Extract from Report of the Operations of the Great Trigonometrical Survey of India during the year 1862-63.—*By Major* J. T. WALKER, R. E. *Superintendent G. T. Survey.*

[*Received 10th November*, 1863.]

In accordance with the sanction of Government, I proceeded, in the autumn of 1862, with the officers and assistants marginally detailed,* to Vizagapatam to measure a Base Line. Vizagapatam is situated nearly on the same parallel of latitude as Bombay; and is the point where the Bombay Longitudinal Series, when extended eastwards to the Madras Coast, will terminate. This series of triangles will form, with the Great Arc Meridional, the Calcutta Longitudinal, and the Coast Series, a vast quadrilateral figure, circumscribing the Meridional Series of triangles which are required as a basis for the interior topographical details. Base Lines had been measured several years ago, by Colonel Everest, at Beder, Seronj, and Calcutta, the S. W., N. W., and N. E. angles of this quadrilateral. One more Base Line remained to be measured, which, for considerations of symmetry, it was desirable to place in the vicinity of Vizagapatam.

Captain Basevi, the officer in charge of the Coast Series, being located at Vizagapatam, was directed to select the site. After several trials, owing to the difficulty of carrying a straight line, several miles in length, so as to avoid the numerous irrigation tanks with which this district is studded, he eventually succeeded in finding a suitable line, on the undulating plain between the Military stations of Vizagapatam and Vizianagram, at a distance of about fifteen miles to the west of the port of Bimlipatam. The ground was chosen before the commencement of the rainy season of 1862, when trenches were dug to carry away the expected rain fall during the monsoon, and every precaution was taken to keep the line dry. But when Captain Basevi took the field early in October, he found that the rains had been so heavy, that the surrounding tanks had been converted into lakes, and the line lay submerged under a sheet of water, in some parts as much as sixteen feet deep. By great exertions the water was drained off into adjoining ravines. A portion of the line was ready for measuring on my arrival in December, and the remainder had become fairly dried by the time it was reached, in the course of measurement.

* Messrs. Hennessy, Taylor, Campbell, Wood, Burt and Mitchell.

The apparatus employed, consisted of a set of Compensating Bars and Microscopes, on the principle of those designed by Colonel Colby, for the Ordnance Survey of Great Britain, which had been constructed under the superintendence of Colonel Everest, by whom they were brought out to India in 1832. This apparatus has been employed in measuring three Base Lines on the Great Arc, two at the north and south extremities of the Calcutta Meridional Series, and two at the extremities of the Indus Series. The length of these bases has, in each instance, been determined in terms of ten foot Standard Bar A, the unit of measure of the Indian Survey.

At the time this Standard was constructed, it was believed that the length of a well made iron bar, supported by rollers at its points of least flexure, might be considered invariable for any given temperature. But, of recent years, there has been a growing tendency to doubt the invariability which has hitherto been assumed. Series of comparisons made by the Ordnance Survey show there is much probability that the texture of an iron bar changes gradually in the course of years; for the factors of expansion obtained from groups of comparisons made at intervals a few years apart, differ from each other by larger quantities than are due to errors of observation. It is preferable, therefore, to employ several Standards, constructed of different metals, rather than to trust to the integrity of a single bar.

To ascertain whether our Standard has altered in length, it would be necessary to remeasure the whole, or part, of one of the Base Lines which were first measured after the arrival of the Bar from England. I wished to obtain some light on this subject, by remeasuring certain short sections of the Calcutta Base Line, the extremities of which were originally indicated by permanent marks. But, on examining the positions of the section markstones, I found that, though concealed from view, there had been a regular thoroughfare over them, for many years, of carts and elephants, as well as foot passengers; consequently, they must, in all probability, have been disturbed, and they cannot be safely referred to, to decide so delicate a matter as the constancy of the Standard.

Disappointed at being baffled in my efforts to investigate this matter by any simpler and shorter process than the remeasurement of a whole Base Line, I determined to mark the intermediate section stations of the Vizagapatam Base as permanently as the extremities,

in order that any future enquiry regarding the length of the Standard, at the time of the measurement of this Base Line, may be conducted without greater labour than the measurement of a short section.

It has been well said, by one of the greatest living authorities on scientific matters, that "the ends of a base line should be guarded with religious veneration." In this country they are liable to be viewed with mingled cupidity and dread; the natives sometimes fancy that money is buried below, or they superstitiously fear that the Englishman's mark will cast a spell over the surrounding district. In either case, the mark is liable to be destroyed, as has already happened at the Seronj Base Line.* To ensure the protection of the ends of the Vizagapatam Base, I have had substantial domes of cut stone masonry built over them, without any openings, so that, before the marks can be reached, the domes must be pulled down, which will be so laborious, that the Police should be able to hear of and arrest the perpetrators, before they have had time to harm the marks.

Captain Basevi, and the Assistants of the Coast Series Party, shared in the measurement of the Base Line, which occupied about two months. The length of the line is six and a half miles. It was divided into three verificatory sections, which were subsequently checked by two series of triangles, one on each flank of the base, to test the measure of each section against the others. These tests were satisfactory; for the extreme difference between the measured length of the whole base, and its computed length by triangulation from either section, has been found to be one inch. The comparison of the measured length, with the computed value brought down by triangulation from the Calcutta Base Line, is singularly satisfactory, for the error of the computed value is only a quarter of an inch, though the triangulation embraces a distance of four hundred and eighty miles,

* On this subject, the following extract is taken from a letter by Colonel Sir George Everest, C. B., to the President and Council of the Royal Society, dated 8th April, 1861:—

"The natives of India have a habit, peculiar to human beings in that state of society, of attributing supernatural and miraculous powers to our instruments, and the sites which have been occupied by them. In cases of death, or any other natural visitations, they often offer up prayers to those sites, and if the object of their prayers be not conceded, they proceed to all sorts of acts of destruction and indignity towards them; nay, as in all cases where it was practicable, my station marks were engraved on the solid rock *in situ*, they have been known to proceed in bodies, armed with heavy sledge hammers, and beat out every vestige of the engraving."

much of it passing over flat plains, which are covered with dense forest and jungle, and very difficult to work through.

On the completion of the Base Line, Captain Branfill was deputed to connect it with the principal triangles of the Coast Series, and to execute the verificatory triangulation between the sections. Meanwhile, Captain Basevi proceeded, by my instructions, to make a reconnoisance of the neighbouring territories of the Rajah of Jeypore.

It is a singular fact that, in the vicinity of the British stations of Vizagapatam and Vizianagram, and within sixty miles of a coast which has been frequented by British traders for upwards of a century, there is an extensive tract of country, subject to a friendly Rajah, of which less is known, than of districts occupied by hostile tribes, along the frontier of our recently acquired Punjab Provinces. A glance at any map of the Madras Presidency reveals a great blank in our geographical knowledge, in the tract of country which lies parallel to the coast, and North-East of the Godavery river. Its deadly reputation appears to have been a bar alike to the explorations of the curious and scientific, and to the visits of sportsmen. No regular survey of it has ever been attempted; the few places given in the map seem to have been obtained from native information, for they are generally exceedingly erroneous.

A reconnoisance of this tract was required for our own operations, in the extension of the Bombay Longitudinal Series to Vizagapatam. As any reliable information regarding lands so little known might be expected to be of much value and general interest, I was much gratified when Captain Basevi volunteered to reconnoitre this *terra incognita;* though, at the same time, I could not but feel apprehensive for his safety in a country so deadly, for his route would have to pass through dense jungle, in which it would be necessary for him to preserve his reckoning by the troublesome process of traversing; which, under such circumstances, is very laborious, and entails the necessity of performing the greater part of each day's march on foot. The inevitable exposure to be thus undergone is very great, in a tropical climate, and when the district to be traversed is known to be exceedingly feverish and unhealthy, no small amount of courage is needed, to prompt a man to volunteer for such a task.

Captain Basevi took with him one European Assistant, Mr. O'Neill, and a few natives. He, himself, fortunately escaped with a

slight attack of fever, but Mr. O'Neill suffered severely, and has not yet recovered, and the natives of the party were also, more or less, incapacitated by fever, so that but for the assistance afforded by the Rajah of Jeypore, the operations would have been stopped almost at their very commencement. The results are, a good preliminary map of Jeypore, which has been forwarded to the Surveyor General, to be lithographed and published; a report by Captain Basevi, giving details of his route, and a general description of the country; several valuable astronomical determinations of latitudes and longitudes, and barometrical determinations of heights; also memoranda of various other routes, the details of which were obtained from native information. In consideration of the great value of Captain Basevi's services, he has been permitted to proceed to Europe on furlough for one year, during which his appointment will be kept open for him.

During the summer of 1862, the Field Season of the Kashmir Survey Party, the triangulation made great progress to the east of Leh, and stations were fixed on the Chinese Frontier, from which a number of peaks in Tartary were determined. Some of these were more than one hundred miles distant, and will materially aid in the construction, from native information, of maps of districts into which the surveyors will probably be unable to penetrate. Several of the stations observed from were over 20,000 feet in height above the sea, and Mr. Johnson visited one peak of a height of no less than 21,072 feet, but, owing to a very heavy fall of snow, was unable to observe from it.

A great many points were fixed in the Pangkong district. The whole of Astor was triangulated, and several peaks were fixed to the north of Gilgit; none of these were of any great height, the highest being only a little over 19,000 feet. The natural difficulties of the country were at first much enhanced by bad weather, which came on with the heavy rains in the southern and outer Himalayan Ranges. Notwithstanding these circumstances the out-turn of work has been good, and the general progress very satisfactory, the total area of the triangulation being about 10,500 square miles, and of topography 10,400 square miles, on the scale of four miles to the inch.

The topographical operations made good progress, though not so great as would have been the case had all the assistants retained

their health. Unfortunately two of them, on entering the higher ranges, broke down completely, and a third had to leave off work early in the season. The ground sketched was generally very elevated and barren, the Surveyor's chief difficulties arising from the want of provisions and firewood, and sometimes even of fresh water. The plane table sketches required for the map of Little Tibet have been completed, and lodged in the Head-Quarters Office at Dehra. A glacier, about twenty miles in length, was discovered by Mr. Ryall at the head of the Nubra Valley. Some large glaciers were also found in the neighbourhood of the Nanga Parbat.

I fully concur in the testimony which is borne by Captain Montgomerie, to the great zeal with which these arduous Survey operations have been carried on by all the assistants under his orders. The good fortune of success has hitherto attended all undertakings executed under the superintendence of this officer.

There is much reason to expect that, if the snows are not unusually heavy, and if most of the Surveyors keep in good health, the remainder of the country to be surveyed in and around Kashmir and Ladak, will be completed during the next field season. Captain Montgomerie has made every effort to persuade the Maharajah of Kashmir to allow one of our Surveyors to go to Gilgit, and has obtained a half promise to this effect. Possibly the fear of being called to account, should any harm happen to a European in his territories, causes the Maharajah to hesitate to sanction an undertaking which might be somewhat perilous. He informed Captain Montgomerie that, during the late winter, his troops in Gilgit had been sleeping; no exacter information could be elicited than what is suggested by this metaphor. If, as Captain Montgomerie thinks likely, the sleep was that which knows no waking, the Sikh garrison of the Maharajah must have been massacred by the hill tribes, in which case there is little hope of our Surveyors being soon able to penetrate into Gilgit.

The Eastern Frontier Party, under the charge of Mr. C. Lane, Chief Civil Assistant, has been employed, throughout the Field Season, in Independent Tipperah. At the end of the preceding season this triangulation had reached a point to the South of Cherra Poonjee, on the confines of Tipperah, where the British Boundary retrogrades Westward to a considerable distance, so that the triangulation would

have had to make an extensive circuit, in its onward progress to Chittagong, had the operations been required to be kept within the British Boundary. Fortunately, Mr. Buckland, the Commissioner of Chittagong, had sufficient influence with the Maharajah of Tipperah to induce him to consent to our operations being carried across his territory, on the direct line to Chittagong.

Mr. Lane proceeded, in the first instance, to Agartolla, the chief town of Tipperah, where the Maharajah resides; and there he succeeded in securing the friendship and good-will of the Prince and his Court to an extent to justify the expectation, which was subsequently realized, of obtaining their cordial assistance and co-operation. Mr. Lane deserves much credit for the tact he has displayed in cultivating amicable relations with the barbarous races that inhabit the hill country of Tipperah, who have long been a terror to the industrious population of the plains within the British Frontier. Mr. Lane has sent a valuable report on the portion of Independent Tipperah traversed by himself and Assistants during the past Field Season, from which extracts will be given in an appendix to this Report.*

* The duty of selecting stations for the Triangulation devolved on Mr. Rossenrode, than whom the party could not have had a better pioneer. The following simple narrative of his operations is extracted from his letters:—"When the Kookies were apprized of my arrival at Heara, they naturally concluded that I had come to apprehend and punish them for the robberies and murders they had perpetrated on our frontier. They hid themselves in the jungles, and left their villages. With much persuasion the Rajah's people brought them to my camp. They watched all my proceedings, and asked me no end of questions. I always keep a man near me to interpret, and I answer every question they put me; all seem satisfied with my answers, and the confidence I place in them. Of course my movements are slow, because my work has the greatest difficulties to contend with; the inhabitants must be conciliated, the site to be fixed upon must be traced and found, and cleared of jungle. To fix on sites at all in this dense and almost uninhabited forest, in which the sun can seldom be seen, is a feat any man may be proud of, especially when the inhabitants try to mislead. I hope to get on faster, when I divest the minds of these savages of all suspicion. I am all day long climbing or descending hills, or wading through water. Wild elephants and buffaloes are numerous, and may be come upon suddenly, when wading through the water-courses. Whenever you see a bamboo signal, avoid the direction it points to, because an unerring arrow is placed there, with a bow strong enough to give an elephant his death blow. The Kookies think of nothing but eating and drinking. Feeding them occasionally is a good plan, and they would become very much attached to you, and follow you like dogs, and, no doubt, prove faithful, and work well, if well fed. Last year I had to deal with the Nagas and Kookies of Cachar, as well as those on the Manipoor frontier. They are the same filthy, naked savages as their brethren in Independent Tipperah. They frequently enquired whether I knew of Captain Guthrie, who made the road from Cachar to Manipur, over the hills, and they said he was the best sahib they had ever met with, and gave them buffaloes, cows, pigs, and goats to eat daily, and grog to drink, so that, even now, they think of his feasts.

The East Calcutta Longitudinal Series Party was formed on the 1st September, 1862, and placed under the charge of Lieutenant Thuillier. The object of this Series is to become the basis for the surveys of the districts of Nuddeah, Jessore, and on, *vid* Dacca, to the Eastern Frontier, along a parallel of latitude slightly North of Calcutta. The publication of the sheets of the Indian Atlas, which embrace these districts, has long been delayed for want of this triangulation.

The party proceeded from Dehra Doon, by steamer and railway, to Calcutta, where they took the field in November, on the termination of the rainy season. Operations were commenced at Chinsurah, on a side of the Calcutta Meridional Series. Much assistance was derived from a carefully executed Map, prepared in the Surveyor General's office, by which Lieutenant Thuillier was enabled to lay out his lines so as to pass through a minimum amount of property. In working through forests and jungle, it is usual, in the first instance, to cut a narrow glade, in a perfectly straight line, through all intermediate obstacles, in the direction of the required station; when this

"I must notice one peculiarity among the Kookies. They all assemble from adjoining villages of the same tribe, and perform the work allotted to them, and share the hire. If you want twenty men from a village, and there are sixty in that village, all will come, whether you wish it or not. If they have to cut jungle, they will all do it; if they are to carry loads, they will divide the twenty loads into sixty, and each man will carry something. One man will never act as a guide, or do any work singly; he must have a companion, and both must be paid. I have tried to break through this habit, but have been told that, if all are not allowed to work, they will not come at all. One might suppose that sixty men would finish the work sooner than twenty, but this is not the case; they eat three times a day, will not begin work before nine, they work until twelve, and then walk off, without asking or telling anybody. They remain away two hours, cooking and eating, and then return and work till an hour before sunset. During the working hours, some are smoking, some making drinking mugs from the bamboo, and others amusing themselves; half are thus occupied, while the remainder are working, and then they change about, and those who are relieved smoke, making drinking mugs, walking sticks, or otherwise amuse themselves. The Rajah's agents have no control over them, and they do not always obey their own Sirdars.

"A Kossyah coolie is really worth four Kookies. When a Kossyah carries a light load, or is lazy, he is called a Kookie by his companions, which annoys him so that he will carry the heaviest load, or tuck up his sleeves, and work in right good earnest. I attribute the Kookie's want of energy and inability to carry loads to the excessive use of spirits, which are distilled in every hut, and partaken freely by every member of the family. There are many Chiefs among the Kookies in the Tipperah Raj. These are all called Rajahs; they have their Wuzeers, Nazirs, and Sirdars, and a number of servants of both sexes. The Kookies have no written language. The Rajahs never pay visits, even to the Maharajah, and their Wuzeers and Nazirs are sent to the Court only on very important occasions."

trial line has been carried over a distance of eight to ten miles, the ground beyond is carefully reconnoitered for a suitable site, to which a line is cut from a convenient point in the trial line; thus two sides and the included angle of a triangle are given, with which data it is easy to ascertain the direct line between the two stations, which is then cleared to obtain mutual visibility. Owing, however, to the valuable nature of the property through which the triangles were carried, it was necessary to run a traverse along each line, with numerous intermediate bends, to avoid houses and orchards. In clearing the final line, great caution was requisite to prevent any tree from being cut down needlessly, a matter of some importance in Bengal, where every tree is more or less valuable, and has to be paid for. These circumstances greatly increased the labour of the preliminary operations, and protracted them over a longer period than is usual.

Further delay was caused in building the principal stations. These are usually, towers, with a central pillar, four feet in diameter, of burnt brick and lime masonry, surrounded by a platform of unburnt bricks and mud, fourteen to sixteen feet square, the whole raised to a height of twenty to forty feet, according to the nature of the obstacles to be overlooked. This structure has been adopted on account of its cheapness, and the rapidity with which it can be constructed; it has hitherto been found to be well adapted for our requirements. But it appears to be inapplicable for the rainy and moist climate of Eastern Bengal, where unburnt bricks rarely have an opportunity of drying sufficiently to be safely used, in raising a structure of such necessarily large dimensions. At one of Lieutenant Thuillier's stations, in consequence of the employment of damp materials in the unburnt brick work, and constant and heavy falls of rain during the construction, the building gave way, under the weight of the instruments and observatory tent. Fortunately, the large Theodolite was packed in its case, and received no injury, but the season was too far advanced for the tower to be rebuilt before the setting in of the monsoon, and as the mishap occurred in the first polygon of the principal triangulation, and there were no more towers ready in advance, the out-turn of work, as measured by the area triangulated, is unusually small, though much valuable experience has been gained, and there is every reason to hope that there will be a full out-turn of work next season. The design of the tower stations will have to be altered to suit the climate

of Eastern Bengal; in lieu of the present solid mass of earthwork, it will be necessary to build a masonry wall around the central pillar, to support the observer's platform.

The Rahoon Meridional Series, under the superintendence of Mr. H. Keelan, First Assistant G. T. Survey, was brought to a termination during the last Field Season, by being extended southwards until it joined the Great Longitudinal Series of Triangles, connecting Calcutta and Karachi. The meridional distance triangulated is sixty-nine miles, by thirteen principal triangles, arranged in polygons, for mutual verification, and covering an area of 1,603 square miles.

This Series has taken six years to accomplish. It was commenced by Mr. Logan, late First Assistant G. T. Survey, but has been chiefly executed by Mr. Keelan. It is double throughout, the triangles being arranged in successive quadrilaterals and polygons of remarkable symmetry. Its meridional length is 457 miles; the principal and secondary triangles cover an area of 23,620 square miles. The computations and maps connected therewith will be completed by the 1st October, when the party will be transferred to the districts on the meridian of 84°, between Sumbulpoor and the East Coast. The total cost of the operations, up to 1st October, will be about Rupees 2,01,609, which gives a rate of Rupees 8-8-6, or about 17 shillings per square mile.

The field operations of the Gurhagurh Series, on the meridian of Umritsur, were brought to a termination at the end of season 1861-62, when it formed a junction with the series of triangles on the same meridian which had been brought up by Captain Rivers as far as Ajmere, from the Great Longitudinal Series. By the 1st October, 1862, the recess computations and charts were completed, and the party was available for transfer elsewhere. This Series has taken five years to complete; the greater portion has been executed by Mr. George Shelverton. Its meridional length is 557 miles; the area covered by the principal and secondary triangles, 19,096 square miles; the cost, Rupees 1,08,212, which gives a rate of Rupees 5-10-8, or about 11 shillings per square mile.

The Sutlej Series follows the left bank of the Sutlej from its junction with the Indus, near Mithunkote, to a side of the Gurhagurh Series near Ferozepoor. It was commenced towards the close of Field Season 1860-61 by Lieutenant Herschel, and was completed

last season by Mr. Shelverton. It is single throughout. The recess computations will be completed by 1st October, when the party will be transferred to the meridian of 80°, to execute the required triangulation between Jubbulpore and Madras. During the past Field Season the triangulation extended over a distance of 112 miles, covering an area of 1,366 square miles. A very creditable amount of secondary triangulation was also executed. The total cost of the Series, up to 1st October, the date of its completion, will be about Rupees 80,743; the total area covered by the trangulation is 8,142 square miles, thus giving a rate of Rupees 9-14-8, or nearly 20 shillings per mile.

The Bombay Party, under the superintendence of Captain Haig, Royal (Bombay) Engineers, having completed the triangulation in Northern Bombay, was deputed to execute a series of triangles to the south of the parallel of Bombay, on the meridian of Mangalore. While the preliminary operations and selection of stations were proceeding, Captain Haig marched to the origin of the Bombay Longitudinal Series, with a view to making this Series double throughout, by adding flank stations, so as to form polygons in parts where there were only single triangles. On reaching the ground, it was found that the ends of the Beder Base Line were, fortunately, in good preservation. Three of the advanced stations had, however, been completely destroyed. Captain Haig judiciously determined to triangulate the Series anew, as far west as the Mangalore meridian. The revision having been executed with a much superior instrument to that employed in the original triangulation, the value of this portion of the Bombay Longitudinal Series is very greatly enhanced.

Having completed this revision, Captain Haig was proceeding with the principal triangulation on the meridian of Mangalore, when an untoward accident brought his operations to an abrupt termination. The large Theodolite was set up for observation on the tower station of Palwan, when, without any previous warning, the tower gave way on one side, causing the fall of the instrument and observatory tent, whereby the instrument was so seriously injured that it is incapable of being again used, until it has been repaired by the makers in England. Fortunately, the horizontal circle, the most valuable portion, appears to have escaped injury, but the vertical circle was destroyed, and the injuries are such that the instrument cannot be repaired in this country. Captain Haig convened a Court of Enquiry to report

on the circumstances; the proceedings of the Court have already been submitted to Government. The Court came to the opinion, in which I entirely concur, that the fall of the tower was occasioned by the sudden and unexpected sinking of the ground below, and that no blame is attributable to Captain Haig, or any other person, for the mishap.

Captain Haig had already turned out a very excellent season's work, comprising thirty-two principal triangles, covering an area of 6,625 square miles, and extending over a length of 260 miles, whereof 66 appertain to the Mangalore meridian, and 194 to the parallel of Bombay.

The Spirit-Levelling Operations were carried on by Mr. Donnelly, Civil Second Assistant, under the superintendence of Lieutenant Thuillier. The party accompanied me to Calcutta, to receive the necessary instructions regarding the programme of the season's operations, which could not be decided on until I had obtained reliable information regarding the Railway levels between Calcutta and Agra. I had hoped to be able to incorporate these into our work, so as to avoid the labour and expense of carrying a line of levels all that distance. During the previous Field Season, a connection had been made, at Agra, with the Railway levels brought up from Calcutta, and the Trigonometrical Survey levels, brought up from the mean sea level at Karachi. The two sets of results differed by about twenty-four feet, and it was hoped that all difference would disappear, on connecting the Railway datum, the site of Howrah Dock, with the mean sea level of the Bay of Bengal.

That level had already been closely ascertained, by a Series of Tidal Observations taken at Kydd's Dock, and subsequently verified by others taken at Kejiri, from the description of which (*vide* footnotes, next page,) it is evident that the mean sea level of the Bay of Bengal may be considered to be known to within a few inches of the truth. On connecting the Railway levels with Kydd's Dock, it was found that there still remained a difference of about twelve feet between the Railway and the Survey height of Agra. On discussing this subject with the Chief Engineer of the Railway, I ascertained that there were several breaks in the Railway levels, that, in consequence of the pressure of other work, there had been no opportunity of preparing a correct and true section of the whole line, and that it was contemplat-

ed to re-level the line, as soon as the Engineers had leisure to do so. I decided, therefore, on deputing the Levelling Party to re-level the line of the Railway, and connect all the Trigonometrical Stations within reach thereof.

Mr. Donnelly made good progress, and accomplished two hundred and forty-two miles of first-class levelling,* forty-one of which had to

* With an Assistant levelling the line, independently, behind him, station by station, after the method described in the published volume of Tables of Heights.

The following description of the connection of Kydd's Dock with the mean sea level of the Bay of Bengal is taken from a Report, dated 1st November, 1854, on the Calcutta Meridional Series, by Colonel Waugh, Surveyor-General, and Superintendent G. T. S. :—

"A Register of the Tides in the River Hoogly is regularly kept at Kydd's Dockyard, near Calcutta, the height of each successive tide being referred to a fixed datum line or zero, which is the bottom or sill stone of the dock, and therefore, an object of invariable character.

"A transcript of the Register of the Tides for two years viz.,—from May, 1846, to April, 1848, having been obtained from the Marine Department, a Monthly Abstract of Mean Tides was deduced therefrom.

"The waters of the ocean would maintain a constant level if undisturbed by the action of the Sun and Moon. La Place has demonstrated that this level is a mean between the highest and lowest state to which the surface of the ocean is reduced by the attraction of those bodies. This mathematical truth is corroborated by observations made on open coasts, from which it results that the mean of high and low water for two consecutive tides represents, very nearly, the level of the sea, and that the average for a lunation is constant within a very small quantity.—*Vide* Professor Whewell's Report, 7 vol., British Association's Report

"An examination of the Abstract of Monthly Mean Tides will, however, show that considerable irregularity exists in the River Hoogly, the monthly means differing as much as six and a-half feet. Now, if the annual average be considered as the true level of the sea, it would follow that for some months, consecutively, the mean height of the River is two and a-half feet below the sea level, a conclusion which is altogether inadmissible.

"The lowest monthly mean tide occurs about February and March, when the fresh water in the river is lowest, and strong Southerly winds do not prevail. The mean tide rises gradually, as the river rises during the South Monsoon until it attains its maximum in September or October, at which time the monthly mean exceeds that of February by no less than six feet. This rise is, obviously, the effect of accumulation, produced by inundation in the valley of the Ganges, and the force of the South-West wind, which dams up the freshes in the long and narrow channel of the river.

"It has been remarked by Colonel Cheape, Chief Engineer, in his Memoirs, dated April, 1825, that the surface of the Salt Water Lake, wherein the rise of the tide is almost imperceptible, would, on account of its wide expanse, represent very accurately the level of the sea with which it communicates. He also observes that Captain Taylor's levels indicate that the surface of the lake in the dry season, is 2*f.* 4·3*ins.* below the mean state of the river. This result corresponds very nearly with the mean tide of the river itself, which in February is 2*f.* 5*ins.* below the level of the annual mean.

"Colonel Cheape further states that the periodic rise of the surface of the lake in the wet season is ten inches. Now, the contemporaneous rise in the mean tide of the river has been shown to be six feet, and as the cause of these elevations is precisely the same, though the effects are in the ratio of seven to

be re-levelled, on account of large discrepancies which were found in the Railway levels. The operations had reached the vicinity of Bha-

one, the greater rise in the river can clearly be attributed only to the narrowness of its channel compared with the bay; it is probable that a considerable portion of the rise of ten inches in the surface of the lake is also due to accumulation; so that, although a rise may be supposed to take place in the level of the sea at the head of the bay, during the continued pressure of the S. W. Monsoon, still, that elevation must be much less than what takes place in the lake, where the effect of this rise is increased by the narrowness of the channel, and the influx of fresh water during the inundation.

"It has been shown that if the annual average of mean water be taken as the sea level, it would lead to the inadmissible conclusion that, in the dry season, the average level of the river at Calcutta is twenty-nine inches below the sea, with which it freely communicates. It has also been shewn that the surface of the Great Salt Water Lake, in the dry season, is on a level, or nearly so, with the mean tide of the river at the same time. It is likewise manifest that the periodic rise of mean tide during the monsoon, to the extent of six feet in the river and ten inches in the lake is occasioned by local causes, independent altogether of the true level of the sea, which is a constant level, and these causes, it appears, operating in narrow channels, are capable of producing exaggerated results in the proportion of seven to one, showing clearly the fact of accumulation. Hence the conclusion is inevitable, that the lowest monthly mean tide of the river, observed in February and March, represents the nearest approximation to the actual sea level, and that the rise of mean tide at Calcutta during other months, may fairly be ascribed to disturbing causes of an inland character, altogether independent of the true and constant level of the ocean. The variable character of the disturbing causes is shewn by the fact that the monthly means of corresponding months for the two years differ considerably, except in the months of February and March, the monthly mean tides of which are very accordant.

"Proceeding upon this principle, I have used the following observations to refer the datum line in Kydd's Dock to the sea level:—

"Mean Tide	February,	1847,	above datum,	as measured on	Guage, ...	8·11 feet.
"	March,	"	"	"	...	8·45 "
"	February,	1848,	"	"	...	8·48 "
"	March,	"	"	"	...	8·50 "
"	February,	1850,	"	"	...	8·28 "
"	March,	"	"	"	...	8·62 "
"	February,	1851,	"	"	...	7·94 "
"	March,	"	"	"	...	8·36 "
				Mean,	...	8·343 feet.

"Correction for Error of Graduation on Guage by Mr. Bedford's Measurements, ... 0·233 feet.

"By Tides measured at Calcutta in February and March, Mean Sea Level above datum, ... 8·576 feet.

"Again, in the years 1850 and 1851, Mr. Bedford, the Marine Surveyor, took a series of tidal observations at Kejiri, and connecting this point by a series of levels with Kydd's Dock, found that the datum line at the latter point is 9·07 feet below the sea level. Mr. Bedford's observations from which this result is derived, are as follows:—

	feet.	inches.
"Mean Height of Sea Level above the datum line at Kejiri, ...	8	9·75
"Datum Line at Kejiri above that of Kydd's Guage, ...	0	2·88
"Sea Level above the datum line of Kydd's Guage, ...	9	0·63

"Which reduced to decimals of a foot becomes, ... 9·053

gulpore, when Mr. Donnelly was compelled, by severe illness, to close work.

Mean Levels of the River's mouth at Kejiri, at Neap Tides, for the years 1850 *and* 1851, *excluding the South-West Monsoon.*

Months.	Highest Low Water.		Lowest High Water.		Mean.	
1850.	*Feet.*	*Ins.*	*Feet.*	*Ins.*	*Feet.*	*Ins.*
January,	5	0	11	9	8	4½
	4	0	11	9	7	10½
February,	5	6	11	0	8	3
	4	9	11	6	8	1½
March,	6	0	11	0	8	0
	4	9	12	0	8	4½
April,	6	9	11	0	8	10½
	4	9	12	6	8	7½
May,	6	9	12	0	9	4½
	5	3	13	0	9	1½
June,	6	6	13	3	9	10½
	6	0	14	9	10	4½
November,	7	0	12	3	9	7½
	4	9	13	0	8	10½
December,	5	9	11	9	8	9
	4	6	12	3	9	4½
1851.						
January,	4	6	11	9	8	1½
	4	3	11	0	7	7½
February,	4	3	11	3	7	9
	5	0	10	3	7	7½
March,	4	9	11	0	7	10½
	6	3	11	9	9	0
April,	5	3	12	9	9	0
	7	0	10	6	8	9
May,	5	6	12	9	9	1½
	7	0	12	6	9	9
June,	6	0	14	6	10	3
	6	9	13	3	10	0

During the year under review, I was called upon to collect all the available data of levels, existing in the Public Works, Railway, and

"Which differs from my determination by half a foot; but, if the tides at Kejiri for February and March be alone taken into account, at which period the inland waters flowing seaward are lowest, the result would agree with that derived from my discussion of the tides at Calcutta to about one inch."

Survey Offices, all over India, in order to reduce them to a common datum. As a first step towards this desirable measure, I have published a volume of Tables of Levels, based on the Spirit-Levelling Operations of this Survey, and reduced to the mean sea level of Karachi Harbour, as their datum. Additional volumes will be published as soon as possible. They will enable officers of the Public Works and Railway Departments to reduce their levels to the mean sea, by connecting them with the nearest Bench Mark, or Station, of the Trigonometrical Survey. In most instances, however, the business of connecting will probably devolve on the Survey Department. At present, we have only one Levelling Party, which is employed in Bengal; I therefore submitted a project for the formation of other parties to carry on operations, simultaneously, in the Madras and Bombay Presidencies, as the only means of speedily accomplishing an operation, of which the practical value will be greatly enhanced by early completion. Unfortunately, financial reasons have interfered to prevent this proposal from being sanctioned.

I now proceed to report on the Astronomical Observations for the determination of the Latitude and Longitude of the Andaman Islands, which were instituted on a representation by the Superintendent of Port Blair, that the erroneous positions assigned to some of these Islands, in the published Charts, endangered the safety of ships sailing between Calcutta and Singapore. Under the orders of Government, in the Home Department, the Surveyor General had deputed a Surveyor, Mr. Nicolson, to conduct the necessary observations, the superintendence of which was subsequently transferred to the Trigonometrical branch of the Survey.

Mr. Nicolson started from Calcutta early in December, 1861, to reconnoitre the Coco and Andaman Islands. He found that, in order to take a complete Series of Astronomical Observations at the Great Coco, it would be necessary to have a steamer placed at his disposal for some weeks, to keep up his communication with Port Blair, and bring the necessary supplies for his party.

About this time, a communication was received from the Bombay Government, representing that there was as much doubt about the accuracy of the position of Port Blair, as of that of the Coco Islands. Under these circumstances, it seemed advisable that Mr. Nicolson should begin operations by fixing Port Blair, in order that the proposed

operations might be commenced at the place where the greatest facilities for their execution existed.

The inaccuracy of the present Charts of the islands lying between Sumatra and Burma being admitted on all sides, it appeared necessary, in the absence of any regular survey of those islands, to fix, by astronomical observations, the positions of Acheen Head, Port Blair, the Great Coco, or the Preparis Island, and an island in each of the other groups, intermediate between Acheen Head and Cape Negrais. It is believed that the relative positions of the mutually visible islands of each group are already correctly shown on the Charts; consequently, by determining the absolute position of a point in each group, it would be possible to rectify the existing Charts, without making a general re-survey.

Mr. Nicolson, having completed his reconnoissance, returned to Calcutta in February, 1862, by which time one of the large 8-foot astronomical circles of the Trigonometrical Survey had been got ready, and a portable observatory, with rotating dome, constructed for the observations. There was no good astronomical telescope available in the stores of the Mathematical Instrument Department; consequently, Mr. Nicolson was directed to take all his observations, whether of occultations, eclipses, or moon culminations, with the telescope of the astronomical circle, which he could point to any part of the sky, through the aperture in the rotating dome of the observatory. Owing, however, to the small number of occultations and culminations which occur monthly, and the risk of losing some of them in cloudy weather, Mr. Nicolson was directed to base his observations for Longitude chiefly on the measurement of lunar zenith distances, for which the astronomical circle is well adapted. He was supplied with an astronomical clock, and all other necessary instruments, from the Calcutta Observatory.

In May, 1862, Mr. Nicolson had set up his observatory at Port Blair, and was ready to commence observations. Unfortunately, the season of fine weather had then nearly terminated; the Monsoon set in with unusual severity, nights favourable for observing were few and far between, and, consequently, several months elapsed before the whole of the necessary observations for Latitude and Longitude were completed. The work was further impeded by the delays attendant on postal communication between Calcutta and Port Blair, making it very

difficult for me to exercise that degree of supervision over the operations, which their delicate and difficult nature required.

By the end of 1862, Mr. Nicolson reported that he had taken a sufficient number of observations to fix the position of Port Blair; he, therefore, applied for a vessel to be placed at his disposal to enable him to proceed to fix the positions of the Great Coco, and other islands. Owing to postal and other delays, it was not until the end of February, 1863, on my return from Vizagapatam, that I learnt from the Marine Department that no vessel was available, nor could one be got ready before the fine weather season would have terminated.

From the same communication I also learnt that the Secretary of State for India had ordered a complete Maritime Survey of the Andaman Islands to be executed. Being then in Calcutta, I went to Captain Rennie, the Secretary to Government of India, Marine Department, and was informed that, under instructions from the Admiralty Hydrographer, it had been determined to find the differences of Longitude between the various groups of islands, chronometrically, by a battery of thirteen or fourteen chronometers.

The circumstances under which it was originally proposed to fix a series of positions by astronomical observations had thus entirely altered. The complete Maritime Survey, which has been ordered by the Right Hon. the Secretary of State for India, renders further astronomical observations unnecessary. The determinations of differences of Longitude, which are the only really difficult portion of the work, can be done chronometrically by the Marine Surveyors, with much greater rapidity and economy, and, probably, even with greater accuracy, than by the best astronomical observations for absolute Longitude.

Consequently, in March last I desired Mr. Nicolson to restrict his operations to taking as many more observations for the determination of the Longitude of Port Blair as could be obtained before the setting in of the monsoon, and then to return to Calcutta. He reached the Presidency in June, and has ever since been employed in reducing his observations. They consist of 32 lunar culminations, 136 lunar zenith distances, 130 transits of clock stars, and 162 meridional zenith distances of stars for Latitude, observed up to the 12th March, when the astronomical clock met with an accident, and Mr. Nicolson was afterwards obliged to employ a chronometer. His subsequent observ-

ations are, consequently, not as valuable as the earlier ones; they consist of 9 culminations, 64 lunar zenith distances, and 36 clock stars. The whole of the Latitude observations have been reduced, and found exceedingly satisfactory. There has not yet been leisure to reduce more than a few of the observations for Longitude, but the results obtained hitherto are satisfactory. The final resulting Longitude will be communicated for publication in the *Calcutta Gazette* as soon as ascertained. It should serve as an excellent datum for the proposed Maritime Surveys, and save the expense of a series of voyages between Madras and Port Blair, which would otherwise have to be incurred to obtain a good chronometric determination of the Longitude of Port Blair.

[A tabular abstract statement of the field-work executed by each party during the official year 1862-3 is given on the next page.]

The Computing Officer has been employed in a variety of preliminary operations, which are necessary to form the basis of a general reduction of the whole of the principal triangulation of this Survey, which will shortly become necessary, now that almost the whole of the triangulation of the tracts of country comprised in the great quadrilateral figure connecting Calcutta, Karachi, Attok, and Purnea, is completed. Though the triangulation has been executed with the very best instruments, and though the system of observation which was introduced into this Department by Colonel Everest, is more rigorous and accurate than that of any European Survey, it is evident that, in consequence of the vast length of each Series, and the imperfections which necessarily attend whatever is the work of human hands, each Series generates a certain amount of error, which becomes apparent as linear error, on the termination of the Series on a measured base line, while on the close of a circuit formed by two Meridional Series, and the portions of the connecting Longitudinal Series at their extremities, it produces errors of Latitude, Longitude, and Azimuth. The dispersion of these errors in such a manner as to obtain the most probable results of the whole, giving its due weight to each fact of observation, and taking into consideration the bearing of every such fact on all the rest, is a matter of great intricacy and difficulty, on which it will be necessary for me to consult with the ablest mathematicians of the present day in Europe, before deciding on the system to be finally adopted. Meanwhile, the necessary preliminaries

The Out-turn of work executed by each party during the field operations of the official year 1862-63 *is shown in the following Abstract :—*

Statistics.	Kashmir Series.	Coast Series.	Sutlej Series.	East Calcutta Longitdal. Series.	Rahoon Meridional Series.	Eastern Frontier Series.	Bombay Party.	Total Out-turn of Work.
Principal Triangles,	...	19	29	4	13	16	32	113
Average error of Principal Triangles in seconds,	...	0. 94	0″.43	0″.44	0″.46	0″.43	0″.89	0″.65 average.
Observed Azimuths,	...	1	1	..	2	...	1	5
Secondary Triangles with all 3 Angles observed,	...	10	132	...	16	...	32	190
Area of Principal Triangulation, square miles,	..	256	1366	220	1603	884	6625	10,954
„ Secondary Triangulation,	10,500	...	4816	...	950	263	1510	18,139
„ Topographically Surveyed, scale 4 miles = 1 inch, square miles,	10,400	...	...	...	...	...	...	10,400
Intersected Points,	...	12	112	...	18	22	110	274
Length of Principal Triangulation in miles,	...	...	112	20	69	49	260	490
„ Secondary ditto,	...	...	340	...	72	...	100	512
Miles of Rays cleared between Principal Stations,	...	...	300	253	159	...	...	712
Towers built for Principal Stations,	...	...	11	5	5	...	2	23
Platforms ditto,	...	12	...	...	6	17	44	79
Platforms built for Secondary Stations,	...	...	95	...	...	...	...	95
Length of Triangulation laid out in advance in miles,	...	...	...	45	...	77	150	272
Principal Stations selected in advance,	...	...	...	8	...	17	36	61

for the eventual calculations are being carefully elaborated by Lieutenant Herschel, to whom I am indebted for numerous very valuable suggestions, and for co-operation as cordial as it has been unintermittent.

While the practical operations of this department may be confidently pronounced to be of a superior order to similar operations in any other part of the globe, it must, on the other hand, be admitted, that the theoretical applications, for the reduction of the triangulation, have not kept pace with recent improvements in geodetical science, which have been introduced into some European Surveys. The method which has hitherto been employed for reducing the observed angles, so as to satisfy all the equations of condition of each figure, though a great improvement on any previous method, has had, in its turn, to give way to the subsequently discovered method of minimum squares. The algebraical solution of the equations necessary to satisfy the condition that the sum of the squares of the errors shall be a minimum, is by no means difficult, but hitherto there has been no practical adaptation of it in this Survey, chiefly owing to the pressure of other and more urgent business, on those alone capable of dealing with the subject. Much progress has, however, been recently made in this direction, and I am indebted to Lieutenant Herschel for devising methods of calculation, which will enable the reduction of our figures to be effected, according to the new and rigorous system, by native computers possessing little more than a knowledge of arithmetic, with even greater facility than the less refined methods of reduction, which have hitherto been employed.

The drawing office has been chiefly employed in compiling maps of the dominions subject to the Maharajah of Kashmir, from the plane table sheets sent in by Captain Montgomerie. A new Chart of the Triangulation of this Survey, up to date, has also been prepared, and a Chart to illustrate the volume of Tables of Heights recently published; both these Charts were lithographed in the office of the Surveyor General, Calcutta. Nine original preliminary Charts of the triangulation, in various parts of India, have been prepared, in duplicate, for the use of the Surveyor General's Office, and the Geographer to the Right Hon. the Secretary of State for India. The Photographic apparatus is also being usefully employed in copying and reducing maps, and in furnishing preliminary copies for current use, until the

originals are engraved and published. Owing, however, to the small establishments at my disposal, the photography is necessarily restricted to the short period of the recess of the Kashmir Party, three to four months, when the services of our best photographer, Captain Melville, are available for their management.

In the Instrumental Department, great advantages may be expected by the appointment recently made by the Right Hon. the Secretary of State for India, of an officer, Colonel Strange, to superintend the construction of the new great Theodolite, and various astronomical instruments, which are being prepared in England for this department. When they are received in India, we shall be in a position to undertake the necessary operations for ascertaining our Longitudes, in connection with the Observatory at Greenwich, by means of the Electric Telegraph, which is now brought across from the Mediterranean to India.

On the Antiquities of Guzerat.—*By Captain* H. Mackenzie.

(Communicated by the Punjab Auxiliary Committee of the Asiatic Society.)

[*Received 16th February*, 1864.]

Guzerat City and Fort.—There are few antiquities in this district and of these few, little is known. Guzerat itself is considered to be of great antiquity: a town had existed here in former ages. I have not heard of any antique coins having been found in Guzerat itself, by which any perfectly trustworthy dates might be fixed, but there seems no reason to doubt that it was a place of some importance prior to Greek invasion. A Hindoo Raja named Raja Buchanpal, a Soorujbunsee, who emigrated from the lower Gangetic Doab to the Punjab, is said to have first built a city here, and called it Oodanuggree, the Everlasting or Sweet Smelling City. It is not known when this city ceased to exist, but it is recorded that in Sumbut 175 or 1740 years ago, Ranee Guzran, wife of Raja Budr Sain, (son of Raja Risaloo of Sealkote) rebuilt the city, and called it Guzran Nuggree. This too passed away. In Sumbut 1350, Sultan Mahmud Guzniwalla laid it waste, and it seems to have remained so until 285 years afterwards, when the Emperor Akbur Shah chose the ancient mound as the site for a stronghold.