ORGANIZATION AND TRANSPORTATION

The general plan for the establishment of control would involve the placing and retention of survey units at main or satellite depots throughout the entire year. In this way, the work could be carried on during the favorable periods of both the winter and summer seasons. In the extreme north, the weather station at Resolute on Cornwallis Island could be used as the main depot. Farther south, Cambridge Bay, Frobisher or Coral Harbor could be used for the same purpose.

In the areas where astronomical methods are to be used, it is proposed that each depot should be manned by two or three survey units, each consisting of an observer, a recorder and two labor assistants, all under the supervision of the depot chief.

The survey units would proceed out radially from each depot to establish the necessary control stations. During the months of March, April, May, October, November and December, helicopter or dog team transportation supplemented by aeroplane drops of food and fuel should prove highly satisfactory. A 10-dog sled team will haul a load of 1,600 to 1,800 pounds under normal winter conditions. During the winter months, aerial co-operation would be more or less limited to the bright periods of the moon. Due to the excessive cold no work would be planned for January or February.

During July, August and September considerable progress could be made using helicopter, aeroplane, or canoe-plane-drop transportation.

In coastal areas, the use of 22 foot freight canoes equipped with outboard motors is recommended. These craft will carry $\frac{3}{4}$ ton with ample free board; they weather surprisingly high seas and have the added advantage of lightness and mobility. In case of theatening danger from ice or storm, both the cargoes and canoes may be removed from the water to the relative safety of an ice pan or on the shore. Geodetic survey parties have travelled hundreds of miles along the Hudson Bay coasts with this type of craft which has proved to be preferable to a schooner or whale boat.

RADIO COMMUNICATION

Good radio communication between the depot and its field survey units is a prime necessity. The modern type of small radio transceivers (G.S.11 or P.F.1) used for some years by the Geodetic Survey of Canada, are quite satisfactory. They are powered by dry batteries and operate on either continuous wave or phone with plate voltages varying from 90 to 200 volts.

In general, the problems of transportation are much more complex than those connected with the technical end of the project. However, if the new high-ceiling, freight-carrying type of helicopters were made available for the work, no serious difficulty would be expected to attend the establishment of mapping control.

Horizontal and Vertical Control for Arctic Mapping

Comdr. Hubert A. Paton, Chief, Baltimore Photogrammetric Office, U. S. Coast & Geodetic Survey

SYNOPSIS

A detailed survey of the Arctic Coast of Alaska by the U. S. Coast and Geodetic Survey has been in progress since 1945. New methods of transportation of supplies and personnel were employed. An arc of second order triangulation was extended along the shore for a distance of 680 miles and astronomic stations were established and base lines were measured. Elevations referred to sea level datum were placed on triangulation stations. Extreme weather conditions required the development of new techniques in surveying methods. New types of clothing were tested and new living procedures devised.

For eighty years the U. S. Coast and Geodetic Survey has been sending field parties to Alaska, but only in recent years has it been feasible to send them into the Arctic regions. The Bureau did cooperate in the early part of this century with the Alaskan Boundary Commission in establishing an arc of triangulation along the 141st meridian; this was completed in 1912. In 1945 a party was ordered to proceed to Point Barrow to begin a detailed survey of the Arctic coast in order that hydrographic charts could be published. These charts require accurate topographic and hydrographic surveys, and to control them it was necessary to extend an arc of second-order triangulation along the entire coast from Cape Beaufort to Demarcation Point, a distance of 680 miles. This arc required the establishment of three astronomic stations and about 400 main scheme triangulation stations. Ten base lines were measured to maintain the required accuracy in the length of lines.

The severe weather conditions required the development of new operating procedures and new types of equipment. Most of the supplies and heavy equipment were sent up by surface vessels each summer. The U. S. Navy sends a fleet of supply ships to the Arctic in August and stores are landed at our base camps. A powerful ice breaker opens a path for this fleet through the pack ice. Most of the personnel for the field part are brought in from the States by air in February and March each year. Additional personnel are brought up in early summer to help make the hydrographic surveys. The early part of the season is devoted to moving supplies out to the secondary camps by cat train, making astronomic observations, measuring base lines and extending the arc of triangulation. The ice begins to break up in July, and by the first of August it generally moves off shore far enough to permit the boats to be launched and the hydrographic surveying to begin. Open water may end any time if the pack ice moves back inshore, but in any event this type of work seldom lasts more than six weeks. In June and July there is a period of 6 to 8 weeks when all field work is prevented by the thaw. It is necessary to complete the triangulation observations and to move all equipment back to the base camps prior to the time travel becomes too dangerous.

About one-fourth of the complement are Eskimos, hired in the villages along the coast. They make good laborers, and a few of the more intelligent ones are trained to be recorders and mechanics. They are very reliable and industrious workmen and they are invaluable as guides when the weather turns "sour" and parties have to return to camp through a blinding blizzard.

In March the sub-camps are established and the reconnaissance for the triangulation is begun. A trained geodetic engineer accompanied by one Eskimo, sets out to select the station sites. He uses a small track vehicle called a Weasel for transportation. The terrain is very flat and it would be advantageous to use towers for observing stands, but transportation and construction difficulties preclude their use. Stations are generally observed with the theodolite on its own tripod and the signals are usually 16 foot poles, which limits the size of a quad to about four miles on a side. In 1949, the longest line observed was only ten miles in length. Visibility is usually very poor in March. On an overcast day, a definite horizon is seldom visible except toward the sea. Differences of elevation are seldom apparent, gullies and hills disappear, and everything flattens out into a vast smooth grey table top. Even snow drifts become invisible in one of these "white-outs." Travel becomes very dangerous for one can drive off a cliff before aware of it. If the sun is shining, the extreme glare and lack of dark objects and shadows upon which your eyes can focus make perception of distances, size, and relief very difficult. A black rectangle may be a box of matches a few feet away or a house a few miles away. Extreme refraction may cause deceptions and stations that are thought to be intervisible will actually need towers before the line can be observed. Then to make life really miserable, along comes a little breeze which stirs up the snow and reduces visibility to a few yards, and then it's up to the observer and his Eskimo assistant to find their way back to camp. This is a trick in itself and one that takes years to learn. A compass is of little help due to the proximity to the magnetic pole. However the surface of the snow generally has a pattern of ridges, formed by the prevailing northeasterly wind and these sastrugi or distinctive snow arrows keep one oriented.

It would be much easier, as far as visibility and personal comfort are concerned, to do the reconnaissance during the summer months, but travel over the tundra at that time is almost impossible and all hands are then engaged in hydrography. The best solution would be to use helicopters and have sufficient man power to make use of them. No doubt a stronger scheme with larger figures could be selected with their use.

After the station sites have been selected a building party follows closely behind. This is a group of four men, equipped with a weasel, a small sled on which to carry lumber, station marks, etc., and another small sled upon which is mounted a prospector's boiler, which is used to steam in the marks and stakes. The permafrost in this region extends down to a depth of about 1,000 feet. To dig holes by hand would be a back breaking and time consuming job. With the thaw boiler a station can be built and marks installed in a little over an hour. The best marks to use are steel or bronze pipes, $2\frac{1}{2}$ inches in diameter and seven feet long. They have a standard disk brazed to one end. A hole for the pipe can be thawed with a steam jet in only a few minutes and the mark is soon frozen solidly in place. In addition to the station mark, two reference marks, a wood witness post painted red or orange, and four stakes for guy wires to the signal pole are steamed into the frozen ground.

During the summer the ground, where protected by tundra, will thaw to a depth of only six inches, but on the bare beaches the sand will thaw down about three or four feet. It is best to allow only a few inches of the pipe to protrude above the surface of the ground, otherwise the heat during the summer will be transmitted into the frozen ground and moisture will collect at the base of the pipe. When this water freezes in the fall it tends to push the pipe up out of the ground. An example of this action was found at one of the marks established by Leffingwell. About forty years ago he made surveys in some portions of this area for the Geological Survey. He marked one of his stations with a barrel of concrete, set flush with the ground. This concrete transmitted sufficient heat down into the permafrost to permit a heaving action to take place, and in thirty-seven years the mark had been pushed up about 24 inches.

As soon as sufficient signals have been built, an observing party begins its work. One of these units consists of three or four men, although when the party is short handed it can be reduced to only two men. The angles are measured with a theodolite, reading to seconds of arc, such as a Wild T2 or T3. The tripod is set on small wooden blocks frozen into the ground and duck boards are placed around the tripod to prevent the movements of the observer from disturbing the instrument. An "*O*" tent is usually set up to protect the instrument and the observer. The theodolite must be handled carefully and should never be taken into a warm room. It should be kept in an unheated storeroom when not in use to prevent moisture from collecting on the inside of the lens. Special oil must be used in the lubrication of these instruments to permit their use in the low temperatures encountered. Good observing weather generally has a temperature reading between minus five degrees and plus twenty degrees Fahrenheit. From long experience it has been found that it is seldom wise to attempt to observe when the temperature is below −5 degrees if there is any wind, or below −10 degrees if there is a dead calm. If observations are attempted when the temperature is below these minima the triangle closure may be excessive and the station will have to be reobserved, and the time and trouble will have been wasted. Observations have been made at −37 degrees but that is a rare exception.

The best observing conditions occur either on cloudy days or when the sun is low in the evening sky. A bright sun causes horizontal refraction. Since most of the lines observed can be termed "grazing" lines, it is remarkable that second-order results are obtained. If the ground is entirely covered with snow, there will generally be little difficulty though it is normal to have 25 per cent reobservation. Under unfavorable conditions this figure may mount to 65 per cent. One year an attempt was made to observe in August and September when the ground was bare of snow, and the closures were so large that the entire arc had to be reobserved the following spring.

In March, wind velocities of about ten to fifteen miles per hour will lift the powdery snow 30 to 50 feet in the air, thereby reducing the visibility to such an extent that surveying becomes impossible. In April and May the snow glazes over, due to the alternate thawing and freezing, and the visibility is not affected by blowing snow until a velocity of 15 miles per hour is exceeded. However when the ground begins to bare, difficulties will be encountered. (As if there had not been sufficient difficulties before!) Any line that passes over the black sand will have some horizontal refraction unless the line is elevated ten feet or more by constructing stands and taller signals. These black sand patches will begin to appear about the first week in May.

The astronomic observations can be obtained any time from February to April in the spring, or from the latter part of August to October in the fall. The latter period is to be preferred because of the more moderate temperatures. During the intervening months there is too much light to permit observations on stars. A Bamberg "broken" transit is used at astronomic stations. Very satisfactory results can be obtained if good radio signals can be received. During times of magnetic storms there is a radio black-out in this region and no signals will come through. One observer had difficulty in getting his break-circuit chronograph to work properly because his breath formed a coating of ice on the sliding electrical contacts. He solved this problem by coating the surface with glycerine. That made a good antifreeze.

Base lines are always measured in the spring in conjunction with the triangulation. Here, again, as in the reconnaissance, it would be more comfortable to do the work in the summer, but transportation difficulties and the press of hydrographic surveying makes it impractical. The base is generally located so the measurements can be made across lagoon ice. Here the surface is level and the stakes can be steamed in with little difficulty. The ice is frozen to the bottom of the lagoon so there is no movement of the ice due to tide or current. The taping has been done when the temperature is as low as -25 degrees. The bases have averaged about $3\frac{1}{4}$ miles in length.

The delineation of the shoreline and adjacent areas is made from aerial photographs. Field inspection and identification of control on the photographs must be made in the summer months when the ground is practically bare. Here again a helicopter would be invaluable if available. The only other recourse is to use the weasels but the rough going over the tundra is very destructive to treads and axles. These vehicles are amphibious but it is dangerous to attempt to cross a large river in one of them. When such a stream is encountered a LCM must be sent in to ferry the crew and their equipment across the dangerous areas.

Vertical control in the Arctic area has been limited to vertical angles observed at triangulation stations. At the present time there is no need for an extensive net of precise levels. Tide gages have been installed at many places along the coast, and these have been connected to the nearest triangulation station by means of spirit levels. In addition frequent ties have been made from stations along the shore to the sea ice, by means of vertical angles and measured distances; these generally give a sea level datum within 6 to 12 inches.

Accurate vertical angles are difficult to obtain due to the excessive vertical refraction. At times there will be three signals showing, one above the other, and the observer is in a quandary on which one to point. One day an observation will give a positive value and on the next it may be negative. However, enough acceptable values can generally be obtained to permit the elimination of the wild ones and fairly good results have been obtained.

That is the picture as far as the actual surveying work is concerned. No doubt you are interested in how one lives up there in the "frozen wastes,"—method of travel, clothing, etc. The Janesway hut was the answer to the surveyor's prayer up there. The hut comes in small sections, which may be transported by plane if necessary. The plyboard flooring sections are bolted together to form the foundation of the house, folding ribs are secured to the floor, and an insulated Koraseal Blanket is spread over them and lashed into place. The entire hut can be erected by four men in a few hours and they then have a warm and secure shelter which will stand up in any blizzard.

For transportation, the best vehicle is the airplane. Large two and four engine planes bring the men and some of the supplies in from the States and land either at Barrow or at Barter Island, and smaller planes shuttle the loads up and down the coast to the base camps. A C-47 can carry 3 tons but it is necessary to smooth out a landing strip on the lagoon ice for its use. A Norseman, which is a small single engine plane made in Canada, using skis can land on the snow covered tundra or ice covered lakes and lagoons with little trouble. It will carry a thousand pounds or more, depending upon the distance it has to fly. Small Cubs or Cessnas can land almost everywhere. They will continue to land on the ice on a fresh water lake after the gound is bare of snow.

For heavy hauling between camps, the caterpillar tractor comes into its own. It has been said that the Arctic is now the "land of the D-8 cat." They haul long trains, loaded with hundreds of tons of supplies, for distances up to 300 miles. The sleds are constructed of steel pipes and are known as "pipe sleds." For ligher hauling of supplies and the transportation of personnel, the weasel has proven to be a handy vehicle. However, they are rather fragile, and even when handled very carefully they are in constant need of repairs and the replacement of tracks and other parts. It has been estimated that their operating cost is about one dollar per mile. Dog teams were used for the first two years but this mode of transportation has been discontinued because of the cost of dog feed and the limitation of the loads that could be hauled. Even the Eskimos find it more economical to charter a small plane than to hire a dog team for a trip of twenty-five miles or more.

For the sake of safety and comfort, every cat-train always hitches on a mess wanigan, like a caboose on a freight train. In it the men can obtain food and shelter in the worst sort of weather. The mobile field parties have been equipped with bunk wanigans, used as sleeping quarters, which enables them to break camp and make frequent moves with little delay.

In the open water season, small planes are equipped with floats and can operate with a high degree of safety because of the numerous lakes on which they can land in an emergency. For surface travel,landing craft developed by the Navy in World War II, such as the LCM, are used to move men and equipment for long distances along the coast.

During the break up period there is a time when every means of transportation is highly restricted. To maintain transport, a small landing strip is usually dozed out on the beach near each base camp on which small planes can land if necessary. In a few cases it has been necessary to drop supplies from a plane by parachute.

The clothing problem has been a difficult one to solve and it is still in a state of experimentation. During the first few years, the men were furnished caribou socks and mukluks, made by the Eskimo women, who have organized native corporations in the larger villages. The fur is turned inside for the socks and outside for the mukluks. The caribou skin is not tough enough however for the soles and for this it is best to use the skin of the ogeruk, a large white seal. In the summer light mukluks can be worn; these are made from seal skins. These are hand sewed and are water proof. Shoe packs and leather or rubber boots are popular. For trousers the men usually wear jersey lined khaki pants. A down-filled parka completes the costume. These items of clothing have been improved in the last few years due to the experiments conducted by the Army and the Navy. A double-wall rubber boot, with rubber tubing between the layers has proven very satisfactory. The dead air space is good insulation against the cold. The feet perspire but the moisture is warm and the feet do not feel cold at all. Various materials have been tested for the insulation of the parkas. Spun glass is good but it breaks down under use into a fine powder. Feathers or down are excellent if sufficient quantities can be obtained for large groups of men. Native cured skins are not used for clothing due to the use of certain liquids in the treatment of the skins. Fur parkas, made in the States, are worn by many of the men but these are rather expensive. All parkas are provided with hoods, and it is a good idea to have a ruff of wolverine fur sewed around the face opening to protect the skin from frost bite. Sun glasses should be worn at all times when out of doors if there is snow on the ground to prevent snow blindness. It is a good idea to keep smooth shaven, for moisture will collect on a mustache or beard and freeze into small icicles.

The major portion of the supplies comes in by the yearly Navy expedition and long range planning is a necessity. Lists of stores must be prepared at the close of each season for purchase in the winter and shipment the following summer. They will be stored over the second winter for use the following spring and summer.

As the season draws to a close, it is wise to take daily temperature readings of the sea water so that all boats may be hauled out on shore just before the freezing point is reached. Supplies are placed in shelters or left out in the open in stacks, well marked with poles and signs, so that they can be uncovered the following spring. If the stacks are well separated and placed normal to the direction of the prevailing wind, the snow drifts will not be more than six feet deep. If these precautions are not taken, there may be a job of digging down through fifteen feet of snow to find the supplies and equipment. Storage batteries are generally placed in a warm hut where a caretaker keeps them charged through the winter. When all is secure, the men are returned home by plane. A small nucleus of men are retained in Seattle through the winter to work up the survey records and prepare for the coming season.

Charting Northern Seas and Harbors

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SYNOPSIS

The Canadian Arctic: Vast areas required to be accurately charted; immensity of the task.

Early charts: Discovery voyages and resultant sketch charts.

Need for modern charts: For defence, scientific investigation and commercial development; beneficial effect of charts on marine insurance rates.

Charting by Canadian Hydrographic Service: Provisional general and harbor charts; charting operations in Frobisher Bay, Ungava Bay, Hudson Strait and Hudson Bay; air-photographic coverage; cooperation with other surveys and Arctic navigators.

United States Hydrographic Office: A major contribution to Arctic charting.

Plans for charting development: Coastal triangulation network; photographic coverage required at both high and low water stages of tide; electronic method of fixing being investigated; new hydrographic ship projected.

Nautical charts of the Canadian Arctic play a vital role in scientific, economic and defence development. The purpose of this paper is to review the need for modern northern charts, to outline briefly what progress in charting has been made, and to indicate the general lines along which it is expected Canadian hydrographic surveys will advance.

A glance at the map shows the vast water areas that require accurate chart coverage. Of vital importance, and one of the most conspicuous features on the map of North America, is that great arm of the sea, Hudson Strait and Bay, which bites into the continent nearly as deeply as does the Gulf of Mexico. It provides some four months of ice-free navigation for the transportation of the products of the Canadian prairies to the markets of the world. Northward, in the Arctic archipelago, are some 10,000 linear miles of water passages. The charting of this vast ramification of interlocking channels presents to hydrographers a tremendous challenge.

As we heard in Dr. Nicholson's address this afternoon, the early history of Arctic charting unfolds a bleak picture of adventurous seamen who had caught a vision of a northern route to the Orient. As their tiny ships groped amongst the islands and along the misty northern margins of the continent they depicted the lay of the land as best they could, in many cases the line between fact and fancy being somewhat vague. Submerged dangers they located by laborious sounding with lead and line, or by the disastrous method of piling their ships on the rocks. Charting the ice-bound passages was, of necessity, a hit or miss affair and, for centuries, tales of shipwreck were common occurrence. Little wonder that most of the early charts, made from sketches and running surveys, have been found to be hopelessly inadequate for modern navigation.

From seaward, the Canadian Arctic presents a forbidding and barren appearance. Fortunate it is that the exposed coasts of the world are not always to be taken as an index of what is to be found within. The bleak coasts of the northern seas contain great mineral wealth, and it is expected that in the near future ore-carrying vessels will be an important factor in the northern water transportation picture. For this purpose, modern coastal charts and large-scale charts of prospective ore-shipping ports must be made available.

An important aspect of the need for nautical charts is their beneficial effect on northern marine insurance rates; the better the charts of a district, the less the risk of marine disaster and, consequently, the lower the cost of insurance which the carriers must pay. These charges, in turn, affect the costs of transportation and, eventually, will be reflected in the expansion or contraction of northern waterborne trade. A striking example of the relation between nautical charts and marine insurance was the case of the new Hudson Bay Route where, year after year as modern navigation charts were made available, shipping insurance rates were lowered.

Safety of ships that ply the northern