Arctic mapping problems. During the war he organized and assisted in the development of trimetrogon mapping and was commissioned in the Air Corps in 1942, where he served as Commanding Officer of the Aeronautical Chart Service until 1946, when he returned to the Geological Survey. He was appointed Chief Topographic Engineer of the Geological Survey on May 22, 1947.

Colonel FitzGerald is past President of the American Society of Photogrammetry and of the American Congress on Surveying and Mapping, is a member of the American Geophysical Union, Washington Society of Engineers, the Cosmos Club, and the Explorers Club. He received the Legion of Merit from General Arnold in 1946 for his work as Commanding Officer of the Aeronautical Chart Service. In 1949 he was awarded the Department of Interior's gold medal for distinguished service.

Last but not least, a member of the highly respected Corps of Engineers of the U. S. Army will tell us why military mapping of the Arctic and sub-Arctic is of such importance. Lieutenant-Colonel Albert Nowicki was born in Milwaukee, Wisconsin and received his education at Marquette University, where he received a civil engineering degree. His advanced degrees in civil engineering were obtained at the University of Minnesota. His experience includes teaching on the faculty of Marquette University and the University of Minnesota in civil engineering and also mapping experience with the Forestry Service, the T.V.A., and the Corps of Engineers.

Colonel Nowicki's civilian position is that of Chief Engineer, Army Map Service, and he is on temporary duty at present with the Army.

## The Contribution of Explorers to the Mapping of Arctic North America

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SYNOPSIS

Early knowledge and mapping of Arctic—Greeks, Romans, Mercator

The idea of a northwest passage—17th century exploration—Hudson's Bay Company—Mapping methods—limitations—the problem of longitude.

18th century activities—Hearne's overland journey—scientific advance in instruments and ships.

19th century—the north magnetic pole—completion of main outlines of continental coast—the search for Franklin—the beginning of the penetration of the northern islands region.

1880—the whaling industry—the assault on the North Pole—Canadian government expeditions.

The end of old style exploration—advent of the airplane—development of separate systematic branches of geography—modern difficulties.

The debt to explorers—names in the north.

The purpose of this paper is to show how the map of the northern part of this continent was gradually unrolled by the various explorers who visited the area, and at the same time to point out some of the difficulties under which these men worked so as to account for any apparent limitations of their contributions.

Whatever knowledge the Greeks and Romans had about the northern part of this continent is always a subject of much discussion among Arctic specialists. However, it is certain that they contributed nothing to the maps of Arctic North America as we know them today. The ideas of the ancients were at best hypothetical and imaginary, a state of affairs which existed until the late 16th century. In 1508, for example, a map was published which maintained that under the Arctic Pole there was a towering boulder made of magnetic stone which was 33 German miles in circumference. It was maintained that this boulder was surrounded by a sea which resulted from the water said to flow freely out of the stone. This general idea was preserved to some extent in the polar inset of Mercator's great Chart of the World, published in 1595. This showed a polar whirlpool fed by four channels entering it from the north, south, east and west. But Mercator's map also indicated a through channel from Europe to the Orient. This belief

in a passage around the north of North America to Asia became widely accepted and formed the first and certainly the strongest and most lasting of the several motives which led to the detailed exploration and mapping of the North American Arctic.

Such exploration began in the late 16th century with the voyages of Frobisher (1576–78) and Davis (1585–87), who outlined the east coast of Baffin Island. Their discoveries showed that this land mass was an extensive north-south barrier to any northwest passage which might exist. Early in the following century Henry Hudson's last voyage revealed a huge sea west of Hudson Strait. But even this was blocked on the western and southern sides by land and on the north by ice, as the subsequent voyages of Button, Bylot, Baffin, Foxe and James showed. Not that these discoveries were without commercial reward for the route to Hudson's Bay was the foundation of the famous trading company which received its charter in 1670, and from that time many ships entered the bay, although their interest lay in the wooded areas to the south rather than the treeless Arctic to the west and north.

Thus exploration in the 17th century was concerned chiefly with finding a route through the Arctic rather than investigating the region itself, and because of this overriding motive as well as the difficulty of travel on land, Arctic journeys were restricted to movement by boat and confined to the coasts and larger inland waterways. Moving slowly along the shore, the early explorers mapped or sketched the shape and distribution of all the land they could see and hence their results were more in the nature of our nautical charts. The accuracy of these documents was in direct proportion to the advances made in the methods and practices of navigation and surveying. Latitude was usually determined by means of an astrolabe. The accuracy of the observations appears to have been reasonable but to take such readings from the deck of a small sailing ship with a comparatively high center of gravity, and therefore prone to pitch and roll, using a hand instrument with no telescopic sights must have been difficult enough. Frobisher used a "ballestilla," an instrument similar to the cross-staff which was the forerunner of the modern sextant. But there was no easy means of determining longitude. A ship's position was usually recorded by dead-reckoning, a method subject to many errors in the days of sailing vessels. Occasionally, a navigator would attempt to find longitude by observing the altitude of the moon and some other heavenly body and measuring the angular distance between them, a method first suggested in 1474. This seems to have been particularly true of Arctic navigators perhaps because they had to be mentally adventurous as well as physically daring. Baffin, for instance, was constantly thinking out new means of finding longitude. He was the first to ever attempt to do so by the moon's culmination at sea, and he produced surprisingly accurate results which show his mastery of the subject and his inventive faculty.

Besides the astrolabe, the earliest Arctic navigators were supplied with large blank globes and armillary spheres, charts of various kinds, compasses and hour glasses. With such slight and unreliable help the seamen of this period, in great peril and difficulty found their way over the trackless ocean. But by 1740 the modern level had been developed and the problem of longitude had been solved with the invention of the chronometer. As a result the maps of northern travellers began to assume greater accuracy.

A short flurry of exploration in Arctic Canada occurred in 1742, aiming at the penetration of northwest Hudson Bay, for Baffin's report had led to the idea that the entrance to the northwest passage lay in this area. But Middleton, Moore and Christopher only succeeded in finding land at the heads of Repulse Bay, Wager Bay and Chesterfield Inlet. Finally, in 1770–72 Samuel Hearne made the first epic overland journey along the edge of the treeline from the Hudson's Bay Company's fort at Churchill to the mouth of Coppermine River. His maps indicated the great size of the Arctic mainland and were the first to depict the western Canadian Arctic. He made two false starts, the second being of interest here. He had been some months on his journey when he had to return because his quadrant was broken when blown over by a sudden gust of wind. The only instrument he could obtain was an old quadrant which had been at Churchill for about thirty years. Unwieldy and unreliable, this quadrant was

partly to blame for the inaccuracy of many of his observations which were never too reliable at the best of times. Hearne was particularly unfortunate with his instruments for he lost his second quadrant on his return journey from Coppermine to Great Slave Lake, and while there his watch stopped, thus depriving him of every means of estimating distance with any accuracy. But his work should not be minimized for he at least proved the existence of a salt sea to the north and the non-existence of a channel through the continent in any of the latitudes of Hudson's Bay. Bering, the Russian explorer who died in the Arctic, and Cook had, meantime, shown that Asia and America were not joined.

By the end of the 18th century the most important period in the development of surveying instruments had closed, and all the important items of the modern surveyors' equipment, such as the theodolite or transit, were in use even though many were still in rather crude form and some were employed by only a few individuals. Ships too had been improved since the days when Davis sailed in a pinnace of 20 tons and which was so leaky that she required 300 strokes of the pump every watch to clear her of water! Armed with these scientific advances, exploration in the 19th century turned to the openings in the coast around Baffin Island. The first voyage of Edward Parry in 1819 was westward into Lancaster Sound as far as Melville Island where he was stopped by heavy eastward moving ice floes. The following summer the same thing occurred, and although for his next two voyages he tried different routes through the Arctic islands, they too failed. In 1821 he found Fury and Hecla Strait jammed with ice and his voyage of 1824 ended when one of his ships was wrecked on Somerset Island. In the meantime, Hearne's journey to the Coppermine River had been followed up with further exploration along the western Arctic coast. Franklin in 1851 mapped the coast between Coppermine and Kent Peninsula, and in 1825–27 the coast east and west of the Mackenzie Delta. The gaps in the map of this coast were not filled in until 1837–39 when Thomas Simpson reached Point Barrow, Alaska, traversed the hitherto unknown area between Kent Peninsula and Chantry Inlet and touched the south coast of King William and Victoria Islands.

But Hearne's journey was not only important for paving the way for this western Arctic coastal work; it was also important because it began a series of inland journeys. From 1829–33, John Ross continued the exploration of the channels about Boothia Peninsula. He was the first to use a steamship in Arctic exploration instead of a sailing vessel which had hitherto been used. His expedition made several sledge trips, also for the first time, into the surrounding rocky countryside, mapped the western side of the Peninsula and visited the approximate site of the north magnetic Pole. An even more extensive land journey was made in 1834 by George Back from Great Slave Lake down the river which now bears his name.

The main outlines of the continental coast were thus completed, and no further major exploration was attempted until John Franklin's tragic voyages. The mysterious loss of this expedition in 1845 was to accomplish more than any other single event in increasing the knowledge of the high north. By far, the greatest number of Arctic islands were discovered and mapped during the search for Franklin. Northern expeditions up to this time had been British, with the one exception of Jens Munk, a Dane, in 1619. But now American explorers generously joined the British, beginning with De Haven in 1850 and ending with Schwatka in 1880. Well organized search parties amounting to some 40 expeditions within the next ten years sailed the Arctic waters. On land they travelled thousands of miles, pulling their own sledges loaded with their equipment, food and instruments. Peary, Austin, Ommaney, Kennedy and Belcher explored the channels off the Lancaster Sound-Viscount Melville Sound route from 1851 to 1852. They thus began the real penetration of the Northern Islands region which was stimulated by McClure's explorations of 1850–54, during which he actually travelled over the Northwest Passage. But the passage was not actually navigated until 1903–05 by Amundsen in the *Gjoa* and not "conquered" until 1940–44 when the RCMP vessel *St. Roch* became the first vessel to make the passage in both directions but also the first to have made it in a single season. Rae made three trips by land in the western area of Hudson Bay and Foxe Basin,

while McClintock, working a little to the north of Rae's area, explored King William Island, from the most favorable route through the channels to the west and completed the story of Sir John Franklin's last expedition. Admiral Inglefield in 1852 finally determined that Smith Sound was open to the north, although it was left to Kane to penetrate the sound.

The results of all this exploration showed that there was no easy route through the Arctic islands, but there were further impulses which extended the map of the northern area from 1880 onwards. This impetus came from three major sources: the whaling industry, the assault on the North Pole, and the efforts of the Canadian Government to maintain jurisdiction and bring law and order to the north.

The whaling industry shifted from the Greenland Sea to Baffin Bay during the early part of the 19th century. For almost 100 years, whaling vessels were to be found somewhere within the region. In the latter part of the century, Scottish whalers were spending the summer seasons hunting in Baffin Bay, and some of them wintered on the east coast of Baffin Island. New England whalers worked in Hudson Bay and wintered there in order to start hunting early in the following season. Many of the inlets and harbors of Baffin and Hudson Bays were explored by these fleets. The whalers shifted to the Western Arctic at the end of the century, reaching Herschel Island in 1890 and from that base they hunted and explored much of the Beaufort Sea. Their contributions to the maps of the Arctic are difficult to assess for they were not given to recording the new information they gathered. It was rather passed on by word of mouth to the "explorers proper" who followed them.

After 1860, the largest remaining unexplored part of the Arctic lay north and west of Baffin Bay while the chief unknown areas to the south were western Baffin Island and northeastern Victoria Island. Successive expeditions from Britain and the United States pushed farther and farther north in attempts to outline the land masses and explore towards the North Pole. Hall, in 1871, was the first to take a ship through to the Arctic Ocean reaching 82°11′ N. with little difficulty. His route was followed by Nares in 1875. Leading the largest and best equipped expedition that had visited the area up to that time, he mapped the northern coast of Ellesmere Island. Other important explorations were carried out in this area by Greely in 1881, the International Polar year which saw a tremendous outburst of scientific activity in the north. The race for the Pole ended with Peary's well-planned dash in 1909 after several unsuccessful attempts to penetrate the Polar Pack by sledge. Peary's expeditions and those which followed were equipped in a very different way from those which preceded him mainly because of their use of dog transport. In addition, by this time the white man had begun to learn the ways of the natives and adapt them to suit his own purposes.

In the meantime, Nanson and Sverdrup had carried out a successful expedition in the Polar Sea in *Fram*—a ship designed to withstand the pressure of the ice and drift with it. The same ship was used again by Sverdrup between 1898 and 1902, when he found and mapped several new islands including Axel Heiberg and the Ringnes group in the area west of Ellesmere Island. This expedition may rightfully claim to have produced immensely greater land discoveries than any other expedition to visit this part of the world. Immensely conscientious about their scientific work, they often rejected or repeated whole series of observations because of the difficulties of measuring accurately at low temperature and with eyes strained with the bright sun and reflected light.

In 1881 the Arctic islands were legally transferred to Canada by Great Britain and from that time the Government of Canada sponsored many expeditions into the north which assisted with the preparation of maps of the area. The first of these expeditions set out in 1884 in the DGS *Neptune;* in 1885–86 an expedition was carried out by the *Alert* and in 1887 by the *Diana* under the command of William Wakeham. From 1902–18, seven Canadian expeditions were sent to the Arctic and the information the members brought back was used to improve the official maps of the north which began to be published in 1904. In 1909 the first officers of the Dominion Observatory made magnetic observations. The map north of Melville Island was finally completed as a result of the expedition under Vilhjalmur Stefansson from 1913–18. Two government topographers were attached to this

expedition, the beginning of the long line of professional map makers who have since joined the attack on the North. In addition to discovering Borden, Brock and Meighen Islands, Stefansson's expedition brought back more accurate descriptions and maps of the already known areas which they traversed.

From this time onward, however, old style exploration practically ceased. The advent of the airplane had released man from the necessity of spending winters under hardships in the north and from the drudgery of time-consuming journeys on foot. Powerful steel icebreakers and specially built overland vehicles have accentuated this process. The early explorers had always had wide interests and in addition to astronomical and hydrographic observations, had noted as many aspects of the physical environment as they could and described any human phenomena that they encountered. Indeed they were often vitally concerned with the interrelationship of natural phenomena. It was the tidal observations taken by Nares' expedition for example which showed the insularity of Greenland. But today this work is carried out by people disciplined in many different fields, and it is not possible to refer to such people as explorers in the same sense that the word was used before World War I. Indeed the modern geographer, if he goes to the Arctic, needs to have maps and/or aerial photographs *before* he begins his survey, since his work emphasizes what might be called "micro-mapping," or the makeup of the surface features and their relationships.

However, many parties have been to the Arctic in recent times imitating as far as they dare the methods of the early explorers in an effort to capture the thrill of adventure into the unknown. Their experiences show that although certain handicaps in Arctic mapping have disappeared with the passage of time, not all have gone. Shackleton, for instance, on Ellesmere Island in 1935 had the advantages of being able to fix his position accurately by radio and of having modern instruments. But he still had difficulty with his theodolite at 20 below zero; he found observations on the sun in the early part of the year difficult because of its low altitude; his sledge meters gave trouble over rough ice and so on. If these are handicaps today, how much more difficult must the early Arctic map makers' task have been. Yet his maps have stood the test of time, for with the coming of aerial survey it has been possible to check the positions of the coasts and their associated features and many have needed little alteration.

It is easy to stress the explorers' deficiencies in view of the number of "new" small islands which have appeared on recent maps as a result of aerial photography. For they did not penetrate to the interiors of many of the Arctic islands, nor did they always investigate coastal indentations to determine whether they were bays or through channels. But they were often handicapped, as far as attention to detail was concerned, by the peculiar Arctic difficulties of travel and supply—not because of lack of skill or determination. It took them a long time to reach their destination, and often they were compelled to winter in the north in order to accomplish any worth while work. It must be remembered too that their primary concern was with the over-all distribution of land and sea, and in this they succeeded for since 1918 the only significant lands discovered have been the islands in Foxe Basin which cover an area of about 6,000 square miles. Indeed the deeper one goes into the record of the explorers, the more one is surprised at what they did accomplish and the debt that our modern maps and charts owe to them. It is a debt that can never be repaid and which cannot even be measured in terms of dollars and cents, for the true price of our Arctic maps can only be assessed in terms of the lives that were lost, the human suffering of these pioneers and the hardships which they endured. They are commemorated by the names that have since been officially adopted for many of the topographical features in the north. As an area becomes better known so will the explorers who first mapped it and so, at least, will their record become a matter of public pride.

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# Arctic Air Photography

## Part 1

## Operational Problems in Arctic Survey Photography

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SYNOPSIS

*Selection of areas:*
Supply of gasoline and oil
Climate, the operational time-table

*The weather:*
Effect of open water
Need for good forecasts
Work of arctic weather team

*Communications:*
Part of weather forecasting system
Navigation aids
Aircraft following service
Contact with supply bases

*Navigational problems:*
Low directional pull of magnetic pole
Effect of local attractions
Map reading
Use of solar navigator and astro compasses

*Servicing the operation:*
Remarkable results in spite of handicaps
Detailed planning of spares
Safety training

*Improvements since pioneering days*

In my talk I will discuss the operational aspects of Arctic aerial photography under the general headings of: selection of areas, operating supplies, climatic conditions, navigation problems, communications, and logistic support. W/C Ross, who will follow me, will provide the technical details of our Arctic aerial photographic problems.

Unlike planning of aerial mapping in more developed areas, the selection of areas in the Arctic involves an important operational problem, because of the scarcity of aerodromes suitable for four-engined aircraft. We have suitable landing strips at Norman Wells, Yellowknife, Churchill, Whitehorse, and one in the Arctic islands. We do not build aerodromes in the Arctic specifically for our photo operations; our requirements therefore affect the maintenance at aerodromes already established. The fact that aerodromes are unserviceable for varying periods during the spring break-up must also be taken into consideration. It is apparent then, that any selection of areas must take into account their accessibility from one of the existing aerodromes, and whether the aerodrome has sufficient supplies of petrol and lubricants in stock to permit flying before the next year's deliveries are made.

Provision of gasoline and oil is a major problem at such places as Yellowknife and in the Arctic islands, since the quantities required can be put in economically by surface transport only. As transportation is by water, and as the season is very short, varying from approximately 4 months at Yellowknife to 6 weeks in the islands, it is necessary to plan the supply approximately 18 months ahead of an operation. If a substantial portion of the available stock is used for some emergency, it may necessitate changing flying plans for the entire season. Such a case occurred at Yellowknife in 1951; an extensive search for a lost commercial pilot consumed some 75,000 gallons of gasoline which were earmarked for photographic operations.

Climatic conditions in the Arctic govern the operational timetable to a very great extent. The best period of photo weather