GEODETIC INVESTIGATIONS IN THE CANADIAN ARCTIC

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The first step in the scientific investigation of an undeveloped district is accurate mapping. Where geodetic surveys, whether by astronomy, triangulation, or by shoran trilateration, are used to establish the necessary control for mapping, the data obtained are also of value in computing deflections of the vertical, in determining the undulations of the geoid and the thickness of the earth's crust, and finally, in deriving the dimensions of the spheroid of revolution which conforms most closely to the geoid.

Over the last one hundred years, geodesists in different parts of the world have derived the mathematical dimensions of five spheroids which are in reasonably close agreement. The ultimate aim of the research is to derive a geoid and a spheroid from data which are world-wide in coverage, and therefore free from the effects of local anomalies. In the Canadian Arctic and Subarctic methods of survey based on geodetic astronomy and shoran trilateration have already been used. In the foreseeable future, geodetic triangulation and precise levelling will also be used and should advance geophysical research in these regions.

The Geodetic Survey started its arctic work in 1935, when C. H. Ney determined the astronomical positions at some of the points of call of the Hudson's Bay Company's R.M.S. *Nascopie*. In 1942 the northern operations of the Geodetic Survey were expanded, and between that year and 1950, 300 astronomical stations were established for control for mapping from air photographs north of the tree-line. About 200 of these were on the mainland, the remainder on the more southerly arctic islands.

The determinations were made by Ball's method, using a precision theodolite set at a vertical angle of 45 degrees or 60 degrees. A minimum of four stars was observed in each quadrant, and the time recorded by stop watch or electric chronograph. In favourable weather a party could complete four to eight stations a month. Occasionally prolonged periods of overcast skies prevented astronomical work. During such periods hourly magnetic observations were taken in the daytime, and botanical and zoological collections were made by some of the parties.

During the past few years the shoran electronic method of position fixation has superseded the astronomic method in most parts of northern Canada. This new system of survey permits the extension of ground control for mapping and charting into remote areas in a much shorter time than would be required by

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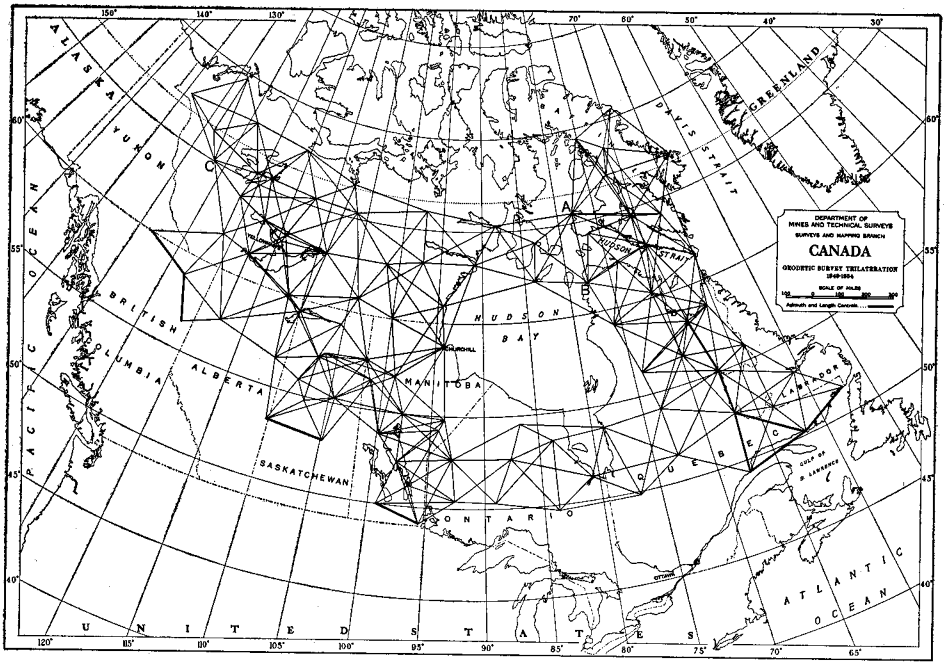

Fig. 1. Shoran trilateration in northern Canada.

the use of the conventional type of triangulation. Shoran trilateration consists of measuring electronically three sides of large triangles joined to form an over-lapping series of geometrical figures. The triangles are extended initially from a known base line joining two previously determined geodetic triangulation stations. By the shoran method distances between points up to 400 miles apart may be determined with an accuracy of 20 to 50 feet.

Through the cooperation of the Royal Canadian Air Force, airborne electronic equipment is used in conjunction with ground sets mounted temporarily at the terminal stations of the line being measured. The aircraft flies back and forth across the line near its central point at uniform speed and height, emitting short radio pulses which are sent to the terminal ground stations and then returned on a different frequency after a very short fixed delay. The elapsed time between dispatch and reception is recorded by mileage dials, which together with other dials are photographed at intervals of three seconds.

Immediately after the return of an aircraft from a line-crossing mission, Geodetic Survey personnel at the operational base camp receive the photographic records of instrument readings and make the necessary mathematical reductions. Corrections to each length obtained are made for delay of signals at the ground stations, height of aircraft and terminal stations above sea level, slope, humidity, temperature, and barometric pressure. Sixteen independent length determinations are made of all lines on two separate days in groups of eight each to ensure a change of atmospheric conditions and to check equipment. Further mathematical checks are made where possible. When field analyses are satisfactory, the ground electronic equipment, consisting of transponders, radio communication sets, power supply units, and radar masts, are dismantled and moved forward to new stations in the network. The final least squares adjustment of the network as a whole, and the computation of geographical positions, azimuths, and lengths are made by the Geodetic Survey in Ottawa.

Since 1949 the Canadian shoran net has been extended from the vicinity of the 49th parallel in Manitoba, north and northwestward as far as the arctic coast in the Mackenzie River area. Beginning some 200 miles to the south of the northern point reached in 1951, a branch was continued eastward 1,000 miles to the western limits of Hudson Strait by the end of 1952. During 1953 the network was extended northward across Hudson Strait to the central part of Baffin Island, and a junction was made near the western end of Hudson Strait with the existing shoran net. This junction completed a 5,600-mile closed loop of survey control. The southern part comprised a 2,000-mile arc of conventional triangulation; the remainder consisted of shoran trilateration. The closure error in geographical position was equivalent to 400 feet. If it is assumed that the entire error was accumulated in the 3,600-mile shoran component of the loop, the ratio of closing error to axial length is only 1/47,000, equivalent to 1⅓ inches in one mile. In 1954 the shoran work was continued in Labrador, more stations being established within the basic framework.

Since its inception in 1949, shoran trilateration had been extended by the end of the 1954 season over 1,900,000 square miles of the Canadian north, a large part being north of the 60th parallel. In all, 86 stations involving 325 measured lines ranging from 16 to 366.8 miles in length are comprised in the network.

Problems and future work

One of the major undertakings for Canadian geodesists will be the extension of primary triangulation arcs from the more southerly areas into the Arctic, so that connections may be made with the northerly sections of the shoran network. This will greatly strengthen mathematically the existing shoran framework in addition to providing a dense pattern of control points in specified areas between the shoran stations.

Geodesists foresee interconnection of the geodetic triangulation networks of Europe, Asia, and Africa with those of North America. This may conceivably be achieved by shoran trilateration connections across Bering Strait, or between the Canadian Arctic shoran net and the triangulation systems of Greenland, Iceland, and the British Isles. A project of this nature would make possible the establishment of a "world geodetic datum" to which all triangulation and trilateration surveys on land masses within electronic measurement distance of the interconnected continents could be referred.

One great advantage of a "world geodetic datum" would be the co-ordination of data from isostatic studies in various countries. Deflections of the vertical determined in the Canadian Arctic by geodetic methods could be accurately related to values observed in England or Africa. In this way, the studies of the geoidal contours and the determination of the best-fitting spheroid of revolution would be greatly advanced.

Gravity observations would be an important part of a planned world program for the study of geophysical problems. If gravity observations were available for all parts of the world on both land and water, an extensive mathematical reduction by Stokes's Theorem would permit accurate calculation of the undulations of the geoid and the extent of the flattening of the earth towards the poles. But from gravity observations alone it is not possible to compute the lengths of the major and minor axes of the earth. At the present stage of development of the science, a combination of astronomy and geodesy constitutes the most effective and practical approach to the determinations both of deflections of the vertical and of the dimensions of the spheroid of revolution which most closely conforms to the size and shape of the earth. The usefulness of the two methods of approach to the study of variations in densities of the earth's crust is suggested by recent findings in the Great Bear Lake region, where the geodetic shoran network has indicated large anomalies in the general pattern of deviations of the vertical. An intensive gravity survey in the same area might provide technical data of both scientific and economic value.

Geodetic investigations of changes in mean sea level should be extended to the Arctic. With the ameliorating climatic conditions of recent years in the north the weight of the glacial remnants has been reduced and increased amounts of water from melting ice have found their way into the sea. The resulting diminution of pressure in several areas may be expected to cause isostatic readjustments of the earth's crust, either suddenly, accompanied by earthquakes, or very slowly in the form of a gradual tilting. Such a tilting has been definitely indicated over a period of years by geodetic levelling in the Great Lakes region both north and south of the international boundary. The alterations in mean sea level can best be measured by repeated levelling over selected lines at intervals of about twenty years. Changes indicated by coastal tide-gauge stations and permanent bench marks, situated at intervals along the lines, will also give a measure of the crustal tilting.

The basic problems of geodesy in the Canadian Arctic are similar to those in other parts of the country, but the amount of geodetic work already done in the north is small compared with that in the south, and increased knowledge of the north would be of great benefit in all geophysical research.