

APPENDIX "H."

TRIANGULATION IN NEW ZEALAND.

Contributed by James Mackenzie, Esquire, Surveyor-General of the Dominion of New Zealand.

In order to realize the position of Triangulation in New Zealand, it is necessary to explain that the Dominion was originally subdivided into six Provincial Districts (afterwards increased to ten), and each carried out its surveys in its own way, under the control of its own Government. These Provinces were abolished in 1876, but Provincial Land Districts still remain, the land and survey matters therein being controlled by a combined Commissioner of Crown Lands and Chief Surveyor. There was no attempt at Triangulation in the original Provinces, except in Otago, Canterbury, Wellington, and Taranaki, and the native surveys of the North Island.

The great pioneer of accurate survey methods in New Zealand under the Provincial Government, was the late Mr. J. T. Thomson, F.R.G.S., then Chief Surveyor of the Province of Otago, who became, in 1876, first Surveyor-General of New Zealand, after the establishment of responsible Government. It was in 1856 that he established a rapid system of reconnaissance survey, and a minor triangulation. In this he was ably assisted first by Mr. Alexander Garvey, and later by Mr. James McKerrow, F.R.A.S., who afterwards succeeded Mr. Thomson in the Surveyor-Generalship of the Dominion. Briefly, the process was to observe latitudes at stations about 60 miles apart on the same meridian, and to use the base so obtained for fixing the positions of all prominent mountains and other important features. Regarding Mr. McKerrow's surveys, the country did not lend itself to Mr. Thomson's system of astronomical bases. Mr. McKerrow selected three mountain peaks, 60 or 70 miles apart, at which the latitude was determined, as also very carefully the times at each place, and by means of chronometers conveyed from point to point, the longitude of these base points was ascertained; and following on this, by ordinary triangulation methods, the topography of the country was filled in.

It may be mentioned that on subsequent close trig. and topographical surveys taking place, the remarkable accuracy of these early reconnaissance surveys, costing as they did only a few shillings per square mile, has been fully demonstrated. The process was extremely rapid, as no stations were built, and was suited to the mountainous nature of the country, while a very fair degree of accuracy was attained. By these means a sufficiently accurate survey of Otago was effected and used for the first disposal of the early pastoral runs, besides being utilized for many purposes of early settlement, leaving closer detail surveys to follow, as well as the marking out of electoral, road, registration, and other districts.

Information was also afforded of the heights of mountains, passes, lakes, and of distances between geodesical stations. Minor triangulation followed on this, and was used to check and control all section surveys. The limit of error in traverses, then adopted (following Indian practice), was 8 links to the mile, and as it was desirable that the error on the ground should never exceed 10 links in these early surveys, the minor trig. stations were established at an average distance of $2\frac{1}{2}$ miles apart. Although the permissible error was 8 links to the mile, most of the work when checked showed errors ranging from half a link to 6 links per mile; the maximum error allowed by regulation has since been reduced to 4 links in rural surveys, and 1 link in town surveys, but in actual practice the error rarely exceeds 2 links per mile in rural surveys.

The Province of Otago was divided into meridional circuits of about 120 miles in longitude, and 90 miles in latitude; in each circuit the true meridian was observed at the initial station, and a system of standard bearings was extended wherever required, stations being established at intervals of about 12 miles. Each meridional circuit was divided into Survey Districts, 12 miles square, with sides parallel and perpendicular to the initial meridian. Thus each Survey District had a geodesical station within it, and a number of carefully observed standard bearings, so that in the event of settlement surveys being carried out, a minor triangulation could at once be put in hand, using the geodesical station as the initial, and the standard bearings for the true, meridian.

Each Survey District was thus complete in itself, and either had its own base line or extended the triangulation from an adjacent district. In this way very great flexibility was obtained and no more triangulation need be carried out than that required for the settlement surveys in hand or anticipated. Triangulation with an accuracy in advance of the original Otago methods was carried out gradually throughout the Dominion after the abolition of the provinces in 1876, when Mr. Thomson took complete control as Surveyor-General of the Dominion; Mr. McKerrow being Assistant Surveyor-General. Long before this date, however, Captain T. Heale, Inspector of Native Surveys under the General Government, and Mr. H. Jackson, F.R.G.S., Chief Surveyor of the Wellington Province, had started in the Provinces of Auckland and Wellington a secondary system of triangulation, Captain Heale's work extending over a large area in

the North Island, principally in connexion with native lands surveys, whilst Mr. Thos. Humphries, Chief Surveyor of the Taranaki Province in the North Island, also made a beginning with a triangulation on sound lines, this triangulation governing his detail surveys. The main object of the triangulation has been practical utility rather than a strictly scientific work, and thus nearly every survey in Otago, since 1856, may be said to be founded upon or connected with triangulation, and since 1876 the same statement applies to the whole Dominion.

The minor triangulation has always been the forerunner of settlement work, and has formed part and parcel of it, and has generally been accompanied by topography on a scale of 40 chains to 1 inch.

These early trig. surveys met all settlement wants, and the topographical plans have given the fullest details regarding the character of the country, altitudes, soils, road routes, and all matters relating to the opening up of land for settlement.

Since 1876, in many of the more settled districts the triangulation has been revised from time to time, and as the topography becomes better known it has been possible to increase the lengths of the sides of the triangles.

The Dominion may now be said to be entering upon a more scientific triangulation, and in the North Island four bases have been measured.

In measuring the bases the greatest accuracy was aimed at, and they will be available for use when the time comes to run a series of primary triangles over the whole Dominion.

Up to the present, four bases have been measured by Mr. John Langmuir, one of the Senior Inspecting Surveyors.

The standards of length used were the ten one-chain steel bands certified to by the Standards Department, Board of Trade, London, in 1903.

Invar bands in five-chain lengths, supported at fifty-link intervals were used, and the details are fully given in the Survey Reports for 1909-1910, and the following years.

The approximate lengths of the bases are as follows:—

“Wairarapa” Base—length 64776·6668 links.

Probable error $\pm 0\cdot0219$, or 1 in 2,962,000; date measured, 25th March to 29th May, 1909 = 47 days = 5·2 days per mile.

“Eltham Okiawa” Base—length 79605·1228 links.

Probable error $\pm 0\cdot0128$, or 1 in 5,142,000; date measured, 5th April to 24th June, 1910 = 46 days = 4·6 days per mile.

“Waitemata” Base—length 41790·7756 links.

Probable error $\pm 0\cdot0077$, or 1 in 5,424,000; date measured, 27th June to 29th August, 1911 = 21 days = 4·0 days per mile.

“Matamata” Base—length 54799·7068 links.

Probable error $\pm 0\cdot01005$, or 1 in 5,452,000; date measured, 2nd December, 1910, to 29th January, 1911 = 22 days = 3·2 days per mile.

In 1901, a Secondary Triangulation was commenced in the Wellington and Taranaki Districts, with a view of bringing into harmony all the different nets of minor triangles which had spread inland from the coastal chain, from time to time, in advance of the settlement work.

A scheme of triangles with sides varying from 6 to 24 miles was drawn out to cover the whole of the minor work, using wherever possible the old minor trigs for the secondary points.

The whole of the scheming out of the triangles, erection of signals, and observation work was done by one field party, which included the surveyor in charge and four men.

The instrument used was a 10-inch Everest, graduated to ten seconds and read by verniers, the best in the Department at that time.*

Owing to the urgency of settlement work in other parts, the revision of the triangulation was dropped in 1902 and not taken up again until 1909.

The same instrument was again used and the work proceeded at intervals during the next three years. The connexion between the two bases is now almost complete.

The computations are being carried out by the Chief Computer, using the latest methods, and of the twenty-eight triangles calculated the value of “ m ” †, using General Ferrero’s formula, comes out at 1·55”; the average error per triangle is 2·25”; the area covered is 2,630 square miles, and there is, on the average, one trig. station in 119 square miles.

Considering the unsuitability of the New Zealand atmosphere for observation work, and the class of instrument used, the results are considered satisfactory, and the work should fully serve the purpose intended.

* New 8-inch micrometer transit theodolites have now been obtained for future triangulation.

† $m = \sqrt{\frac{\sum \Delta^2}{3N}}$ where $\Delta =$ error of triangle.
 $N =$ number of triangles.

The smoke from bush fires during the summer, and the haze caused by the sun on the moisture-laden country during the winter, prevented the signals showing out distinctly even on comparatively short lines. Numbers of trigs. were situated on the high backbone ranges, which were very rarely clear from mist.

In many cases over a month elapsed before the observations at a station were completed.

When the primary work is undertaken, the observations will have to be taken at night in order to get over the vagaries of the atmosphere. Signals 25 miles distant can very rarely be seen during the day in New Zealand.

The map accompanying this report shows that practically the whole Dominion is covered by a minor triangulation, while the secondary triangulation in progress in the Wellington and Taranaki Districts is also shown.

I would like to point out that observations were made at a large number of stations for latitude and azimuth in 1883, 1884, 1885, by Mr. C. W. Adams, then Geodesical Surveyor, using a zenith telescope, also prior to this observations were made by Mr. J. W. A. Marchant. These stations, as well as a number of the others, where observations for latitude and azimuth were carried out in earlier years by other officers of the Department, are shown on the map. Longitude has been determined on a number of occasions, at first by absolute methods or by the transportation of chronometers, later by telegraphic signals. The more recent determinations for longitude by telegraphic signals are those between Wellington and Sydney, by Mr. C. W. Adams, and the late Mr. H. C. Russell, Government Astronomer of New South Wales, in 1883; and between Wellington (*via* Doubtless Bay) and Norfolk Island, by Dr. O. Klotz, in 1903, thence from Norfolk Island to Australia and Canada by the Pacific Cable.

In conclusion I should like to place on record here, without making invidious distinctions, that the names in the past standing out prominently in connexion with the advancement and control of the Dominion's geodesical minor triangulations, and accurate system of surveys generally, from their initiation up to the present day are—John Turnbull Thomson, F.R.G.S., Alexander Garvey, James McKerrow, F.R.A.S., Captain Theophilus Heale, Henry Jackson, F.R.G.S., Stephenson Percy Smith, F.R.G.S., John William Allman Marchant, Thomas Humphries, Charles William Adams, John Strauchon, Gerhard Mueller, John Holand Baker, John Samuel Browning, John Hay, Eric Charles Goldsmith, George John Roberts, William Arthur, and many others; whilst among the many who have been employed from first to last, the following might be mentioned as probably the principal observers:—Messrs. Alex. Dundas, James Mitchell, John Arthur Connell, Anthony Dixon Wilson, Henry James Lowe, Morgan Carkeek, John Annabell, James Arthur Thorpe, Thomas Noel Broderick, Harry May Skeet, Llewellyn Smith, Horace Baker, Lawrence Cussen, James Baber, jun., Hubert Earle Girdlestone, John Langmuir, Thomas Maben, James Daniel Climie.

Many of these men are not now with us, and not a few have joined the "great majority," but it is only fitting that in the brief outline of New Zealand surveys that these men who had so much to do with the building of the structure should not be forgotten.

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