THE SEARCH FOR THE NORTH MAGNETIC POLE*

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Abstract

The Dominion Observatory has extended its network of magnetic stations in the Arctic to such a stage as to indicate the presence of the north magnetic pole in northern Prince of Wales Island. A brief historical summary of magnetic observations in the north is given followed by an account of the observations made in the summer of 1947. Preliminary values of 1947 results from Arctic magnetic stations and a chart of magnetic meridians constructed from recent declination observations are included.

ON JUNE 2, 1831, Ross fixed the British flag to a spot on Cape Adelaide Regina, Boothia Peninsula, and took possession of the north magnetic pole in the name of Great Britain and King William the Fourth. The spot was a fixed geographical point—70° 5′ N. Lat., 96° 46′ W. Long.—about which the magnetic pole was perpetually moving. During Ross' observations, extending over a 24-hour period, the pole was moving within an area whose diameter was of the order of 16 miles. Ross arrived at the north magnetic pole on foot having walked from his base at Victory Harbour about 100 miles away.

On May 3, 1904, Amundsen reached a point on Boothia Peninsula apparently about 20 miles from the magnetic pole. He had travelled by sledge from Gjoahavn, King William Island, some 150 miles distant. The pole at that time was computed to be in 70° 30′ N. Lat. and 95° 30′ W. Long., about 40 miles northeast of Ross' position. Amundsen established at Gjoahavn a temporary magnetic observatory which operated from November 1903 to May 1905 and furnished control to field observations made during a magnetic survey of parts of King William Island and Boothia Peninsula. This long series of magnetic measurements showed, among other things, that the pole could be displaced in a north-south direction by a range of 150 miles. Had Amundsen been able to surround the magnetic pole area by magnetic stations his site for the mean position of the pole might have been somewhat different.

On August 22, 1947, Serson and Clark landed on the shore of Allen Lake, northeastern Prince of Wales Island, from a Royal Canadian Air Force Canso having flown from Cambridge Bay, Victoria Island, about 325 miles away. The north magnetic pole was probably within 10 miles of them before receding on its uneasy course. The observations at Allen Lake offered evidence that the magnetic pole described some sort of a rough orbit whose radius was of the order of 25 miles on a magnetically quiet and 50 miles on a magnetically disturbed day. The results for this station appear in Table 1.

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TABLE 1

Preliminary values of declination (D) inclination (I) horizontal intensity (H) total intensity (F) and distance (R) from magnetic pole according to local mean time (L.M.T.) at Allen Lake*, northeastern Prince of Wales Island latitude 73° 41′N. longitude 98° 26′W.

DATE	L.M.T.	D	I	H	F	R
1947	h m	o ′	o ′	gammas	gammas	miles
Aug. 22	16 43	108 58	89 35	422	58177	50
	17 41	130 46	89 21	670	58397	79
	18 09	130 18	89 29	525	58194	62
	19 13	128 35	89 27	563	58241	66
	20 07	127 59	89 24	613	58196	72
	21 07	115 26	89 22	650	58234	77
	22 08	110 25	89 26	574	58245	68
	23 01	111 34	.....	.....	.....	..
23	00 07	112 41	89 33	464	58268	55
	10 03	107 39	89 46	235	58158	28
	11 11	114 00	89 56	59	58272	7
	11 35	133 38	89 45	248	58396	29
	12 03	143 02	89 46	245	58622	29
	12 33	113 41	89 56	69	58236	8
	12 55	131 02	89 40	345	58470	41
	13 21	138 44	89 30	493	58196	60
Means.....		122 24	89 36	412	58287	49

*This name has been used for convenience, but has not been approved by the Geographic Board of Canada.

Nature of the Magnetic Pole

The magnetic pole may be defined as an area rather than a precise point. There the earth's magnetic field is vertical and the dipping needle points towards the centre of the earth. The compass needle is useless since the horizontal force required to hold it in its direction has vanished. The daily fluctuations in position of the pole result from deformations in the magnetic field caused by solar activity operating in the earth's upper atmosphere, while the secular or long term movement has its origin within the earth. The daily fluctuations are limited to a movement about a fixed geographical point which represents the mean position of the pole at the time. It is understood, therefore, when a position for the magnetic pole is indicated it represents the mean centre of an area at a particular epoch.

There exist throughout Canada centres of local attraction where the earth's field is distorted by the presence of magnetic materials in either the rocks or the overburden. The attraction at some of these centres has sufficient strength to create local poles. The effect of local poles is quickly dissipated

in a comparatively short distance from the area. The Canadian Arctic is not free from this condition. There are, for example, known areas of local attraction at Fort Ross, southern Somerset Island, on King William Island and in Coronation Gulf. The effect of restricted areas of local attraction falls off rapidly with altitude above the surface so that aircraft flying at 6,000 feet or higher may employ magnetic charts free of the sinuosities apparent in ground level values. The idea has been advanced that the position of the north magnetic pole, as deduced from magnetic observations made in aircraft at various altitudes, may differ from that calculated from ground observations. Definite conclusions about this must necessarily await the precise determination of the ground position of the magnetic pole.

Earlier Determinations of Magnetic Pole

The position of the north magnetic pole has been the subject of investigation by mathematicians and explorers for almost 250 years. In the past, as today, the position of the magnetic pole was of great scientific interest. A knowledge of the positions where the magnetic axis of the earth intersected the surface was needed to arrive at a complete picture of the earth's magnetic field. Many attempts were made to deduce the position of the north magnetic pole from observations made at various points not in northern regions. Certain assumptions were made which held in the laboratory but were not valid when the earth itself was considered. For example, mathematical formulae were derived on the assumption that curves of equal inclination and horizontal force were concentric circles with the magnetic pole as a common centre. This is not the case since the curves are rather eliptical in shape and not necessarily regularly spaced in relation one to another. Again, it was assumed that the total force of the earth's magnetic field was a maximum at the magnetic pole. This does not agree with measurements made on the earth's surface, as the maximum total force in Canada is to be found in an area to the west of Churchill about 1,000 miles south of the magnetic pole.

If uniformity in design, such as a system of uniformly spaced concentric circles, existed and if the compass needle pointed directly at the pole instead of generally along a curved magnetic meridian, then it would be possible to deduce a geographical position of the pole from values of declination, inclination and horizontal force at any single station. This method was commonly used in the distant past with the result that each station gave a different position of the magnetic pole. The only uniformity in the results was an indication that the north magnetic pole was somewhere north of the Arctic Circle between Greenland and Alaska.

The first magnetic observations made in Arctic regions which assigned a definite restricted area for the pole were those made by Sabine, Parry and Franklin between the years 1818 and 1826, while endeavouring to discover a Northwest Passage through the Canadian Arctic to the Orient. A preliminary analysis based on the results of these observations placed the magnetic pole in 70° N. Lat. and 98° 30′ W. Long., but a more detailed analysis by Professor Barlow placed the pole exactly where it was later found by Ross. Ross was probably the only scientist who has ever stood at the centre of the magnetic pole area. Observations of inclination made during a 24-hour period extending from noon June 1, 1831, gave a mean value of 89° 59′, only one minute short of the 90° which defines the pole. However, during the observing period values of inclination ranged between 89° 56′ and 90° 3′. The assumption that the magnetic pole actually was in the position determined by Ross is substantiated by a series of observations made during the previous winter in a temporary magnetic observatory at Victory Harbour and en route from Victory Harbour to Cape Adelaide Regina.

Modern Studies

The only way to fix accurately the position of the magnetic pole is to compute first a position using data from stations not too distant. The declination data will establish the centre of convergence of the magnetic meridians, the inclination data will establish the point where the dip should be 90 degrees and the horizontal force data will establish its vanishing point. The next step is to surround the area indicated with magnetic stations which will further restrict the pole area. The mean pole point must then be found by an intensive ground survey in case the earth's field is deformed by the presence of certain geological formations.

All positions assigned to the north magnetic pole between 1904 and 1946 were computed principally from magnetic data applying to regions remote from the pole and mainly between 60° N. Lat. and 50° S. Lat. Eminent scientists in Great Britain, the United States of America and the U.S.S.R. have made careful analyses of such data and computed positions of primary and secondary poles ranging from three to eight hundred miles northerly from the 1904 position. These locations do not appear to be entirely valid when Canadian observations made north of 60° N. Lat. are taken into account. This statement does not discount the valuable contribution to the problem made by these scientists, who will be interested in revising their calculations in the light of recent Canadian observations.

The Division of Terrestrial Magnetism of the Dominion Observatory, Mines, Forests and Scientific Services Branch, Department of Mines and

Photos from Dominion Observatory, Ottawa.

Top: Paul H. Serson, of the Dominion Observatory, Ottawa, observing with a new type of induction magnetometer at Aberdeen Lake, N.W.T. Canada.

Centre: Dominion Observatory magnetic station at Agnew River, eastern Boothia Peninsula, N.W.T. Canada.

Bottom: Dominion Observatory magnetic station on a lake in the northern part of Prince of Wales Island, N.W.T., Canada. This is the closest station to the north magnetic pole.

Resources, has been responsible for conducting a systematic scientific magnetic survey of Canada since the Division was instituted in 1907. Since that time it has established over one thousand magnetic stations in Canada and Newfoundland. The Dominion Observatory early realized the importance of fixing the position of the north magnetic pole and decided that the best way to ensure this and at the same time provide accurate information for the construction of magnetic maps, was to extend the magnetic survey steadily and persistently northward until the entire country was covered by a network of base magnetic stations. The most strategic stations were to be reoccupied at intervals to gather secular change information.

The Dominion Observatory's network of magnetic stations was extended north of 60° N. Lat. to Great Slave Lake and the mouth of the Mackenzie in 1923 by French who travelled by canoe and Hudson's Bay Company river boats; to Nueltin Lake in 1922 by Madill useing a canoe, to Hudson Strait in 1928 on C.G.S. *Montcalm*; to Ellesmere Island in 1934 on Hudson's Bay Company R.M.S. *Nascopie* and to Baker Lake and Repulse Bay in 1937 on the Company's vessels R.M.S. *Nascopie* and M.S. *Fort Severn*; to Coppermine and Cambridge Bay in 1945 by Serson using R.C.A.F. Canso and to Fort Ross in 1946 on R.M.S. *Nascopie*; to Denmark Bay in 1946 by Innes who travelled by snowmobile with Exercise Muskox; to northern Prince of Wales Island in 1947 by Serson and Clark using R.C.A.F. Canso; and to Slidre Bay, Eureka Sound, in 1947 by Cumming on board U.S.S. *Edisto*. In addition to the Dominion Observatory's stations, where values of declinations, inclination and force were measured, many declination stations were established north of 60° N. Lat. by officers of the Geodetic Service and Topographical Survey. Since 1943 magnetic observations have been made at 235 stations in this part of Canada.

The Dominion Observatory has been fully aware for many years that the north magnetic pole was travelling in a northerly direction. This was evident from a study of the results of observations made periodically at repeat stations extending from Newfoundland to Yukon. However, it was only after the completion of the work of the 1946 and 1947 field seasons that a position of the north magnetic pole could be indicated with some degree of assurance.

An examination of the information at hand following the close of the 1946 field season—which did not include any magnetic data north or west of Somerset Island—indicated quite definitely that the north magnetic pole was neither on Boothia Peninsula nor on Bathurst Island. The latitude of the pole was computed to be 73° 15′ N. Lat. There was more uncertainty regarding the longitude, as western and northern information were lacking

but a longitude of 94° 30′ N. appeared reasonable. This placed the pole in northwestern Somerset Island although there were indications that the pole might eventually be placed to the west of Peel Sound on Prince of Wales Island. It was therefore obvious that northern Prince of Wales Island must be investigated.

Observations During 1947

The 1947 plans comprised the establishing of magnetic stations in the Arctic islands to the north and west of Somerset Island. Stations to the south of Barrow Strait and Melville Sound were to be established by air and those to the north by water transportation.

The results of the 1947 season were most gratifying. The R.C.A.F. assigned a Canso amphibian aircraft to magnetic survey operations in the neighbourhood of the north magnetic pole. The captain of the aircraft was Flying Officer Drake and the navigator Flying Officer Goldsmith. Serson and Clark, geophysicists of the Division of Terrestrial Magnetism, Dominion Observatory, were responsible for carrying out the magnetic program. Despite extraordinarily adverse flying conditions, the magnetic survey of Canada was extended into areas heretofore untouched by scientists. Ice conditions were such as to prevent coastal landings and uncharted inland lakes were sought out and used. Abnormal fog conditions were the order of the day. The interest, experience and skill of the R.C.A.F. officers and crew members were exemplary with the result that a remarkably fine job was completed.

The standard types of magnetic instruments were used. They included a magnetometer for measuring declination and horizontal force, dip circle with intensity needles for measuring inclination and total force, and a transit with compass attachment for astronomical observations and auxiliary declination measurements. In addition, there was used for the first time in Canada an induction type magnetometer made up in the Division of Terrestrial Magnetism under the supervision of Serson. The detecting element was attached to the telescope tube of a transit instrument. The instrument measured declination, inclination and force and could be used for astronomical observations as well. The performance of the instrument was better than hoped for and it worked perfectly in regions of low horizontal force where the standard type magnetometer was useless.

Complete sets of magnetic observations were made at Allen Lake, northeastern Prince of Wales Island; Guillemard Bay, southern Prince of Wales Island; Greely Haven, northeast Victoria Island; Cambridge Bay, southeast Victoria Island; Agnew River, eastern Boothia Peninsula; Tasekyoah Lake,

King William Island; and inland stations at Aberdeen Lake, Jolly Lake, Point Lake and Yellowknife.

Cumming, travelling by U.S.S. *Edisto*, covered the regions north of Barrow Strait and Lancaster Sound. Observations were made at Peddie Bay, southwest Bathurst Island; Freeman's Cove, southeast Bathurst Island; Resolute Bay, south Cornwallis Island; Port Leopold, northeast Somerset Island; Croker Bay, southern Devon Island; Olsen Island in Goose Fiord, southeast Ellesmere Island; Slidre Bay in Eureka Sound, northwestern Ellesmere Island; and Etah, Greenland.

The magnetic results obtained at these 18 stations which appear in Table 2, have provided information of great value in revising the position of the north magnetic pole. A complete solution will not be possible until magnetic stations have been established in northern Victoria Island, Banks Island, Prince Patrick Island, Melville Island and northwest Bathurst Island. Plans are now in a formative stage to establish magnetic stations on these islands in 1948. Reliable observations were made by Jackson, in 1908 and 1909, at a number of stations between Winter Harbour, Melville Island, and Point Hotspur, Bathurst Island, but secular change corrections must be applied before the results can be used in a rigid mathematical solution. These will not be available until new observations are made in the same area. However, certain information is available whereby declination values can be corrected to such a degree as to make them of use in the construction of preliminary charts.

Determination of the Position of the Magnetic Pole

Perhaps the quickest way to ascertain the approximate position of the north magnetic pole area is to construct magnetic meridians and find their point of convergence. The direction of the magnetic meridian at a station may be shown by a short straight line inclined to the true meridian by an angular amount equal to the declination. Each line will lie along or be tangent to a magnetic meridian. It is important that there should be a sufficient density of stations to enable the curvature of the meridians to be determined. Such a chart of magnetic meridians for a portion of northern Canada has been constructed from recent Canadian declination observations, which are represented by short arrows depicting the declination at magnetic stations. This chart (fig. 1) shows that the meridians converge toward an area in northern Prince of Wales Island. The centre of this area would occupy approximately the position of 73° N. Lat. and 100° W. Long. The area thus determined indicates the region in which a more detailed survey should be made. The accuracy of the delineation of magnetic meridians in the Canadian Arctic

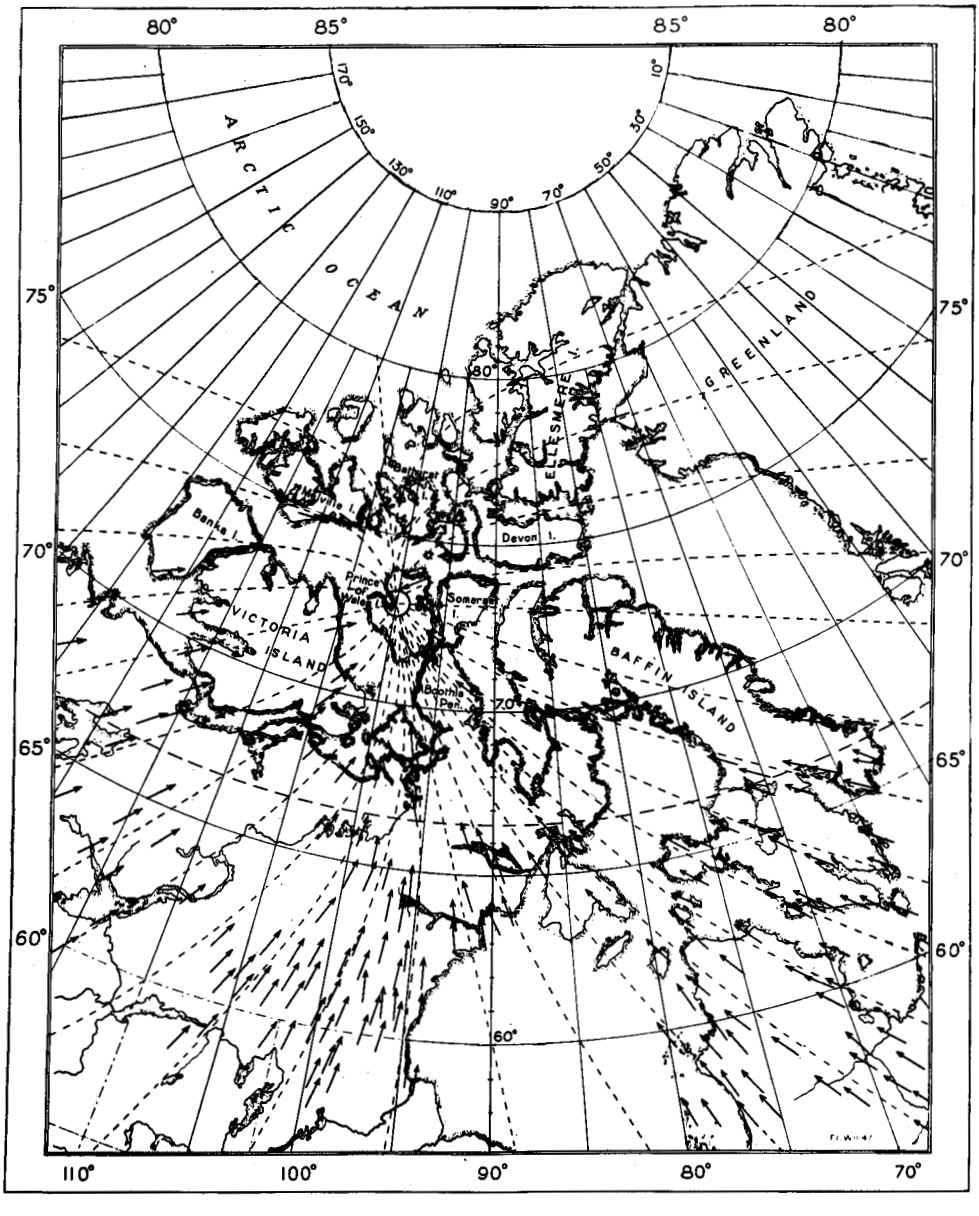

Fig. 1—Chart of magnetic meridians for a portion of northern Canada constructed from recent Canadian declination observations by the Dominion Observatory, Ottawa. The magnetic meridians converge on Prince of Wales Island where the region of the north magnetic pole as at present determined is shown by a circle.

archipelago suffers from a paucity of magnetic stations but it is believed that the meridians drawn on fig. 1 are reasonably correct.

Examination of declination data from northern Canada reveals some interesting coincidences. In the first place, the declinations seem to follow

TABLE 2

Preliminary values of declination (D) inclination (I) horizontal intensity (H) and total intensity (F) at magnetic stations, 1947.

Station	Lat. N.	Long. W.	D	I	H	F
	o ′	o ′	o ′	o ′	gammas	gammas
			West			
Etah	78 19	72 44	91 12	86 12	3691	55808
Croker Bay	74 33	84 21	.....	87 21	2801	57412
Slidre Bay	79 59	85 56	109 36	87 24	2532	56256
Olsen Island	76 27	88 42	.....	88 04	1978	56914
Port Leopold	73 52	90 17	94 50	88 22	1668	57722
Agnew River	70 38	92 35	55 27	88 30	1527	58637
Resolute Bay A.	74 41	94 50	101 10	89 02	892	57894
Resolute Bay B.	74 41	94 54	.....	88 58	1092	57698
Tasekyoah	68 52	96 37	11 48	88 26	1638	59772
Freeman's Cove	75 12	98 04	128 33	89 19	675	57420
Guillemard Bay	71 51	98 18	41 46	89 28	549	58604
Allen Lake	73 41	98 26	122 24	89 36	412	58287
			East			
Aberdeen Lake	64 39	99 35	17 42	86 36	3589	60590
			West			
Peddie Bay	75 11	100 39	148 06	89 35	500	57938
			East			
Greely Haven	71 56	104 50	61 36	89 04	970	59122
Cambridge Bay	69 07	104 57	35 09	87 38	2466	59810
Jolly Lake	64 08	112 04	35 37	84 04	6256	60473
Point Lake	65 21	113 40	40 18	84 18	5979	59922
Yellowknife	62 29	114 30	33 30	82 30	7754	59811

the trend of the coast lines or the general trend of the land masses towards the central part of the Arctic archipelago. It has been previously noted by the Division of Terrestrial Magnetism that acceleration and deceleration in secular variation in Canada are regional phenomena and apparently linked with broad geological formations. Again, it is remarkable that the magnetic meridian represented by a straight line running from the intersection of 60° N. Lat. and 90° W. Long. passes over Ross' position for the pole on Boothia Peninsula to the present indicated position. This line is in the same direction as the major axes of approximate elipses denoting curves of equal horizontal force and inclination. It is of interest to note the coincidence between the direction of this meridian and the approximate north-south geographical axis of the Canadian Shield, north of 60° N. Lat. The writer has not the temerity to suggest at this time either that movement of the north magnetic pole may be constrained along a definite track or that the secular movement of the pole is controlled by changing conditions in that part of the earth's crust, nevertheless the coincidences are under review by the Division.

Complicated mathematical analyses of recent Arctic magnetic results, based on declination, inclination and horizontal force measurements, are now being made by the Division of Terrestrial Magnetism and show fairly conclusively that the north magnetic pole is in northwestern Prince of Wales Island, not far removed from 73° N. Lat. and 100° W. Long. This position is sufficiently accurate for all practical purposes, and a more refined value must await the conclusion of the 1948 investigations.

Work still remains to be done

The work of the Division of Terrestrial Magnetism in the Arctic will not be finished when the location of the magnetic pole is definitely established. The entire Canadian Arctic will be covered by an adequate network of base stations and sufficient magnetic observatories to control field observations. Future movements of the pole must be continually under review and there can be no cessation of effort until the Arctic is accurately charted; until it is fully understood why the north magnetic pole has been located in northern Canada at least since magnetic observations first were made and whether the pole is confined by geological barriers across which it can not pass.

ARCTIC INSTITUTE 1949 GRANTS-IN-AID

The Arctic Institute of North America has available a total of at least $5000 for several senior grants-in-aid for scientific work in the North American Arctic and Subarctic during 1949. Research must include field investigations either in Alaska, northern Canada, Labrador, Newfoundland or Greenland.

The grants-in-aid are open to anyone who has demonstrated his ability to carry out research work of superior quality in some field of science.

Applications must be received by November 1, 1948. Grant-in-aid will be awarded on the recommendation of the Board of Governors of the Arctic Institute, and will be announced by March, 1949.

Application forms may be obtained upon application to: The Arctic Institute of North America, 805 Sherbrooke Street West, Montreal, Canada or Audubon Terrace, Broadway and 156th Street, New York 32, New York, U.S.A.