accordingly commuted to exile for two of the lesser offenders while the chief offender was ordered to be thrown into the river,

a mode of punishment much practised there. Owing to the rapid current of the river flowing over a rocky bed, this practice seldom fails to prove fatal to the victim; in this case, the offender, though escaping immediate death by being washed to the other bank, yet died 10 days after of the wounds he had received from being dashed against the rocks. The place of exile to which the other 2 men were sent is called Sarab, a spot so hemmed in by dangerous and steep mountains that once in the spot it is almost impossible for the victim to escape.

During their stay in Faizabad, the Sapper heard a rumour that Abdool Rahman Khan assisted by the Russians had marched on the city of Shahri-Subz, but was repulsed. On learning that the leader of the enemy's force had been shot down, they were said to have returned to the attack and to have taken and plundered the city.

On the 27th October they began their return journey and reached Robat village, on the 28th Yardar, on the 29th Soofian, on the 30th Suffaid Durra, on the 31st Zebak where they halted the next day, the 1st November, and witnessed the meeting of the chiefs of Chitral and Badakshan who had journeyed thither for friendly intercourse. The former had 700 sowars with him as his escort and the latter 2,000, sowars or mounted men. It was supposed that the meeting of the two chiefs was dictated from fear of their countries being taken from them by the Amir of Caubul, and hence negotiations for offensive and defensive alliance were entered into on the occasion. Presents were interchanged between the chiefs; the Chitral chief giving 21 slaves of both sexes and also his daughter in marriage to the Faizabad chief's son and the latter presenting the other with 60 Chogas of Bokhara manufacture, also 2 swords and a horse.

On the 2nd November they halted at Zebak. On the 3rd they travelled along with the traders accompanying Shah Zada Mir Walli to Sanglech. On the 4th November they reached another village also called Sanglech. On the 5th they encamped in a desolate spot at the foot of the Dora pass. On the 6th they crossed the Dora ridge and encamped at the foot of the pass on the other side near the site of a hot spring the water of which is hot enough to boil eggs in a short while.

On the 7th November they reached the village of Lotko situated in the Chitral district. The Badshah and his followers passed on this march on their return from the interview with the chief of Badakshan. On the 8th they reached Drosh village (not the Drosh mentioned on their first journey). On the 9th they reached Shogoth, the same place they passed on their first journey. Here they were detained for 6 days in consequence of the traders in whose company the party travelled refusing to pay the higher rate of toll imposed by the collector of the place by the orders of the Badshah.

On the 16th they reached Chitral and on the 17th the Sapper again presented himself to the Badshah, but his treatment of him this 2nd time was cold, for he said that he had heard the Sapper was in the employ of the English and could not be persuaded to the contrary. He however did not molest them in the least.

On the 23rd they left Chitral and continued their march over the same road they had gone up by, halting daily at nearly all the same places as on the former journey but from unavoidable circumstances they halted for 2 days at Darosh, 3 at Dir and 2 at Hotee Murdan. They reached Peshawur on the 13th of December 1870, and thence returned to the Head Quarters of the G. T. Survey.

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Offg. Superintendent G. T. Survey of India.
and Incharge Trans-Himalayan
Exploring Parties.

Observations for Latitudes taken in Central Asia with.

No. of Observation.	Astronomical Date.		Watch Time.	Stations.	Object.	Upper or Lower Transit.	Double Altitude.	Single Altitude.	Index Error.	Deduced Latitudes.	Mean Latitudes.	REMARKS.
	1870		*h. m.*				° ′ ″		′ ″	° ′		
1	August	5th	P.M. 8 55	Camp Peshawur.	Polaris.		67 0 0		+4 30	33 56	° ′	Not observed on Meridian.
2	,,	,,	11 20	,,	,,		68 40 0	}	,,	33 56	33 56	Do.
3	,,	,,	11 36	,,	,,		69 0 0	}	,,			Do.
4	,,	,,	9 32	,,	Altair.		115 41 0		,,			Do.
5	,,	,,	9 57	,,	,,		121 18 0		,,			Do.
6	,,	,,	10 2	,,	,,		123 0 0		,,			Do.
7	,,	6th	A.M. 2 2	Peshawur Mundee.	Fomalhaut.		51 31 6		,,	34 0	° ′	On Meridian.
8	,,	,,	3 48	,,	β Ceti.		74 43 0		,,	34 0	34 0	Do.
9	,,	19th	P.M. 11 36	Miankilai (District Bajaur.)	Fomalhaut.		43 37 0		,,			Not observed on Meridian.
10	,,	,,	11 45	,,	,,		44 34 0		,,			Do.
11	,,	,,	11 53	,,	,,		45 33 0		,,			Do.
12	,,	,,	A.M. 0 40	,,	β Ceti.		56 30 0		,,			Do.
13	,,	,,	0 45	,,	,,		57 37 0		,,			Do.
14	,,	,,	0 50	,,	,,		58 41 0		,,			Do.
15	Sept.	1st	Noon.	Chitral.	Sun.		125 35 0		,,	35 36	° ′ ″	On Meridian.
16	,,	4th	A.M. 1 50	,,	β Ceti.		71 6 0		,,	35 49	35 44 40	Do.
17	,,	,,	2 45	,,	Polaris.		74 30 28		,,	35 49		Do.
18	October	2nd	P.M. 11 36	Faizabad (Badakshan.)	Fomalhaut.		45 22 0		,,	37 5		Do.
19	,,	,,	A.M. 0 36	,,	Polaris.		77 10 0		,,	37 9	37 7 20	Do.
20	,,	3rd	1 12	,,	β Ceti.		68 27 0		,,	37 8		Do.