# THE SURVEY OF INDIA
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## PAPER VIII.

# THE SURVEY OF INDIA.

(*Lecture Delivered at the School of Military Engineering on 27th November*, 1902, *by* LIEUT.-GENERAL C. STRAHAN, R.E.).

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I PROPOSE to give a short sketch of the history of the Survey of India, and a brief outline of the work now carried on by that Department. For all the early historical information I am indebted to the two memoirs on the Indian Surveys by Clements Markham and by Charles Black.

Up to the year 1800 scarcely any attempt was made to survey the country accurately; part of Bengal as far north as Agra had been roughly mapped, and surveyors had been attached to the armies that had taken the field in different parts, and they had brought back route maps and reconnaissances, by which means a considerable amount of information had been accumulated, but nothing had been published.

It was not until later that a scientific survey was commenced. This was suggested by an officer of the 33rd Regiment, William Lambton by name, who had served under Lord Wellesley during the Siege of Seringapatam. After the fall of Tippoo, Major Lambton submitted a project for the measurement of an arc of the meridian and for a trigonometrical survey across the peninsula. This project was approved of, but the necessary instruments could not be procured till 1802.

From this time the operations may be divided into three more or less distinct branches, the trigonometrical and scientific, the topographical, and the revenue. I will first deal with the trigonometrical and scientific branch.

## Trigonometrical Survey (*Map* I.).

The instruments made use of by Lambton were a 36-inch and an 18-inch theodolite, a zenith sector of 5 feet radius, and two steel chains, one of which was kept as a standard, by which the chain in actual use was constantly checked. The point of origin of the survey was the Madras Observatory; it became therefore of the greatest importance to fix the position of this with the utmost accuracy, as on it depended the position of India as a whole; it was comparatively easy to determine the latitude with considerable accuracy, but it was not nearly so easy to ascertain the true longitude; it was measured, as well as it could be in those days, by observations of eclipses of Jupiter's satellites and by lunar distances; the results were by no means concordant, but Lambton eventually adopted 80° 17′ 21″ E. longitude for the survey.

Actual work was commenced in 1802, by the measurement of a base line 7½ miles long in the neighbourhood of Madras; the steel chain was fitted into five coffers of wood, each 20 feet long, which were supported on tripods with elevating screws. From this base line a chain of triangles was carried up to the plateau of Mysore, where a base line of verification was measured, and from this the triangulation was extended to the Malabar coast. In measuring the horizontal angles Lambton took them three or four times; and each time the object was intersected the microscopes were read three times, but no change of zero was made.

The distance across the peninsula thus obtained was found to be 40 miles less than that shown on maps of the day, thus proving the absolute necessity of a trigonometrical survey. Major Lambton then turned his attention to the measurement of an arc of the meridian, and the chain of triangles that was observed for that purpose is known as the Great Arc Series. By 1811 Major Lambton and his assistants had completed this series from Cape Comorin to Bangalore, besides covering nearly the whole of the southern part of the peninsula with a network of triangles. On one occasion, when hoisting the great theodolite to the summit of the Tanjore Pagoda, one of the guys gave way, and the instrument was dashed

against the wall with great violence, distorting the limb. Such a catastrophe might well have discouraged any man, but Lambton never lost heart; he hurried back to Bangalore, where he shut himself up in his tent with a few Ordnance artificers, and in six weeks he had with patience and skill brought it back to nearly its original form; the instrument remained in use for upwards of 20 years after this. The actual amount of damage done to the graduation was never known, but this accident eventually led to taking the horizontal angles on different parts of the limb, so as to eliminate as far as possible any inaccuracies in the graduation. This system has been in use ever since, and all angles of the principal triangles are repeated not only on two faces, but on several parts of the limb.

Difficulties in the field were not the only ones; Lambton had many others to contend with. The utility of his work was called in question, and his resources were crippled by the Finance Committee at Madras. Even the scientific societies in Europe gave him no encouragement, and for years he never received any sympathy or advice from Government or from the Royal Society; eventually however, in 1817, he was made corresponding member of the French Institute, and in 1818 he was elected a Fellow of the Royal Society. In January of that same year the Governor-General at last recognized the importance of his survey and transferred it to his immediate control, ordering it to be called the Great Trigonometrical Survey of India, a title which it has held ever since.

Capt. G. Everest, R.E., had been appointed Lambton's chief assistant in 1818. At that time Central India was in a most unsettled state, and instead of attempting to push on the Great Arc, Lambton employed his parties in triangulating the country between the Kistna and Godavery Rivers. Everest was despatched on this duty, and overcame the difficulties arising from the disturbed state of the country; but he was prostrated by jungle fever, which forced him to take leave to the Cape of Good Hope to recruit. In the meantime Lambton, who was now aged and much broken, again proceeded with the Great Arc; but it was a last effort, and on the 20th of January, 1823, he died on the road to Hinganghat, at the age of 70. His work comprised the measurement of the Great Arc from Cape Comorin to Berar, and upwards of 165,000 square miles of triangulation in Southern India. He was succeeded by his assistant, Capt. Everest.

In December, 1823, Everest attempted to prolong the Great Arc, but he had to face many difficulties arising from the death of his

colleague, Dr. Voysey, the retirement of his chief assistant (a half-caste from Madras who did not relish the exposure and hard work), and the unhealthiness of the country, which at last brought on a severe attack of jungle fever, causing partial paralysis; still he persevered, but he had to be lowered into and hoisted out of his observing seat. In spite of all this he succeeded in carrying the series over the Satpura range on to the Sironj plateau, where a base line was measured with the old chain. Early in the year 1825, however, he completely broke down, and was obliged to go to England, where he remained for five years, employing his time in studying the latest improvements and in superintending the construction of new instruments on the most approved principles. He took back with him a 36-inch theodolite and two double vertical circles, 36 inches in diameter; also a complete set of compensation bars, to take the place of the old steel chains.

About this time a most important change in the procedure of the field parties was made. Up till now the surveyors had been kept in the field all the year round; opaque signals only had been used; it was therefore necessary to observe during that portion of the year when the atmosphere was clearest, that is, in the rainy season. On the high plateau of Mysore this was not of so much consequence, but on proceeding northwards Everest found the climate so deadly that a change had to be made, and the out-of-door work was thereafter done during the cold dry season, the surveyors retiring into recess quarters for the hot weather and rains. This necessitated the use of luminous signals, the atmosphere being as a rule too thick to allow of flags and poles being seen; Everest then introduced heliotropes to flash the sun by day and powerful Argand lamps for use by night.

On Everest's return in 1830 he found that the longitudinal series from the Great Arc to Calcutta was nearly finished, and he decided on measuring a base line of verification with the new bar apparatus; the site he selected was along the road from Calcutta to Barrackpore, along which it extends for $6\frac{1}{2}$ miles. He then resumed the work connected with the Great Arc, but he had first to overcome many difficulties, which could have only been surmounted by a combination of qualities rarely met with in one man. He had to train his staff, and in addition to his incessant labours in the field, he had to transact all the business connected with his office as Surveyor-General, for in him had been combined the two appointments of Surveyor-General and Superintendent of the Great Trigonometrical Survey. Moreover, the series, which had hitherto had

the advantage of hills on which to erect the stations, had now reached a flat country thickly covered with villages and groves of trees, which completely obscured all distant views; to obviate this, solidly built towers were erected, high enough to see over the bulk of the trees and other obstacles (*Figs.* 1 to 7, *Plate* I.).* At first the selection of the sites for these stations was made with the assistance of a mast 30 feet high, surmounted by a circular table, on which was placed a 12-inch theodolite; round this was built a square bamboo platform for the observer; thirteen other masts, 70 feet in height, carried signals. But this was found to be a cumbersome method, and he then introduced the system of ray tracing, as it was called; this consists of a traverse run between the two mutually invisible points, from which their relative direction can be calculated, so as to admit of a line being carried between them; along this all obstacles can then be cleared, or, failing that, one or both of the points must be shifted.

Day and night at all hours Everest was at work, but it was not till May, 1834, that all the stations between the Chambal River in Central India and the foot of the Himalayas had been selected. In the end of that year the most northern base line of the Great Arc was measured in Dehra Dun, twice in opposite directions; the difference between the two determinations was only 2·4 inches. The Sironj base was re-measured with the same instruments, and was found to be 2·8 feet too short. In the years 1834–35 all the angles of the triangles across the plain were observed, and the series was connected with the Dehra base. Thus was completed the Great Arc, which extends throughout the entire length of India, from north to south. In addition to this great work, the Bombay longitudinal series was executed by Everest. He also designed and partly carried out a scheme for covering Bengal and Behar, in the southern part of the peninsula, with a gridiron of chains of triangles instead of Lambton's network. The gridiron system may be described as one of meridional series of triangles, tied together at their extremities by longitudinal series, thus forming a figure resembling a gridiron. These series have generally been made to follow closely meridional or longitudinal lines; thus the Great Arc follows the 78th meridian, and the longitudinal series from Calcutta to Karachi keeps as nearly as possible to the parallel of latitude of 24 degrees.

Colonel Everest finally quitted the scene of his labours and triumphs in 1843. He had completed one of the greatest works in

* *Figs.* 8 *and* 9, *Plate I., show the towers employed since* 1852.

the whole history of science; no scientific man ever had a greater monument to his memory than the Great Arc of India. His was a creative genius; the whole conception of the trigonometrical survey as it now exists was the creation of his brain. He substituted the gridiron system for that of the continuous network; he introduced the compensation bars; he improved the system of observing by the change of zero; he invented the plan of observing to heliotropes; and he designed the towers. There have been modifications and improvements since; but nearly everything of importance connected with triangulation was originated by this great geodosist. He was made a C.B. and knighted in 1861. He was succeeded by one of his assistants, Capt. A. Waugh, R.E., of whom he said that "he had attained a decree of accuracy and perfection of skill which it would be impossible to surpass."

Waugh took charge in 1843, and, like his predecessor, received the double appointment of Surveyor-General and Superintendent of the Great Trigonometrical Survey. His first work was to complete the project for the triangulation between the Great Arc and Calcutta, which I have already mentioned. Regarding the several series which cross this area, I should like to allude especially to the difficulties and dangers incurred by the officers who had to carry on that which connected the northern ends of the different meridional series. It was commenced in 1845 and completed in 1850, and is the longest series between measured bases in the world, extending for no less than 1,690 miles from Dehra Dun to Sonakhuda, in Purneah. In consequence of the refusal of the Nepalese Government to allow it to be carried through their country, the stations had to be located in the deadly tracts of marsh and jungle which lie along the foot of the Himalayas. In 1847 no less than 40 natives died of jungle fever, and Mr. Logan, the observer, was himself prostrated, and the whole party was conveyed in a helpless condition to Gorakpur. Lieut. Reginald Walker then took charge, but he was also attacked, and was found dead in his dooly when hurrying up to Darjeeling. The completion of the worst part of this series is due to the courage and perseverance of Mr. Logan, who died three years later from the effects of disease contracted at this time. Of the five officers who held charge of it at different times, Colonel Waugh himself being one, two retired and two fell victims to the climate. From the stations of this series were fixed the mightiest peaks of the Himalayas; the rays to these were in many cases of great length, the longest being upwards of 200 miles. The loftiest

peak was well named by Waugh after his old chief, Mount Everest; it is the highest known in the world, and is 29,000 feet in height.

Waugh extended the gridiron system to other parts of India, but time will not allow of my entering into details of how the various difficulties met with by the observers were overcome; at one time having to work their way through deadly jungles, at another having to carry their work through a waterless desert, where special arrangements for the supply of both food and water had to be made, not only for the observer's own camp, but also for the outlying camps of the signallers; in Kashmir, where they had to observe at stations far beyond the limits of perpetual snow, even up to 18,000 feet, whilst the signallers showed their heliotropes from peaks up to 20,000; building materials for the stations had to be dug out of the snow, and on one occasion the surveyors were detained for 33 days owing to the storms of snow and the foggy weather.

A series of levelling operations to determine the heights of base lines in the interior was instituted by Waugh. Reciprocal vertical observations had already been taken at all the trigonometrical stations; but, owing to the very uncertain effects of refraction, the results were not always reliable; taking into consideration this and the great lengths of the series, it was thought desirable to check the heights thus obtained by lines of levels. In 1858 these levels were commenced by Major James T. Walker, R.E., and he connected the Karachi, Chuch, Dehra, and Sironj bases with the sea. The errors thus discovered varied from 1 foot 8 inches to 5 feet 1 inch.

Waugh became a major-general and was knighted in 1861; he retired in March of the same year, having been Surveyor-General for 17 years. His labours were recognized by the Royal Geographical Society, and in 1856 he was awarded its Gold Medal.

On the retirement of Sir Andrew Waugh, the two offices of Surveyor-General and Superintendent of the Great Trigonometrical Survey were once more separated, after having been united for 31 years. Colonel H. L. Thuillier became Surveyor-General and Major J. T. Walker Superintendent of the Great Trigonometrical Survey.

The gridiron system and the measurement of base lines were vigorously carried on under Walker. The base at Vizagapatam was first taken in hand, and was completed in two months, in the autumn of 1863, by Walker himself, assisted by three other Engineer officers. The difference between its measured length and that computed from the triangulation starting from Calcutta, 480 miles distant, was only half an inch. This base line was then

connected with the Madras Observatory, Lambton's starting point 60 years before. A few years later it was decided to re-measure the base lines at Bangalore and Cape Comorin, and to revise the intervening triangles with the more modern instruments. Owing to the changes in the surface of the country, it was found necessary to select new sites for the base lines. The Comorin base was the last required for the verification of the triangulation of India proper, and the tenth that had been measured with the bars taken out by Everest in 1830. Under the superintendence of Walker the triangulation of India proper was thus completed.

### Levelling Operations.

The spirit levelling operations, which Walker himself had commenced under Waugh, were continued by him, and a line of levels connecting Karachi with Calcutta was finished, being the longest and probably the best line of its kind that has ever been run; it is 2,200 miles in length. Branches from this main line join it on to the railways of Delhi, Lahore, Mooltan, and other places.

### Observations for Longitude.

For topographical purposes the values deduced from the triangles are all that are necessary, but for accurate geodetic purposes astronomical determinations of the stations, or at all events a certain number of them, are also required. In 1863 two parties were organized to take observations for latitude and azimuth; one party was to begin at Calcutta, and take observations along the Calcutta Longitudinal Series at the stations whence the Meridional Series emanated, whilst the other was to work on the Great Arc, selecting stations at about 1° apart. In 1876 the determination of differences of longitude by the electric telegraph was commenced, the latitude observations being held in abeyance meanwhile. In the first year arcs between Bombay, Haiderabad, Bellary, Madras, and Bangalore were measured; in the next year three other arcs in India were added, and then the two officers (Capts. W. M. Campbell, R.E., and W. J. Heaviside, R.E.) proceeded to find the differences between Bombay, Aden, and Suez, in order to complete the connection between England and India, of which the section from Greenwich to Suez had already been determined on the occasion of the transit of Venus in 1874, under instructions from Sir George Airy, the Astronomer Royal. The result of these measurements was to reduce the longitude of the Madras Observatory by 2′ 31″ of arc. In

1895–96 a second determination was made *viâ* Karachi, through Persia to Potsdam and Greenwich, which still further reduced it to 80° 14′ 46″·7; this may be looked upon as final; any future alteration that may be made will be of so small an amount as only to affect the most rigorous calculations of the figure of the earth.

A result of these longitude observations was to show a difference of nearly 14″ of arc between the longitude of Madras and Mangalore (on the east and west coast respectively), as determined by triangulation and by the telegraph, the former being the greater. This is consistent with the result of pendulum observations, which show that the density of the earth's crust is greater under the depressed beds of oceans than under the elevated portions of land. In consequence of this the plumb line at Madras is probably deflected to the east, whilst at Mangalore it is deflected to the west, thus making the astronomically determined difference of longitude less than it actually is.

These pendulum observations had been commenced by Capt. J. P. Basevi, R.E., in 1865, under the instructions of Colonel Walker. In the course of the next five years he swung the pendulums at nineteen stations on the Great Arc, at two stations on the east, at two stations on the west coast, and in Minikoi (one of the Laccadive Islands). He then started for the lofty plateaus of Thibet; he there swung the pendulums at a station on the More Plain at a height of 15,500 feet above the sea; thence he made his way back to the Upper Indus, and, although suffering from a severe cold, he set up his instruments on a mountain in Ladak, 17,000 feet in height. There, protected only by a tent, in a climate where the thermometer rose to 70 or 80 degrees in the afternoon, and fell below zero at night, his illness increased; one morning, when gallantly striving to rise from his bed to commence work, he died. The operations were subsequently carried on by Capt. Heaviside, who swung the pendulums at some stations in India, and then proceeded to England, swinging them *en route* at Bombay, Aden, and Ismailia, in Egypt. I have already alluded to one interesting fact that was deduced from these observations; another was that the density of the earth's crust is less under and near the Himalayas than under the plains to the south.

### Tidal Survey.

Yet another important set of operations was set on foot by Walker, viz.:—Observations to record the height of the tides, in

order to ascertain the changes in the relative height of land and sea which were believed to be occurring, more particularly on the coast of Kattiawar, and also to determine the mean sea level at various points on the Indian coasts. Some observations had been taken in a desultory way in the Hooghly, at Madras, Bombay, Karachi, and a few other places. Mr. Parkes had also taken tidal observations at Karachi and Bombay, and had computed very accurate tables for those two ports. But more than this was now required, and in 1868 Walker was requested to take steps to obtain the necessary self-registering tide gauges, and to connect the selected tidal stations by accurate lines of levels. But the proposed operations were postponed for four years; and it was not till 1872 that Lieut. A. Baird, R.E., was deputed to study the practical details of the method of tidal registration and the harmonic analysis of the observations, as practised by the British Association. Six new gauges with chronometric escapements were made, and with each gauge self-registering aneroids and anemometers were supplied. Baird selected three stations at the head of, at the entrance to, and about half-way up the Gulf of Kutch. The preliminary result of a year's observations at these stations was to show that the mean sea level at the head of the gulf is 7 inches higher than at the mouth. Subsequently Baird arranged for tidal stations at Bombay, Karachi, Aden, Madras, and other places along the coast; at each a man was placed in charge of the instruments, and taught to manipulate them; the correct time, which is a most important factor in the operations, was obtained from the telegraph office, one of which was to be found at nearly all the places selected. At those which were out of reach of telegraph offices chronometers were supplied, or, if they were not available, a sun dial, devised by Colonel George Strahan, R.E., was given, by which, when the sun is near the meridian, the time can be estimated within 10 seconds or even less. In 1880–81 the stations at Bombay and Madras were connected by a line of levels carried across the peninsula; the line was 730 miles in length, and for the most part ran near the railway. The result was that the mean sea level of Madras was made out to be about 3 feet higher than that at Bombay. It is supposed that the discrepancy may be due to local attraction of the hills and table lands over which the levels were carried, or else to an accumulation of small errors. The total number of places at which tidal observations have been or are being taken is 41, extending from Suez to Port Blair, in the Andaman Islands. Seven of these have been made permanent observatories,

whilst at the others observations were taken usually for five years.

The tide gauges have on more than one occasion furnished some interesting results regarding earthquakes. In December, 1881, there was an earthquake in the Bay of Bengal, which was very violent in the Andamans and Nicobar Islands, and was felt all along the east coast of India, and slightly on the west coast. The earth waves appear to have lasted for a few seconds only, but the ocean was greatly disturbed. Major M. W. Rogers, R.E., was at this time triangulating on an island near Tenasserim, and was at the very moment observing to one of his stations some 15 miles off; he actually saw the earthquake before he felt it, for he saw the signal rise and fall in the field of his telescope; then, on looking at his instrument, he saw the levels were violently agitated. Again, the gauges recorded the effects of the great eruption of Krakatoa, in Java, on the 27th and 28th of August, 1883; the primary effect was a marked fall in the sea level, which was succeeded by a great positive wave; great waves, ranging in height from 22 inches at Negapatam to 9 inches at Aden, 4,000 miles distant, were registered at all places which were so situated as to receive the full force of the disturbance.

## Exploration in Thibet.

About 1860, whilst Capt. T. G. Montgomerie, R.E., was engaged on the survey of Kashmir, it occurred to him that it would be feasible to employ trained natives to explore portions of Central Asia which it would be impossible for Europeans to enter; he accordingly selected some men and proceeded to train them to run route surveys with a compass, pacing the distances, and to take meridional altitudes with a sextant. After much trouble and many disappointments, one man was found suitable, and sent to Yarkand, the position of which he fixed; another died on his way home under very suspicious circumstances; whilst a third was sent towards Chitral, but he had a blood feud in his family, and the avenger followed and murdered him. After this the scheme met with better success. In 1865 Pundit Nain Singh, a Bhutiya, after two unsuccessful attempts to pass the Chinese outposts on the boundary of Thibet, succeeded in getting to the Sanpu, as the portion of the Brahmaputra north of the Himalayas is called, and there he joined a caravan sent by the Rajah of Kashmir to the Government of Lhasa. Travelling with this caravan he reached that place, where he stayed for some time, and made a sketch map

of the town. On another occasion he and another man, after a most trying journey, during which they crossed a pass 18,760 feet above the sea, reached the gold mines of Thok-jalung. On retirement this Pundit not only received his well-earned pension, but the Government gave him a village in addition, and he was awarded the Gold Medal of the Royal Geographical Society. The most remarkable journeys of any native explorer were made in 1878–82 by Kishen Singh, a first cousin of Nain Singh, by whom he was trained; one much vexed question he set at rest, and that was whether the Sanpu formed the upper part of the Brahmaputra or the Irrawaddy. From the northern side of the Sanpu he made his way east and south until he arrived close to the boundary of Assam without crossing that river, thus showing that it could not flow into the Irrawaddy. Although so close to home, he was unable to pass through the last few miles, owing to the hostility of the inhabitants; and he was forced to make an enormous detour in order to once more reach India. Kishen Singh was rewarded by a free grant of land and the title of Rai Bahadur, a sum of money from the Royal Geographical Society, a Gold Medal from the Paris Geographical Society, and another from the Venice Geographical Congress. The adventures experienced and the hardships undergone by these native explorers are full of interest, and I should like to dwell more upon them, but I must pass on to other subjects.

## Re-Organization of Department.

In 1878, when Walker became Surveyor-General, Government called upon him to re-organize the department, and to amalgamate the three branches which had up to this been virtually separate departments, each with its own cadre of officers and establishments. As time went on the special scientific duties of the Trigonometrical Branch gradually approached completion, and many of its officers were employed on topographical work; and, similarly, the work of some of the revenue parties was more of a topographical than of a revenue nature. The duties of the three branches had thus become much intermixed, whilst it was found impracticable to be constantly transferring officers from one branch to another, according to the work they were employed on. The amalgamation was carried out, but not without difficulty, and in some cases not without damage to individual prospects, more especially as at the same time extensive

reductions were ordered. The united department was then styled the Survey of India, and was administered by a Surveyor-General, who was also Superintendent of the Great Trigonometrical and of the Topographical Surveys, whilst a Deputy Surveyor-General superintended the Revenue Branch. On General Walker's retirement this was again altered, and a Superintendent of the Trigonometrical Branch was added, the Surveyor-General retaining the supervision of the Topographical Branch.

## Computing Office.

Hitherto I have alluded to only the field parties of the trigonometrical surveys. Preliminary values had been computed of sufficient accuracy to afford a basis for the mapping; but the final determinations, in which all the different circuits forming the grid-irons should be consistent not only each in itself, but with all the others, had yet to be made; this was beyond the powers of the field parties, who had hitherto carried on the preliminary calculations during their recess seasons; so a computing office was organized at Dehra Dun; and the results, as they were completed, were published in the volumes of the *Account of the Operations of the Great Trigonometrical Survey of India*. Of these, nine were published under Walker; Vol. No. I. treats of the Base Lines; Nos. V. and IX., of the Pendulum and Longitude Operations respectively; and the remainder of the Triangulation. It will thus be seen that during Walker's time, not only was great progress made in the operations which had already been started, but that several other most important ones were initiated. He was indefatigable in work, never sparing himself, as is evidenced by the fact that he found time to issue nine of the great volumes in addition to his onerous duties as Surveyor-General and Superintendent of the Trigonometrical and Topographical Surveys. Of his abilities, these volumes alone afford ample evidence. For his military services on the Trans-Indus Frontier and in the Mutiny he was made a C.B., and he was also a Fellow of the Royal Society. He left India in 1883, and died a few years after.

Colonel C. T. Haig, R.E., succeeded him as Superintendent of the Great Trigonometrical Survey, and Colonel G. C. Depree, Indian Staff Corps, as Surveyor-General and Deputy Surveyor-General of Topographical Surveys.

The principal triangulation in India proper having been completed, attention was directed to its extension into the countries on either side of it. In Burmah a more accurate basis for the topographical surveys was required, so in 1889 a series, emanating from that which had been carried along the west coast, was commenced; it was to run northwards through Mandalay up to the latitude of 25°, whence it was connected to the west by a series through Manipur. Great difficulty was experienced in observing across the Chindwin valley on account of the want of elevated positions from which to see over the huge jungles, and also on account of the haziness of the atmosphere. The difficulty was finally overcome by using special acetylene lamps with powerful parabolic reflectors, devised by Capt. H. A. D. Fraser, R.E., which could be seen across the whole valley.

In Baluchistan, on the extreme west also, accurately fixed stations were necessary to strengthen the mass of secondary triangulation which had gradually accumulated there; a principal longitudinal series was therefore started in 1894 from the Great Indus Series, to run through Mekran. This unfortunately came to an abrupt and a most unpleasant end; for in the third year the party was attacked at night, and the headquarters camp was completely looted, the theodolite hopelessly damaged, and 13 natives were killed. Capt. J. M. Burn, R.E., the officer in charge, was luckily sleeping on a small hill at a short distance from the main camp, and he and the men with him escaped, but with great difficulty and no little hardship, as they had to make their way as best they could for 130 miles to the nearest European station. It has not been considered desirable even yet to continue this series, which will in all probability form a connecting link between the Indian and European surveys.

Meanwhile tidal observations and the accompanying levelling operations were carried on without a break. The electro-telegraphic determinations of differences of longitude, which had been unavoidably stopped, were re-commenced as soon as two suitable officers could be spared, and after the instruments had been thoroughly overhauled and strengthened; in the intervals the latitude and azimuth observations were resumed.

Colonel Haig retired in 1888 and was succeeded by my brother, Colonel George Strahan, R.E., who in his turn was succeeded in 1894 by Colonel St. George Gore, R.E., the present Surveyor-General. The present Superintendent of the Great Trigonometrical Survey is Lieut.-Colonel S. G. Burrard, R.E.

## Earthquakes.

In June, 1897, an earthquake of great severity shook the hills in Assam most severely, and its effects were felt more or less all over India. Calcutta suffered very seriously, numbers of houses being dangerously cracked and a portion of the spire of the cathedral being thrown down. The amount of permanent displacement to which the hills had been subjected was a matter of great interest, and an attempt was made to measure this by re-observing at the principal trigonometrical stations nearest the centre of disturbance. No large instrument was available, but the best in hand at the time was given to an assistant, and he re-observed the horizontal and vertical angles at thirteen stations, fixing the positions of twenty-two and the heights of twenty-five old stations over an area of 1,000 square miles. The results showed that the whole of this area had been affected by the earthquake, so it is impossible to say how much these stations had been displaced in comparison with the unaffected area outside; the average displacement amongst themselves amounts to about 7 feet, whilst the changes in height vary from a subsidence of $4\frac{1}{2}$ feet to an upheaval of 24 feet.

Financial reasons prevented any extension of these interesting observations with a larger and more accurate instrument, so it is much feared that this almost unique opportunity of ascertaining with accuracy the actual displacement of a portion of the earth's surface due to an earthquake will be lost.

On January 22nd, 1898, a total eclipse of the sun took place in India. The Survey Department sent a detachment under Mr. Pope (one of the Assistant Surveyor-Generals) to Dumraon in Bengal, with an equatorially mounted camera; his object was to obtain as good a picture of the corona as possible; his results were excellent. At Sahdol, in Central India, the Astronomer Royal and Prof. Turner erected their instruments; the camp was managed by Survey officers, and I had the pleasure of being present myself, and a most interesting time we had. The observatories were mere grass sheds, but they answered the purpose well enough. Another camp was also in our charge at Pulgaon, where Mr. Newall and Capt. E. H. Hills, R.E., conducted their observations.

## Magnetic Surveys.

The latest scientific operation undertaken by the Trigonometrical Branch is a magnetic survey of India and Burmah. In 1899 Capt. H. A. D. Fraser, R.E., who was then in England on furlough, was

deputed to consult Prof. Rücker, and to make a study of the subject, and to obtain suitable instruments. In December, 1900, Capt. Fraser returned to India and took charge of the work. The general scheme is to determine the declination, dip, and intensity at points between 30 and 40 miles apart. At Colába, Kodaikánal, Dehra Dun, Madhupur, and Rangoon permanent magnetic observatories will be established and self-recording instruments installed.

## Topographical Surveys (*Map* II.).

Having thus given a brief outline of the growth and progress of the more scientific branch of the Department, let us take a glance at the topographical surveys. The first attempt at a regular detailed survey was made by Colonel Colin Mackenzie, who from 1790 to 1809 was employed in making maps of part of the Deccan, and was then made Surveyor-General of Madras; his work, which comprised an area of 40,000 square miles, was embodied in one general and seven provincial maps. His details were based on triangulation, which was independent of that of Lambton, with whom it appears he did not work harmoniously. I am unable to tell you what his system of detail survey was. In 1816 he was removed to Calcutta, and was made Surveyor-General of India, which office he held till 1821, when he was succeeded temporarily by Colonel Hodgson until Colonel Blacker took up the appointment in 1823. During this first period of the topographical surveys, maps were made of all the districts south of the Kistna River, mostly based on Lambton's triangulation. At about the same time surveys were made of the Ganges, first from Hardwar to Allahabad, and afterwards northwards nearly to its source at Gangotri. Route surveys were also made in Oudh and Rohilkund; then followed rough maps of the Himalayas between the Ganges and the Sutlej and of the provinces of Kumaon and Garhwal, as well as a map of Bandelkund and a route survey of Bhopal and Barsia, in Central India. The Sunderbands were also surveyed in 1812–18 by two young brothers Morrieson, who related how they were much annoyed by tigers and alligators, and how a tiger sprang out of a tree just over their instrument whilst they were in the act of observing; also how their instrument vibrated from the shaking of the ground caused by the tread of huge monsters in the jungle. On the Bombay side the most important work consisted of a careful survey with compass and perambulator of Gujerat and Katiawar.

When Sir George Everest was made Surveyor-General as well as Superintendent of the Great Trigonometrical Survey in 1830, his attention was so much taken up with the more scientific part of the work that the geographical delineation of the country somewhat languished. Yet considerable progress was made, more especially in the Revenue surveys, of which I shall speak presently. Topographical surveys were made of the wild country about the sources of the Nerbudda River up to Jubbulpore, and a survey was commenced to connect Assam with the maps already made of the Ganges in Lower Bengal; this was, however, suddenly suspended by the orders of Government. The breaking out of the first Burmese war had given an opportunity of gaining much information in the direction of the N.E. Frontier of Bengal; and Capt. Bedford, with Lieuts. Wilcox and Burlton, had been sent in 1825 to explore the Brahmaputra to its source; Burlton made a survey as far as Sudiya, Bedford made journeys up the Dihong and Dibong Rivers until he was stopped by wild tribes, and Wilcox succeeded in making one excursion beyond the frontier up the Brahmaputra valley, and on another occasion penetrated to the banks of the Irrawaddy. Meanwhile the survey of the Nizam's territory, based on Lambton's triangulation, was progressing systematically and steadily; in Madras some districts were re-surveyed and others were completed; in Bombay some compass surveys, not based on triangulation, were made, but they were of little value.

From 1843 to 1861, during the administration of Sir Andrew Waugh, great progress was made in topographical surveys, the most interesting and valuable being undoubtedly those of the Sind Sagar District in the Punjab by Capt. D. G. Robinson, R.E., and of Kashmir by Capt. T. G. Montgomerie, R.E. The former is on the 1-inch scale and has been published in 28 large sheets, comprising the whole of Rawal Pindi and Jhelum and the hilly parts of Shahpur and Liah, covering an area of 10,554 square miles; it was completed in 8 years. It was based on triangulation, and the detail was filled in with great accuracy and fidelity on the plane table by men trained by Robinson himself; the hills are shown by brush shading and the maps are beautifully executed. On the completion of this Major Robinson commenced the survey of Central India; he may be looked upon as the father of the topographical system as it now exists, and is therefore entitled to more than a mere passing notice. He introduced the present accurate method of using the plane table and of delineating the ground, which, with

very small modifications, is still in use, and in suitable country is never likely to be superseded. He trained almost all the best men who held charge of parties for some 15 years after his retirement from the Department in 1865. He officiated as Superintendent of the Great Trigonometrical Survey in 1863–64, and as Deputy Surveyor-General, Revenue Branch, in 1865; but in that year he was invited to take the appointment of Director of Telegraphs, which he accepted, and held till his death in 1877.

The Kashmir survey under Montgomerie was made in a similar way, but on half the scale, and parts of it were sketchy owing to the inaccessibility of the country, which rendered it impossible to climb to every peak or along every ridge to get in the details with rigorous accuracy.

In 1861, when Colonel H. L. Thuillier succeeded Sir Andrew Waugh as Surveyor-General, topographical parties were at work in Central India, in the Nizam's territory, in Ganjam, and in Chota Nagpur. The following year a fifth was added to survey Rewah; a sixth was soon after organized to map the forest-clad hills of Assam, Naugong, and North Cachar; whilst a seventh started work in Rajputana. At the same time that the country in general was thus being delineated on the 1-inch scale, large scale plans of the most important towns and forts were prepared. In 1871 a party was sent to the hill tracts of Assam and Manipur, the object being to demarcate and survey that portion of the Naga Hills which is contiguous to Manipur, and to explore the extreme frontier along the Patkoi Range as far eastward as possible. This part of India presents immense natural difficulties, which are greatly increased by the hostility of the tribes which inhabit it; Government was constantly having to send punitive expeditions against them, and much geographical information was obtained by the survey officers who accompanied them. But even when they were working in places where peace was supposed to reign our parties were always accompanied by strong escorts, and not without good reason, as the following instances will show. On one occasion Capt. W. F. Badgley, I.S.C., who was in charge of the party, was treacherously attacked by Nagas, who murdered Capt. Holcombe (Political Officer) and 80 natives, besides severely wounding Capt. Badgley and 51 natives, some of whom died afterwards; it was entirely due to his pluck and energy that the remainder succeeded in extricating themselves. Again, Lieut. W. G. Woodthorpe, R.E., accompanied by Capt. Butler as Political Officer, entered the Naga Hills with a detachment; they

had hardly commenced work when they were attacked by the inhabitants of a large village, whom they defeated; this fortunately had the effect of inducing the surrounding villages to send in friendly deputations.

In 1874 a party was formed out of that which had been working in Rajputana to commence the survey of Mysore; here they were working over the ground originally triangulated by Lambton, and traces of his old stations were in some cases found. This survey was completed in 11 years.

Since that time there have been generally six to eight parties at work in India and Burmah; in the latter country some excellent reconnoitring work was done by Capt. J. R. Hobday, I.S.C., during the war in 1886 and in the years immediately succeeding it; subsequently, regular topographical parties have been at work there, and now there are no less than four working on the 1-inch scale. A great deal of most valuable sketching has been done in that country by small detachments, under Major F. B. Longe, R.E. and Capt. T. F. B. Renny-Tailyour, R.E., who were deputed to accompany the Political Officer sent to demarcate the boundary between Burmah and China. On these occasions the dilatoriness of the Chinese caused many delays; but this rather assisted the surveyors, who thus often had time to do more than they otherwise would have been able to accomplish. Instruments had been supplied to the Chinese for their use, but none of them had the slightest knowledge of surveying, and so they were never used. An amusing thing was the way the Chinese imitated our officers in all they did; at first they had no flag, but they very soon hoisted one, with the Chinese Commissioner's name in very large letters; if our officers went out for a ride, a riding party from the Chinese camp was soon seen setting out; revolver practice on our part was followed by shots in their camp; the Chinese soldiers took to saluting like our sepoys; and so on. Hurried though these reconnaissances necessarily were, they were excellent of their kind, and were all based on triangulation.

The name of Woodthorpe, of the Royal Engineers, will long be remembered in Assam and on the extreme N.E. Frontier, as for many years he was reconnoitring and surveying in those wild tracts. Almost his whole time in the Department was passed more or less on what may, without exaggeration, be called active service. In his first four years he was attached to three different expeditionary forces; he was with the Kuram

column in the Afghan War, and he accompanied Lord Roberts on his famous march from Kabul to Kandahar; on this occasion he received the thanks of the Governor-General in Council and of the Secretary of State for India, and was made brevet lieut.-colonel. He then returned to the N.E. Frontier and visited the Bor-Kamti country with Major Macgregor, reaching the banks of the western branch of the Irrawaddy; on their return the whole party was very nearly lost, owing to the flooding of the rivers in front of them, whilst behind them were many marches of inhospitable country. Notwithstanding the exposure he had undergone during this journey, he took no rest, but went on special duty to the opposite corner of British territory, viz., to Gilgit; the change from the damp malarious jungles of the N.E. to the dry and bracing climate of the mountainous regions on the N.W. did him good; after a year he returned once again to the east, and went in charge of a survey party with a military column from Assam, *viâ* Manipur, into the Chindwin Valley, in Upper Burmah, bringing back sketch maps of a very large area of previously unknown country. He was made a C.B. and became a major-general, but died in May, 1898, when officiating as Deputy Surveyor-General, to the regret of all who knew him.

But it must not be supposed that all the luck was confined to one man; during the Afghan War of 1879 to 1881, 13 military and several civilian officers of the Department were attached to the different columns, and many of them obtained brevet rank, one, Capt. (now General) E. P. Leach, R.E., winning the Victoria Cross. It is hard work keeping up a reconnaissance with an army on the march, as I can say from personal experience; it almost always entails not only constant tramping all day up and down the neighbouring hills as far as possible, but also work which has to be done at night, such as inking in the day's work or computing out the observations if triangulation has been possible, or (not infrequently) astronomical observations for latitude or azimuth. Native surveyors greatly assist at such times, as they can run plane-table traverses along the actual route, whilst the officer can devote his time to triangulating and sketching among the surrounding hills. Some 39,500 square miles in Afghanistan and 7,800 in Baluchistan were added to our geographical knowledge during this war.

In 1884 three officers, Major (now Colonel Sir) T. H. Holdich, R.E., Capt. St. G. C. Gore, R.E., and Lieut. M. G. Talbot, R.E., were deputed to accompany Lieut.-Colonel (now Sir) West Ridgeway on

the Afghan Boundary Commission. The two junior officers started a triangulation from the stations fixed during the war, and carried it on, with great difficulty on account of the haze, as far as the Helmund; after that it was impossible to keep up an unbroken chain, and each day's halting place was fixed by latitude observations, and, whenever possible, triangulation was again started on short measured bases; at the same time a plane table survey on the $\frac{1}{4}$-inch scale, embracing an area of country averaging 20 miles in width, was made. In this way Kuhsan was reached, a distance of 310 miles being covered in 19 days. From there several small series of triangles, depending on detached bases, were run in different directions; astronomical checks were introduced, in which our officers were assisted by the Russian officer, who had a higher class of instrument than our 6-inch theodolite. On the basis of this triangulation all the topography was executed, whether by the Russian surveyors on a comparatively large scale along the boundary, or by our survey officers and native surveyors, who not only took up their share of the boundary work, but executed on a smaller scale a reconnaissance of a vast area in Persia and Afghanistan, amounting to over 110,000 square miles. The general scale was 4 miles to the inch, but this at times had to be reduced to half, so as to allow of a sufficient number of fixed points being plotted on the plane table.

In the same way that the name of Woodthorpe will ever be connected with the N.E. Frontier, so will the name of Holdich be connected with that on the N.W.; in addition to his services in that part of the world, he was in the Bhutan Campaign, and also accompanied the expedition to Abyssinia; he is now a C.B. and K.C.I.E., and quite recently has been made a K.C.M.G. for his services connected with the Chili-Argentine Boundary.

Such records as these will show you that there are as good opportunities for an officer to distinguish himself in the Survey Department as in any other in the world.

Whilst the Afghan War was occupying a large number of our officers in the extreme N.W., on the N.E. Frontier Lieut. H. J. Harman, R.E., was making a survey of Sikkim, a Native State north of the well-known sanatorium of Darjeeling; he personally undertook the northern part amongst the gigantic mountains east of Kanchanjinga, the second highest mountain in the world. He proceeded in the first place to the ranges on the frontier of Thibet, hoping to survey them in the brief interval between the rainy season and the setting in of the winter with its heavy snowfalls. When ascending the

Donkia La Pass on the boundary his feet were so badly frostbitten that he eventually lost several of his toes; but with great pluck and energy he persevered, going as best he could on the backs of coolies, ponies, or on crutches. He also visited the Kangra Lama Pass, and penetrated into parts of Sikkim which no European had previously explored. He was in Sikkim about $3\frac{1}{2}$ months, during which he surveyed 1,000 square miles on the $\frac{1}{4}$-inch scale; he greatly overtaxed himself in this arduous work, and his health broke down, forcing him to retire from the service; he lived to join his family in Italy, but died soon after.

In telling you of the adventurous expeditions and good services of our military officers I must not omit to mention what some of our civilian members have done. In the early part of the Afghan War, Mr. G. B. Scott, whilst reconnoitring the hills north of the Khyber Pass, in the neighbourhood of Fort Michni, was attacked by a considerable number of Mohmands; with great courage and coolness he kept his men together and steadily retreated, fighting every inch of the way for some miles; the fight, which at one time was actually hand to hand, lasted the whole afternoon, but he took his party back in safety, with the exception of one naik (corporal) and one sepoy killed and wounded. He had already received a sword of honour and an honorarium from the Government of the Punjab for conspicuous gallantry in 1868, and he now received another honorarium on this occasion.

In 1883 Mr. W. W. McNair, accompanied by a native explorer, started on a most hazardous journey into Kafiristan; he assumed the dress and disguise of a native doctor, shaving his head and staining his face and hands. The party consisted of 40 men in all, with 15 baggage animals; among the goods McNair stowed away some small instruments and a specially constructed plane table, the paper on which could be quickly slipped inside, and the plane table became a doctor's prescription book. On one occasion he was very nearly detected by four men armed with matchlocks, but in a moment the ruler was slipped up his long loose sleeve, and the men found nothing but a doctor hunting for roots. A report having reached the ruler of Chitral that two Europeans were travelling about the country in disguise, he sent for McNair and compelled him to return. For the work he did during this expedition the Royal Geographical Society awarded him the Murchison Grant.

About the same time Mr. T. E. M. Claudius undertook an expedition less ambitious than this, but still one full of danger and requiring

great audacity, combined with coolness and readiness of resource. He disguised himself and advanced up the valley of the Bar Marai, and ascended a lofty peak commanding the Urukzai Tirah; he was without companions or servants of any kind, and relied solely on the protection of the chiefs; his equipment was a small plane table, which took to pieces. Fraternizing with the people, he obtained all the opportunities he required, and returned in safety. In a second attempt in another valley his disguise was detected, and he was turned back.

Besides the regular topographical parties, which usually work on the 1-inch scale, there are others which make special surveys of the valuable forest lands which are found in all parts of India; these are generally on the 4-inch scale, but in some places the 8-inch and, in certain small areas, even the 16-inch is used. Originally a special branch, to work in the Bengal Presidency, was organized under the Director-General of Forests, but subject to inspection by the Surveyor-General, and for many years it did good work; but quite recently it has been amalgamated with the Department, its programme being laid down by the Director-General of Forests. Now all the surveys in India, except the Revenue Surveys of Bombay and Madras, are united in one department.

I have thus far only spoken of the field duties of a topographical party, which are performed during the cold season, and continued till the weather becomes so hot as to endanger the health of the men. Roughly speaking, the field season extends from the 1st of November to the end of April; at its close all natives who have done good work, and who are not wanted for the office duties, are given leave up to the commencement of the next field season, with a promise of half pay or less, according to their deserts, and on condition that they return punctually on the day appointed. The remainder of the party then proceed to their recess station, which is always situated at the most healthy station within reach, generally in the Himalayas. There being no suitable place in Burmah, all the topographical parties from there recess at Bangalore, which is, I think, the best station in India not a hill station. The principal recess duties are to compute out the triangulation and to fair draw the field sheets in a style suitable for photozincography. It is generally found that the office duties occupy the whole time during which the party is in recess. Each party must have amongst its surveyors draftsmen of sufficient skill to prepare the fair maps, and all must be more or less conversant with the ordinary computations.

Up to 1878 General Sir Henry L. Thuillier, R.A., was Surveyor-General and superintended the topographical surveys; he was succeeded by General J. T. Walker, R.E., who, for the five years from 1878 to 1883, administered both the trigonometrical and topographical surveys, in addition to carrying on the duties of Surveyor-General. On his retirement Colonel G. C. Depree, I.S.C., was appointed Surveyor-General and Deputy Surveyor-General of Topographical Surveys, which posts he held till 1887, when he died. Colonel Sir Henry R. Thuillier, R.E., son of the General, was then made Surveyor-General, and took charge of the topographical surveys till 1895, when he retired. I had the honour of succeeding him in the same appointments, which I held till 1899, when Colonel St. G. C. Gore, R.E., was appointed.

During the ten years from 1890 to 1900 the area accurately surveyed in India on the scales of $\frac{1}{2}$ inch, 1 inch, and 2 inches to the mile amounted to 146,700 square miles, in addition to nearly 40,000 on larger scales. During the same time upwards of 700,000 square miles of reconnaissance and small scale geographical surveys were executed in the neighbouring countries.

## Revenue Surveys (*Map* II.).

The Revenue surveys were commenced in the N.W. Provinces in 1823 under Colonel Valentine Blacker, who was then Surveyor-General. Their chief object was to lay down the correct boundaries of villages, to assist in making a land settlement; accuracy of topographical detail was a minor consideration. In addition to the plan of each village, which was on the 4-inch scale, a list of the fields with their measurements was made. Up till 1834 the interior details were fairly well shown, but after that, by an order of Lord Bentinck, a new plan was adopted, introducing economy and rapidity at the expense of quality. The maps were to delineate boundaries and village sites, whilst the roads and drainage lines were to be only roughly outlined. Moreover, they preceded the trigonometrical survey, and no subsequent connection was made.

In 1847 Major (now General Sir) Henry Thuillier was made Deputy Surveyor-General in Calcutta, under Sir Andrew Waugh, and great improvements were made in Revenue surveys by him. They were conducted in the following way:—The settlement officer marked the boundaries of Parganas (as certain groups of villages are termed), and furnished the surveyor with a rough sketch map of

the same; with the help of this map trained native surveyors ran a theodolite traverse closely following the boundary, all measurements being entered in a field book; the interior village boundaries were treated in the same way. Thus a correct skeleton was made which afforded a check on the field measurements; the topographical details were filled in on a plane table; the traverses were connected with the trigonometrical stations wherever they were met with.

Rapid progress was now made on a scientific system, and Revenue surveys were gradually undertaken in the Punjab, Nagpur, Oudh, and the Lower Provinces, in fact all over the Bengal Presidency except the N.W. Provinces, which had been surveyed in the rough way I have alluded to. Most of the original village plans were destroyed in the Mutiny, only those of twelve districts being saved. When the time arrived for a second settlement of these provinces, it was proposed to again dispense with an accurate survey, as it was argued that the measurement of the fields by natives was all that was required, and if topographical detail were wanted it could be entered by topographical surveyors. As a matter of fact, these field measurements, having no fixed points to depend on, necessarily accumulated large errors, amounting sometimes to as much as 7 per cent. in area. Fortunately such a short-sighted policy was not carried out, and in 1871–72 the whole system was revolutionized, and the cadastral system of field by field surveys was introduced, and has been in use ever since.

By this system theodolite traverses are run close to the boundaries as before; these are plotted village by village on the 16-inch scale and mounted on a plane table; the fields are then carefully surveyed in minute detail by a chain survey. The theodolite stations of the traverse lines, or a large proportion of them, are marked permanently by stones, bricks, burnt clay pipes filled with charcoal, or some cheap indestructible material sunk in the ground and covered with mounds of earth; the headmen of the villages are made responsible for their preservation. By this means it is hoped that the accurate skeleton on which each map depends will always be found ready for use hereafter in revision surveys. Each field or bit of waste land, including the village site, is numbered on the map, and the area is taken out by a planimeter; the total is then compared with the area as found by calculation from the exterior traverse line. In the case of disagreement the areas obtained by the planimeter are taken out again. The field survey is checked by chain lines run between fixed points across the maps themselves by Europeans and native

inspectors, and by independent lines recorded in a field book, the map remaining in the hands of the European in charge. All appreciable differences are shown in red ink, and if these exceed a certain amount, a re-survey is made. The men who run the traverses are members of the Department, but the field surveys are made by men trained by the Department, but paid by contract. The system of chain survey is easily learnt by natives, and the results are excellent. These field maps are in most provinces photo-zincographed, and a few copies are struck off, a certain number of which go to the Local Government, the remainder being kept for sale. This is the system now in use in the Department, and it is admirably suited to the country. In the Madras and Bombay Presidencies they have always conducted their own Revenue surveys, and I do not know exactly their systems.

About 15 years ago a large-scale map of Calcutta was commenced. No such survey of the town had been made since 1847–49, when a topographical survey on the scale of 100 feet to the inch was made by Mr. Simms, C.E.; on this was added a survey of the boundaries of holdings by Mr. Heysham, in 1851 to 1855; but this had become out of date, and a newer map on a larger scale was much wanted. One was started in 1886 on the scale of 50 feet to the inch, but owing to the dilatoriness of the authorities in demarcating the boundaries of holdings it was not completed till 1894. It was executed with the utmost care and in great detail, and is being kept up to date, at a small annual expense, by a native surveyor attached to the headquarters office, whose duty it is to enter, on copies of the original sheets, all alterations or additions as they occur, these being pointed out to him by the municipal authorities without whose consent no changes in the town can be made. From these large scale sheets an engraved map on the 16-inch scale has been made.

## Instruments.

In Lambton's time the instruments, though the best that could then be procured, were not only inferior to those made nowadays, but they were much larger and heavier (*Fig.* 10, *Plate* I.); moreover, there was no means of getting them repaired. It was the custom for officers to supply their own instruments; Colonel Hodgson had instruments and books to the value of £1,300, and nothing belonging to Government, as he considered this to be better than trusting to the only alternative, the supply by contract, for he declared that

the instruments that had been sent out to the Revenue survey in 1821 were not such that a good surveyor would consent to use. Everest saw these evils, and, whilst in England, personally superintended every detail in the construction of his own instruments; and when he returned to India in 1830 he took with him an accomplished maker (Mr. Barrow), and started a mathematical instrument manufactory in Calcutta. The second 36-inch theodolite, known as the Barrow theodolite, was made here under Everest's direction; the graduation was executed by Barrow, and the instrument was built of old musket barrels and parts of Lambton's theodolite that had been damaged. Barrow's successor was a native of Arcot, Syud Mohsin by name, who, though he could not write English, would have taken his place amongst European makers. Since his death the head mechanic has, I think, always been supplied from Cooke's establishment at York. In 1862 Colonel Strange, who had himself been a member of the Great Trigonometrical Survey for 13 years, was entrusted by the Secretary of State for India to design and superintend the construction of a set of geodetical and astronomical instruments for the trigonometrical survey, and in the following year he was appointed to examine and test all instruments sent to India. For the testing of these an observatory was built at Lambeth. The special instruments designed by Colonel Strange consisted of the following:— A 36-inch theodolite and two zenith sectors by Theobald & Synge; two 5-foot transit instruments and two smaller ones by Cooke; two 12-inch vertical circles by Repsold of Hamburg; two galvanic chronographs for registering transit observations, by Secretan & Hardy of Paris; and three astronomical clocks, by Frodsham. In more recent years two 12-inch theodolites have been added (*Plate* II.), which, owing to the greater perfection of the graduating machinery of the present day, are very nearly, if not quite, equal to the old 36-inch theodolite, and are about a quarter of the weight. The instruments for recording the tides, for determining the differences of longitude by the electric telegraph and, lastly, the magnetic instruments have all been supplied in more recent years. The Mathematical Instrument Office at Calcutta does not attempt to make large instruments; it would not pay to do so even if the requisite appliances and skill were available, but it accomplishes an immense amount of excellent work in making the smaller kinds, and in repairing or converting old and obsolete theodolites and levels into ones of more

modern patterns, making them as good as new. In the report for 1899—1900 it is stated that 140 old levels and 98 old theodolites were converted into serviceable instruments, and 21,577 instruments of all kinds, great and small, were manufactured; 57,160 instruments were received into store, and 59,743 were issued; from England 12,082 were received. I should explain that all these instruments do not go to the Survey Department, as the mathematical instrument office supplies all the other Government departments in India as well.

*Figs.* 1 to 3, *Plate* III., show some of the instruments in use in ancient times, before the invention of the telescope; from pictures only it is difficult to understand how they were used, but surprisingly good results were obtained from them. They belong to the ancient observatory at Jeypore, in Rajputana.

## Survey Department Offices.

In conclusion, I should like to say a few words about the other headquarters offices in Calcutta and Dehra Dun. Five-and-twenty years ago there were no special buildings for the Department; the Surveyor-General held his office in one house, the Deputy Surveyor-General of the Revenue Branch in another, the Mathematical Instrument office was in a third, whilst the Photo, Litho, and Engraving offices were located in three separate houses; none of these had been built to suit the purposes for which they were used, and were ill adapted and badly lighted. This became so inconvenient that Government decided to erect suitable buildings, specially designed to suit each branch. These, which were three in number, were all completed by 1888; the largest of the three is occupied by the Surveyor-General and Deputy Surveyor-General, with their numerous clerks and assistants, who occupy the first floor, whilst above them is a large, well-lighted drawing office, and on the ground floor the printed and original maps are stored; the Engraving office is also in this building. The central building is occupied by the Photo, and Litho, and Letterpress-printing offices. The third contains the Mathematical Instrument office. To assist the Surveyor-General and his deputy there are three Assistant Surveyor-Generals, each of whom is in charge of one or more of the different sections into which the whole is divided.

The main duties of the Drawing office are to compile and draw all general maps of districts, provinces, or of India as a whole; to

prepare brush-shaded copies of the field sheets on the ¼-inch scale for the engravers; to examine all the fair maps received from the field parties, to see that they have been suitably prepared for photozincography; and to examine and pass all the photozinco proofs of all maps before publication. But in addition to these there is an immense amount of miscellaneous work, not only for the Department itself, but for Government generally, which often so hampers the draftsmen that the general maps have to be put on one side at times for want of hands to draw them.

The Engraving office was started in 1869 by General Sir Henry L. Thuillier, who engaged a staff of trained engravers while he was in England. Its principal work is to cut on copper the sheets of the ¼-inch atlas of India, and to keep up to date as far as possible those already cut; and to engrave maps of the provinces on the 16-mile and of India as a whole on the 32-mile and smaller scales. The sheets of the atlas are being engraved as the survey parties send in reliable material; in many cases sheets have been published based on old and incorrect work; these are all being re-engraved from modern surveys; on the completed ones new railways and roads have to be entered. The 32-mile map of India is gradually being prepared in the same way; meanwhile temporary editions are issued by transferring the engraved portions on to stone and filling in the blanks by lithography. Quite recently a new engraved map of "India and Adjacent Countries" on the scale of $\frac{1}{1000000}$ has been started.

When I first joined the Department in 1863 there was but a very small Lithographic office, altogether too weak to cope with the work of the Department; hence the topographical maps had to be sent to England for publication, and it was not for many years that any results were received. General Sir Henry L. Thuillier greatly increased the strength of this section; but at best lithography is a slow process, and had we been dependent on that alone the public would have received very little benefit from our labours. Photozincography, however, came to our rescue, and it was introduced into India by Mr. Hennessey, who executed the first photozinco at the Dehra office. Its first appearance in Calcutta was in 1866, and ever since that all cadastral and topographical maps, triangulation charts, etc., have been published by this process; there is still ample work for the Litho office, but it is of a somewhat different nature, and a great deal of it is for other Government departments. As photozincography will not satisfactorily reproduce half-tones, the style of drawing of the field sheets had to be altered, and pen and

ink had to be substituted for brush shading; this at first caused great trouble in the field parties, as the draftsmen had to teach themselves an entirely new style. To give an idea of the amount of work done by the publishing offices I will quote a few figures from the report of 1899—1900:—

Of Department maps there were 983 different subjects, of which 99,176 copies were printed; cadastral, 4,942, of which 162,733 were printed; outside departments, 1,534, of which 588,593 were printed; giving a total of 9,459, of which 850,502 were printed.

The actual number of pulls to complete these maps, several being on more than one sheet, was over 1,000,000. General J. Waterhouse, I.S.C., has been closely connected with this most important part of the headquarters offices for many years, and its present high state of efficiency is entirely due to him. He devoted his whole time to introducing new methods and to improving existing ones, so as to be suitable to the pernicious climate of Calcutta. Photo-collotype, photo-etching, photogravure, photo blocks, were all initiated by him. He retired in 1897 after a service of 30 years in the Department, all of which were spent in charge of the publishing branches.

At Dehra Dun is located the office of the Superintendent of the Great Trigonometrical Survey; attached to it is a small Photozinco office; but its most important duty is to compute out the final values of the triangulation and of the astronomical observations. There is also a solar photographic section, by which photos of the sun are taken every day that it is visible; and the results are sent to England to supplement the daily record which is kept of the appearance of the sun. A complete set of meteorological observations is kept there as well. Under the direction of the Superintendent, a school of training for all members of the Department, Europeans as well as natives, has of late years been established. In former days each field party taught its own men; but it was found that this occupied so much of the time of the older hands, and interfered so much with their legitimate duties, that this school was started to enable them to devote their whole time to their field work.

It may not be inappropriate if I give my opinion to those officers of the Royal Engineers who are going out to India as to the desirability of joining the Survey Department. For a young officer who has no objection to steady and somewhat hard work, and has any taste for accuracy and for dealing with delicate instruments, or

any turn for practical geodosy or astronomy, I most strongly recommend the Trigonometrical Survey. To the somewhat less scientific I recommend the Topographical Branch, in which I served for 20 years; the last 16 years of service in the Department were spent at the Headquarter offices in Calcutta. I consider that the work in itself is most interesting, for half the year the members spend their time in that pleasantest of all lives, camp life in India, not infrequently having opportunities of seeing countries rarely or perhaps never before seen by Europeans, and as good opportunities of seeing active service as anyone else. Those who are fond of sport are pretty sure to meet with it during the field season, and then, when the weather begins to be unpleasantly hot, they retire to a pleasant station and lead a civilized life by way of a change for six months. Good health, zeal, and energy are absolutely necessary qualifications, and without them I do not recommend anyone to join the Department.

*Plates* IV. and V. give some examples of the exceedingly interesting country with which the surveyor in India may meet.

# LIST OF PLATES.

## ELEVATION, SECTIONS & PLANS,

*Illustrative of Colonel Everest's Towers on the Great Arc.*

Fig. 2.
*Transverse Section*

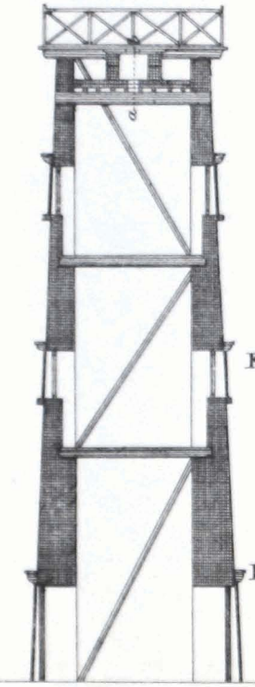


Fig. 1.
*Elevation.*

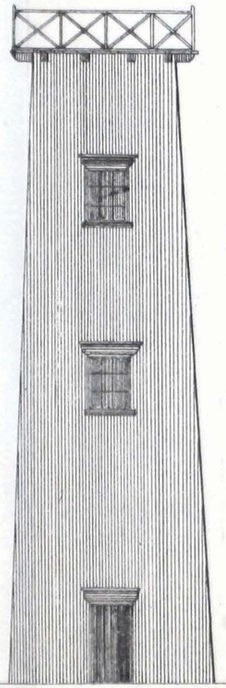
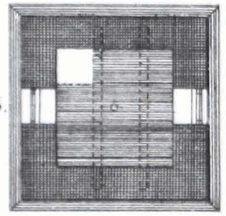


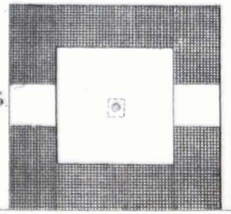
Fig. 7.
*Plan of Platform*

Fig. 6.



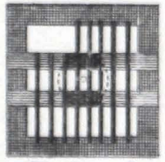
*Plan of 1st Story.*

Fig. 5.



*Ground Plan*

Fig. 3.



*Plan of Platform showing joists.*

Fig. 4.

*Section on line a-b*


## PLAN AND SECTION.

*Illustrative of the towers employed since 1852.*

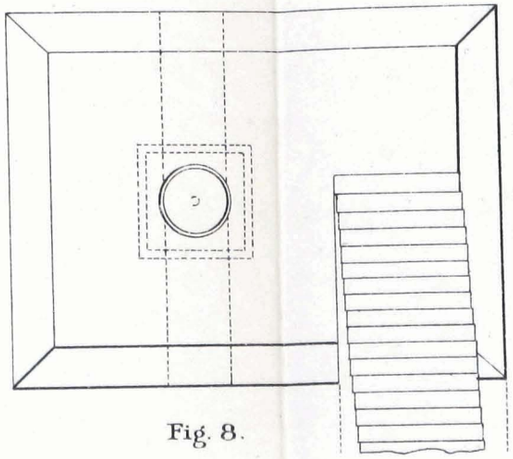


Fig. 8.

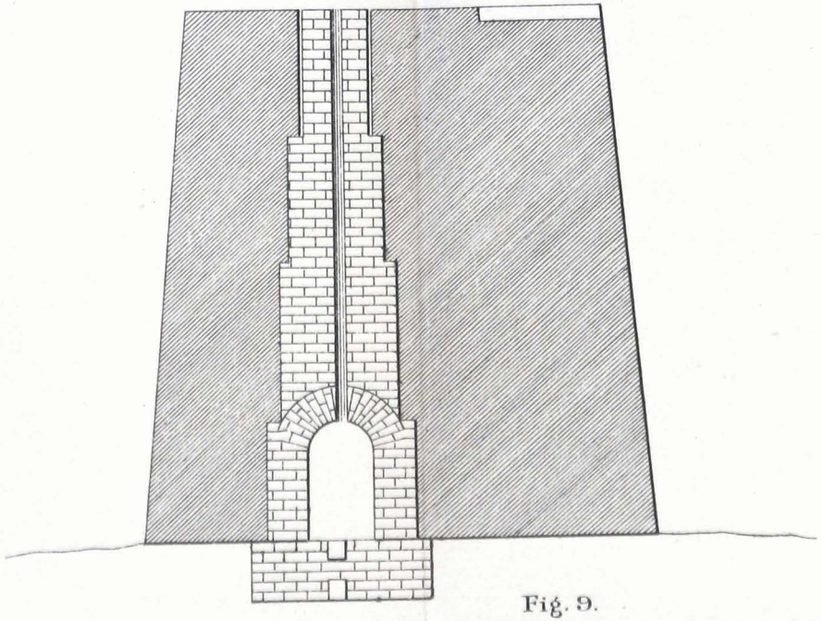


Fig. 9.

*Scale 1 Inch - 9 Ft.*

## OLD ZENITH SECTOR, (RAMSDEN'S)

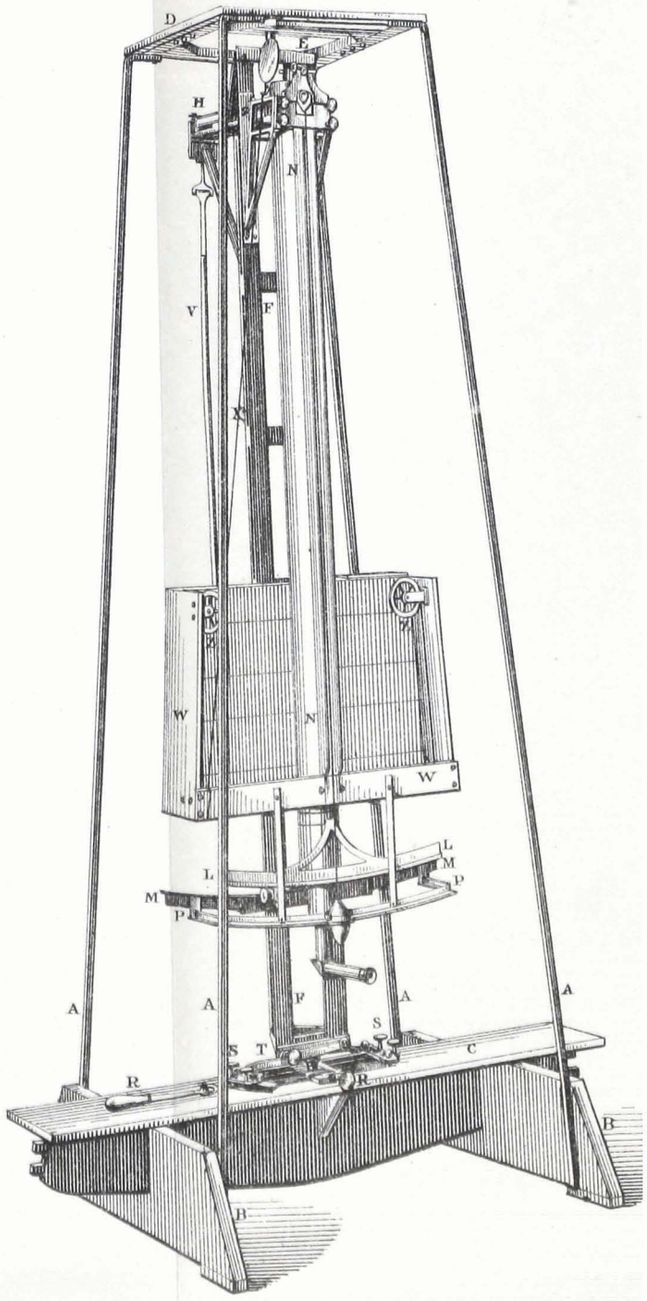
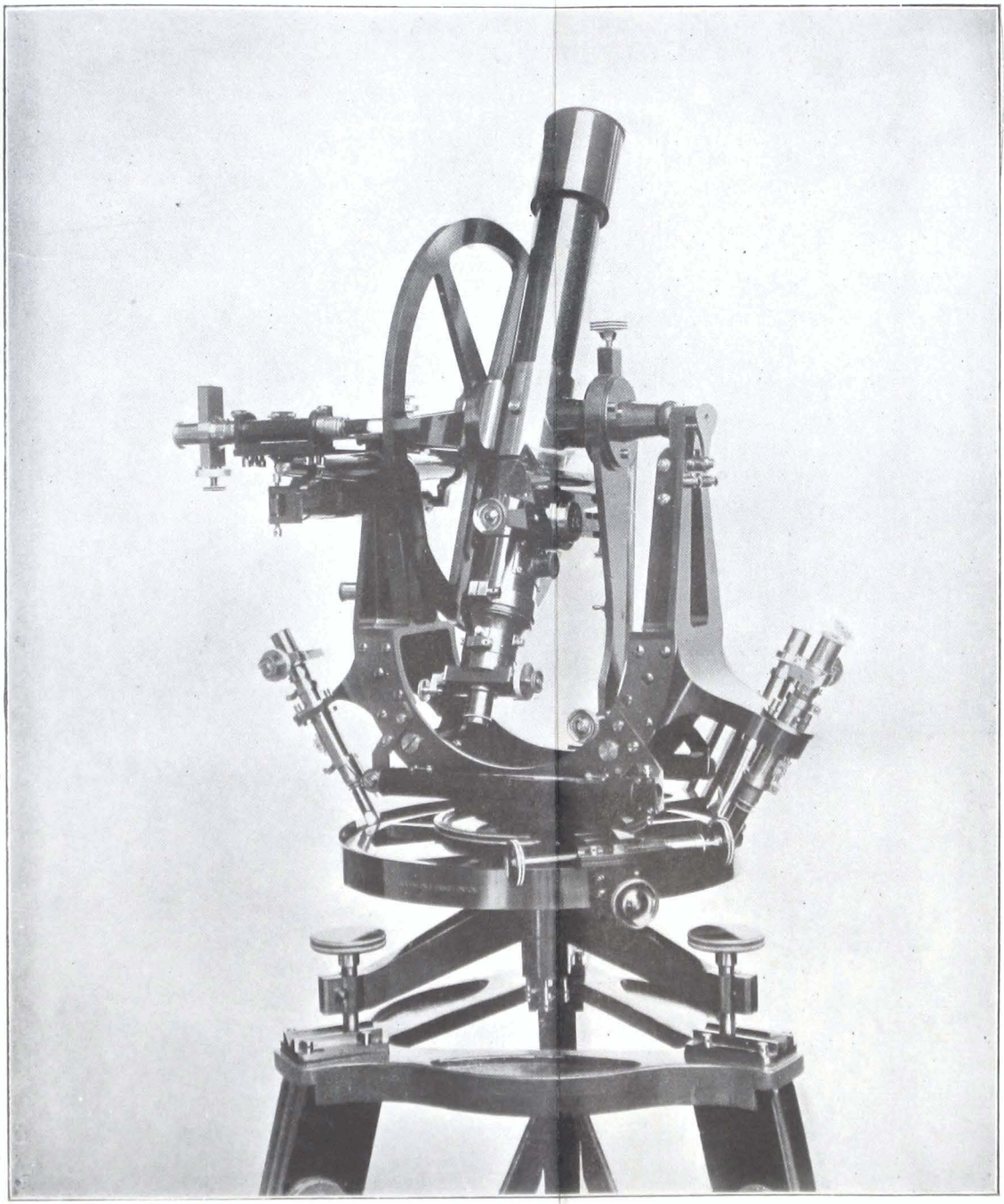



Fig. 10.



MODERN 12″ THEODOLITE.

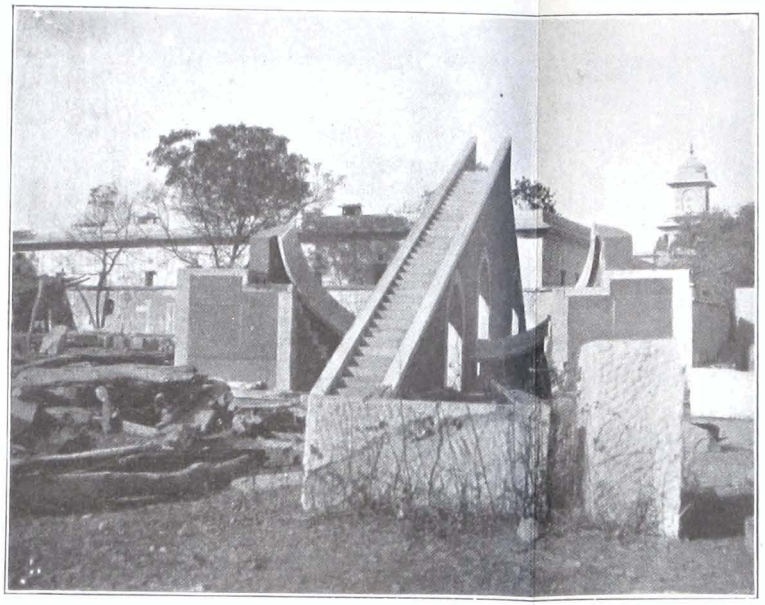


FIG. 1.—GNOMON AND ARC, JEYPUR OBSERVATORY.

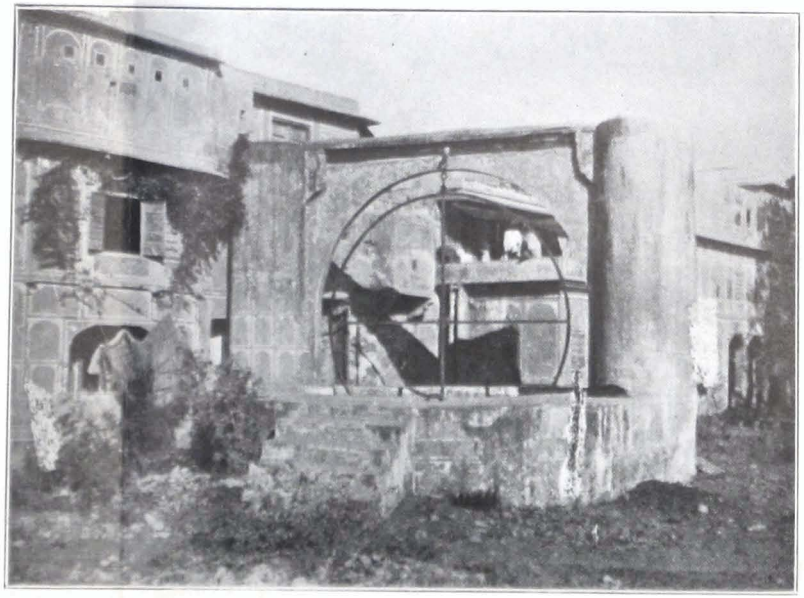


FIG. 2.—LARGE COPPER QUADRANT, JEYPUR OBSERVATORY.

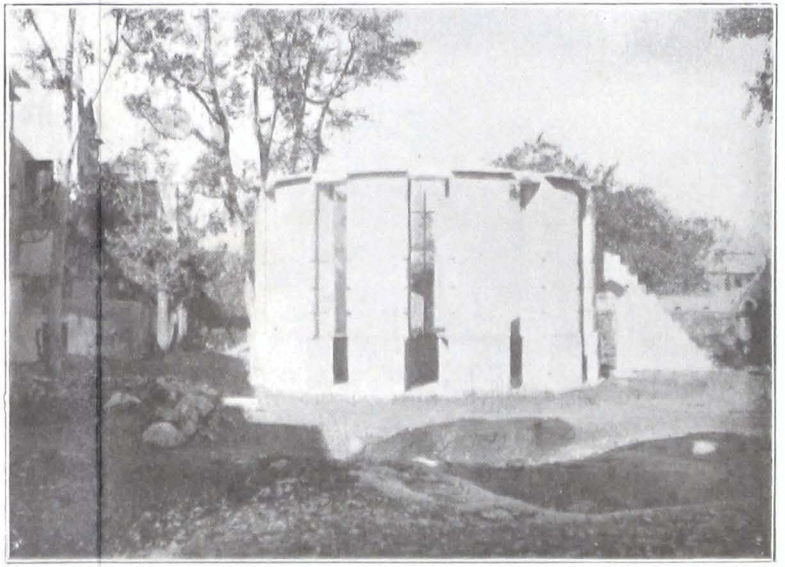
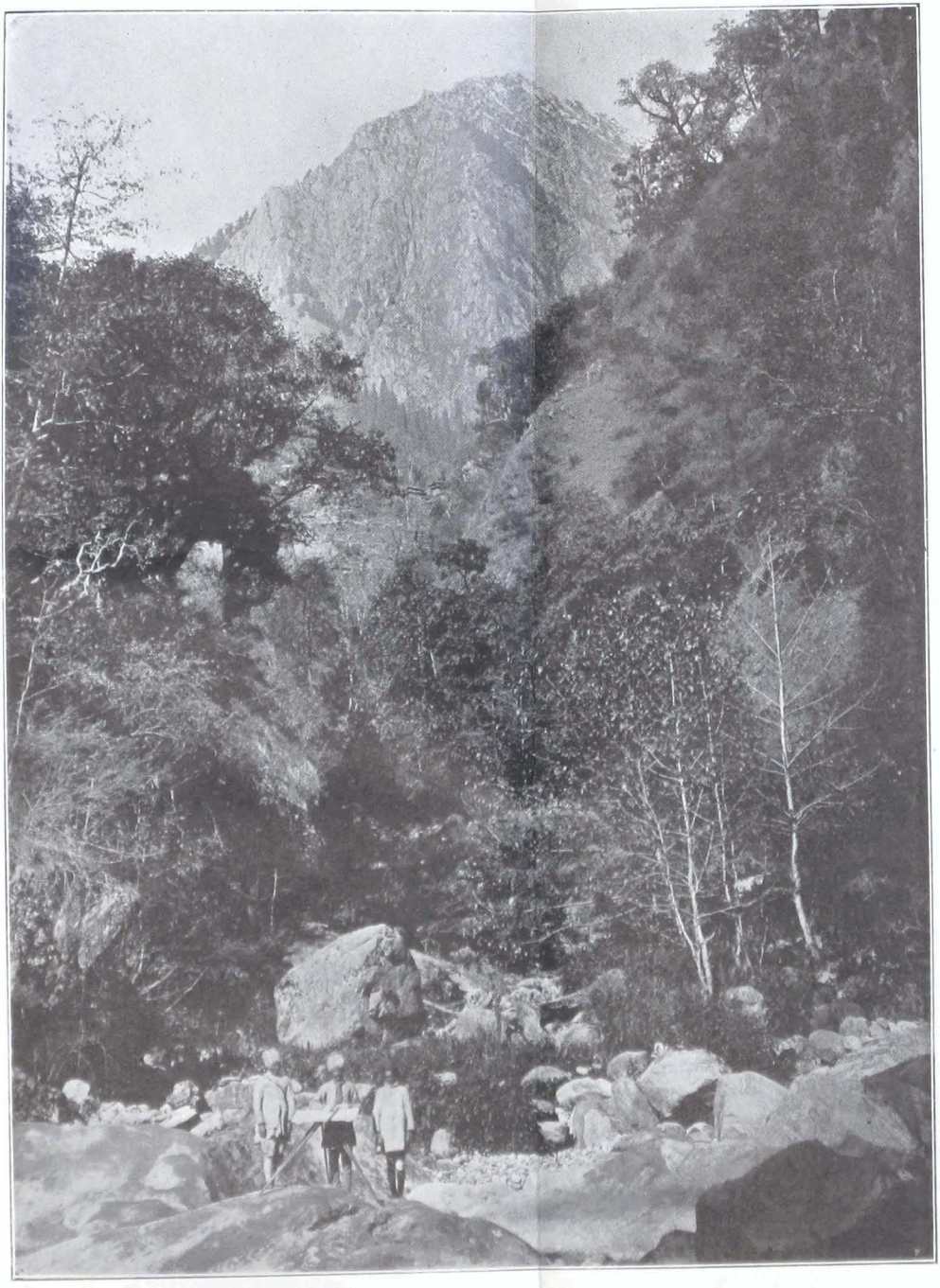


FIG. 3.—ALTAZIMUTH, JEYPUR OBSERVATORY.

A SURVEY PARTY IN THE HIMALAYAS.

View from Drashar Thách looking North across the Hurla Nál, with Deo-thakh Peak in the distance.

PLATE V.



A SURVEY PARTY IN THE HIMALAYAS.

View looking up gorge of the Manihar Nál.