Franklin Institute,' published in Philadelphia. This I did, for the first time, on the 9th of that month, finding a fair agreement between the southern portions of his prominences 5 and 10, and the dark bands given in my sketch. I have, therefore, little doubt but that in locating these dark intervals in my original sketches, I intended to place the western one near 285°, and the eastern one near 120°, great exactness not being obtainable in the few moments given to the observation. In speaking of these bands as *dark*, I would be understood only as meaning that they were sufficiently so to be *readily seen*.

A comparison of the Des Moines and Ottumwa pictures of the "anvil" protuberance gives the following measurements. It will be noticed that the figures are somewhat in excess of those obtained from the last totality picture made at Burlington.

	"		Miles.
Extreme length of the "anvil"	265	or	119·800
" " base of the "anvil"	205	"	92·500
Greatest altitude above the sun's surface	81	"	36·500

Thus if, as is probable, the entire protuberance was not visible, its base being beyond the sun's limb, we have a bright cloud in the solar atmosphere nearly, if not quite, equal in volume to the planet Jupiter, and which in the direction of its length would suffice to reach more than half way to the Moon in her perigee.

THE SURVEYS OF INDIA.

II. THE TRIGONOMETRICAL SURVEY.

(*With a Sketch-map.*)

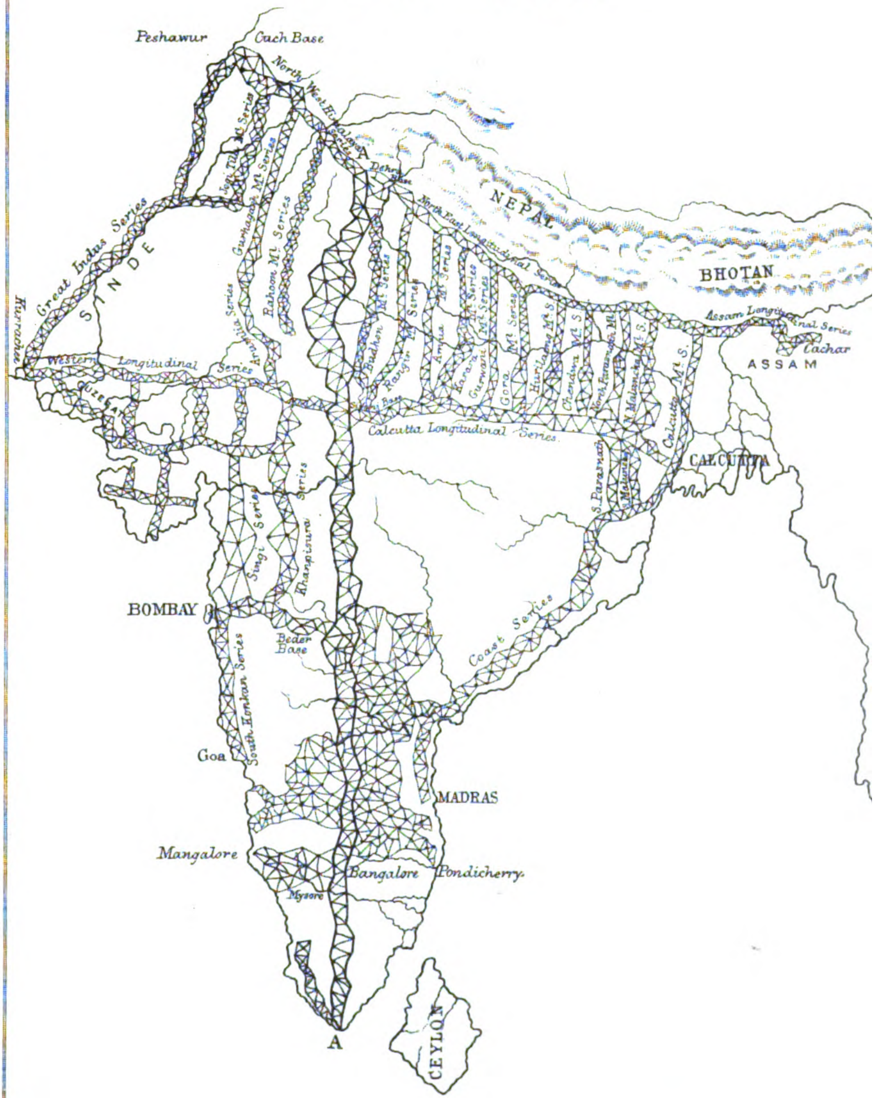
By F. C. Danvers, A.I.C.E.

The surveys of India may be divided into two classes—*viz.* the Great Trigonometrical, and the Geological. In connection with the former, other minor operations are undertaken under the title of topographical and revenue surveys, to which we shall refer more particularly in due course.

The idea of a great trigonometrical survey of a country, to be undertaken by the Government of that country, was first conceived by General Watson, at the suppression of the rising in Scotland in 1745. The execution of it was committed to General Ray, and was originally intended to extend no farther than the disaffected districts of the Highlands. The design, however, was subsequently enlarged, and the grand trigonometrical survey of Great Britain

OUTLINE MAP OF INDIA
shewing the Principal Triangulation Series
of the
GREAT TRIGONOMETRICAL SURVEY.

A.A. *The Great Arc Series* –



and Ireland was projected. Perhaps a more important survey, in some respects, than the British one was that undertaken by the French nation at the period of the Revolution. About that date the philosophers of France undertook to introduce a great reformation in regard to all those habits and usages of men which have reference to numbers, and everything—lengths, areas, moneys, weights, periods of time, arcs of circles—was to be numbered by tens, hundreds, thousands, &c. The question then came to be, What should be adopted as the basis of this standard, which was designed not only for France, but for the world? This question having been brought to the attention of the Constituent Assembly, it was proposed by M. de Talleyrand, and decreed accordingly, that the Parliament of England should be requested to concur with the National Assembly in fixing a natural unit of weights and measures; that under the auspices of the two nations, an equal number of Commissioners from the Academy of Sciences and the Royal Society of London might unite in order to determine the length of the pendulum which vibrates seconds in the latitude of 45° (as proposed originally by Huyghens), or in any other latitude that might be thought preferable, and to deduce from them an invariable standard of measures and of weights. The Commission named by the Academy had under their consideration three different units, namely, the length of the pendulum, the quadrant of the meridian, and the quadrant of the equator. The length of a quadrant of the meridian having been determined on, the measurement of an arc was entrusted to MM. Mechain and De Lambre, who began their labours in 1792, and thus commenced the trigonometrical survey of France.

The origin of the Great Trigonometrical Survey of India was not unlike that of the first Scottish Survey. After the successful termination of the war with Tippoo Saib, at the close of the last century, Captain Lambton (who had previously served as a surveyor in America, and who joined Her Majesty's 33rd Regiment at Calcutta in the year 1797) brought forward his plan of a geographical survey of part of the territory that had been conquered, and he proposed to throw a series of triangles across from Madras to the opposite coast, for the purpose of determining the breadth of the peninsula in that latitude, and of fixing the latitudes and longitudes of a great many important places, which were believed to be very erroneously determined in the survey previously executed by Colonel MacKenzie. Captain Lambton first submitted his plan to Colonel Wellesley, in whose regiment he had formerly served, who at once sent up the proposal to Government supported by his strong recommendation. Lord Clive was at that time Governor of Madras, and warmly approved of the undertaking, and it was accordingly sanctioned by Government.

The first base line measured by Colonel Lambton was on the table-land of Mysore, near to Bangalore. The chain used by him was one of blistered steel, constructed by Ramsden, and precisely similar in every respect to the one used by General Roy in measuring his base of verification on Rumney Marsh. It consisted of forty links of 2½ feet each, measuring in the whole 100 feet, at a temperature of 62°, and fitted with two brass register-heads, with a scale of 6 inches to each. This chain, it appears, had originally been sent with Lord Macartney's embassy as a present to the Emperor of China, and having been refused by him, it was made over by his Lordship to the astronomer, Dr. Dinwiddie, from whom it was purchased. The measurement of this base line was commenced on the 14th October, 1800, and completed on the 10th December following. Its total length was 7·4321 miles.

Whilst these operations were being carried on, an order was on its way to England for a supply of instruments of the best manufacture that could be obtained. Amongst these was a new chain which Colonel Lambton never allowed to be taken to the field, but it was reserved as a test, whereby that actually used was constantly verified. The other instruments received from England were a 36-inch theodolite, by Cary; an 18-inch repeating theodolite by the same maker; a 5-feet zenith sector, by Ramsden; 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 the present century could produce.

On the 10th April, 1802, the real commencement of the Great Trigonometrical Survey of India was made, although at that time the extent to which those operations would be ultimately carried was not even contemplated. Upon the resumption of operations no notice appears to have been taken of the Bangalore base line. Work was commenced by the measurement of a fresh base line of 40006·4 feet, on a plane near Saint Thomas' Mount, Madras, at no great distance from the shore, and nearly on the level of the sea. From this a series of triangles was carried, about 85 miles eastward, north as far as the parallel of 13° 19′ 49″ N., and south to Cuddalore, in latitude 11° 44′ 53″, embracing an extent of about 3700 square miles. Before describing further the progress of the survey, we must pause for a moment in order to give some account of the care taken in measuring the base line. The chain was in all respects similar to the one used at Bangalore. It was laid in coffers or long boxes, supported on stout pickets driven into the ground, and their heads dressed even by means of a telescope. At one end of the chain was a draw-post, to the head of which the near end of the chain being fastened, it could be moved a little backwards or forwards by means of a finger screw. Near the handle of the chain, and at a point where its measuring length was supposed to commence, there was a brass scale, with divisions, which was fixed to the head of another picket, distinct both from the draw-post and from those supporting the coffers. This scale could, by means of a screw, be moved backwards and forwards on the head of the post till it coincided with the mark on the chain. A similar arrangement was made at the other end, but the handle of the chain, instead of being firmly attached to the weigh-post, as it was called, had a rope passing over a pulley; and to this rope was appended a weight of 28 lbs. to keep the chain stretched. This arrangement enabled the measurer to move his chain backwards or forwards with the greatest nicety, and when satisfied that it was correctly placed, to keep it there perfectly steady; while, by means of the registers, he marked the places of the two extremities of the chain. The chain was then lifted by twenty coolies and carried forward, the near end being adjusted to the scale which had before marked the fore end. A new chain's length was then laid off in a similar manner, and so on, until the base was finished. During these operations tents were erected over the line, and thermometers were placed in the coffers to determine the temperature of the chain; and the rate of expansion having been previously determined by experiment, the necessary corrections were made for the varying temperature of the measurement. The quantity of this correction was ·00725 inch for every degree of Fahrenheit.

Many of the triangles carried forward from this base line had sides of from 30 to 40 miles in length. In computing their length Colonel Lambton reduced the observed angles to the angles of the chords, according to the method of De Lambre; and though he computed the spherical excess, he did not use it in any other way than as a measure of the accuracy of his observations. The chords, which were the sides of the triangles, were then converted into arches; and as Colonel Lambton had contrived that the sides of the four triangles which connected the stations at the south and north extremities should lie very nearly in the direction of the meridian, their sum, with very little reduction, gave the length of the intercepted arch, which was thus found to be 95721·326 fathoms. By a series of observations for the latitude, at the extremities of this arch, made with a zenith sector, the amplitude of the arch was found to be 1°·53233, by which, dividing the length of the arch just mentioned, Colonel Lambton obtained 60494 fathoms for the degree of the meridian bisected by the parallel of 12° 32′. This, till the survey was extended farther to the south, was the degree nearest to the equator—excepting that in Peru, almost under it—which had yet been measured. The next object was to measure a degree perpendicular to the meridian, in the same latitude. This degree was accordingly derived from a distance of more than 55 miles, between the stations at Carangooly and Carnatighur, nearly due east and west of one another. Very accurate measures of the angles which that line made with the meridian at its extremities, were here required; and these were obtained by observations of the Polar star when at its greatest distance from the meridian. For this purpose a lamp was lighted, or blue lights were fired at a given station, the azimuth of which was found by the Polar star observations, and afterwards its bearing was taken in respect of the line in question. Thus the angle which the meridian of Carangooly makes at the pole with that of Carnatighur, or the difference of longitude of these two places, was computed. It was then easy to calculate the amplitude of the arch between them; and thence the degree perpendicular to the meridian at Carangooly was found to be 61061 fathoms. Upon comparing this degree of the perpendicular with the degree of the meridian, the compression at the poles would appear to be equal to $\frac{1}{210}$. A writer in the 'Philosophical Transactions' for 1812, p. 342, contended that, on account of an error in calculation which escaped Colonel Lambton, the foregoing measurement should be diminished by 200 fathoms, thus reducing the length of the degree of the perpendicular to 60861 fathoms, which would give $\frac{1}{330}$ for the compression. These measurements were made in 1803.

In May, 1804, a base of verification of 39793·7 feet (7·536 miles, reduced to mean sea-level) was measured by Lieutenant Warren, Colonel Lambton's assistant, near Bangalore; and though the distance was nearly 160 miles, the computed and measured lengths of this base differed only 3·7 inches, or about half an inch in the mile; a proof of the great care and accuracy with which the work was conducted. This base was adopted for the origin of the great Indian arc series, to which we shall presently refer more particularly. From it a series of triangles was carried across the peninsula to the Malabar coast, which they intersected at Mangalore on the north and Tellicherry on the south. The heights of the stations were all determined from the distances and observed angles of elevation. The most considerable heights were at Soobramanee and Taddiandamole, in the western ghauts, not very far from the coast, the former being 5583 feet, and the latter 5682 feet above the level of the sea; but notwithstanding having to cross such elevations, after carrying the survey over a distance of 360 miles, it was found that the sum of all the ascents, and of all the descents, reckoned from the level of the sea, differed from one another only by 8½ feet. From the triangles thus carried across the peninsula, a correct measurement of its breadth was obtained, and one considerably different from what was before supposed. The distance from Madras to the opposite coast, in the same parallel, was ascertained to be very nearly 360 miles; whereas, until then, the best maps made it exceed 400 miles. All the principal places on the old maps, which had been fixed astronomically, were also found considerably out of position: for example, Arcot was out 10 miles, and Hydrabad no less than 11 minutes in latitude and 32 minutes in longitude.

For a long period the operations referred to above 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 Pindaree confederacies in 1818 that the peninsula and Deccan settled down into quiet and repose. The mysterious character of the instruments and operations, as well as the planting of flags and signals, always more or less awakened the apprehensions or excited the jealousy of the native princes; and it required, therefore, no ordinary tact, firmness, and patience, in order to conciliate their good-will.

Between the years 1802 and 1815, a network of triangles was, under the superintendence of Colonel Lambton, carried over the whole country as high as 18° latitude, 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 Bombay. The area comprised by the whole of the operations prosecuted during the time Colonel Lambton was superintendent aggregated 165,342 square miles. In October, 1817, the Marquis of Hastings, impressed with the important utility of the trigonometrical survey, resolved to transfer the control over its operations to the Supreme Government of India, which took effect from the 1st January, 1818, and Colonel (then Captain) Everest was appointed assistant to the superintendent, whom he subsequently succeeded upon the death of Colonel Lambton on the 20th January, 1823. Colonel Everest first acted as chief assistant during the latter part of 1818, and he was employed, in the first instance, in the triangulation of the eastern parts of the Nizam's dominions, and subsequently on a longitudinal series of the great triangles emanating from the Beder base line towards 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 on the extension of the great arc series, which, after many difficulties, was at length carried up to latitude 24°, where a base line was measured at Seronj.

After this, Colonel Everest proceeded to England, returning thence, in 1830, provided with geodetical instruments and apparatus of every description executed by the most skilful artists of the day, including 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; two 18-inch theodolites; and a variety of smaller instruments from 12 inches diameter downwards. 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.

In addition to the duties of Superintendent of the Trigonometrical Survey, Colonel Everest had, on his return to India, to perform those of Surveyor-General of India. In 1833 the offices of Deputy Surveyor-General at Madras and Bombay were abolished, and their duties devolved upon the Surveyor-General, so that Colonel Everest had now to perform the work which had hitherto occupied the undivided attention of four officers.

By the end of 1832 a longitudinal series of triangles had been completed from Seronj to Calcutta, where another base line was measured. Upon the completion of that work the measurement of the great arc was re-commenced, after a cessation of seven years. It was carried on from that time unremittingly till December, 1841, when the whole Indian arc from Cape Comorin to the Himalayas, forming the main axis of Indian geography, was finally completed. The area comprised by the great arc operations, principal and secondary, aggregated 56,997 square miles, including the revision of the section from Beder to Kalianpoor, and the measurement of three base lines, each from 7½ to 8 miles in length, *viz.* those of Beder, in latitude 18°; Seronj, near Kalianpoor station, in latitude 24°; and the Dehra base, about 70 miles north of Kaliana station, in latitude 29° 30′, where the great arc actually terminates; this distance being observed on account of the proximity of the Himalayas. On comparing the actual measurement of the Debra Dhoon base by Colley's apparatus with that calculated from the Seronj base, measured by the chain in 1824, a difference of nearly 3½ feet was found. In former times this would have been considered a very satisfactory agreement, seeing that the length of the base is 7½ miles, and its distance from the new base upwards of 400 miles in a straight line; but Colonel Everest considered the difference as indicating a much larger error than ought to exist, regard being had to the precision of the new methods. In order to set the question at rest, he resolved to re-measure the old base with the more complete apparatus he now had at his command. This operation was completed in January, 1838, when it appeared that the length given by the chain measurement of 1824 was too short by nearly 3 feet, as compared with the new result.

In the year 1829 a trigonometrical survey in the Bombay Presidency was commenced by Lieutenant Shortrede, on an independent base and point of departure. This survey proceeded in an unsystematic manner until it was brought under Colonel Everest's control in 1831, when, finding that no use could be made of this confused net of triangulation, the Colonel directed that the longitudinal series should be taken up where he left off in 1823. This was concluded in 1841, the series extending over a distance 315 miles in length.

The space at our disposal will not admit of a detailed account of the several series of triangulation carried out by the Trigonometrical Survey Department; they will, however, be seen by reference to the accompanying map. Besides the great arc series, extending from Cape Comorin to Dehra Dhoon, there are two longitudinal series, the one extending from Cachar, in Assam, to Peshawur, and the other from Calcutta to Kurrachee: between these are numerous series of triangles, those to the east of the great arc being at distances of about one degree, or 60 miles apart, taking meridional directions, thus forming what is called a gridiron system, similar to that adopted in the French and Russian surveys. Base lines are measured at the extremities of the longitudinal chains, and at the points where the chains cross Colonel Everest's arc; thus the triangulation is divisible into large quadrilateral figures, with a base line at each corner.

Colonel Everest was succeeded in the appointment of Superintendent of the Great Trigonometrical Survey and Surveyor-General of India by Captain (afterwards Sir) Andrew Waugh, in December, 1843, who held the combined offices for seventeen years. Sir Andrew Waugh left the service in 1861, when he was succeeded by Colonel J. T. Walker, R.E., as Superintendent of the Great Trigonometrical Survey, and by Colonel Thuillier, R.A., as Surveyor-General of India, both which officers respectively fill those appointments at the present time.

The charts of the trigonometrical operations are zincographed on a scale of 4 miles to the inch, and the geodetical co-ordinates for each station with azimuths and linear distances are entered upon them, so that each chart forms a brief but complete record of the survey results. Skeleton charts of levels, on a scale of 2 miles to the inch, are also prepared and photozincographed; these show the combined results of both trigonometrical and spirit levelling reduced to the common datum of the mean sea-level of Kurrachee harbour.

Revenue Survey.—The Revenue Survey Branch, in the Bengal Presidency, first commenced in the year 1822. It comprises a scientific periphery admeasurement of the land by means of angular and linear measurements, performed with theodolites and steel chains;

and its operations extend into such parts of the country as are under British administration and yield a fair revenue. It is a definition and survey of village boundaries and estates, and may also be termed a large scale topographical survey, as it affords accurate topography of every district falling within the scope of its operations. The system followed is that of traversing with the theodolite and steel chains, known as Gale's method of land-surveying, modified to secure greater accuracy and efficient checks on both the boundary and interior detail measurements. Large areas are first traversed with the better class of small theodolites having from 12 to 8 inch horizontal circles, starting from an initial station, where the azimuth is observed, to obtain the true bearings of stations in advance, the distances between stations being measured with steel chains twice over and repeated in rough ground, or wherever any doubts arise. These traversed areas, called main circuits, being in the first instance traversed and proved, afford a complete check on the minor or block circuits into which they are subdivided; and these minor circuits, being in their turn traversed and proved true on the basis of the main circuit containing them, reduce the errors in the village boundary work to a minimum. The trifling angular and linear discrepancies which may occur in the village traverse circuits are adjusted *inter se.*

The interior or detail survey, which is filled in by plane-table or compass and chain, rests on these small village polygons, plots of which are furnished to the native plane-tablers. The stations of the main circuits are permanently marked, and the masonry platforms which mark the tri-junctions of villages are, whenever practicable, made theodolite stations. The boundaries of villages are measured by offsets taken to all boundary pillars from the lines enclosing the village polygons, these linear and offset measurements being carefully recorded in the village boundary field-book.

Along the Revenue Survey lines of levels, all masonry platforms marking the junction of three villages which fall on or near the line are invariably adopted as permanent bench-marks. These being all marked prominently on the maps of the Revenue Survey, the entry of the data will be readily and easily made, showing the height of each bench-mark above the mean sea-level, as determined by starting from and closing all the lines of Revenue Survey levels on the Great Trigonometrical stations, or the bench-marks of the principal series of levels of the Great Trigonometrical Survey of India.

In connection with the Revenue Survey, levelling operations were carried on, during 1868–69, in Oudh and Rohilcund, and they have subsequently been extended to the central provinces, Bhamulpoor and Bengal. The object of these is to run series of levels across districts not yet contoured, and to combine the results of the levelling operations of the Revenue Survey with those already completed, or about to be prosecuted, by the Irrigation Branch of the Public Works Department.

The field mapping is all executed on a scale of 4 inches to the mile.

In addition to the regular professional revenue survey of villages, there has always been a minute measurement of fields for assessment purposes, conducted by native agency, entirely under the collector or settlement officers. These are crude operations after native fashion.

In the presidencies of Madras and Bombay, minute cadastral measurements of fields are in progress under European officers; these surveys are essentially for settlement and revenue purposes, and have no connection with the Indian Survey Department, nor are they under the direction of the Surveyor-General of India.

Topographical Survey.—The Topographical Branch of the Indian Survey Department is under the immediate superintendence of the Surveyor-General of India, and had its origin in the Revenue Survey. Its operations are confined chiefly to hilly and jungle-covered ground, yielding but little revenue, in parts of the country not actually under British management, and in friendly native states along the British frontier; and its object is to obtain a cheap, rapid, and reliable first survey for geographical and administrative purposes. The groundwork or basis of its operations is secondary and minor triangulation dependent on the Great Trigonometrical Survey operations, from which all the initial elements of latitude, longitude, elevation, distance, and azimuth are derived. The triangulation is carried on in a network covering the ground with points or stations at about 3 to 4 miles apart. The instruments employed for the secondary triangulation are vernier theodolites with 12 and 14 inch azimuthal circles; the horizontal observations are taken on four zeros repeated and the vertical angles on two zeros. For the subsidiary or minor network of triangles, theodolites with 7 and 8 inch azimuth circles are used, and the angular measurements are made with two zeros repeated.

The detail work, or delineation of the configuration of the ground, is executed usually on the scale of 1 inch to the mile by means of the plane-table. Some topographical surveys in cultivated or valuable tracts are on a scale of 2 inches to the mile; and a few others, in very broken and wild ground, on a scale of 2 miles to the inch. In addition to the 1-inch survey, the Topographical Branch undertakes the plans of all the important cities, forts, and strongholds in native states; these are mapped on scales varying from 6 to 16 inches to the mile.

References.

Asiatic Researches. Vol. VII. 1803.
Edinburgh Review. Vol. XXI. 1813.
Calcutta Review. Vol. IV. 1845.
Everest's Measurement of the Meridional Arc of India. 1847.
Calcutta Review. Vol. XVI. 1851.
Trigonometrical Survey (India). Printed Parliamentary Paper. No. 219 of 1851.
Report on the Survey of India for the three years ending 1858–59. By Lieut.-Col. Sir A. S. Waugh. 1861.
General Reports on the Operations of the Great Trigonometrical Survey of India. 1862–63 to 1868–69.
Professional Papers on Indian Engineering. Vols. II., III., and IV. Published at Roorkee.
Report on the Cartographic Applications of Photography, and Notes on the European and Indian Surveys. By Lieut. J. Waterhouse, R.A. Calcutta, 1870.

III. THE GEOLOGICAL SURVEY OF INDIA.

(*With a Sketch-map.*)

By H. Woodward, F.G.S.

Sixteen years have now elapsed since the Geological Survey of India commenced its systematic labours, and it may now be interesting to give some account of the progress that has been made, and to note a few of the results to which the Government officers have been led.

Some time beforehand, in 1851, Mr. (now Dr.) T. Oldham, the Superintendent of the Survey, arrived in Calcutta.

The work which he was then required to do was to go from place to place, and, without loss of time, to search for coal and other minerals of economic value; to furnish reports, and thus to indicate by observations in a few places the important results that might be obtained from a detailed survey of the whole of the country. Great were the difficulties with which he had to contend at the outset, and for a long time afterwards; so that not until 1856 was he able to establish that regular system of operations carried on by a staff of officers, small at first, and even in 1863 numbering but fifteen geologists.

No one was better fitted for the task in hand than Dr. Oldham; he had been Local Director of the Geological Survey of Ireland, and was previously Professor of Geology in Trinity College, Dublin.