APPENDIX "B."

THE TRIGONOMETRICAL SURVEY OF NEW SOUTH WALES.

Contributed by Fred. Poate, Esquire, Surveyor-General.

INTRODUCTORY.—BASE LINES.

The trigonometrical survey of New South Wales had its inception in 1867, when information was first sought with regard to suitable sites for base lines, the measurement of a base line at Lake George being commenced in 1863. The work then done was, however, abandoned in consequence of an abnormal rise in the lake by which the line was covered in parts to a depth of 2 ft. 6 in., and in 1870 a new site, close to the former, was chosen and the base measured, work being commenced on 31st October of that year. A report of the mode of measurement, with remarks as to the comparisons of the standard bar with the wooden bars actually used on the base, will be found in a Return to Parliament, 31st May, 1871. The standard bar is the O.I.4, referred to at page 175 of Colonel Clarke's work on the comparison of standards, published in 1866. The difference between the lengths of the base as found from the measurement and re-measurement was ·542 of an inch in the total length of 5½ miles.

A base line of verification was measured at Richmond in 1879–80, first with the wooden bars with which the length of the Lake George base had been ascertained, and afterwards with steel bars. A description of the measurement will be found as an Appendix to the Annual Report of the Department of Lands for the year 1880. The difference between the two determinations of length was ·662 of an inch in the total length of 7 miles.

When the Lake George and Richmond bases had been connected by triangulation, the combined errors of measurement of the two bases and of the intervening triangulation produced an apparent discrepancy of only 1⅝ inch in the length of the Lake George base. In this connexion it may be mentioned that the triangulation has now proceeded so far that it is highly desirable other bases of verification should be measured. A suitable location for a base line, some 15 to 20 miles in length, to form a side of one of the main triangles has been found on the railway line some 40 miles south-east of the town of Bourke, and the triangulation has been extended in this direction. The modern method in the conduct of geodetic surveys elsewhere is to considerably increase the number of bases of verification. This modification is largely due to the great rapidity and consequent economy with which such measurements are now made owing to the use of bands and wires of the nickel-steel alloy known as "Invar." The extreme precision as well as cheapness with which bases may be measured by "Invar" bands has caused this method to entirely supersede the more costly methods hitherto adopted.

Six "Invar" bands, each 24 metres in length, have recently been purchased, together with apparatus for use in this class of base measurement. The absolute lengths of these bands have been determined at the National Physical Laboratory, Teddington, Middlesex, to one part in 1,000,000, at temperatures from 5° to 40° C.

STAFF.

The survey is under the immediate control of the Director of Trigonometrical Surveys. The field work is supervised by the Surveyor-in-Charge of Field Operations, and the office work by the Chief Computer.

Field Staff.—During the last ten years there has been but one observing party, that of the Surveyor-in-Charge of Field Operations, who employs a clerical assistant to act as recorder, four labourers, and a cook. For five years past there have been two piling parties. Each party is in charge of a piling overseer, who employs four labourers and a cook. In the earlier years of the survey the field staff was greater, as will be seen from an inspection of Schedule 1.

Office Staff.—During most of the time this has consisted of the Chief Computer, an assistant computer, and a junior.

SCOPE OF THE SURVEY.

From its inception, the survey has been partly geodetic and partly trigonometrical. The stations are classified in three divisions.

First-class Stations, which form the main skeleton of the survey.—Observations are made at these stations of the highest degree of precision, and are intended to provide material for critical investigations as to the dimensions and figure of the earth. To the date of this Report, 119 first-class stations have been fixed by observation, and some fifteen others have been piled in advance of observation. An endeavour has always been made to so locate first-class stations that the sides of the triangles should range from about 35 to 40 miles. At 66 of these stations astronomical observations have been made for azimuth, and at 74 for latitude; 10 of them are longitude stations.

Second-class Stations.—These, with the first-class stations, are intended to form the basis of the purely trigonometrical survey, the object of which is to cover the State with a network of permanently marked stations relatively fixed with sufficient precision to meet all the exigencies of map production, and to which alienation and other detail or topographical surveys may be referred and adjusted. The second-class stations are all observing stations, but the instrument with which the horizontal angles are measured has in the past been smaller and less precise than that used at the first-class stations, the number of rounds of observation being also fewer, the same degree of accuracy not being required as for geodetic purposes. To date, about 583 second-class stations have been connected by observation, and some 75 others have been piled in advance. The sides of the triangles connecting second-class stations range from about 15 to 20 miles in length. No astronomical observations are taken at second-class stations.

Third-class Stations.—These are not observed at, but are fixed by intersection from surrounding first or second class stations; the length of the fixing lines run from about 7 to 10 miles. In some few cases observations have been taken at third-class stations where the fixing by intersection of them or stations visible from them has not been considered satisfactory. To date, the positions of about 1,380 third-class stations have been determined, and some 400 others have been piled in advance of observation.

From the foregoing it will be seen that the survey is mainly trigonometrical, and only in a secondary sense geodetic. First-class or geodetic stations form only one-nineteenth of the total, and one-sixth of the observing stations. It may be stated that the average number of geodetic stations observed to from the 119 geodetic stations is 5, making, say, about 600 observed directions. Of other stations observed on to from geodetic stations the average is 18, giving slightly over 2,000 observed directions, while the average number of stations observed from the 583 second-class stations and 21 third-class is 13, making 7,800 observed directions. Considered therefore in the light of the stations observed to the geodetic part of the work as compared to the whole is in the ratio of 600 to 10,400, or rather less than one-seventeenth.

On the other hand, it is to be noted that a greater number of repeats are involved in the measurement of directions between the geodetic stations than elsewhere in the survey, and that the astronomical observations which are restricted to the primary work also increase the labour. It is difficult to state the proportion of labour so added, but it is estimated that, taking account of all the factors, the geodetic part of the work constitutes about one-seventh of the whole.

INSTRUMENTS.

Eighteen-inch Altazimuth (Troughton and Simms).—For the measurement of horizontal angles at the first-class stations and for astronomical observations two altazimuth instruments, by Troughton and Simms, have, up to the present, been provided. The one generally used has a telescope of 3 inches aperture, and 36 inches focal length, provided with a filar micrometer eye-piece, the value of one revolution of the screw of which is 58·7″. The horizontal circle, diameter 18 inches, graduated at every 5′ of arc, and firmly attached to the base of the instrument, is read by four equidistant micrometer microscopes to tenths of a second of arc; these microscopes revolve with the telescope upon the centre of the graduated circle. Two oil lamps, with series of lenses, reflectors, and prisms, serve to illuminate the telescope and reading microscopes. The instrument has no vertical circle, but a setting circle, 3½ inches in diameter, graduated to 30′, is attached to the telescope. There are two levels attached to the revolving part of the instrument, one 4 inches above the horizontal circle, the other at right angles to the first, on one of the standards, immediately below the horizontal axis, 17 inches above the horizontal circle; there is also a striding level. The values of one division of each of the last two levels are respectively 0·53″, 0·76″. The vertical axis is bored, and takes a small telescope, which can be focussed on the plug marking the station. This has not been generally used, centering being done by a plummet.

In use the three levelling screws of the instrument rest in grooves on a steel triangle, which is supported by a truncated cone of sheet steel, about 33 inches in height, the lower diameter being about 27 inches and the upper 21 inches. By means of screws pressing against the upper ring of the cone the triangle can be moved laterally about 1 inch, which admits of accurate centering of the instrument over the plug. Any part of the horizontal circle may be brought under the microscopes (the direction of the telescope remaining the same) by rotating the triangle and instrument on the cone. The inconvenience of this method of changing arc is great, as the operation requires considerable exertion, and disturbs the centering of the instrument over the plug, fresh adjustment being required after each change. The cone is covered with a jacket of thick felt, outside of which is another jacket of canvas, only the upper ring, on which the triangle rests, and the lower flange, which is provided with levelling screws, being uncovered. The cone is erected on the live rock or on a solid foundation of brick or stone set in cement, built some time before around the plug. The upper ring is made roughly level by means of the levelling screws in the bottom flange, and, by means of a plummet, is approximately centered over the plug. Then cement mortar is packed underneath, and all round the bottom flange; the screws are withdrawn a little and equally until the weight of the cone presses out the superflous cement mortar, which is used to cement the outside of the flange, more cement mortar being added if necessary. When all is set and dry, it is considered that the cone is rigidly fixed to the foundation and to the ground.

Ten-inch Theodolite (Troughton and Simms).—For the measurement of vertical angles at first-class stations and of vertical and horizontal angles at second-class stations, a theodolite by Troughton and Simms has been generally employed. The horizontal circle, 10 inches in diameter, has independent motion, is graduated at every 5′ of arc, and is read by two micrometer microscopes to tenths of a second of arc. The telescope has a focal length of 26 inches and an aperture of 2½ inches. Attached to it are two opposite arcs (each 90°), parts of a circle 10 inches in diameter, graduated at every 5′ of arc, and read by two verniers to the nearest 5″. About 2 inches above the horizontal circle two levels at right angles are attached to the revolving pillar, from which the standards branch. There is also a striding level and a level attached to the arm carrying the verniers of the vertical arcs. One division of the latter level is equal to 2·85″. The instrument is supported on a strong wooden tripod, the feet of which rest on three pegs, or, where the ground is too rocky, on three small pedestals of stone and cement.

The difficulty of transporting from place to place such a heavy instrument as the 18-in. altazimuth (it is in two cases, one of which weighs over 300 lbs.), and carrying it to the first-class stations, generally some distance from the surveyor's camp, and many hundreds of feet above it, together with the inconvenience of using two instruments, one for horizontal and the other for vertical angles, has led to the purchase recently of a theodolite from Messrs. Repsold and Sons, of Hamburg, similar in pattern to that used on the geodetic survey of South Africa, and described with figures at page 77 of the Report of that survey, published by the Government Printer, Capetown, in 1896. The following brief description is largely extracted from that Report:—

Ten-in. Theodolite (Repsold).—The sight telescope is of the "broken transit" pattern, having an aperture of $2\frac{3}{8}$ inches, and a focal length of 20 inches, and is provided with a filar micrometer eye-piece. The horizontal circle (diameter 10 inches) is graduated at every 4′, and read by two micrometer microscopes to tenths of a second of arc. The micrometers are provided with two pairs of double webs; the centres of these pairs are 1·5 revolutions apart. By reading the circle with both pairs of webs, *i.e.*, by placing the image of the left-hand division between the left-hand pair of webs and recording the reading, and next the image of the right-hand division between the right-hand pair of webs, and again recording the reading, then, in the mean of the two readings, the result is free from the effects of the periodic errors in the screw, which depend on the sine and cosine of the angle of revolution, and the resulting angle is affected only by the error of run. Two revolutions of the screw correspond with 4′ of arc, so that the sum of the readings of the two pairs of webs gives the mean reading for the microscope. The rim of the horizontal circle has a brass cover, which serves the double purpose of protecting the graduated surface from dust and accidental injury, and of preventing direct radiation of heat from the observer's body to the circle. The horizontal microscopes can be changed in azimuth, and held in the required position by a clamping screw, so that the arc can be readily brought into any position without disturbing the centering of the instrument. The vertical circle is 8 inches in diameter, is graduated at every 4′, and read by two micrometer microscopes to tenths of a second. A watch telescope, with micrometer eye-piece, is attached to the arms carrying the microscopes of the horizontal circle, and, by this means, any changes in the azimuth of the microscopes may be directly measured; it has an aperture of 2 inches, and a focal length of 19 inches. Two levels are provided which are detachable, and can be used in the striding level carrier or in the two carriers attached to the revolving part of the instrument, one of which is placed $3\frac{1}{2}$ inches above the horizontal circle, and the other, at right angles to it, on one of the standards, immediately above the horizontal axis, 12 inches from the horizontal circle. These levels are protected from sudden changes of temperature by glass outer tubes. The illumination throughout is effected by means of small incandescent electric lamps, which can be lighted by two small dry cells. The instrument is packed in two cases, weighing 75 and 51 lbs. The following advantages may be expected to follow from the substitution of the 10-in. Repsold for the 18-in. instrument:—

(1) Portability of both instrument and stand.
(2) The eye-piece of the telescope is always at the same height, and is conveniently placed for comfortable observing.
(3) No changes from ordinary to diagonal eye-piece (with consequent loss of time) are required.
(4) The micrometer head and the heads of slow-motion screws, also clamping screws, are all readily manipulated or read in all positions of the telescope.
(5) The centering of the instrument over the plug can be examined and verified at any time without disturbing the instrument.
(6) The setting of the horizontal circle can be altered rapidly without disturbing the centering of the instrument.
(7) The same instrument can be used for measuring horizontal or vertical angles, and for astronomical work.
(8) Any twist of the stand during observation can be detected and measured by the "watch telescope," and the observations corrected accordingly.
(9) The vertical circle enables the telescope to be set more accurately than could be done with a small setting circle, hence faint stars can be more readily identified.
(10) The microscopes of the vertical circle are close to the eye-piece of the telescope, and at the same height, hence an observation of a star can be made, and the setting in zenith distance of the telescope changed for observation of another star very rapidly, and without requiring the observer to move from his place. Stars following each other at an interval of a few seconds only can thus be observed.
(11) The micrometer wires can be illuminated more satisfactorily because their position, with reference to the source of light, is invariable.

METHODS OF THE SURVEY.

The operations of the trignonometrical survey naturally fall into three divisions, namely:—

1. Reconnaissance and piling.
2. Observation.
3. Computation.

Reconnaissance and Piling.—This includes the selection of suitable sites for the stations, permanent marking by plugs of the stations, and erection of masts and vanes as observing signals, clearing of sight lines, making approximate observations to surrounding stations, surveying and marking of the trigonometrical reserves, and connecting them to neighbouring detail surveys, and collecting data to generally facilitate the work of the observing party. The general direction in which the survey shall extend having been decided on, the Surveyor-in-Charge of Field Operations, after an examination of the maps, instructs the piling overseers as to the positions near which he desires the first and second class stations to be located. The securing of well-conditioned triangles, with sides of suitable length, is the principal object in view. Third-class stations are selected from 7 to 10 miles apart, and, so far as the nature of the country will allow, second-class stations are formed at about 15 to 20 miles apart, whilst an endeavour has always been made to get first-class triangles with about 35 to 40 mile sides. The piling overseers then proceed to reconnoitre the country, and carry out their instructions as closely as the configuration permits. Where any serious obstacles are presented, the circumstances are reported to the Surveyor-in-Charge, who decides what modifications of the scheme shall then be made. The following is an outline of the duties of the piling overseers :—

To make a general examination of the country, fixing its most prominent features in the mind, care being taken to note the different phases presented by the principal elevations as seen from different points of view.

Rapid outline sketches in the rough field-book will be found of service in identifying the same point from different aspects.

Full notes and sketches should accompany every "Description of Station," and amongst these notes some of the most important are :—Means of access, condition of roads to be travelled over, what tracks must be made for the final occupation of a station, names of persons living near, the number of the portion (if not on Crown lands) on which the station is erected, the name of the owner of the site, and whether he has given written permission to clear and use it, including permission to have access thereto at any time for survey purposes, the nearest post-office, and nearest place where supplies can be got, and any other ftems of interest. Also the name and address of any person living near who will undertake, if called upon, to clear off any new growth of timber, and for what sum.

First-class stations should occupy the summits of the ranges, so that the triangulation can be extended in every direction.

The intervisibility of stations should, where needful, be determined beyond the possibility of doubt. This may often be a difficult matter when the weather is thick and hazy, still it is better to wait patiently and send a man to make a smoke signal (failing a flash from a heliostat, owing to cloudy weather), or to erect a calico screen, rather than allow doubt to exist, and perhaps delay and loss of time caused to the observer who follows the piling overseer.

Permanence of position, especially of first and second class stations, is to be carefully looked to. In addition to the usual underground and surface marks, a round of angles upon prominent near objects, natural and artificial, will often serve to recover and identify a long-disused station, and this is specially helpful when the character of the hill is not very distinctive. Assuming that topographic surveys will, sooner or later, be extended over the greater part of New South Wales, it is of the highest importance that each trigonometrical station shall be so marked, and the records of its marking so clear and definite that the exact site can be recoverable at any future time.

Where any choice exists, that site should be chosen which allows the line of sight to pass at least 10 feet above the intervening ranges, so as to avoid the disturbed stratum of air which may deflect laterally, as well as vertically, besides being more difficult to see through.

When it can be done without incurring much extra expense, the whole of the timber should be cleared off the top of the hill; where, however, the summit of the hill is flat, and the timber heavy, it will suffice to clear front and back lines to the stations required. These "rays" should be at least 15 to 20 links wide, but 30 links is better still.

All stations are to be marked by a muntz-metal plug, 6 inches long, set either in live rock or in a large round stone (containing from 4 to 5 cubic feet), and sunk into the ground so that its upper surface is about 9 to 12 inches below the natural level of the ground, the earth being well rammed on all sides.

The plug is set, using a mixture of sand and melted sulphur, by drilling a hole (half to three-quarters of an inch greater diameter than the plug) into the plug-stone, and pouring the mixture of sulphur and sand, whilst hot, round the plug inserted in the hole. About an inch of the plug is to be left protruding so that the mast (referred to further on) may be stepped, by means of a hole bored in its end, and of slightly larger diameter than the plug.

First-class stations should have foundations built of cement and bricks or stone for the steel cone stand of the 18-in. altazimuth, the "bottom" of the foundation to be down to the level of the lower surface of the plug-stone, when the station is not marked on live rock. At second-class stations the ground should be cleared of loose rocks and stones all round the plug-stone, so as to facilitate the driving of pegs for the stand of the 10-in. instrument to be used there. Where it is very rocky, and likely to be troublesome, if not impossible, to drive pegs, then three pedestals should be built of stone and cement at 120° apart and about 21 inches distant from the plug.

The masts are, as a very general rule, made of Oregon pine, are 12 feet long, and 5 inches by 5 inches for second class and third class stations, and 6 inches by 6 inches for first-class stations.

The vanes, which are of sheet galvanized iron, are fixed by screws and coach bolts to one end of the mast, and strengthened by galvanized iron bars bolted across the middle, the outer ends of these bars being connected together by tie-wires. The vanes are of varying sizes; of late, the most-used sizes being 30-inch and 36-inch; the latter are used on observing stations, and the former on third-class stations, or "intersections." In a few cases, where the line of sight is over 45 miles, special vanes (48 inches) have been used. All vanes are painted black, a space of 18 inches below them and on the mast is painted white, and the remainder of the mast is painted black.

The mast is made vertical by using a 24-in. carpenter's level, and it is supported and retained in position by a cairn of stones, about 8 feet in diameter across the base, and about 7 feet high, in appearance something like an inverted thimble. A piece of calico, 1 yard square, tacked diagonally to the mast, and also to a sapling, nailed square across the mast, about midway between the top of the stone cairn and bottom of vanes, will be very serviceable in cases where the vanes (being black) are projected against a dark background, and, therefore, difficult to see from an observing station. After the station has been marked, but before the mast has been erected, provisional observations on the magnetic meridian are taken by the piling overseer to all the surrounding visible stations and prominent hills and ranges.

Steel alphabet dies are supplied to the piling overseers, so that the name of the station can be stamped on each vane. A ↑ is cut on each mast, and a notice is tacked to it cautioning against the wilful destruction of these marks.

Besides a theodolite, chain and tape, the piling overseers are supplied with heliostats for signalling, hand telescope, prismatic compass, and aneroid barometers, for the preliminary examination of the country when searching for new sites for stations, also blank forms for the "Description of Station". About the end of 1893 it was decided that the functions of a piling overseer should be extended by asking him to supply a duly-surveyed connexion between every newly-formed station and the nearest available corner of a measured portion. Still later, the piling overseers were instructed to measure such trigonometrical reserves as were necessary, instead of merely submitting a "design" for each reserve. From the piling overseer's notes and sketches a plan of the survey is prepared in the District Office, and the reserve then charted on the official maps.

OBSERVATION.

This includes the measurement of horizontal and vertical angles between stations, the approximate determination of the magnetic declination, and, where it can conveniently be done, connexion of the station with railway or other bench marks, by spirit-levelling. At a number of first-class stations stellar observations are taken, for the purpose of determining the astronomical azimuth and latitude. During the years 1874–1890 stellar observations for time were taken at 39 stations scattered over the State, and chronometric comparisons were made with Sydney Observatory, by medium of the electric telegraph lines, for the purpose of determining the difference of longitude between the Observatory and these stations.

When the observing surveyor has pitched his camp at the spot indicated by the piling overseer as most suitable, work begins at the station preparatory to observation. At a first-class station the procedure is as follows:—

The cairn of stones is pulled down, and the mast removed, thus leaving the plug and surrounding foundation clear, the steel cone is then cemented in place, as previously described. A portable observatory is now erected. Four pieces of bush timber, 8 inches or more in diameter, are halved and pegged together so as to form a square, the corners of which are supported on pieces of rock, &c., the timbers being kept clear of the ground, except at the corners, the upper faces of these timbers or floor-plates are adzed roughly flat, and holes mortised, two in each plate, to receive eight uprights, to which a circular wooden ring is then screwed. This ring, being too large to be transported whole, is built up of sectional arcs overlapping each other, and held togther by bolts and washers. By taking out some of the bolts the ring can be broken up into sections of convenient size for transport. Another ring of similar size and construction forms the foundation of a portable dome, which is provided with small rollers, so that it can be revolved in azimuth over the lower ring. An opening is left from side to side of the dome, between two semicircular wooden arcs, which are held in place by the wooden ribs of the dome. The dome and the sides of the observatory are covered with canvas; a canvas cover slides over the opening of the dome in such a manner that any part of it may be left uncovered for observation. On the floor-plates before mentioned a rough wooden floor is then laid. This is kept clear of the cone. It will thus be seen that the weight of the observatory and the observer is distributed over four points, each about 10 feet away from the cone. At second-class stations the observatory is erected, but no floor is laid down.

Near the observatory a tent is set up for the recording clerk, and (at astronomical stations) to shelter the chronograph.

The Chronograph.—This instrument, made by Fauth, is driven by clockwork, actuated by a weight, and is electrically connected with a chronometer, the seconds ticks of which are marked off by a pen resting on a sheet of paper wrapped about a cylinder, which revolves once in a minute. The pen, which is actuated by an electro-magnet, is borne by a carriage, moving on two rods parallel to the axis of the cylinder. As the latter revolves the pen-carriage is drawn slowly along by means of a cord fastened to the carriage, and passing over a pulley to a small drum connected with the clockwork, the pen thus leaving a spiral trace on the paper. When this is removed from the cylinder successive minutes are found recorded in successive parallel lines. A sheet contains the record of about two hours' work. The chronometer, which has an electric contact fitted to it, breaks the circuit every second, and allows a spring to move the pen laterally for a short distance, but, circuit being almost immediately closed, the magnet again attracts the pen, and the pen draws a straight line until the next second. Of recent years a single dry cell has been found quite satisfactory for operating the pen. By means of a contact key at the instrument the times of observation are similarly registered on the paper. No record is made by the pen at the sixtieth second, and, if the hour and minute corresponding to one of these breaks be marked on the sheet, the times of observation throughout the sheet can be afterwards read off, fractions of a second being obtained by estimation of the distance between the observation mark and the preceding and following seconds' marks.

The altazimuth is now placed on the cone, centered over the plug, and levelled up ready for observation. A well-defined station is selected, and the eye-piece being brought into focus on the micrometer wires, the telescope is focussed on the station. Care is taken to see that these adjustments are satisfactory, and that movement of the observer's eye produces no parallax. The error of collimation is reduced to small limits by setting the micrometer head at zero, and, by means of the tangent screw of the horizontal circle bisecting any well-defined station or other distant terrestrial mark. The telescope is then rotated as exactly as possible through 180 degrees, readings of the horizontal circle being taken to effect this, and made to transit. The mark is again bisected, this time by moving the micrometer screw. Half the difference of the reading of the micrometer head from zero is the collimation correction, and the micrometer head is set to this. A repetition of the observations is usually made to verify this adjustment. The observer has provided himself with a list of the stations to be observed, and the number of observations of each required. Making use of the piling overseer's approximate bearings, he proceeds to pick up the signals, and, as he identifies a station, pastes a strip of paper, bearing its name, on the fixed wooden ring of the observatory, immediately in line between the instrument and the station. These paper strips act as guides for rapidly picking up the stations when observing. On them is also stated the number of observations to be made to the station, and room is left to show the date when such observations have been made.

MEASUREMENT OF HORIZONTAL ANGLES.

The method of observation is as follows :—

A complete observation of a horizontal angle includes or is comprised of two separate measures, one with the telescope "arc right," and the other with telescope "arc left" (that is, alidade turned through 180 degrees, and the telescope turned about its axis of support without changing either its pivots or Y's) in order to eliminate any constant errors arising from imperfect collimation, from inequality in the heights of the standards, irregularity in form of pivots, &c.

As the telescope of the 10-in. Troughton and Simms' theodolite will not transit, it must be lifted out of the Y's, turned end for end, and then carefully replaced, avoiding all jar or shock, the same pivot resting in the same Y as before.

Bessel's method of "directions" is followed. Thus, for any one position of the horizontal circle a number of such combined observations is made, each consisting of consecutive pointings to, and micrometer readings of, all stations to be observed to in that set or series, following the order of graduation of the circle, beginning with one station selected as the R.O. (referring object) for the particular station now occupied, and closing, finally, on the initial or R.O. station. The concordance or disagreement of the readings on the R.O. at beginning and ending of each series of pointings serves to show whether there has or has not been any material shift in the body of the instrument, or twist in the stand during the time taken to observe that series. In the earlier years of the survey the surround with "arc left" was made revolving the instrument in the same direction as with "arc right." In the later measures the direction of revolution of the instrument has been changed after the telescope has been reversed, *e.g.*, if the instrument were revolved clockwise with "arc right" it would be revolved contra clockwise with "arc left."

That station is selected as "R.O." which is likely to be generally or always visible and steady during the time horizontal angles are being measured. Such a station will nearly always be found between east and south, and it should have a sky back ground. It is not often that a station in the north or west will be found so suitable for the R.O. When it is a second-class station which is being occupied then one of the first-class stations to be observed from it should be selected as the R.O.

The mean of the two directions (arc right and arc left) is taken as one "reading" at that particular setting, and, when all the directions at that particular setting have been observed, the horizontal circle must be moved into a new position. It has been considered that five positions are sufficient; giving directions at $0° + x$, $36° + x$, $72° + x$, $108° + x$, and $144° + x$, "x" here representing the various angles between the R.O. and any individual station. When the telescope is reversed, readings are obtained at $180° +$ readings first obtained.

Each series of directions, be they few or many, *must* be completed on the same day, not "arc right" on one day, and "arc left" on a subsequent day.

Should there be any doubt as to being able to complete the ordinary series on the same day, then the third-class stations can be omitted (and done on another day), and only first and second class stations included, so as to form a set or series short enough to be completed on the same day.

As a general rule, the best time for observing horizontal angles is from about two hours before up to the time of sunset on days that have been wholly free of clouds. On days which are wholly cloudy (the sun never once showing through) it is often possible to observe the whole day through. As these occasions are somewhat rare, every endeavour is made to make the most of them when they do occur. But, even if possible, it is not advisable to completely finish a station in one day, because the stations observed to are seen then under practically the same conditions of illumination. Hence, observation is spread over different days, so as to vary the conditions as much as possible. It is seldom of any use endeavouring to observe in the early morning, because, although it may be possible occasionally to get two or three directions, still, the duration of the "steady definition" is so brief that there is seldom any chance of completing the series.

All visible objects, such as church spires, finials on towers and lighthouses, &c., are observed two or three times. Even though they may not all be visible from another observing station, still the bearings will be useful to detail surveyors as "References."

The number of observations (each combined of a measure with arc right, and another with arc left) which shall be made to a station is governed by the classes to which it and the observing station belong, thus :—

From a first-class station to a first-class station, twenty observations.
From a first or second class station to a second-class station, ten observations.
From a first or second class station to a third-class station, five observations.

MEASUREMENT OF VERTICAL ANGLES.

The 10-in. theodolite, by Troughton and Simms, has been generally used for this purpose at both first and second class stations.

Vertical angles for the determination of heights are measured at the time of minimum refraction, that is to say, from about ten or eleven o'clock a.m. to about three o'clock p.m. (or four o'clock p.m. in summer), for experience has shown that, although at that time the stations appear to be unsteady and somewhat difficult to observe, yet the results are more accurate than those obtained from observations taken earlier or later in the day, when the atmosphere, and, consequently, the image, of the station is quiescent. If vertical observations be delayed to a late hour in the afternoon, or be taken early in the morning, the results will generally be found to be of little value, and the very worst time for such observations is at sunrise and sunset.

So far as practicable, the back and fore observations between any two stations are taken under as nearly similar conditions as possible, so that both angles may be about equally refracted. This, if the zenith distance of *A* from *B* be measured at, say, two p.m., then the zenith distance of *B* from *A* is measured about the same time of day.

The method of observing vertical angles is somewhat similar to that of measuring horizontal angles, except that there is no R.O. selected. Having measured a surround of zenith distances with the vertical circle on the right hand, the telescope must, as before, be lifted out of the Y's, turned end for end, and then put back, the same pivot resting in the same Y, but the vertical circle will now be at the observer's left hand when looking through the eye-piece of the telescope. The surround will then be observed in the reverse order.

Each end of the level attached to the vernier of the vertical arc is read immediately after the distant station has been bisected. The plan of adjusting the level at every observation is not followed, it being axiomatic that it is better to calculate the corrections for small errors rather than to attempt to adjust mechanically for small deviations.

Barometer and attached thermometer readings are noted at beginning and ending of each day's vertical observations. The height of the telescope axis above the plug, as well as the "official name or number" of the instruments used must be entered in the observation book.

Four measures of a zenith distance (two with arc right and two with arc left) have been considered sufficient.

ASTRONOMICAL OBSERVATIONS FOR AZIMUTH.

The astronomical observations have all been made with the 18-in. altazimuth.

Prior to observation an "Azimuth Lamp" is lighted. This is placed somewhere between 1 and 2 miles distant from the observatory, in such a locality as to be easily attended to by a man at night, and readily seen for connexion with the horizontal observations during the day. The light of the azimuth lamp is, at night, seen through a ¼-in. circular hole in a diamond-shaped piece of tin, which is painted black for day observations, and mounted on a vertical board painted white for ready identification.

The method of observing is that used to determine the azimuth error of a transit instrument in a fixed observatory. This method is known as that of "high and low" stars, or "upper and lower" culmination, and Chauvenet says of it, "All the most favorable conditions can be best fulfilled by two circumpolar stars, both as near the pole as possible, and differing in right ascension by nearly twelve hours. . . . . . It is one of the most refined methods of determining the direction of the meridian, or by which the deviation of the instrument from the plane of the meridian is measured."

The 18-in. altazimuth is put approximately in the plane of the meridian, either by using the bearing from a previous station (after applying convergence), or, where such bearing is not available, by first getting roughly the clock error, by means of a 6-in. theodolite, and, using that error as a first approximation, following a circumpolar star with the middle thread of the reticule, using the tangent screw, until the chronometer ± its error indicates the apparent right ascension of the star; then getting a better value of the clock error by observing the transit of a star, and, finally, following another circumpolar star as before, now, of course, using the later value of the clock error. The reading of the horizontal circle is noted when the transit of the second circumpolar star is completed, and thus it is easy at any time to put the instrument very near to, if not quite on, the meridian, say, within three or four seconds of arc.

Programmes are prepared containing all the available and suitable stars within 10 or 12 degrees of the pole, and also such standard time stars as culminate within 10 or 15 degrees of the zenith, the former for the determination of the azimuth error, and the latter for the determination of the clock error.

The transits of stars over the wires of the 18-in. altazimuth are electrically recorded by means of a battery and key connected to the Fauth chronograph (a chronometer being in the circuit). The chronograph is set up in a tent a little distance from the observatory.

Striding level readings are made for almost every star that is observed, and readings are made on the horizontal circle of the position the telescope occupies whilst star transits are being observed, also readings when the telescope is directed to the azimuth lamp. Then the upper part of the instrument is turned through 180 degrees, and another set of precisely similar observations made.

Four upper and four lower culminations are taken "circle west," and the same number "circle east," but this does not mean that the four upper culminations are taken first, and then followed by four lower ones, for the stars are taken as they happen on the programme, so that four of each (together with a time star) are obtained, quite irrespective of order.

Astronomical Observations for Latitude.—The well-known method of "Zenith Pairs" (commonly called Talcott's Method) has been adopted.

The observer prepares a working list of stars selected from the "Cape Catalogue of Stars for 1880." These are chosen in pairs, which culminate at nearly equal zenith distances, one to the south, and the other to the north. The differences of zenith distance should be well within the run of the micrometer to avoid observations near the edge of the field. The stars' right ascensions should be so nearly the same that their transits will occur within a period during which the state of the instrument may be assumed to have remained unchanged, but sufficient time must be allowed between each star for reading the micrometer and level, and for reversing the instrument in azimuth. In the working list the approximate apparent places for the date of observation are given, also (to facilitate identification) the approximate readings of the eye-piece micrometer at culmination of the stars when the telescope is set at the mean meridian zenith distance of the pair. The instrument is levelled and brought as nearly as possible into the meridian, the telescope is then set and firmly clamped at the mean meridian zenith distance of the pair o stars to be observed, and the micrometer eye-piece set at the calculated reading. When the first star comes into the field the recorder starts counting seconds from the chronometer, and the observer bisects the star by the movable micrometer wire as it crosses the middle vertical thread. The clock time of observation, a reading of the level which lies parallel to the telescope, and the reading of the micrometer head are then recorded. The instrument is next rotated 180 degrees in azimuth, and similar setting and records made for the second star; this completes an observation. If the observer fails to satisfactorily bisect the star when it is on the middle thread, this is done as soon after as possible, and, in all cases, the actual time of bisection is recorded. Usually some 50 or more pairs of stars are observed at a station, the observations being spread over two or more nights.

Astronomical Observations for Longitude.—Longitude observations have been confined almost entirely to determination of the differences of longitude of the station concerned and of the Sydney Observatory.

The method of observing adopted consists in causing the clock at the trigonometrical station to record on the chronograph at the Sydney Observatory whilst the Sydney clock is recording on the same chronograph. Then the Sydney Observatory clock records on the chronograph at the trigonometrical station whilst the clock there is recording its seconds. In this way the difference between the two clocks can be obtained to within a hundredth of a second, and all that remains to be done is to obtain the actual clock errors at the time of comparison. The instrument, having been adjusted very closely for collimation and level, is brought as nearly as possible into the meridian. A previously-prepared programme is arranged in groups of three or four stars at or near the zenith, and one of two circumpolar stars, one, if possible, being *sub-polo*. For this purpose those stars only are used whose right ascensions are well determined. The zenith or time stars, and, where possible, the circumpolars, are selected from the Nautical Almanac, otherwise the circumpolars are selected from the Melbourne catalogue. It is necessary that the intervals between the stars should be as short as possible, so as to eliminate unknown variations in the chronometer rate. When possible, the striding level is read, reversed, and read again just before and after each star. The times of transit of the stars over the wires are recorded on the chronograph by the observer pressing the signal-key, every individual second being automatically recorded by the chronometer. The instrument is now rotated through 180 degrees, and another group of stars observed as before; any error in collimation, and also inequality of pivots, is thus eliminated, and a mean of the two corrections deduced from these two groups is the clock correction at or about the middle time of all the observations. This process is repeated with two other groups of stars, and then, if practicable, clock signals are exchanged with Sydney. The observations then proceed in the same manner; that is, a group of stars, instrument reversed, another group, instrument reversed, and so on, until, if possible, a second exchange of signals is made, when two or more groups will close the evening's work. A single night's work (says Chauvenet), however, is not to be regarded as conclusive, although a large number of stars may have been observed, and the results appear very concordant; for experience shows that there are nearly always errors which are constant, or nearly so, for the same night, and which do not appear to be representd in the corrections computed and applied.

Generally signals are exchanged with Sydney on from three to five nights, depending somewhat on the observers' good fortune in having clear, cloudless nights at both stations.

Magnetic Declination.—This is only approximately determined by means of 5-in. or 6-in. Troughton and Simms' theodolite with trough compass. The procedure is as follows:—

The theodolite is set up, as usual for ordinary surveying, and in line between, and close to, the station being then occupied and any other trigonometrical station which can be seen with certainty by the theodolite telescope.

The compass box is attached to the lower plate, and the needle released, the lower plate being rotated until the north-seeking end of the needle points to its fiducial mark, and then clamped. The telescope is now directed to the distant station, which is bisected. The reading of the horizontal circle gives one magnetic bearing. Next, the south end of the needle is made to coincide with its fiducial mark, the distant station again bisected, and a second magnetic bearing is obtained. Now detach the compass box, draw the glass cover, lift the needle from its supporting pin, turn it (the needle) end for end, replace it on the pin, return the glass slide, and again attach the compass box to the lower plate. Evidently now the lower plate must be rotated through about 180 degrees, to enable the needle to swing freely, and the fiducial marks have changed places. Make the north-seeking end coincide with its new fiducial mark, and again bisect the distant station, thus getting a third magnetic bearing. Finally, cause the south-seeking end of the needle to coincide with its new fiducial mark, and, by again bisecting the distant station, a fourth magnetic bearing is obtained. The first two bearings are with "Box direct," and the third and fourth bearings with "Box reversed," and one series is complete.

Repeat the above step by step, only in the reverse order, south-seeking end to its mark, bisect station, then north-seeking end to its mark, bisect station, reverse needle in box, then south-seeking end to its mark, and, finally, the north-seeking end to its mark, thus arriving at the status when observations were commenced. This makes a second series, and at least a third and a fourth series should be obtained to complete the observations for one day.

As no means are provided for measuring the dip and intensity, the foregoing observations only afford an approximate value of the magnetic declination, hence it is hardly necessary that more than four series should be taken. The time of beginning and ending of each double series should be noted, also the date when the observations were made.

COMPUTATION.

This includes the cataloguing and custody of the records furnished by the piling and observing parties, the reduction of the observations, the recording and preparation of the results for publication, and the supervision of such publication.

As soon as the report of the piling of a station is received at head office from the piling overseer the name of the station, together with the parish and county in which it is located, are entered in a register. When the station has been visited or observed to a number is given to it, and, as the observations are reduced, further references to the record books, in which these particulars are to be found, are added in the register; likewise the register numbers of the stations which observe this station and those which are observed from it.

Field-books as received at head office are numbered and catalogued, and the contents abstracted, numerical operations made by the observer on the recorded observations being first checked. The observed bearings to each station are brought together in proper sequence, and the means taken. In the case of observations between first-class stations the residuals are then tabulated, and Peirce's criterion for the rejection of any doubtful observations applied. (See "Chauvenet's Astronomy," Vol. 2, page 558.) The reciprocal of the weight of the observations $\left(\frac{1}{w}\right)$ is also calculated from the squares of the residuals by the formula $\frac{1}{w} = \frac{\Sigma (vv)}{n(n-1)}$ where "n" = the number of observations, and $\Sigma (vv)$ = the sum of the squares of the residuals. In observations to second-class stations rejection is made where the individual observation differs from the mean by two and a half times the mean of the residuals, or more. This empirical criterion has been adopted as the result of experience. Where only five observations have been made none are rejected. The abstracts of horizontal angles are checked and entered in duplicate in the abstract books, all rejected observations being shown ruled through with red ink.

Calculation of Triangles.—In the computation of the lengths of the sides of the triangles, the triangles formed by the first-class stations are first dealt with, and form a complete scheme, considered quite apart from the secondary work, that is, while secondary work may, and generally does, depend on the lengths of sides of first-class triangles, no secondary work enters into the computation of the positions of the first-class stations themselves. In this way the purely geodetic work of the survey is kept distinct from the trigonometrical, whilst at the same time forming part of the latter. By carrying on the geodetic survey in this way, concurrent with the trigonometrical, a purely scientific service is performed, without any sacrifice of accuracy, and at much less cost than could possibly be done it if were treated as a separate operation. For the secondary triangulation the practice has been to treat each county by itself, a scheme of computation being prepared as soon as possible after the observations in the county have been completed and forwarded to head office.

Computation of the lengths of the sides of triangles proceeds from one or more sides, of which the lengths have been previously determined, and which are adopted as the initial bases. In the first instance an approximate calculation is made, the triangles being treated as plane, and the angular differences between the observed bearings to the stations adopted as the angles of the triangles. With the approximate lengths of the sides thus deduced the spherical excess of each triangle is calculated by the formula $\frac{a\,b \sin C}{2\,NR \sin 1''}$, where a, b, C are respectively two sides and the included angle of the triangle, and N and R are respectively the radii of curvature of the prime vertical and of the meridian at the centre of the triangle. The difference between the spherical excess and the excess over 180 degrees of the sum of the three observed angles of the triangle gives the error of closure of the triangle. The error of closure is an indication of the degree of precision of the observations themselves. For 171 triangles, the angles of which were all observed with the 18-in. instrument, the error of closure averages 0·70 seconds. For 235 triangles two of the angles of which were observed with the 18-in. instrument, and the third with the smaller instrument, the error of closure averages 1·15 seconds. For 245 triangles, two of the angles of which were observed with the smaller instrument, and one with the 18-in. instrument, the error of closure averages 1·29 seconds. For 173 trangles, the angles of which were all observed with the smaller instrument, the error of closure averages 1·30 seconds. In the case of the 171 main triangles referred to above the smallness of the average error indicates the high precision of the work. To further illustrate this, General Ferrero's "m," which may be taken as representing with close approximation the mean error (as deduced from the closing errors of the various triangles) of the angles used in the survey, and which is the criterion now in general use, has been computed for these main triangles by the formula—

$$m = \left(\frac{\Sigma\triangle^2}{3n}\right)^{\frac{1}{2}}$$

where $\triangle$ is the closing error of the triangle, and "n" the number of triangles dealt with. The value deduced is "m" = 0·54″, and this value would be reduced to 0·45″ by the omission of eight triangles in which the error is abnormally great (over two seconds). For comparison the values of "m" for surveys made in other parts of the Empire are given below :—

	″
Great Britain, 1792–1852, 476 triangles	1·790
India, Dehra Dun, 80 triangles	0·780
India, Gurhagerh meridian series, 108 triangles	0·930
India, Singi and Khaupisura meridian series, 101 triangles	1·215
South Africa, with 10-in. Repsold theodolite, 134 triangles	0·495
South Africa, with 18-in. Troughton and Simms' theodolite, 100 triangles ..	0·735
South Africa, Maclear's angles generally, 64 triangles	1·140

For the 173 triangles referred to above, as observed with the smaller instrument, General Ferrero's "m" equals 1·00″.

In the case of triangles, where the three angles have been observed either all with the 18-in. or all with the 10-in. instrument, one-third of the error of closure is applied to each angle. Where the angles have not all been observed with the same instrument a distribution of the error is made proportioning three times as much correction to an angle observed with the 10-in. as to one observed with the 18-in. After correction for the error of closure one-third of the spherical excess is deducted from each spherical angle, and the sides of the triangle, treated as a plane triangle with these reduced angles, are then calculated. In the case of third-class stations (intersections), the two observed angles are treated as plane angles, and the third angle is considered to be the supplement of the sum of the observed angles. None of the fixing triangles for third-class stations being large, the spherical excess is small, and may be neglected. The calculation of closed triangles is carried out to the nearest tenth of a second of arc, that of intersections to the nearest second. The computations are made in duplicate, one computer using Bagay's tables, the other Shortrede's. This system of working in duplicate, using different tables of logarithms, is adopted throughout the major part of the computations, and insures accuracy in the results. Where any discrepancies in the tabular logarithms have been found the correct values have been ascertained from "Vega's Thesaurus Logarithmorum Completus." For logarithms of numbers Sang's "Table of Seven Place Logarithms" has been used.

It frequently happens that two or more values of the logarithm length of a side will result from different triangles; in such cases the mean of these logarithm lengths is taken and used in all subsequent operations. In fact, in all the computations of the survey, where two or more values are obtained, the mean is taken and used thereafter.

Local and Figure Adjustments.—Part of the main triangulation, south from Lake George base, has been reduced by (1) determination of the most probable directions at each station with reference to the observations at that station only; (2) formation of equations of condition for each geometrical figure involved, using the angles between the directions derived from the previous step; (3) reduction, by the method of least squares, of the most probable corrections to satisfy the equations of condition, which work forms the most laborious part of the whole operation. Numerical illustration of the mode of adjustment will be found in a paper on the trigonometrical survey of New South Wales, by the present Director of the Survey, read before the Association for the Advancement of Science, January, 1898. The amount of work involved and the small strength of the computing staff has prevented this rigorous system from being followed out in other parts of the survey. It is anticipated that further least squares adjustment of the main work will be made when new bases have been measured, so that agreement between computed and measured lengths can be introduced as further conditions to be satisfied.

The geodetic latitudes and longitudes and relative true bearings of the main stations have been computed by the formulæ given at page 252 of the Report of the Ordnance Survey of Great Britain, 1858. The position of Sydney Observatory, as given in the Nautical Almanac for 1890 and onwards (namely, latitude 33° 51′ 41·1″, S., longitude 10h. 4m. 49·54s., E.) has been adopted as the zero point; and the azimuth of the meridian mark of the same observatory, as determined by the Government Astronomer, is the initial azimuth of the survey.

The formulæ referred to above are—

$$\log\,(\psi_{,} - \psi) = \log \frac{S \cos A}{R \sin 1''} + 2g$$

$$\psi' - \psi_{,} = -\frac{S^2 \sin^2 A \tan \psi_{,}}{2NR \sin 1''}$$

$$\log \omega = \log \frac{S \sin A}{N \cos \psi' \sin 1''} - f + h$$

$$\log \nu = \log \left(\omega \sin \frac{\psi' + \psi}{2}\right) + \frac{3f - g}{4},$$

in which ψ and ψ' are the latitudes of the points at the extremities of a line, the azimuth of which is A; R is the radius of curvature at the middle latitude; N the normal; S is the length of the line; $f = \frac{MS^2}{6NR}$; $g = f \sin^2 A$; $h = g \sec^2 \psi'$. M is the modulus of the common system of logarithms, and ω is the difference of longitude. These formulæ may be taken as precise for all distances up to 50 miles.

The dimensions of the earth, used in the reductions, are—

Major semi-axis $= a =$ 20,923,134 feet.
Polar semi-axis $= c =$ 20,853,429 feet.

$$e^2 = \frac{a^2 - c^2}{a^2} = \cdot 00665186.$$

These appear to have been derived from Captain Clarke's determination of the elements of the figure of the earth, which are as follow:—

Major semi-axis of equator (longitude 15° 34′ east) $= a =$ 20,926,350 feet $=$ 6378294·0 metres.
Minor semi-axis of equator (longitude 105° 34′ east) $= b =$ 20,919,972 feet $=$ 6376350·4 metres.
Polar semi-axis of equator $= c =$ 20,853,429 feet $=$ 6356068·1 metres.

It would seem that in the early days of the survey the equatorial diameter, in longitude 152 degrees east, had been computed and adopted with the above polar diameter as defining the spheroid of revolution on which to calculate the work.

As previously stated, the trigonometrical calculation proceeds county by county. A first-class station near the centre of the county (or a second-class station in some few cases, where there happens to be no first-class station suitably situated) is adopted as the origin of co-ordinates for the county. All other first and second class stations in or near the county are then referred to this origin by spheroidal co-ordinates, and the mutual bearings between the connected stations calculated, these bearings being referred to the true meridian through the origin. The formulæ of computation are—

$$y_{,} = y + n - \frac{m^2 y}{2NR} - \frac{m^2 n}{6NR}$$

$$x_{,} = x + m + \frac{m y_{,}^2}{2NR} - \frac{m n^2}{6NR}$$

$$a_{,} = a \pm 180° - \frac{my}{NR \sin 1''} - \frac{mn}{2NR \sin 1''}$$

in which N and R are the radii of curvature of meridian and perpendicular to the meridian at latitude of a point midway between the two stations : "m" $= s \sin a$, and "n" $= s \cos a$.

The bearings of the lines connecting third-class stations (intersections) to the fixing stations are derived from the mutual bearings of the latter by applying the angles used in the solution of the intersections triangles. With the bearings thus deduced the co-ordinates of the intersection stations, with reference to the fixing stations, are computed by the formulæ—

Difference of latitude $= s \cos a$.
Difference of departure $= s \sin a$.

where "s" and "a" are respectively the length and bearing of the line between the fixing and the intersection station. By addition of the co-ordinates thus derived to the spheroidal co-ordinates of the fixing station, the co-ordinates of the intersection station referred to the origin of the county are obtained.

By means of tables, which have been prepared in the trigonometrical branch, and which give the values of one degree on the meridian for every degree of latitude, and one degree on the parallel for every 10′ of latitude throughout the State, the computed co-ordinates are converted into differences of latitude and longitude.

The heights of stations at which reciprocal observations of zenith distance have been made are calculated by the formulæ :—

$$h_B - h_A = 66s \tan \tfrac{1}{2}(\zeta_B - \zeta_A) \left(1 + \frac{h_A + h_B}{2\rho} \ldots\ldots\right)$$

in which h_A and h_B are respectively the heights of the initial station, and that station the height of which is sought, ζ_A and ζ_B are the reciprocal zenith distances (corrected for heights above plugs of instruments and objects observed), s is the horizontal distance between the stations, and ρ the mean radius of curvature of the surface in the vertical plane passing through the two points. The initial height of the survey is that of Lake George, which was connected by spirit levelling with Bench Mark 33 (near 150 miles) on the Main Southern Railway line, and with the terminals of Lake George base. The heights of the terminals of the Richmond base were also determined by spirit levelling. No corrections have been made for subsequent connexions to Bench Marks, but that such correction would be small is indicated by the following comparisons :—

Station.	Height by Spirit Levelling.	Height by Computation from Observed Zenith Distance.
	feet.	feet.
Lambie	4,220	4,219
Blackheath	3,562	3,560
Skeletar	1,065	1,055
Sutton Forest	2,490	2,487
Hudson's Peak	4,039	4,035
Bukalong	2,917	2,910
Merrimbula	117	118
Bimmil	1,031	1,030
Gilringanbil	1,235	1,234
Kalinga	918	922
Bogan	1,281	1,277

The mean value of the co-efficient of refraction (k), as determined from reciprocal observations by the formulæ $2k = 1 - \frac{P \sin 1''}{s}(\zeta_A + \zeta_B - 180°)$, is 0·061. This value is used in the reduction of heights from observations at one station only by the formulæ :—

$$h_B - h_A = 66s \cot Z_A + \frac{66Ms^2}{\rho} + \frac{66Ns^2 \cot^2 Z_A}{\rho} + (I_A - O_B)$$

where Z_A is the observed zenith distance, I_A and O_B the respective heights, in feet, of the instrument and object observed, $M = \frac{1 - 2k}{2}$, and $N = 1 - k$, k being the adopted co-efficient of refraction.

The co-ordinates and heights of stations are made available as soon as possible after computation by publication in the form of registers for each county.

Astronomical Computations.—The four principal ephemerides, *i.e.*, The Nautical Almanac, Connaissance des Temps, Berliner Astronomisches Jahrbuchm, American Ephemeris and Nautical Almanac, and the Star Catalogues, Melbourne 1880, Cape 1880, Lewis Boss' Preliminary General Catalogue for 1900, and a catalogue of 920 latitude stars for the epoch 1880, compiled in the Trigonometrical Branch, are the authorities consulted for mean places of the stars observed. The star constants are computed and apparent places derived for the dates of observation. The formulæ used in latitude reductions will be found in "Chauvenet's Spherical Astronomy," Vol. 2, page 342 *et seq.*, and those used in azimuth computation at page 169 *et seq.* of the same work. It is not thought necessary to repeat them here.

In all cases Peirce's criterion for the rejection of doubtful observations (see Chauvenet, page 596) is applied, and the doubtful observations discarded. The probable error of the resulting latitude or azimuth is determined by the formulæ $P.E. = \pm \cdot 6745 \sqrt{\frac{\Sigma(vv)}{n(n-1)}}$. The average of the probable errors of the latitude series at the stations is $0 \cdot 10''$, and the average of the probable errors of the azimuth series is $0 \cdot 17''$.

PROGRESS AND COST OF THE SURVEY.

The progress which the survey has made is illustrated in the attached map. The area now covered is about one-fourth of the whole State.

Since the operations were resumed in 1891 about 43,000,000 acres have been covered, at a total cost of £88,859, or about 0·496d. per acre. When it is considered that for this sum not only has this large area been triangulated and the co-ordinates of stations made available to map compilers and surveyors, but, at the same time, geodetic results of the highest accuracy and of great scientific value have been obtained, it must be conceded that the results amply repay the moderate expenditure involved.

In the preparation of the foregoing Report extracts have been freely made from the Annual Reports of the Department of Lands; from a paper on the trigonometrical survey of New South Wales, read before the Australasian Association for the Advancement of Science, January, 1898, by Mr. T. F. Furber, now Director of Trigonometrical Surveys; and from a report to the Under Secretary for Lands, dated 31st October, 1906, by Mr. J. Brooks, then Surveyor-in-Charge of Field Operations.

(Sgd.) FRED POATE,
Surveyor-General, N.S.W.

20th May, 1912.

A map showing the triangulation is attached.