

ART. VIII.—*Trigonometrical Survey—India: Return to an order of the Hon'ble the House of Commons, dated 12th February, 1850, for returns "of full and detailed Reports of the extent and nature of the operations and expenditure connected with the Grand Trigonometrical Survey of India, and of the Grand Triangulation thereof, for the Measurements of the Arcs of the Meridian, from the year the first Base was measured to the latest date;" &c. &c. 1851.*

WE have been favoured with a copy of the report of Colonel Waugh, the Surveyor-General of India, which was drawn up in obedience to an order of the House of Commons, on the motion of our indefatigable friend, Mr. Joseph Hume, and ordered to be printed on the 15th of April last. This Blue Book, as the *Bombay Times* expresses it, is more like a lively article for a review than what we are generally accustomed to in publications of this nature; and, as it is a subject intimately connected with the prosperity of the country, and, we presume, of considerable interest to our readers, we shall endeavour to present them with a full abstract of the progress, that has hitherto been made in this magnificent national work.

In a very recent number of this journal,\* we had occasion to speak of the survey operations, as now in force, under the Revenue Department; and we then alluded to the account of the great Trigonometrical Survey, which was given in one of our early numbers.† Those, who may have perused the latter article, will find the succinct and able report of Colonel Waugh's, on the progress and expense of this great geodetic undertaking—which, at the present time, extends from Cape Comorin to Thibet, and from the meridian of Calcutta to that of Peshawur—to afford such a popular description of the nature and extent of the operations, and the manner in which they have been achieved, as cannot fail to be both instructive and interesting.

We believe that there are very few persons, even in India, who have any notion whatever of what the Trigonometrical Survey really is, or what it does for geography or science: or who can comprehend what has been already done, and why it has not long since been brought to a conclusion.

\* No. XXXI. September, 1851: Art. VIII.

† No. VII. September, 1845: Art. III.

We have even heard of men, who believed and argued that India might be trigonometrically covered in five years! To such persons we would commend the Report before us. It is evidently written for the million—or for members of Parliament, who may be supposed to require something not over-professional or scientific; and we venture to believe, that it will be the means of placing the question in a more practical and rational view before the public in general, than has ever yet been done. The results of the Trigonometrical Survey, on this side of India, are scarcely published to the world as yet; which may account for the uncertainty and ignorance, which prevail regarding its utility, and even its progress or existence; but from the details now published in the Report, it will be evident, that, independently of the contributions to science afforded, we are speedily about to derive immense benefit from an accession of geographical materials, all based on this operation, which will furnish maps of the very first order; and for the want of which, many may have had good cause to regret that this Survey, so inexplicable in its proceedings, and so apparently dilatory in its movements, did not take place years ago.

The Report—which, with its tabular statements, and appendix, occupies sixty-one folio pages—opens with an account of the commencement of the operations in 1801, under the superintendence of Colonel Lambton, who drew up his project for a trigonometrical survey across the Peninsula, immediately after the fall of Seringapatam. On the recommendation of the Duke of Wellington, and approval of Lord Clive, then Governor of Madras, this proposal was sanctioned by Government; and to the cordial support of the *Iron Duke*, the Trigonometrical Survey of India may be said to owe its origin. But we must allow the Report to speak for itself, and shew what the equipments were in those days, which were considered the *ne plus ultra* of perfection. In the account previously given in No. VII. of this *Review*, the instruments first employed, and the source from whence they were obtained, have been spoken of at considerable length; and the general principles and objects of a Trigonometrical Survey have been detailed so freely, that our present intention is to treat more of the executive results, and the present state of the operations, and the means by which they have been prosecuted so far.

The instruments, used in Colonel Lambton's operations, were a 36 inch theodolite, by Cary; an 18 inch repeating theodolite, by the same maker; a 5-foot zenith sector, by Ramsden; two steel chains, by the same maker; a standard brass scale, by Cary; and several small theodolites, by different makers, for minor purposes. These instruments were the finest that the

state of art. at the commencement of this century. could produce ; but the great theodolite received an injury in the year 1808, while it was being hoisted to the summit of a lofty pagoda in Tanjore. This injury was repaired by Colonel Lambton himself; who, with the duties of astronomer and surveyor, had, throughout his operations, to combine those of a mathematical instrument-maker. In Europe great facilities exist for repairing and preserving instruments; but in judging of geodetical operations in India, more particularly in Colonel Lambton's time, allowances must be made for want of aid in every part of the work.

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It must also be borne in mind, that for a long period these operations were frequently interrupted by the disturbed political condition of the country, which was often the scene of warlike operations; for it was not until the Marquis of Hastings destroyed the Pindari confederacies in 1818, that the Peninsula and Dekhan settled down into repose. The mysterious character of the instruments and operations, as well as the planting of flags and signals, have always more or less awakened the apprehensions or excited the jealousy of the native princes; it requires, therefore, no ordinary tact, firmness, patience, and good nature on the part of the head of the department to conciliate good will.

Shortly after the commencement of his labours, Colonel Lambton was called on to demonstrate the utility of his work. It was asserted that surveys on an astronomical basis would be equally accurate, and more economical than geodetical operations. The futility of these views was ably exposed by the Colonel: and, being supported by the Astronomer Royal of the day, the Rev. N. Maskelyne, all open opposition was withdrawn; and even Major Rennell, who was the chief advocate of the astronomical basis, afterwards concurred in the trigonometrical system. As this view of the subject has been confirmed by the practical testimony of every nation in Europe, and the importance of trigonometrical operations is now universally admitted by all practical scientific men, as the only trustworthy basis for extensive national surveys, it is unnecessary to discuss the first principles any further in this place. They are only adverted to in illustration of the formidable prejudices the Trigonometrical Survey in India has all along had to contend with. The Honourable the Court of Directors, however, when once convinced of the important practical utility of the work, have ever since continued its firm and powerful supporters: and, in the words of the *Edinburgh Review*, "their liberal and enlarged views cannot be too highly commended."

With reference to the length of time occupied by Colonel Lambton's operations, it may be proper to remark that, in addition to the interruptions caused by the disturbed state of India, that officer's establishment was on the most circumscribed scale, and his arrangements were often thwarted by the Finance Committee at Madras. It required, indeed, all the powerful support of the Honourable Court of Directors, and of influential men in office in India, to keep the operations on foot, even on this limited scale. Amongst those most instrumental in furthering the great objects he had in view, were the Duke of Wellington, at that time Colonel Wellesley; Lord Clive; Mr. Josiah Webb, Chief Secretary; Lord William Bentinck; Mr. W. Petrie, Member of Council; Mr. Andrew Scott, First Judge of Appeal; Colonel Munro, Quartermaster-General; Sir Thomas Munro; Lords Minto and Hastings, and Mr. H. Russel, Resident of Hyderabad; from all of whom he received cordial support and sympathy in his arduous and useful undertaking.

Colonel Lambton remained at his post till his death, which occurred on

the 20th January, 1823, at the age of 70; at Hinghan Ghât, about 50 miles from the city of Nagpore in the Dekhan.

The best proofs of the soundness of these views, and for the advocacy of nothing short of a general trigonometrical system, were the facts established by Colonel Lambton's operations. An error, of no less a quantity than forty miles in the breadth of the Peninsula, as previously laid down astronomically in the way Major Rennell proposed, was detected. All the principal places in the old maps, fixed astronomically, were found considerably out of position;—Arcot being out 10 miles, and Hydrabad no less than 11 in latitude, and 32 in longitude. Although such errors could scarcely be committed in the present day, even with instruments within the reach of almost every amateur; still it sufficiently shews, that, for the survey of an enormous empire, the trigonometrical system is not only the most rigorous, but the most economical in the end. In addition to the manuscript general reports deposited at the India House, condensed accounts of the more scientific part of Colonel Lambton's labours have been published at various times in the Transactions of the Asiatic Society, and the Philosophical Transactions of the Royal Society.\* The early portions only of his works were reviewed by the late Professor Playfair in 1813, in the 21st volume of the *Edinburgh Review*; and they have been pronounced by competent judges—so writes Colonel Waugh—to be equal to the best geodetical operations of those days:—

It would be impracticable to discuss the professional merits of those operations in a more succinct form than Colonel Lambton himself has done in his published statements, to which reference can be made by those desirous of possessing complete information regarding the character of his work. It only remains to notice the financial part of the question, viz., the extent of area triangulated, and its cost, which come more especially within the scope of this Report.

Colonel Lambton, between the years 1802 and 1815, covered the whole country as high as 18° of latitude, with a net-work of triangles, whereby the Peninsula was completed from Goa on the west to Masulipatam on the east, with all the interior country from Cape Comorin to the southern boundaries of the Nizam's and Mahratta territories. Subsequent to this achievement, the Great Arc triangulation was extended nearly to Takal Khera, in latitude 21° 6'. The greater part of the Nizam's eastern territories were triangulated by meridional series between the Kistnah and Godavery; and considerable progress was made in the longitudinal series from the Beder base towards

* Vide Transactions of the Asiatic Society, vol. 7,	pp. 312	—	337
Ditto	" 8	" 137	—193
Ditto	" 10	" 291	—384
Ditto	" 12	" 1	—101
Ditto	" 12	" 286	—356
Ditto	" 13	" 1	—127

Bombay. All these operations are described in minute detail in the volumes of the General Report at the India House.

The area, comprised by the whole of the operations prosecuted during the time Colonel Lambton was superintendent, aggregates 165,342 square miles, as shown in the accompanying statement, marked (C). The expense incurred amounted to 8,85,977 Company's rupees. Consequently, the rate at which the triangulations have been executed, averages Company's rupees 5-0-10, or less than 10 shillings per square mile, which cannot but be considered remarkably cheap.—more especially as this calculation includes the expense of Dr. Voysey's geological researches.

From the circumstance of Colonel Lambton's operations having commenced in Southern India arises the great superiority of the maps of the Madras Presidency; the atlas sheets whereof, published by order of the Honourable East India Company, are nearly complete. This part of India was surveyed in detail upon the basis of Colonel Lambton's operations, and on a scale of one mile per inch, by the officers and sub-assistants trained at the military surveying schools. No complete record exists in this office of the cost of most of these surveys: but, judging from the analogous operations of the Hyderabad survey, the expense appears to have averaged about six Company's rupees, or less than 12s. per square mile.

We now come to an important era in the survey of India, viz., the transfer of the control of its operations to the supreme Government of India, and the appointment of an assistant worthy of acting under such a man as Lambton, and eventually of becoming his successor. This resolution of the Marquis of Hastings, the Governor-General, who was impressed with a well-founded conviction of the importance and utility of the Trigonometrical Survey, was made known in a letter written by Lieut.-Colonel Young, Secretary to the Governor-General in the Military Department, and bears date the 25th October, 1817. This masterly State document is so well worth perusal, that we give it entire. It is seldom that we now meet with such liberal sentiments, or such statesmanlike views:—

It is well known to Government, that since the year 1801-2, Lieut.-Colonel Lambton, of His Majesty's 33rd Regiment, has been employed under the Presidency of Fort St. George, in a series of trigonometrical operations, instituted originally for the purposes of establishing, with perfect accuracy, certain important points in the geography of the Peninsula, and of ascertaining the length of a degree of the meridian in those latitudes. The success, with which that learned person's labours have been conducted, naturally led his employers to extend their views, and to desire that the Lieut.-Colonel's operations should gradually be expanded, so as to embrace nearly the whole south of India, and then be pushed progressively towards the north.

Those employers, it is needless to mention, are the Hon. Court of Directors. This magnificent work was projected, and is carried on under their particular auspices and munificent patronage, in a manner befitting that dignified body: their perseverance in this grand enterprize is worthy of the splendid original design: and this single public act has raised the name of the English East India Company, in the eyes of the scientific world, to a level with those of the great sovereigns of Europe, who have been their only rivals in similar undertakings.

Independently of the benefits reaped by mathematical science from labours like Lieut.-Colonel Lambton's, in regard to the more accurate knowledge of the figure of the earth, as deduced from his measurements of an arc of the meridian—the most important practical advantages must obviously accrue from the prosecution of this Trigonometrical Survey on its present plan. There is no other solid basis, on which accurate geography can so well be founded. The primary triangles, thus spread over this vast country, establish almost beyond error a multitude of points; and the spaces comprehended within these, when filled up by the details of subordinate surveys, will afford to the Lieut.-Colonel's employers, and, through their liberal communication, to the world, a map without a parallel, whether in relation to its accuracy, to its extensiveness, or to the unity of the effort, by which it will have been achieved. The importance, attached to such works by the economists and statesmen, as well as by the learned of Europe, is proved by the perseverance for so many years of England and France in similar undertakings. The Governor-General ventures to speak to this point with no ordinary confidence, because it came under his personal knowledge, when he had the honour of presiding over the Royal Ordnance department. Under the superintendence of that Board, and the patronage of His present Majesty, the great Trigonometrical Survey of Britain commenced above 30 years ago, under General Roy of the Royal Engineers; and it is continued unremittingly at the present day by Colonel Mudge, of the Royal Artillery. His Royal Highness the Commander-in-Chief, actuated by consideration for the magnitude and interesting nature of Lieut.-Colonel Lambton's parallel operations in India, has acceded to the wishes of the Hon. Company, by granting the Lieut. Colonel unlimited leave of absence, although his regiment has long since returned to England.

Such is the scale and character of this splendid undertaking. The great extent, to which the Trigonometrical Survey has now reached, appears to the Governor-General to indicate the time as having arrived, when expediency requires that it be taken under the direct and immediate control of the Supreme Government. His Lordship is persuaded, that its operations will henceforward be greatly facilitated by this measure; for they have already passed the British boundary into the territories of His Highness the Nizam, and, the Governor General trusts, will now progressively advance into Hindūstan and the east, until the net of triangles shall be woven over the whole continent of India. In the meantime, all those public British authorities, with whom, for obvious purposes, Lieut.-Colonel Lambton must now hold correspondence and intercourse, are under the sole orders of the Governor-General in Council; and they will be enabled to give immediate attention to his wants and wishes in cases where otherwise a reference to the Governor-in-Council of Fort St. George (his immediate superior) must be followed by a further reference to Bengal. But, besides these considerations of convenience and facilitation, the Governor-General is of opinion that others of a higher nature lead to the same inference. His Lordship has no scruple in avowing his sentiments, that an undertaking of such national importance and general interest is only in its appropriate place, when drawn under the direct orders and countenance of the supreme authority in British India.

The Governor-General is not unaware, that, with minds of a certain order such a step as his Lordship purposes may be open to the idle imputation of vainly seeking to partake the gale of public favour and applause, which the labours of Lieut.-Colonel Lambton have recently attracted. To some it may possibly seem to savour of ostentation, that the direct countenance of the Supreme Government has been withheld until the moment when

the learned Societies of England and France, the first in the world, have borne illustrious testimony to the character of this Survey, and the merits of its conductor, by enrolling his name in the distinguished lists of their members. But the discerning candour of the superior authorities, who sit in judgment on the acts of the Governments in India, will lead them to a juster interpretation of the conduct of their servants. The analogy of the Governor-General's procedure to their own resolution in the parallel case of the General Survey Department will not escape the notice of the Honourable Court; they will mark the striking practical facilitation afforded to Colonel Lambton's operations by their transfer, at this period of progress, to the only authority politically connected with those countries within which the Survey has arrived; and, if it should appear that from more immediate contact with the Supreme Government, that even the smallest portion of additional encouragement, or of respectability in the eyes of the world, can be conferred on Lieut. Colonel Lambton, or his labours, the Governor-General is well assured that the transfer will be approved and applauded even on that single ground.

I am now therefore formally to communicate to the Honourable the Vice-President in Council the resolution of the Governor-General (in his absence from the seat of his Government), for effecting the transfer of the Trigonometrical Survey of India from under the presidency at Fort St. George, to the immediate direction and control of the Governor-General in Council of Fort William: the transfer to take effect from the 1st January, 1818. The Governor-General in furtherance of the determination has been pleased to direct, 1st. That from that date Lieut. Colonel Lambton, and all persons connected with the establishment of the Survey, shall be considered as under the sole control of the Supreme Government, and as belonging to the Bengal Establishment. 2nd. That the Survey be denominated the Great Trigonometrical Survey of India, and Lieut. Colonel Lambton the superintendent thereof. 3d. That all the salaries, allowances, gratuities, reversionary claims to recompense or pensionary support, and, generally, all right or reasonable privileges, which any of the persons now attached to the Survey possess from the Government of Fort St. George, shall be admitted in the fullest manner as binding on the Government of Bengal. 4th. That a duly qualified officer be appointed chief assistant to the superintendent, on a salary (besides the pay, full batta, gratuity and tent allowance of his regimental rank) of 600 sicca rupees, which is not to be subjected to deduction for any broken periods, that the Survey may not actually be employed in the field. 5th. That a person skilled in natural science, and capable of affording medical and surgical aid to the Survey establishment, be permanently attached to it as geologist and surgeon, on a salary of 600 sicca rupees. 6th. That the Trigonometrical Survey be considered wholly distinct from, and independent of, the Surveyor-General of India; but as this measure is adopted out of respect to the rank, talents and eminent services of the present superintendent, in the event of that officer ceasing to hold the direction of the Trigonometrical Survey, the Governor-General will consider this regulation as open to revision. 7th. That the whole expense of this Survey be considered a civil charge. 8th. That the Trigonometrical Survey be placed immediately under the public department, and that all reports, instructions or other correspondence regarding it be conducted through the Secretary to Government in that department. 9th. That all records, documents, plans, &c. connected with the Surveys, which may now be deposited at Fort St. George be removed to Bengal as soon as possible, when arrangements will be made for their reception and custody in the public department.

On these several provisions the Governor General does not conceive that it is necessary for him to make any particular remarks, except as to the 4th and 5th articles. His Lordship desires to observe on the 4th, that the intense mental and bodily labour of conducting the Trigonometrical Survey has been performed heretofore by Colonel Lambton alone, and, that the rank and the advancing age of that zealous and distinguished person now demand some relief from such severe fatigue. But, independently of the consideration so eminently due to the individual, the Governor-General is decidedly of opinion that the strongest reasons of public expediency exist for associating an assistant in this great employment. The mathematical qualifications for conducting such labours are of a very high order, and possessed by few in India. They require to have been kept up by habitual exercise; and moreover the extreme accuracy, indispensable in trigonometrical calculations on the scale of Colonel Lambton's undertaking, demands a dexterity in the use of the instruments, and a scrupulous degree of attention in what may be termed the practical part of the labour, which can scarcely be conceived by persons unaccustomed to it, and which is to be learnt only by a rigorous apprenticeship. The regretted time must one day arrive when Lieut. Colonel Lambton's task is to devolve on a successor. It would not be wise to trust to chance for producing one fully equal to the duty at the moment when he is wanted; neither is it right that this important Survey should thus hang on the life of a single individual. Lieut. Colonel Lambton himself has urged this point to the Governor-General, and has pressed on his Lordship the propriety of giving him an associate. The Governor-General therefore has selected for this office, Captain Everest, of the artillery, of whose eminent degree of science as a mathematician he is assured, and whose talents are known to the Vice-President in Council both by his surveys in Java, under the Quarter-master General's department, and by his successful exertions as an engineer, in recently clearing the navigation of the Matabanga and other rivers. His Lordship purpose to grant Captain Everest a salary nearly similar to that of an ordinary land surveyor, or 600. rupees besides regimental allowances, to be considered, like all the other expenses of the Survey, a civil charge.

The selection of Captain Everest, as an associate with Lambton, and the reasons given in the above extract for so doing, must be acknowledged to have been peculiarly felicitous. The increasing age and infirmities of the Father of Indian Geodesy demanded, that some provision should be made for relieving him of at least some portion of the corporeal and mental fatigues necessarily attending on his situation: and, as the Governor-General expressed it, "it would not be wise to trust 'to chance for producing a successor fully equal to the duty 'at the moment when he is wanted, neither is it right that 'this important Survey should thus hang on the life of a 'single individual.'" Thus, for nearly five years, prior to Lambton's death, Everest had the advantage of a close intimacy with him: and, as remarked by Colonel Waugh, "to the mathematical acquirements, practical genius, and undaunted resolution of Colonel Everest, in contending against difficulties, is to be ascribed the high state of efficiency afterwards attained, and



‘now existing undiminished, in this hard-working establishment.’

The following extract shews the nature of Colonel Everest’s labours up to the time of his departure for England :—

Captain Everest joined the Colonel, as chief assistant, in the latter end of 1818, and was employed, in the first instance, in the triangulation of the eastern parts of the Nizam’s dominions ; where, in consequence of the extremely unhealthy character of the country, together with great exposure induced by indefatigable labour in the duties of the Survey, he twice fell a victim to jungle fever, and eventually was ordered to the Cape of Good Hope for the recovery of his health. While at the Cape, Captain Everest employed his leisure in investigating the circumstances appertaining to the Abbé de la Caillé’s arc, which formed the subject of a valuable paper, published in the first volume of the *Astronomical Society’s Transactions*.

On his return to duty, Captain Everest was deputed on a longitudinal series of the great triangles, emanating from the Beder base line, and intended to connect Bombay. He was engaged on this important work at the time of Colonel Lambton’s death ; by which event he succeeded to the office of superintendent, and immediately proceeded to concentrate the resources at his disposal for the extension of the Great Arc series. It would unduly lengthen this Report to recount all the formidable difficulties that were encountered : but notwithstanding the state of his health, which suffered severely from the insalubrity of the climate, and the unremitting labour of his professional duties, the measurement was at length carried to the latitude of  $24^{\circ}$ , when it was terminated by the Sironj base line.

An account of these operations is given in detail in the fifth and sixth volumes of the General Report, deposited at the India House. All the scientific portion, relating to the fifth section of the great Indian arc, was further published by order of the Honourable East India Company, in the year 1830.

After the termination of the Sironj base line, Captain Everest proceeded to England for the recovery of his health ; and, as there was no person in India competent to succeed him, the Supreme Government resolved to retain the situation of superintendent open until his return.

Notwithstanding the somewhat invidious allusion in the foregoing extract, that there was no person competent in India to succeed Colonel Everest, the determination of the Government to keep his appointment open for him during his stay in England, may be said to be a very flattering compliment—evincing the high opinion entertained of this officer’s services and attainments by the home authorities, as well as by the Government of India ; and it doubtless tended to the eminent advantage of the operations : for we read subsequently of the manner in which the Colonel’s time was spent in England, and what a stock of information and fresh experience, as well as of strength and vigour, he brought to bear on his duties when he returned.

What a comment on our existing furlough regulations ! Here is an admirable specimen of what might be the case in every

department of the public service, if the fatal meridian of the Cape of Good Hope did not still interpose, and say to every one, "Go and idle your time for two long years amongst the Africans, or the Australians, or Egyptians, or in any other desert place, where you have no friends, no interest, no common ideas; enjoy your pay and emoluments, and return to your appointment when you like;—but pass my threshold for only six months, and you forfeit *all*." When will this anomaly be removed from the statute-book? When will the Indian Government allow their servants to do, as Colonel Everest did—to go and benefit by the rapid progress of arts and sciences, and practical improvements in all things, which can only be seen and understood in England? Let us hope that this reasonable boon to the servants of the State, and equally reasonable advantage to the State itself, may be secured on the passing of the Charter. But we are digressing.

We are told then, that during the interregnum caused by the absence of the superintendant, the establishment was usefully employed under a subordinate officer, Mr. Joseph Oliver, in extending a longitudinal series from the Sironj base line, in the Great Arc series, to connect Calcutta. This work was brought to a close in the year 1832, at the Calcutta base, having occupied a period of six years in accomplishing a direct distance of 671 miles, through a wild, desolate, and unhealthy tract of hill country, which presented formidable difficulties. The work, however, having been executed with instruments of a secondary order, its professional value is said to be only of a similar nature. It embraced an area of 33,442 square miles, with a total outlay of 1,30,740 rupees: the average rate of expenditure is, therefore, 3-14-6, or a little more than six shillings, per square mile, including the costs of measuring the Calcutta base line with Colonel Colby's apparatus—a result which cannot but be considered wonderfully cheap.

In the year 1824, some anxiety seems to have been felt as to the progress and probable duration of the Trigonometrical Survey: and the Court of Directors called for a Report on the subject, which was prepared by the late Colonel Valentine Blacker, at that time Surveyor-General of India, who is described as the ablest and most scientific man, with the exception of Colonel Everest, that ever presided over the department. This paper is so masterly and worthy of the subject treated of, that we give it entire, though at the risk of being somewhat verbose. The letter is addressed to the Secretary to the General Military Department, and dated the 11th August, 1824:—

I shall assume for granted, that a great trigonometrical triangulation,

corrected for spherical excess and the spheroidal figure of the earth, is the only accurate basis for the geography of any country ; because this point is acknowledged by all the first mathematicians in Europe ; and because, as well in England, as on the Continent, the same has been made, with more or less zeal and effect, the object of expensive operations by almost every Government in Christendom. In some states they have been completed, and in others partially accomplished, or only attempted, according to the exigencies of war, or peace, or the characters of individuals in the several Government. But their importance has been questioned by none ; and it therefore remains for decision with the ruling authorities of India, whether they will prosecute to accomplishment a princely undertaking, hitherto conducted with success, restrict its course to a less complete result, or discontinue it immediately.

Considerable time elapsed at its origin in procuring the instruments ; and some effect was lost in the gradual training of sub-assistants and followers attached, to comprehend and perform all those parts of the work, which did not belong to the immediate province of the superintendent himself. The commencement, therefore, including cost of instruments, was the most expensive part of the proceeding in proportion to the effect produced ; and, as that loss and inconvenience has been incurred, it appears impolitic to sacrifice all subsequent advantage derived from it, by an immediate or premature termination of the Survey.

It is extremely difficult to recommend any restriction of the great triangulation, short of that imposed by the features of the country and the limits of British control, so long as its operations are conducted with zeal and intelligence ; but, if such a suggestion were exacted, I should propose for limit the termination of the Doddagunta meridional series of triangles in the Thibet mountains ; the continuation of the western series along the coast from Goa to Cambay ; and the prolongation of that on the eastern coast from Masulipatam to the nearest practical point to Fort William. From four to five years with the present establishment, would be the probable time necessary for the completion of the meridional arc ; which may justly be denominated the great axis of Indian geography, and would connect the minor surveys of the Deckhan with those of Hindustan, which are at present but vaguely related ; for the accomplishment of the other two, which would nearly complete a correct outline of India to the sea, and show the extent in longitude of the British possessions, about four years each would be required.

I cannot, however, too forcibly, as Surveyor-General of India, deprecate the adoption of a restriction so inconsistent with the liberal views under which this survey has been hitherto conducted ; so unworthy of the fame,\* which the rulers of India have already acquired among scientific societies for their promotion of geodesy ; and so completely destructive of all hopes of an accurate knowledge of the geography of the greater part of Central India and all its extremities, excepting the Presidency of Madras and part of

\* I beg leave to quote here an extract from the *Edinburgh Review*, vol. XXI, page 313.

*Note.*—They have sent out parties in all directions for the purpose of ascertaining the bearings and distances of the places, which compose or limit their extensive dominions. A late volume of the Asiatic Researches contains an account of the march of an officer, at the head of a detachment, into one of the most remote and unknown districts of India, for no other purpose, but to decide a question interesting only to philosophers, viz. Whether the Ganges rises within or without, that is, on the south or the north side of the great chain of Himalah, the Snowy Mountains, or the Immaas of the ancients ? There are but few of the most enlightened cabinets in Europe, which can boast of an expedition equally disinterested and meritorious.

the Deckhan and Konkan. Rather, on the contrary, let there be employed more hands and more instruments to give fresh vigour to the undertaking, and to reduce the period of its accomplishment within a calculable time, by the protection and facilities afforded to it.

I feel a difficulty in adding more in reply to the demand for precise information in regard to the objects embraced in the Survey, and the particular purposes to which it is to be applied, as it may respect the geography of the country. Without this basis, which is itself independent, all detailed surveys must not only be wrong, but extremely tedious in producing even erroneous results; no single point can be accurately placed, nor can the extent of India, particularly in longitude, be known without it. Such is the proneness of maps to exceed in that direction, that an error of 500 leagues was discovered by Gassendi in the length of the Mediterranean sea, and De Lisle shortened Asia from east to west more than 24 degrees. The King of France complained that Cassini's great triangulation had deprived him of a large portion of his dominions; and the late Lieut.-Colonel Lambton found the breadth of the Peninsula in the parallel of Madras some miles overrated by all the maps existing previously to his survey, notwithstanding the able and zealous labours of Messrs. Topping and Goldingham, to establish the longitudes of several points on both coasts by astronomical observations.

One of the great questions of general service, whose determination depends on the highest geodetic operations, is the ascertainment of the magnitude and figure\* of the earth, through various measurements on different meridians, and under different parallels. The scientific world agree nearly among themselves now, although from different grounds, on the comparative lengths of the earth's axis and equatorial diameter, notwithstanding that no two meridians may be similar; and the latest observations in various latitudes on the lengths of the seconds pendulum (an expedient, which has been adopted as a substitute for geodetic operations, where the latter from sundry reasons are impracticable), have generally corroborated the conclusion deduced without its assistance. Lieut.-Colonel Lambton's operations have had their full share in the ascertainment of the earth's figure; and the prolongation of the Doddagũnta meridian to the Thibet mountains, at about the latitude of  $81^{\circ} 30'$ , will be of equal importance in clearing away remaining doubts, or throwing light on new phenomena. But in fact there is no branch of physical science specially affected by the three co-ordinates of latitude, longitude, and elevation, to which the great trigonometrical operations are not of primary importance; whilst the determination of the changes of gravity in different latitudes, the laws of terrestrial and celestial refraction, the attraction of mountains, the phenomena of magnetism and temperature, with several important branches of geology, should properly accompany or follow them.

I have now placed the question of the continuation of the Great Trigonometrical Survey in the most conspicuous light, which the limits I have assumed will permit. In pointing out the expedient for a complete accomplishment of this great desideratum, I have rejected the method hitherto followed of an uninterrupted triangulation, for that of several meridional series, which appears to me, if less satisfactory, to be a saving in time of 20 years; and, should the resumption of the former system be ever desired here-

\* It may not be amiss here to notice that the figure of the earth is so far from being an object of mere curiosity, that it affects a large portion of the tables used by navigators, especially all those of which the moon's parallax is an element. No power has more reason, therefore, to be interested in this investigation, than the East India Company.

after, its execution will be advanced by the previous work, exactly in proportion to the ground covered. The next alternative comprises the completion of the Doddagunta meridian, and continuation of the series on each coast; and, if that be considered too extensive, the meridian may stand alone, whilst the survey of the coasts shall be abandoned.

From para. 50 to 54 relates to the memorandum received from Major Rennell, regarding "the best mode of obtaining a complete map of India within a reasonable time." The character of that distinguished geographer for talent, industry, and literature is so well established, that his opinions on the subject, to which so much of his attention has been successfully directed, claim immediate respect. But there is a distinction between geography and geodesy; and the latter is the object of the present inquiry. Notwithstanding, that Major Rennell's celebrity chiefly rests on the ingenious use and sagacious reasoning with which he has turned to account a variety of uncertain authorities, and that his Bengal atlas, although said to be founded on actual survey, depends neither on measured base or triangulation, as far as I have been able to ascertain, he is evidently aware that transcendent geodetic methods are now employed in Europe, however, he may have overlooked their latter progress in this country.

The mode at present suggested of insulated astronomical observations, and estimation of distance by time, was applicable to the limited influence of the British power half a century ago, and has since been occasionally practised by solitary and adventurous European travellers in the wilds of America. Not only have the grounds of accurate knowledge been extended over Southern India, but accurate surveys in detail have been erected on them. How irreconcilable, then, will be the inconsistencies of the proposed loose method with the results of science already accomplished—and how unworthy of the character, power, interests, and opportunities enjoyed by the Honorable Company, to return to such a rude expedient, after having originated and promoted, during more than 20 years, an operation approved by science, and after having received for their conduct the applause of the scientific of Europe? Were this all, perhaps, the arguments, powerful as they deserve to be considered, might fail of carrying conviction to every mind: but in fact the proposed experiment would be entirely nugatory. Incorrect throughout itself, it could form no correct ground for minor surveys; so that it must be either useless or baneful. Its erroneousness would be inconsistent with the scale of four miles to an inch, which always supposes, in a general map, accurate data; and if ever it were engraven in the proposed form, it could have no other fate than that of being thrown aside in vexation for the expense incurred and the misconceptions it produced, to make way for a new and accurate survey.

These observations apply to the proposal for substituting astronomical observations for high geodetic operations, and estimation of distance by time for actual measurement. If, on the other hand, the celestial observer be confined to those tracts, whose nature forbid the approach of the Great Trigonometrical Survey, much advantage may be derived from his labours. This benefit, however, must depend on a different principle of calculation from that to be inferred from Major Rennell's memorandum. No astronomical result is of value, unless it be more accurate than that which it proposes to correct; and the propriety of its adoption or rejection depends therefore on the local surveys supposed to follow or accompany it. An itinerary, corrected for the true azimuth, will not, in general, if conducted with moderate skill and attention, be in error more than two miles in 100, which is near the average distance proposed to separate any two points astronomically determined. The memorandum estimates at  $2\frac{1}{2}$  to 3 years, the period requisite for the astronomer to merely travel over his ground; but no estimate

is made of the time necessary for making observations and calculations. This omission is the more to be regretted, as on the number of observations, as well as on the skill of the observer and excellence of his instruments, depends the value of the results. In a subsequent paragraph, it is added, that with five surveyors, three or four years would suffice to fill up all the localities; and that period, therefore, is probably considered at least sufficient, both for travelling and the determination of the 85 primary points, as they are intended to precede the operation in detail.

It would require more attention, than possibly I may be entitled to expect, to follow the reasoning necessary to show the fruitlessness of the proposed hurried observations. The distances in latitude of the local survey may be checked at considerable intervals by a good sextant in the hand; and many seasons of the year are favourable to observations of the sun or stars. But I should apprehend that no professed astronomer would be satisfied to hang his character on such a procedure, which is properly restricted to the purposes of navigation. No instrument but such as is too large for the hand, and must be adjusted by the plummet or spirit level, is capable of giving the latitude with sufficient accuracy to render the result worthy of a professional astronomer and assistant, or adequate to the expense of his establishment; \* and this instrument, whether a zenith sector, or an altitude circle, requires time and patience for its adjustment, previous to any observation. This delay, added to the occasional want of proper stars sufficiently high during all hours of the night, will render evident the necessity of continuing much longer at one station for latitude alone, than could have possibly been anticipated by the memorandum, which avoids any explanation on this subject. Mr. Biot did not think 1,400 observations for latitude unnecessarily numerous, when ascertaining the length of the seconds pendulum at Unst, a few years ago; which, I hope, will be sufficient to show the opinion of the scientific, respecting the difficulty of ascertaining that element with the precision suitable to professional observations on shore †

But if the determination of the latitude requires so much time and care, what shall be said regarding the still more important element of longitude, which involves the errors of tables, the rarity of phenomena, the inaccuracies of the time-keeper, the uncertainty of the method, the delay and mistakes in operose calculations? The rate of the time-keeper requires the most attentive vigilance; so much so, that the French astronomer, on the occasion above mentioned, thought it necessary in two months to observe 1,200 absolute altitudes of the sun and stars, to regulate his clock.

\* A good sextant, in the hands of a practised and skilful observer, is not thus lightly to be disposed of. It ought not to err, even for a single observation, more than 10" from the truth; and, we should say, that 30 or 40 observations would be sufficient to determine a latitude very nearly to the nearest second, or certainly, with an error of not more than 200 feet.—ED.

† Within the last half century, almost all the Observatories in Europe, with all their facilities, have corrected their latitudes, and in some instances considerably. That of the Cracow Observatory has been altered 15" or a quarter of a geographic mile; that of Gottingen, 19"; the Berlin Observatory 1 geographic mile; and that of Manheim has been augmented even 1' 23". But, without depending on instances in the west, reference may be made to the practice of Colonel Lambton, who invariably devoted several weeks to observations, for the latitudes of his principal stations: thus—

	No. of Days.	No. of Observations.
At Doddagunta	.. .. 59	.. .. 98
At Putschapolliam	.. .. 26	.. .. 173
At Punuse	.. .. 28	.. .. 236
At Namthabad	.. .. 28	.. .. 120
At Daumergidda	.. .. 34	.. .. 206

If the eclipses of Jupiter's satellites be used as the most simple expedient for determining the longitude, there are parts of the year, in which they are either below the horizon, or so little elevated as to be invisible or indistinct. The tables of these eclipses are not to be depended on where great accuracy is proposed, being more an approximation to direct the observer when to look out, than a final result for comparison with the observation \* ; add to which, that the gradual disappearance and re-appearance of the satellites, the unequal powers of the telescopes used, the various state of the atmosphere, and visual power of the observer, give rise to no inconsiderable differences in the times observed.

The eclipses of the moon furnish another method of equal simplicity : but they are of rare occurrence, and so inexact, from the uncertainty of the edge of the shadow, that the use of them for determining the longitude has been generally abandoned.

The remaining means, such as lunar distances, eclipses of the sun, and occultations of the stars and planets by the moon, the passages of the inferior planets over the sun's disk, the right ascensions of the moon with its hourly angles and the differences of declination, are all attended with onerous calculations, on account of the element of parallax, which affects them all. These methods have different degrees of certainty ; but the occurrence of the phenomena on which they depend, are too rare to admit of any choice in a very limited time : and hence arises the great uncertainty of conclusions for longitude. Even the arc of the meridian measured in Peru by two French and two Spanish astronomers is found to have been placed too much to the east, 50' in arc ; and the longitude of the Madras Observatory, which has existed 30 years, was not long since discovered to be in excess 1' 8". Nothing less than an average residence of two lunar months at one place, exclusive of the rainy season, can be considered sufficient for a result in longitude worthy of any consideration.

The errors of astronomical tables have been already adverted to as a source of error when unlimited reliance is placed on them : but those deductions of longitude, which depend on instantaneous phenomena, such as eclipses, transits and occultations, may be rendered more or less independent of those inaccuracies by corresponding observations at a place, whose longitude has been already satisfactorily determined. Many of the phenomena observable in India are invisible under the meridian of Greenwich ; and some even of those, which may be visible in parts of India, influenced by the south-west monsoon, are not observable at the Madras Observatory, on the coast of Coromandel. A considerable portion of the observations, which may be made in various parts of India, will therefore be without correspondents ; and it was a consideration of this circumstance, which, in part, induced me to suggest in my letter, under date the 4th February last, the establishment of a limited Observatory at the Surveyor-General's office, for the purpose of supplying the above-mentioned deficiency.

To avoid trespassing any longer on the attention of superior authority, I shall hasten to a conclusion of this most important subject, by remarking that no future survey should deserve to be considered final, unless it shall have been conducted on the most approved principles, with appropriate instruments, and by skilful hands ; and that the accomplishment of such a work, which is alone worthy of the expense it costs, demands time and encouragement. Since the discovery of high scientific principles, all the advantage, derived from the application of them to practical purposes, has depended on the accuracy

\* This is no longer the case. The Eclipses of Jupiter's satellites are now given in the Nautical Almanac, with an accuracy equal to that of observation ; but, from the other causes mentioned, we have found single results liable to an error of about 10 or 25 seconds of time.—Ed.

of minute corrections in the execution, which never can be hurried without loss of effect; nor should the principles themselves be any more abandoned, as on them depends the calculus, which "should ever" (to use the words of the late Professor Playfair) "be so instituted as to preserve to the conclusions all the accuracy possessed by the data themselves." These, from the great perfection of modern art, may be rendered by skilful hands extremely correct; and the great desideratum therefore is reduced to the employment of good surveyors, with suitable instruments. Let these arguments, which challenge contradiction, stand in favour of the continuance of the great Trigonometrical Survey on an enlarged establishment, commensurate with the extent of country still open to its operations; or, if arguments without examples be insufficient, let the want be supplied by a reference to the extension of the great Ordnance Survey of Great Britain, after mature experience, to the shores of the sister kingdom.

The residence of Colonel Everest in England, and the representations he must have made to the Court of Directors, doubtless, had a direct influence in finally settling the question, as to the prosecution of the Trigonometrical Survey in all its integrity, as so ably contended for in Colonel Blacker's Report.

We now come to that part of the narrative, where Colonel Everest returns from England, with renewed health and vigour, with every available appliance which science or ingenuity could supply, and the most liberal encouragement of the Court could provide, to prosecute the great undertaking in which he had embarked, and for the success of which he naturally felt personally responsible. We shall see how he set about the task assigned to him, and what were the improved means he had at his command:—

Colonel Everest returned to India in 1830, liberally provided by the munificence of the Honourable Court of Directors, with geodetical instruments and apparatus of every description, in the construction of which the most skilful artists of the day, Messrs. Troughton & Simms, exhausted every resource of modern invention. The equipments consisted of a complete base line apparatus, the invention of Colonel Colby, precisely similar to that employed on the Ordnance Survey; a great theodolite, 36 inches in diameter, designed by Troughton, which even, at the present day, is supposed to stand unrivalled by any other instrument of the kind in the whole world, and which, most probably, will never be surpassed; two 18-inch theodolites, and a variety of smaller instruments, from 12 inches diameter downwards, all by the same celebrated maker. The signals, all of the most efficient kind, and recently invented, consisted of heliotropes, reverberatory lamps, and Drummond's lights, of which the two former have been exclusively used; and, here it may be remarked, that the substitution of luminous signals for opaque ones has contributed vastly to the improvement of the observations. These modern inventions, together with the extreme precision of Troughton's graduation, as well as the high optical power employed, and the rigorous system of changing zero, introduced by Colonel Everest, have brought the terrestrial operations to a refinement of accuracy which may almost be pronounced unsurpassable.

During his absence from India, Colonel Everest had made himself acquainted with the English Ordnance Survey system, and with every modern improvement in geodetical matters, that had taken place in Europe.



The apparatus, supplied by order of his Honourable masters, was superior to any in the world. A London artist, Mr. Henry Barrow, was sent out to maintain the apparatus in order. Thus splendidly equipped, Colonel Everest returned to India in the prime of life, the full vigour of his faculties, and with an undaunted determination of character, that never quailed before any difficulties, nor yielded to any opposition. The task before him required indeed the full display of all the vigour he possessed. In addition to the duties of superintendent of the Trigonometrical Survey, he had now to perform those of Surveyor-General of India, to which office he had recently been appointed by the Honourable Court of Directors. This union of offices, though it served to facilitate arrangements, nevertheless vastly increased his labours at the outset; for, the apparatus being new to India, and the establishment untrained, the whole task of teaching devolved on him unaided. In 1833, moreover, the offices of Deputy Surveyor-General at Madras and Bombay were abolished, which further increased the duties of the Surveyor-General of India, so that Colonel Everest had, in fact, to perform the work, which had hitherto occupied the undivided attention of four officers. In the sequel, these reductions have been found to operate conveniently enough, and so far have justified the expectations of the Honourable Court by whom they were ordered, but the additional labour thrown on the Surveyor-General is still immense; and occurring as these events did, at the time that the Trigonometrical Survey was about to recommence on a new organization, the task, Colonel Everest had to achieve, was of the most arduous kind.

He was detained by all these arrangements, by official delays, and by the measurement of the Calcutta base line, until the end of 1832: from which time the Great Arc may be considered to have actually recommenced, after a cessation of seven years. The work was carried on unremittingly till December, 1841, when it closed with the measurement of the Beder base line; and the whole Indian arc, from Cape Comorin to the Himalaya Mountains, forming the main axis of Indian geography, was thus completed.

These operations are fully detailed in Colonel Everest's book, published in 1847, by order of his firm and constant patrons, the Honourable the Court of Directors. The work has been most favourably noticed in the 87th volume of the *Edinburgh Review*, April 1848, to which reference can be made. The area comprised by the Great Arc operations, principal and secondary, aggregates 56,997 square miles, including the revision of the section Beder to Kalianpur, and the measurement of three base lines, each from  $7\frac{1}{2}$  to 8 miles in length. The average progress, therefore, was about 5,700 square miles per annum, and the total cost being 8,98,326 Company's rupees, the rate per square mile averages Rs. 15-12-2, or, say, 29 shillings.

This rate considered *per se* is very moderate; but, contrasted with Colonel Lambton's, it exhibits a ratio of three to one. This is easily accounted for by the great superiority of the work, which is, perhaps, unsurpassed by any similar undertaking in the world. The instruments were much heavier and more numerous, requiring a larger establishment of porters. The signals, being all luminous, necessitated an increased number of attendants; the base line apparatus, infinitely more complicated and ponderous than Colonel Lambton's steel chains, demanded an additional number of observers, as well as greater cost of transport. A considerable part of the triangulation likewise passes through the plains of the Ganges, which is the garden of India. In this part of the country, compensation had to be paid wherever private property was interfered with; and costly masonry towers were erected for stations. These are the reasons, which enhanced the charges; but if the work be considered in relation to its superior

merits, as well as to the peculiarity of the circumstances, the rate of 29s. per square mile must be reckoned moderate.

The account of the measurement of the great longitudinal series from the Sironj base to the Calcutta base, and of the northern section of the arc of the meridian, is fully detailed in Everest's last book above quoted, published in 1847; of which a sufficient abstract for our present purposes is given above. This "axis of Indian geography" was satisfactorily determined by December, 1841.

We now proceed to notice the minor series contained in the Report. These may be said to emanate from, or be dependent on, the two great meridional and longitudinal measurements before described. In these series, each follows, as near as practicable, the meridian of one of the principal stations of the longitudinal series, from whence it takes its origin, and is named after these stations, from villages at, or near the locality. The appellations, given to these operations, have often appeared to us rather unintelligible; but attached to Colonel Waugh's Report in the appendix is an excellent tabular statement of the expenses incurred, which enlightens us greatly as to their geographical position: and we therefore have been at some pains to detail the several districts traversed for the benefit of the uninitiated.

Between the meridian then of the Great Arc, passing through the centre of the continent of India in  $77^{\circ} 41'$  of E. longitude, from Cape Comorin to Dehra Dhún at the foot of the Himalayas, and the meridian of Calcutta, in  $88^{\circ} 25'$  of E. longitude, there are 10 series of triangles, all emanating from the great longitudinal series, at distances of about one degree, or 60 miles apart, taking meridional directions, and terminating at another cross or longitudinal series, traversing the foot of the hills from the Sonakhoda base in the Purneah district, due north of Calcutta, and extending to the Dehra Dhún base. These series, or sets of triangles, all running in as straight and direct a manner as possible, form a figure not very unlike a *gridiron*, to which they have, with some apparent reason, been likened. The first series, in the order, next and eastward of the Great Arc, is the *Budhon*, which, taking its origin at the principal station of that name, on the longitudinal series in the Saugor and Nerbudda territory, passes through Scindia's dominions, the district of Agra; Moradabad, &c., until it reaches the hills at Hurdwar. The area covered by this series, amounts to 12,468 square miles. From various untoward circumstances, caused by deaths of the officers employed and other difficulties, it occupied a period of eleven years, from the commencement in 1833. The cost was

1,72,510 rupees, giving an average of 13-13-5 per square mile, or about 25 shillings.

Next comes the *Ranghir* series. It starts from nearly the same parallel of latitude ( $24^{\circ}$ ) follows the meridian of  $79^{\circ} 28'$  for about 400 miles through the districts of Bundelkund, Etawah, Mynpuri, Bareilly, &c., and within the hills to Almorah, where the work closed in 1841. In this series, 16,088 square miles of country were covered, at an expense of 18,378 rupees, shewing an average cost of 7-5-9 per square mile, or only 14 shillings.

East of this follows the *Amna* series, cutting through the districts of Bandah, Humirpur, Cawnpur and the territory of the king of Oude, commenced in 1834, and concluded in 1839. It covers 5,565 square miles, performed at an outlay of 1,04,958 rupees, giving an average cost of 18-13-9 per square mile, or about 35 shillings.

The *Karara*, the *Gurwana*, the *Gora*, in like manner, pass through the districts of Allahabad, Mirzapur, and Benares respectively, and intersect all the districts of the Doab. After which the *Chendwar* takes Hazaribaug, Gyah, Behar, Patna, and Tirhut. The *Parasnath*, rising from the celebrated mountain of that name on the Great Trunk Road, traverses Monghyr and Bhaugulpur, both north and south of the Ganges. The *Maluncha* takes the eastern part of Bhaugulpur and Purneah: whilst the *Calcutta* series provides for the Hughly, Nuddea, Murshedabad, Malda, and Dinagepur districts, closing on the base of verification at Sonakhoda, in the Purneah district. The north longitudinal series extends from the Dehra Dhún base, along the frontier to the Sonakhoda base, a distance of 690 miles. The difficulties as regards climate and forest must have been immense, but they were as usual successfully overcome. The only triangulation carried south of the longitudinal series is that of the *Maluncha* and *Parasnath* series, the former extending to Midnapore, and the latter to Balasore. The coast series is also now in progress towards Madras, emanating from the Calcutta base, hitherto proceeding very slowly, owing to the nature of the country and the various difficulties which Lambton originally apprehended.

In the Bombay Presidency, a longitudinal series of 312 miles in length, commencing from the Great Arc near the Beder base, and terminating at Bombay, has been accomplished after some difficulty, and after the rejection of the work previously executed, which was found to have been prosecuted on an independent base and point of departure, contrary to the original design. In addition to which, a meridional series called the

*Khansipur*, commencing from the longitudinal series and extending north up to Indore, along the meridian of  $75^{\circ}$  E. longitude, is now in progress, and has been so since 1846. The result of all these operations may be summed up as follows:—

The accuracy attained by the modern operations, may be thus briefly stated. In the large triangulation, where, of course, the greatest refinement and most scrupulous care is observed, an error of one inch per mile, or 1-63,360th part, amounts to 500 inches or 42 feet, or nearly half a second in arc of latitude or longitude in 500 miles, which distance is even exceeded between some of the bases. The work is reckoned liable to half this error, when executed with the great theodolite, on the principle of double series. The results attained by the new 24-inch theodolites are but little inferior to this degree of accuracy. When the series are single, the liability to error is reckoned to approach nearer to one inch per mile. When performed with good 18 inch theodolites, the error will exceed one inch per mile, according to the character of the graduation. With inferior instruments, or a less careful system, the accumulation of error would approach a foot per mile, which is equal to a ratio of 1-5280th in linear dimension, or 1-2,640th in area, or  $\frac{1}{25}$  per cent, or six seconds of arc in the above distance.

In reviewing the whole progress of the Trigonometrical Survey of India, from its commencement by Colonel Lambton to the year 1848, it will be seen that the grand total of area triangulated amounts to 477,044 square miles, and the grand total of cost, to Company's rupees 34,12,787, or about 312,389*l.*, showing an average cost of Rs. 7-2-5 per square mile, or about 1*s.* 1*d.*: which cannot but be considered remarkably moderate, especially when the nature of the country and climate, as well as the absence of all the usual resources to be found in Europe, are taken into account. The hardships and exposure of surveyors working in the field for the greater part of the year, in such a climate as India, and living under canvas, whilst all other servants of Government seek the protection of cool houses, are either little known or little appreciated. We have, on several occasions, kept the field throughout the year. The duties of the Trigonometrical Survey, likewise, are often unremitting day and night, because the best observations are obtained during the nocturnal hours, when the dust raised by hot winds subsides, and the atmosphere becomes clear and calm. The fatigue and exposure are trying to the most hardy constitutions: and this history will show how few officers have been able to withstand their effects. The loss of trained officers entails a considerable increase of expense, for their places cannot be efficiently taken by newly-appointed officers, until they have been thoroughly trained, while the cost of training is always an unproductive item in the account.

We regret that time and space will not permit us to go into the more minute details regarding each of these operations, or to dwell on the indefatigable and meritorious labours of the officers employed, which are so apparent throughout. We believe that Colonel Waugh's Report and Everest's book cannot be perused without a feeling of pride at the indomitable spirit and perseverance displayed in this great undertaking, alike honourable to the department and to every one connected with it. To those, who wish for an elaborate discourse on the geodetical principles involved, we refer to the *Edinburgh Review*, vol. 87, for 1848, page 392, where they will find more learned criticism than it is in our power to enter into, and with it high commendation—the work of Everest being

described as “ a creditable one in every respect, and which, after the *base metrique* of the French astronomers, must be regarded as the most important contribution, which has been made to geodesy since the beginning of the present century.”

The duration of the Trigonometrical Survey next comes to be considered. This is a point, which can only be decided with the certainty of the limits of our Empire. With the immense additions made within the last few years, have these limits been yet reached? With the Burmese war on our hands, who can say whether or not we are to add another country for survey? The Ordnance Survey of England and Ireland was, we believe, commenced in the last century, long before Lambton measured his first base—and they have not finished yet. Let this be an answer to those who expect our British dominions to be completed off-hand. Let us see what Colonel Waugh writes on this important point:—

With regard to the duration of the Survey, it has been already remarked by the late Colonel Blacker, that the question depends on the strength of the establishment employed: which statement is true within certain limits defined by the power of supervision and training. The chief point is the rate per square mile, which I have shown to be on an average 1*s.* 4*d.* The Survey has been about 48 years in operation, chiefly on a small scale. Now, as the area of India exceeds Great Britain and Ireland some 12 times, we have, comparatively speaking, been only four years at work. Since the commencement, the object in view has perpetually extended. Successive wars have added continual accessions of territory to be surveyed. The late wars alone have given new kingdoms, with no less additional surface than 169,827 square miles, as will be apparent from the following statement:

Scinde.....	...	60,240	square miles
Jalander, Doab, and Kohistan ...		16,400	„
Protected Sikh and Hill States ...		15,187	„
The Punjab Proper.....		78,000	„

Total... .. 169,827 square miles.

The limits of our Empire, however, appear to have been at length reached. The total area of British India, as it now stands, including Scinde, Punjab, Jalander, Doab, and Tenasserim, has been carefully estimated at 800,758 square miles, and the native states at 508,442 square miles, making a grand total of 1,309,200 square miles, as the area of survey under my charge. A complete delineation of this vast superficial extent, amounting to 1½ million of square miles, confined within an external boundary of 11,260 miles in length, including every variety of configuration and climate, is an undertaking of unprecedented magnitude, demanding considerable time to accomplish with any pretensions to mathematical accuracy. The exertions hitherto made have been unremitting, and it is but justice to say that the progress has been, generally speaking, as honourable to the officers employed, as the results have been useful to the country.

Attached to the Report, there appears to have been a chart, shewing, at a glance, the extent of country triangulated, as well as surveyed in detail, up to the present time: but as the Honourable House ordered it to be deposited in their Library, it can

only there be inspected. If this chart had been lithographed, and published with the Report, it would have been a valuable addition, and a most useful document for reference.

The present strength of the Trigonometrical Survey consists of seven parties; and from their present employment a good idea of the existing state of the operations may be derived:—

The Trigonometrical Survey consists of seven parties, employed as follows:—

Two parties in the Punjab... ..	2
One party in extending the great longitudinal series, from Calcutta to Karachi, in Scinde... ..	1
The operations have reached Mount Abu; and there only remains to complete the hiatus through the desert.	
One party on the coast series from Calcutta to Madras; the results of which will be most important to maritime geography... ..	1
One party employed on the Hurlong series in Behar. (if possible, to be extended into Nipal) ... ..	1
One party employed in Bengal, on the Parasnath series... ..	1
One party employed in the Bombay Presidency ... ..	1
Total number of parties... ..	7

And the instrumental equipments, which are described as admirably adapted for the work in hand, and most liberally supplied by the munificence of the Court of Directors, for whose undeviating support Colonel Waugh pays a grateful tribute, consist of the following apparatus:—

- One Colby's compensation apparatus for measuring base lines.
- Two Great theodolites, 36 inches diameter, by Troughton & Simms, and Barrow, respectively.
- Four 24-inch theodolites, by Simms & Barrow.
- Two 18-inch theodolites, by Troughton & Simms.
- Six 14-inch Vernier theodolites, by Simms.
- Six 12-inch theodolites, by Troughton & Simms.
- Twenty 7-inch theodolites, by Troughton & Simms.
- Two Astronomical Circles of 3-feet diameter, by Troughton & Simms.
- Five Astronomical Clocks.
- Fourteen Chronometers.
- The signals consist of Argand lamps and Heliotropes.

The project for the future operations is full of promise; and, from the consideration of what remains to be done, Colonel Waugh is of opinion, that, in six or seven years time, such progress will have been made, as will bring the termination of the Trigonometrical Survey of all India in view: but before that time, no satisfactory opinion can be given, as, we think, will be evident to our readers after a perusal of the following details:—

The programme of future operations, which have been sanctioned, is as follows:—According to Colonel Everest's design, an ellipsoidal space is included between the Great Arc on the west, the Calcutta meridional series on the east, the great longitudinal series on the south, and the north longitudinal series along the frontier; which are verified by four base lines at their origin and termination; all measured with Colby's apparatus. This immense ellipsoidal area is filled up by subordinate meridional series nearly

one degree of longitude apart, which series depend on the great longitudinal series for origin, and on the north longitudinal for verification. This has been denominated the 'gridiron' system, and obviously possesses superior facilities for rapidity and accuracy. This design of Colonel Everest's has been nearly completed: for there remains only a small portion of the Hurlong meridian, and the northern part of the Parasnath meridian, which will be finished in two years. The country to the west of the Great Arc is intended to be triangulated on precisely the same principles. 1st. The north-west Himalaya series will extend from the Dehra Dhún base line to Peshawur, where it will be verified by a measured base. This series has reached the meridian of Cashmere, and may be expected to be completed in two or three years. 2ndly. The great longitudinal series will be extended from the Sironj base to Karachi, where it will be verified by a measured base. It has been carried as far as the borders of the desert, across which its further progress is uncertain, because no analogous operations have ever been attempted. 3rdly. Between the Peshawur and Karachi bases, will extend a great meridional series, between which and those before described, will be included an immense ellipsoidal area, averaging  $9^{\circ}$  of latitude by  $10^{\circ}$  of longitude. As all the bounding series will be executed with superior instruments, and duly verified by base lines, whereby limits will be placed to the intrusion of error, those series will be fit to verify the subordinate meridional series, by means of which the intermediate space is intended to be rapidly filled up at every degree of longitude apart, according to Colonel Everest's system.

To the east of the Calcutta meridian, it is proposed to extend the north longitudinal series, from the Sonakhoda base into Assam. From this series will depend other meridional triangulations at one degree apart, upon which the accurate geographical delineation of Eastern Bengal will be based.

The Bombay party will complete the remaining triangulation of that Presidency in a few years. There only remains, therefore, to be considered the vacant space to the south of the Calcutta longitudinal series, in which is embraced the hill country of Gondwana and the tributary Mahals, between the sources of the Son and Narbada, the Godaveri river, and the sea. This region, inhabited by Aboriginal tribes, is unhealthy in the extreme, and of no value; but from its rugged configuration, any survey not based on triangulation would accumulate vast errors. It is proposed to triangulate this region by meridional series at every two degrees apart, filling up the interstices with secondary triangulation. In this way that space can be most rapidly surveyed. The accomplishment of these several plans will complete the trigonometrical survey of all British India; and in six or seven years such progress will have been made, as will bring the termination in view; before which time no satisfactory opinion can be given.

In estimating the probable future rate of progress, Colonel Waugh enters into some important considerations, as to the efficiency of the department in respect to officers. Unless adequate provision is made for filling up vacancies by competent men, of course, there would be much to fear. The life of a surveyor, is no child's play: and but very few can stand it. The Report shews how many have died, or been obliged to retire, just when they were becoming efficient. The following remarks, therefore, are worthy of consideration:—

With regard to the probable rate of progress, much depends on the efficiency of the officers, and on the accidents of climate to which the parties are so much exposed. In a hilly country, the average advance made per season by each party is now about 120 miles in length by 30 in breadth,

or say, 3,600 square miles. In a flat country, the average is 80 miles in length by 12 in breadth, or about 1,000 square miles. The average for both kinds of ground may be taken at the mean, or 2,300 square miles, which, multiplied by seven, gives 16,100 square miles per annum of probable progress. The cost is not likely to exceed the general average hitherto attained of 10s. or 12s. per square mile of hilly country, and from 20s. to 30s. in flat land, or a general average of 15s. to 16s. over all. This rate might be expected to diminish, if the department were made more efficient in officers. It has been shown in the foregoing narrative that few succeed in these arduous undertakings. A rigorous training is indispensable at the outset, without which success cannot be certain, nor any adherence expected to system. Widely dispersed as the surveys are, and remote from constant supervision, little by little innovations would creep in, and the character of the work become compromised. To prevent evils so calculated to retard the completion of the survey of India, due provision should be made for contingent vacancies, instead of waiting till they occur. A newly appointed officer is not effective for two years, and, when more than one vacancy occurs at a time, the task of training is inconvenient. The department is now so under-officered, that a few casualties occurring together would leave it unofficered—an anticipation which would give me more anxiety than it does, were it not for the great ability of a few of the subordinates, who are themselves competent practically to conduct series. It is evident that at the present stage of the business, when so large an area remains for survey, effective establishments are most important. In fact, an augmentation of two or three officers now would be more useful than filling up vacancies towards the close of the work. Such an augmentation would most likely provide for every contingency, without any further addition hereafter, as vacancies occur.

We are glad to see, that before concluding his remarks on the Trigonometrical portion of the Survey of India, Colonel Waugh takes the opportunity of bearing testimony to the meritorious services and high character of that useful class of subordinates, the uncovenanted sub-assistants. "A more loyal, zealous, and energetic body of men, (says Colonel Waugh) than the sub-assistants, forming the civil establishment of the Survey, is nowhere to be found: and their attainments are highly creditable to the state of education in India." Amongst these he particularly distinguishes Babu Radhanath Sikhdar, of whom we lately also had occasion to speak, when reviewing the Manual of Surveying. We believe, that the encomiums bestowed on these gentlemen are richly deserved, and most honourably earned.

Had Mr. Joseph Hume's motion referred simply to the Trigonometrical Survey, our labors might have ended here, but looking at the title page of the Blue book, we find it included "also Reports of the Surveys, whether general, revenue, or military, which have hitherto been carried on, completed, or are in progress, specifying the divisions or portions of India—also the number, and what sheets of the grand atlas have been completed and engraved, with the cost thereof to the Government, and the selling price per sheet to the public, and what progress the remaining sheets of the atlas are in:—" also "of the nature of the information collected in connection with



‘ the grand survey, and with the detailed surveys of India ; and  
‘ list of all the memoirs and their contents sent in.’

Mr. Joseph Hume never does things by halves. Consequently here we have an elaborate tabular statement of all the revenue and military surveys, with a detailed opinion as to the value and importance of each, with the authors’ names and dates. The Report proceeds to speak of them thus :—

Having discussed the trigonometrical part of the subject, it remains to report on the land surveys, by which the interior is filled up. These are enumerated in a tabular statement, marked (D.) in the Appendix. The greater part of the Madras peninsula has been taken up on the basis of the great triangulation, by means of minor triangles, and military plane table surveys executed on a scale of one inch per mile. This style of work is remarkably cheap—the cost per square mile not exceeding six rupees, or less than 12s. ; and in favourable localities, free from jungle fever, which is the dire enemy of all survey operations in India, the expense becomes much lower. This kind of survey, being based on triangulation, cannot accumulate error, and gives an admirable representation of the land ; but it requires good draughtsmen, who are difficult to be obtained in India. The system is peculiarly adapted to mountainous countries, where the value of the land being small, an expensive system is inapplicable. It has already been extensively carried out in the native states, and it is proposed to extend the same principles to the remainder.

At page 333 of No. XXXI. of this journal we gave our readers some idea of the extent to which the revenue survey in this Presidency has proceeded, with what remains to be accomplished. It is, therefore, not necessary to quote again from the Report before us ; we go on, therefore, to shew the accuracy, cost, and progress of this operation, as now attainable :—

As respects the accuracy attainable by the measurement of the revenue survey, it may be stated generally that the maximum error allowed in linear dimension, according to the test it is submitted to by traverse proof, is 10 links in 100 chains, equal to 5.28 feet per mile ; but in the actual prosecution of the extensive surveys of the season 1847-48, covering an area of about 16,000 square miles, the average ratio of correction employed for the closing of the traverses, is found to be only two feet per mile, or rather more than one-third of the allowed correction :  $\frac{1}{15}$  per cent. therefore, for the Pergunnah, or main circuit measurement, is fully within practical ability ;  $\frac{1}{10}$  per cent. also may be allowed for the area of the district ;  $\frac{1}{4}$  per cent. for the village survey area, and 1 per cent. for the interior detail measurement of cultivation and waste. But the most severe test to which a revenue survey can be subjected, is the comparison of its results with those of the Trigonometrical Survey ; and that this comparison may be performed as readily as possible, a due and proper connexion between the two Surveys is essential, and is now scrupulously maintained.

As a sample of the progress now made by the combined efforts of the officers employed on this side of India, and the cost at which the work is performed, the following analysis of the general average rates per square mile, with the total area completed, is given for the North Western Provinces, from the year 1833, and for Bengal from the year 1838—the first commencement of operations—down to the present time. The average for the North Western Provinces in the twelve seasons’ work, amounts to Rs. 18-8-8 per square mile ; and for Bengal it is, in a similar period, Rs. 20-14-10 per square mile ; whilst the general average on the whole area executed is only Rs. 18-6-8 per square mile. In the two

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seasons of 1847-48, and 1848-49, upwards of 16,000 square miles of country appear to have been surveyed by the united exertions of eight different parties in the two provinces.

NORTH WESTERN PROVINCES.			BENGAL PROVINCES.		
Season of Survey.	Area completed.	General Average Rate Per Sq. Mile.	Season of Survey.	Area completed.	General Average Rate Per Sq. Mile.
	Sq. Miles.	Rs. As P.		Sq. Miles.	Rs. As P.
1833-34	3,747	29 4 1	1838-39	1,901	60 0 1
1834-35	5,282	24 7 5	1839-40	2,450	49 9 4
1835-36	5,391	27 5 11	1840-41	5,145	23 3 4
1836-37	7,455	23 15 0	1841-42	9,132	22 5 7
1837-38	12,400	13 7 0	1842-43	6,035	22 13 0
1838-39	10,974	13 15 8	1843-44	7,079	18 4 4
1839-40	12,698	11 12 5	1844-45	7,043	16 10 2
1840-41	12,698	11 12 5	1845-46	8,967	12 10 8
1846-47	3,583	20 1 7	1846-47	7,420	14 9 5
1847-48	8,997	14 4 5	1847-48	7,097	18 2 5
1848-49	9,858	12 5 0	1848-49	6,243	21 0 4
1849-50	5,552	22 12 0	1849-50	5,162	24 14 10
Total... 12	98,636	16 8 8	Total... 12	73,684	20 14 10

Area in Sqr. Miles.    Cost in Rs.    Rate.

Total of the two Provinces ..... 172,321    31,74,101    18 6 8

It will be apparent, from the foregoing statements, that the revenue surveys supply the interior filling up of the triangles in the British revenue districts, which are chiefly flat lands, to which that system is most applicable. In native states and wild hilly countries, the topographical surveys before described are admirably adapted to the object in view, which is a complete and inexpensive first survey of all India. Considered in this point of view, the work may challenge comparison with any in the world. The triangulation supplies a permanent and accurate basis for the present, as well as for future internal surveys; for it must be borne in mind that, as the resources of this country become developed under the fostering protection of British rule, the topographical aspect of many districts must, in a moderate number of years, be completely changed. Tracts now covered with jungle will be reclaimed, canals will be dug, marshes drained, and roads established. New towns and villages will arise, and fresh groves be planted, and rivers will change their courses. That these views are not chimerical may be attested by my own experience, during 22 years of wandering throughout the length and breadth of the land; for places where, in my early days, I hunted the tiger, the bear, and the boar, are now covered with smiling fields, yielding a plentiful harvest to the cultivator. The greatest difference is also perceptible in the extension of towns and villages, showing the increase of productive wealth, which is taking place on all sides. On the other hand, in many native states, the jungle is advancing on cultivation, and the people thus become the alternate prey of men and wild beasts. These alterations cannot but produce, in the course of time, considerable changes in the topographical features of the country, for which reason revised surveys will be required; and these, like the present ones, will be based on the operations of the Great Trigonometrical Survey, of

India, which are intended to form a lasting monument for future generations, and an imperishable record of the landmarks of the present time.

The Report concludes with a "list of distinguished officers, in connexion with the accurate survey of India," which we cannot resist giving verbatim. It is in our opinion an honour to be associated with such men, and an equal honour to have shared in the toils and labors of a department presided over by an officer of Colonel Waugh's high reputation—a reputation second to that of neither of his predecessors:—

Before concluding these Memoirs, it may be considered a just tribute to those officers, who have been most conspicuous for meritorious service in connexion with the accurate geography of India, to place their names on record. Colonel Lambton and Colonel Everest stand pre-eminently above all others for scientific services, and their names are held in affectionate remembrance in this department. To these may be added, Captain Renny Tailyour, of engineers, astronomical assistant; Captain Jacob, of the Bombay engineers, late 1st assistant, and Mr. G. Logan, 1st assistant, all of the Trigonometrical Survey, whose services have been as valuable as of long duration; and Colonel Wilcox, afterwards astronomer to the king of Lucknow; the late General Hodson, Colonel T. Oliver, Major Herbert, and Major W. Brown, of the old revenue survey; together with Captain Thuillier, the present Deputy Surveyor-General, whose abilities are of a high order, and Captain R. Smyth, of the Bengal artillery, both of whom are ardent admirers of accuracy. In the Madras Presidency, Captain Du Vernet, the late Captain Garling, Major Ward, and Captain Snell.\*

In the appendix are to be found several statistical tables of the area population of the several districts and native states, under the three Presidencies; and a return by Mr. Walker, the Hon'ble Company's hydrographer, shewing that 41 sections of the *Indian Atlas* have already been engraved, at a cost for drawing and engraving of £5,844, the selling price to the public being 4 shillings colored; and that 14 sheets, or sections† more, embracing portions of each Presidency, are now in course of being engraved in England.

\* Evidently by inadvertency the distinguished name of Colonel Blacker is omitted.—ED.

† SHEETS of the INDIAN ATLAS now in course of being Engraved.

Number according to Index Map.	
24	contains Northern Konkun.
25	" part of Southern Konkun, including Bombay.
26	" part of Southern Konkun.
27	" parts of Southern Konkun, Southern Mahratta country, Goa territory,
41	&c.
39	" Poonah, Ahmednuggur, parts of Bhir, Purrainda, &c.
40	" The Satara territory, Kolapur, Bijapur, &c.
51	" parts of Scindiah's Dominions, Kotah, &c.
55	" Bassin, Maiker, parts of Jalnah, Patri, &c.
57	" Mulkhaid, Kulburga, Suggur, and part of Scholapur.
74	" Eilgundel, Mullungur, Wurungul, &c.
88	" Allahabad, Jounpur, parts of Bandah, Futtehpur, Mirzapore, Benares, Azimgurh, and of the southern part of the territory of Oude.
102	" parts of Goruckpur, Sarun, Tirhut and Nepal.
103	" Ghazipore, parts of Shahabad, Behar, Patna, Azimgurh, Sarun, Benares and Tirhut.