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GEOS Commemorates International Polar Year, 1882

It's 100 years since the first International Polar Year, in 1882-83. That year revolutionized polar research by introducing a coordinated multidisciplinary approach, instead of the traditional emphasis on feats of exploration with research as a subsidiary interest.

In this issue, GEOS commemorates that event. But what we're remembering is not only the establishment of this principle. We're also remembering what emerges in several articles: the bravery, tenacity and innovative abilities of the men involved — qualities still manifest today.

EMR's primary contribution to the celebration of the centenary is CESAR — the Canadian Expedition to Study the Alpha Ridge. This is a major multidisciplinary geoscience expedition to investigate the nature and origin of the Alpha Ridge, a major subsea mountain range in the Polar Basin. It will be similar to LOREX, the 1979 experiment to float on a great ice island across the Lomonosov Ridge, another undersea mountain range near the North Pole.

CESAR will incorporate 19 separate geoscience projects in three months beginning in March 1983. The scientific teams will be primarily from Earth Physics, Geological Survey, and Geodetic Survey of Canada, all EMR branches, but other government agencies and universities will be involved.

GEOS will present more material on CESAR as the plans and action proceed. We will also, throughout this centennial year, have more articles on EMR in the Arctic: on the Beaufort Sea Atlas; on the re-discovery and examination of the Breadalbane, the Royal Navy supply ship that sank 129 years ago in Lancaster Sound; on the voyage of the research ship 'Hudson' through the Northwest Passage; on what scientists know now about permafrost; on new research on oil spills and their effects on Arctic environment, and finally a profile of Ray Thorsteinsson, who in the 31 years he's been with the Geological Survey has spent 28 summers in the Arctic, observing radical changes over that time.

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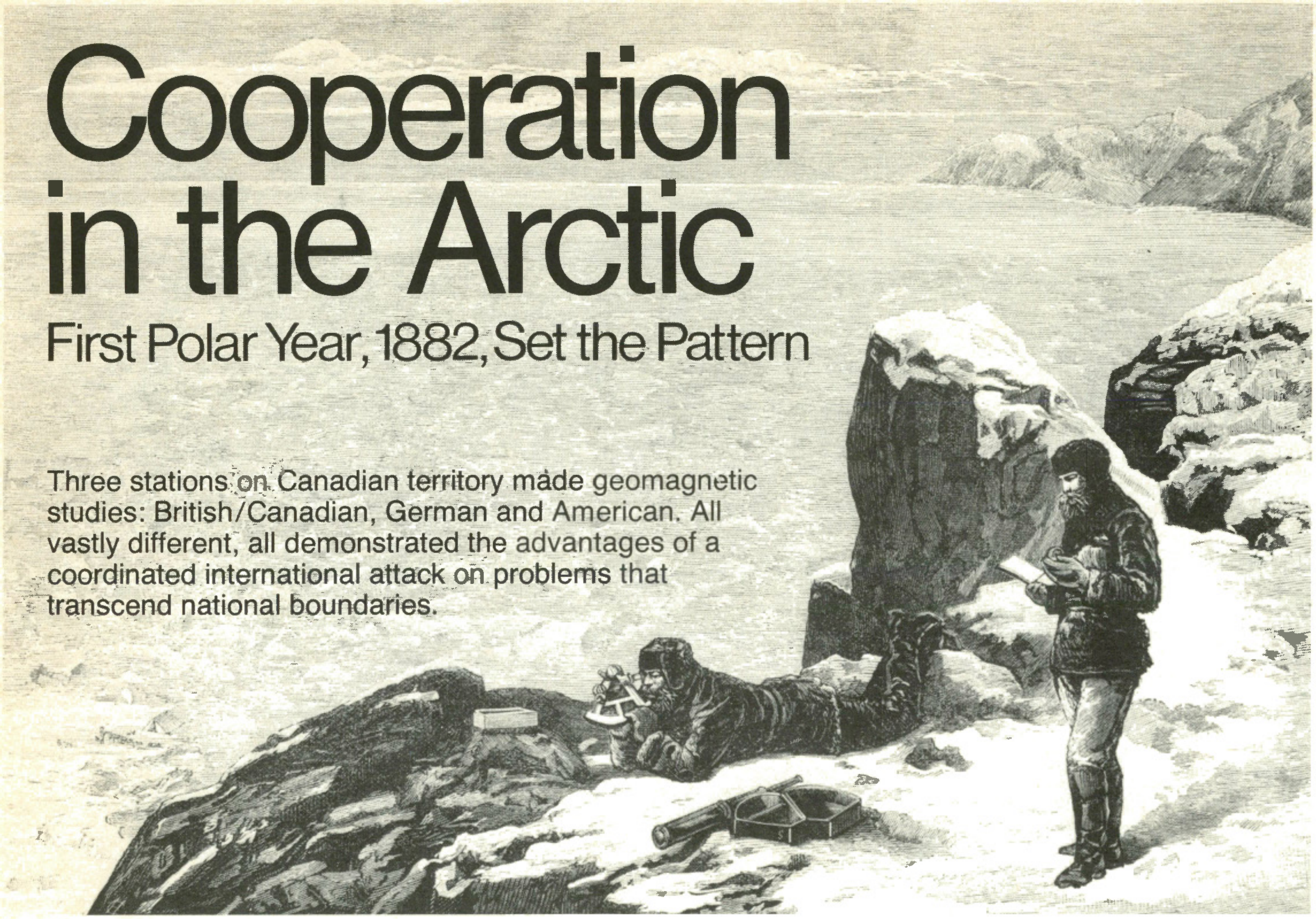
COVER: *A geoscientist takes measurements as part of EMR's Lomonosov Ridge Experiment 1979, near and over the North Pole. Photo by Hans Weber, expedition leader.*

COUVERTURE: *Un géotechnicien prend des mesures pendant l'expérience de la dorsale de Lomonosov effectuée par EMR en 1979 au pôle nord. Photographie par Hans Weber, chef de l'expédition.*

Cooperation in the Arctic

First Polar Year, 1882, Set the Pattern

Three stations on Canadian territory made geomagnetic studies: British/Canadian, German and American. All vastly different, all demonstrated the advantages of a coordinated international attack on problems that transcend national boundaries.



The Greely Arctic Expedition reached a new 'farthest north' on the north coast of Greenland
L'expédition Greely dans l'Arctique atteint un point, a l'extrême nord sur le côte septentrionale, du Groënland

Illustrations Public Archives of Canada, C-118002,3

By Paul H. Serson

On 11 May, 1882 four men sailed from Liverpool for Canada, heading for Fort Rae on Great Slave Lake. They were Captain Henry Dawson of the Royal Artillery, two 'serjeants' and a gunner, and they constituted the British-Canadian Expedition for the International Polar Year. The British government had approved the project barely six weeks before, and preparations had been hectic — borrowing instruments, learning to use them, and making arrangements with the Hudson's Bay Company for supplies to be picked up in Winnipeg. The party was already en route to Quebec City when Parliament in Ottawa voted $4000 as Canada's contribution to the travel expenses of the expedition.

Time was critical. Dawson's task was to establish a magnetic and meteorological observatory at Fort Rae and to operate it for a full 12 months. Fort Rae had been chosen as the most northerly of the Hudson's Bay Company mainland posts where this was possible without getting trapped for a second winter by the freezing of the rivers.

STATIONS OF THE FIRST INTERNATIONAL POLAR YEAR 1882-83

The expedition arrived at Fort Rae on 30 August, and the following night began their hourly observations which were to continue without interruption for the next 365 days. It was actually six weeks before all the observatory buildings were finished and the complete observing program was in operation.

The winter of 1882-83 at Fort Rae was unusually mild, and fresh meat was plentiful. In fact, the expedition consumed nearly 1 kg of meat per man per day, 'in addition to fish, ducks, geese, &c.' On 1 September, 1883, they made their last hourly observations and left Fort Rae for England, perhaps a little overweight but otherwise none the worse for their year in the Arctic.

Fort Rae was one of the fourteen 'circumpolar' observatories established especially for the first International Polar Year. Four stations were originally planned for the southern hemisphere but only two were actually set up: the French one in Tierra del Fuego and the German one on South Georgia Island. The other twelve special observatories were in the Arctic:

STATION	LATITUDE	LONGITUDE	SPONSOR
Fort Conger (Ellesmere I.)	81°44′N	64°44′W	U.S.A.
Cap Thordsen (Spitzbergen)	78°20′N	15°—′E	Sweden
Sagastyr I. (Siberia)	73°23′N	126°35′E	Russia
Moller Bay (Novaya Zemlya)	72°23′N	52°45′E	Russia
Point Barrow (Alaska)	71°18′N	156°24′W	U.S.A.
Jan Mayen (Jan Mayen)	70°60′N	8°28′W	Austria
Bossekop (Norway)	69°58′N	23°15′E	Norway
Kara Sea (Russia)	69°42′N	64°45′E	Netherlands
Sodankylä (Finland)	67°26′N	26°34′E	Finland
Kingua Fjord (Baffin I.)	66°36′N	67°19′W	Germany
Godthaab (Greenland)	64°11′N	51°44′W	Denmark
Fort Rae (Great Slave L.)	62°39′N	115°44′W	U.K.

In addition to the circumpolar stations, thirty-four permanent observatories contributed to the Polar Year program, following schedules of special observations.

EMR is planning to commemorate the centennial of the first International Polar Year by sending a magnetic survey team to the sites of the three 1882 Polar Year stations in Canada. in May and June 1982, Larry Newitt of the Earth Physics Branch will spend a week at each of Fort Conger, Kingua Fjord and Fort Rae, carefully measuring the strength and direction of the earth's magnetic field over the same points where the corresponding measurements were made a century before. He will be assisted by Ed. Dawson, who recently retired from the Earth Physics Branch, after 28 years of plotting the changing magnetic field of Canada as head of the Magnetic Charts Section. The expedition is being organized with the help of the Polar Continental Shelf Project.

The Polar Year was proposed in 1875 by Karl Weyprecht, an Austrian naval lieutenant and an experienced Arctic explorer. He deplored the nationalistic rivalry which led to an 'international steeplechase to the North Pole' and the 'christening of islands in different languages', and pleaded for a co-operative international enterprise of Arctic scientific research. Weyprecht enunciated guiding principles for the project which were adopted unchanged for the Second International Polar Year, 1932-33, and for the International Geophysical Year, 1957-58. Among his objectives:

- the use of standardized instruments and agreed techniques to obtain simultaneous observations at permanent observatories as well as at special stations;
- the free interchange of data;
- The prompt publication of results in an agreed common format.

Weyprecht played a leading part in organizing the first Polar Year, but he died of tuberculosis just before its commencement, at the age of 43.

There were two other First Polar Year stations besides Fort Rae on Canadian territory. One was established by Germany at Kingua Fjord, near Pangnirtung, southern Baffin Island. In addition to the usual meteorological, magnetic and auroral observations, this expedition made regular measurements of earth currents — the electric currents induced in the ground by rapid variations of the geomagnetic field. Professor George Garland of the University of Toronto recently came across the carefully published record of the Kingua Fjord earth current observations, and is applying modern computer techniques to their analysis.

The other Polar Year station on Canadian soil was on northern Ellesmere Island, about 100 km south of Alert. It was the Fort Conger of the ill-fated Greely expedition.

Unlike the Fort Rae expedition, the United States Army expedition to Ellesmere Island was planned well in advance, under an act of Congress passed in May 1880. By August 1881, Lieutenant Adolphus W. Greely and 24 others were comfortably settled in their new house at Fort Conger, and they started regular observations a full year before the official beginning of the Polar Year. The large party was equipped for exploration trips by dog-sled, and several were carried out. The group discovered Hazen Lake, was the first to cross Ellesmere Island to Greely Fjord and reached a new 'farthest north' at latitude 83° 24′N on the north coast of Greenland. In fact, Greely was authorized to try for the North Pole if conditions appeared favourable, but he

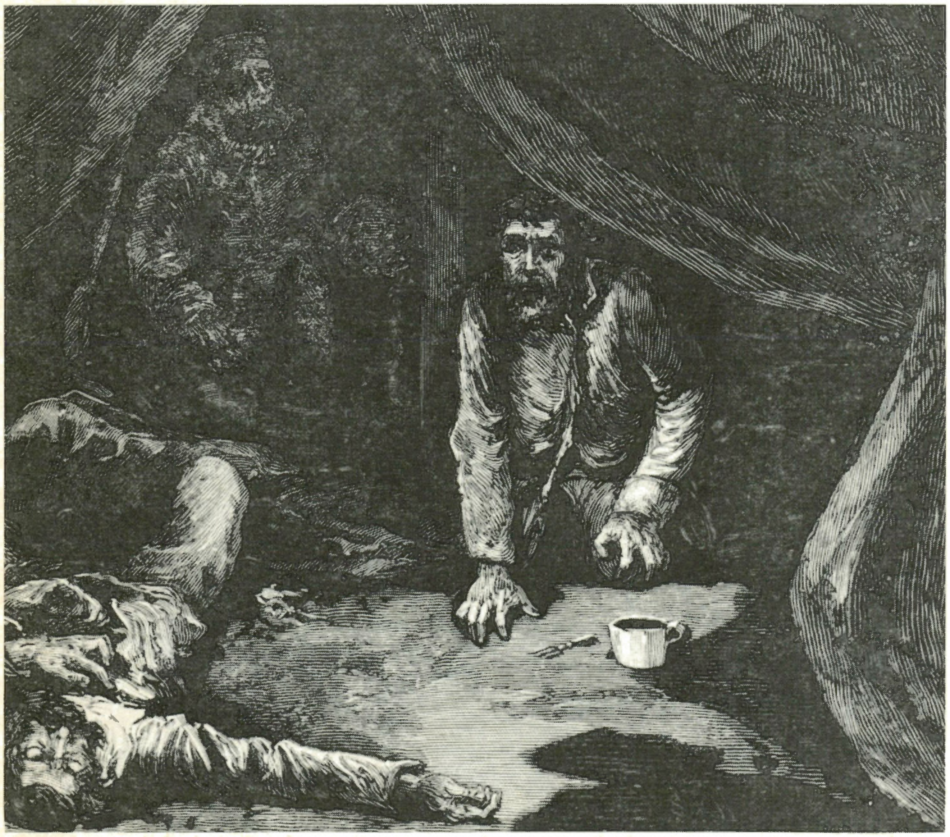
Paul Serson first saw the Arctic as a student assistant, measuring the earth's magnetic field as a member of a Dominion Observatory survey party. On graduating from the University of Toronto, he joined the Observatory's Division of Geomagnetism and developed electronic instruments for magnetic measurements in high latitudes. He is shown here, in 1947, with the first. He obtained his Ph.D. from Toronto for the development of a three-component airborne magnetometer, and conducted many surveys with this instrument over Canada, Greenland, Iceland and Fennoscandia. He became Chief of the Division in 1962, and retired in December 1981 with the title of Director, Division of Geomagnetism, Earth Physics Branch EMR.

was soon preoccupied by problems of dissension and insubordination among his crew.

The first great disappointment was the failure of a relief ship, blocked by ice in Smith Sound with supplies and a replacement team, to reach them in 1882. Then in 1883 the second relief ship was crushed by the ice and sank. Obeying orders, Greely abandoned Fort Conger and headed with his party for Cape Sabine, 400 km to the south, in two small boats. The party probably could have survived for several years at Fort Conger without much hardship, since muskox and other game were plentiful, and an excellent coal seam a few km from camp provided all the fuel they could use.

The zigzag voyage to Cape Sabine took seven weeks and covered nearly 1000 km, but all 25 men arrived safely. They found a tiny cache of food at the Cape left by the 1883 relief expedition, and a note giving the locations of more generous stores in the vicinity. They never found them. The official investigation later showed that these caches were never established, and that almost all the food sent north with the relief ships had been returned to the United States. As a result, Greely's men died of starvation one by one until there were seven left at their rescue in June 1884. One of the seven did not survive the voyage home. Greely himself recovered to tell the tragic story, and lived until 1935, dying at the age of 91.

Was it all worth while? It has been estimated that 700 people, including those at permanent observatories, took part in the first International Polar Year. By today's standards the results are certainly of limited value. Without sounding balloons or rockets, the meterorological observations were confined to ground level. The most serious deficiency in the magnetic data was the lack of photographic recording. Although continuous recording of magnetic variations had been carried out photographically at permanent observatories for over 30 years, none of the temporary Polar Year stations in the Arctic were supplied with automatic recording equipment. In high latitudes where the magnetic field is usually disturbed and subject to sudden and violent changes, spot readings taken once per hour give a very inadequate description of the variations. In an attempt to overcome this limitation, magnetic readings were taken every five minutes throughout the first and fifteenth day of each month of the Polar Year, and during prearranged hours, magnetic readings were taken every 20 seconds! The data obtained by such laborious means was unsuitable for statistical analysis and could at best only emphasize the need for automatic recording of the complex polar phenomena.



Discovery of Lieutenant Greely and his companions in their tent near Cape Sabine on Smith Sound, June 1884
Découverte du lieutenant Greely et de ses compagnons; on les aperçoit dans leur tente, à proximité de cap Sabine, dans le détroit de Smith, en juin 1884

Of course, the first Polar Year provided much more detailed coverage of Arctic meteorological and magnetic conditions than had ever been available. It coincided with a maximum in the 11-year sunspot cycle and many large magnetic storms were observed. Two magnetic storms in particular are classed as among the greatest on record, and have been studied extensively as the best documented great storms up to the time of the International Geophysical Year 1957-58.

All of the Polar Year stations recorded hourly or more frequent visual observations of aurora. Weyprecht's own instructions for reporting aurora were an important contribution towards a standardized and precise description of the elusive forms, and it has been said that modern auroral physics began with the first Polar Year. Many attempts were made to photograph the aurora and its spectrum during the Polar Year, but the fastest plates were far too insensitive. The first successful photographs of the aurora were taken 10 years later, and it was not until 1910 that auroral photography became useful scientifically. But the excellent visual observations of the Polar Year established some of the basic facts about aurora, such as the variation of its occurrence with distance from the geomagnetic pole, and the shift of the zone of maximum occurrence toward the equator during large magnetic disturbances.

Naturally, for many scientific investigations, data from the Polar Year have been superseded by modern data from improved ground instrumentation as well as rockets and satellites. One hundred years later, the most important result of the first International Polar Year is that it demonstrated the advantages of a coordinated international attack on problems which transcend national boundaries. A century ago such problems were mainly scientific. Today we can apply the approach to global problems of concern to everyone.

La première Année polaire internationale soit 1882, a fourni aux scientifiques de l'époque l'occasion de faire une moisson sans précédent de données détaillées sur les conditions météorologiques et magnétiques de l'Arctique. Des douze observatoires qui ont été aménagés à cette fin, dans l'Arctique, trois étaient situés en terre canadienne dans le cadre d'un projet anglo-canadien, à Fort Rae, au Grand Lac des Esclaves, d'un projet allemand dans le sud de l'île Baffin, et d'un projet américain à Fort Conger, au sud d'Alert, dans le nord de l'île Ellesmere.

Mapping Sea Ice with Radar

The Research and The Application

GEOS presents on the following pages two points of view on one subject vital to northern development: remote sensing of Arctic ice. One article is research oriented, from EMR scientists. The other is about the commercial application, from engineers of INTERTECH Remote Sensing Ltd., a private company.

Long before technology transfer became a buzz word, it was part of EMR policy. Research and Development is, after all, a wealth-producing activity. In the last century, prospectors lined up to get the first maps from the Geological Survey of Canada. They still do, but now they're joined by oil and mining company representatives. Canada Centre for Mineral and Energy Technology (CANMET), another EMR component, also has a long history of passing along research results to drillers, mine and mill operators, foundrymen and metallurgists. CANMET has identified 16 separate procedures it uses to relay its research to industry, and they are monitored at quarterly review meetings.

Usually, the technology transfer follows a path from scientific concept to laboratory development, to pilot plant or prototype production, to engineering design, to full scale operation or production.

Sometimes things move so fast, the steps are telescoped. Remote sensing is a fast developing field, and the need to monitor sea ice and icebergs is so pressing that researchers at Canada Centre for Remote Sensing (CCRS) and in industry sometimes leap from step 1 to step 4 and even carry on the two processes simultaneously.

INTERTECH is one of several applications-oriented companies which lease the CCRS Convair 580 and its synthetic aperture radar (SAR) to monitor for oil companies in the Arctic the position and motion of ice. SAR is still primarily a research system, and a CCRS researcher, Chuck Livingstone, one of the authors of the article on research in this area, sometimes accompanies the flights to continue refining the instrument and its interpretation. At the same time, INTERTECH engineers have developed a special link to transmit the SAR imagery to the drillship below, so interpreters on board can know if and when to disengage the wellhead and move on because pack ice threatens. Obviously, SAR is vital to northern development.

Technology transfer has already been proved at EMR to be most effective in cost-shared projects. Dome Petroleum Ltd. wants the constant protective surveillance of the radar, and that oil company and CCRS are joining in the financing of a new SAR. It will be produced by two more Canadian high technology research and development companies, MacDonald Dettwiler & Associates (MDA) of Vancouver, which designs and builds SAR processors, and Canadian Astronautics Ltd., Ottawa, which manufactures microwave nodules for SAR.

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The Research

Testing Radar Systems in Polar Ice

By A.L. Gray, C.E. Livingstone and R.K. Hawkins

Resource exploitation in the Arctic depends on solving engineering, scientific and environmental problems. Offshore oil rigs and tankers will need accurate and timely ice information, supplied by a variety of satellite and aircraft remote sensing systems. Radar systems that operate through cloud, darkness and even snow and rain must be used when traditional visual techniques fail.

EMR's Canada Centre for Remote Sensing (CCRS) is improving design and operation of radar systems to answer these needs, showing how some radar parameters can be changed to improve detection of different ice conditions and hazards. Moreover, our research shows that specially designed radar is a very good general use tool as well as the best one to use in darkness and in poor weather.

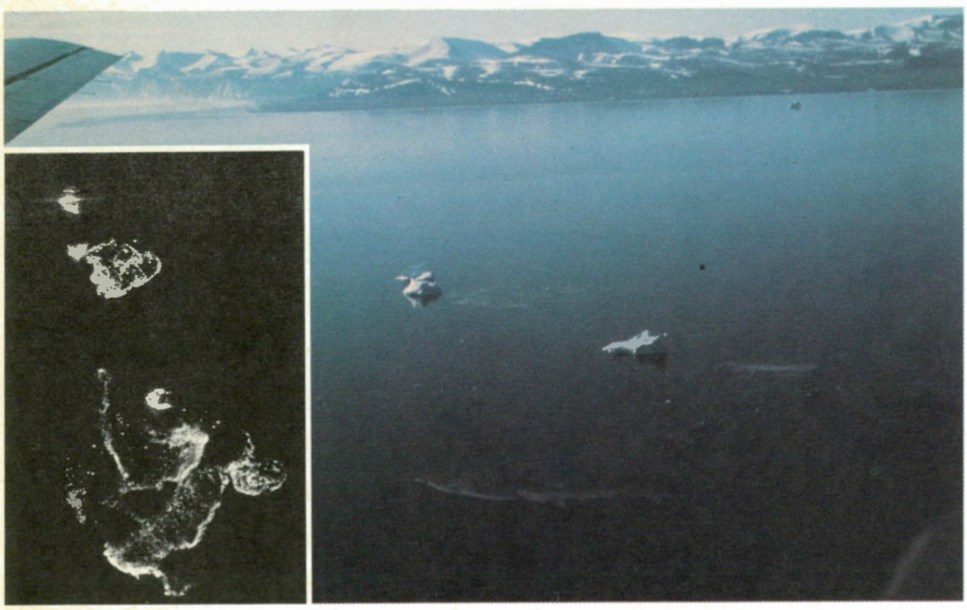

Figure 4. *Simultaneous visible and radar imagery of icebergs and small fragments off Baffin Island*

Banquises et glaces flottantes au large de l'île Baffin. On les aperçoit ici vues à l'oeil nu et par l'image du radar

With similar Arctic conditions, the U.S.S.R. has studied ice physics and developed and used radar systems for many years. Although the U.S. is supporting polar research, their application of remote sensing of sea ice is limited at present. And Scandinavian nations, also interested, are beginning to study and use ice reconnaissance. Denmark operates an ice reconnaissance service for shipping around Greenland which is based partly on the Canadian Ice Branch reconnaissance program and experience.

The most practical radar system to use from aircraft or satellite for this purpose is the 'side looking' radar (Fig. 1) from which a pulsed microwave beam is transmitted sideways to the flight direction or track. The resulting radiation reflected (or backscattered) by the ice and water surface arrives back at the

Cont'd on page 7

The three authors are all research scientists in the Canada Centre for Remote Sensing. Dr. Laurence Gray works on design and application of air and spaceborne microwave sensors for cold ocean reconnaissance. Recently he spent a year as Visiting Professor in the Microwave Remote Sensing Group at Denmark's Technical University. Chairman of the Ice Reconnaissance Working Group of the Canadian Advisory Committee on Remote Sensing, he is also a member of an advisory group to the European Space Agency on the design of the microwave sensor system on the first European remote sensing satellite.

Dr. Chuck Livingstone, former assistant professor of electrical engineering at the University of Western Ontario, helped introduce synthetic aperture radar technology into Canada, and studies quantitative microwave signatures of sea ice and is a member of the subcommittee for Arctic Oceanography Panel on Ice.

Dr. Bob Hawkins has worked extensively on analysis of microwave remote sensing techniques to detect open ocean oil spills and ice hazards and to classify sea ice types with microwave sensors. His background is in liquid state physics using neutron scattering.

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The Application

Technology Transfer at Work

By Brian Bullock and Mike Kirby

Sensors such as side looking airborne radars, laser profilometers, infrared line scanners, laser fluorosensor and multispectral line scanners have been employed in recent years to detect and map sea ice, icebergs and oil spills. INTERTECH Remote Sensing Ltd. is a Canadian company which applies techniques of data acquisition and analysis commercially.

With its parent company INTERA Environmental Consultants Ltd., it has routinely used these sensors for support of exploratory and transportation projects in the Beaufort Sea, the high Arctic and eastern arctic. As a result of this experience it has been possible for INTERTECH to assume the momentum from R and D programs and develop additional techniques.

SURSAT, the Canadian government sponsored component in the oceanographic satellite experiment conducted by the U.S. in 1978, had many benefits. A major one was the demonstration of the utility of high resolution synthetic aperture radar (SAR) imagery for the identification of ice features that could interrupt drilling operations. The fact that SAR imagery can be generated independent of weather and light conditions makes it a very useful system for operations in the Arctic.

Following SURSAT, INTERTECH began to market the application of SAR for ice studies. Dome Petroleum Ltd. requested a pilot project to prove the utility of the SAR system for real-time support of exploration operations in the Beaufort Sea. As part of the transfer to industry program, CCRS has implemented a mechanism that allows equipment like

Brain Bullock is President of both INTERA Environmental Consultants Ltd., Calgary and INTERTECH Remote Sensing Ltd., Ottawa. He has played a major role in introducing SAR to Canada and applying it to resource management.

Michael Kirby is vice president and general manager of INTERTECH and has been with the parent company, INTERA since he gained his master's degree in Image Processing and Remote Sensing from the University of Waterloo in 1975.

SAR to be leased for commercial use. INTERTECH has leased SAR from CCRS and employed it successfully in support of Dome's Beaufort Sea drilling operations for the past three years.

In the first season, 1979, the SAR-equipped aircraft was dispatched to Inuvik in the last week of November. Sea ice images were produced on the first day after arrival and then routinely every day until drilling operations were suspended. The sea ice images were delivered to the drillship in near real-time using an electronic downlink. This was developed by INTERTECH to prove the concept of using airborne SAR in realtime support of marine operations. An ice interpretation expert provided by INTERTECH was resident on the drillship to study the SAR images and locate features such as pressure ridges, rubble fields and old floes that could cause an interruption of drilling activity if they were allowed to enter the vicinity of the drillship. (Fig. 5). The locations of these targets were provided to the drillship's captain and other support vessels. Then the icebreaker Kigoriak could be dispatched to break up the ridge or rubbled ice to ensure continuation of drilling activity.

As the season progressed and hours of light turned to hours of twilight, the real utility of the SAR was proven. On occasion, the weather was so poor, with fog and freezing rain, that no other method of reconnaissance was possible. Visibility from the ship itself was limited to a few hundred yards. Even then the SAR was flown and produced clear images of ice conditions for the drillship. The first season was an overwhelming success. Even veteran Arctic mariners on the Dome crews expressed a desire to see SAR support become a routine part of the operation.

For the second drilling season significant improvements were made to the downlinking of the realtime imagery to a drillship. In particular, a downlink system was developed in which a digital data stream was transmitted directly to a receiver on the drillship. This not only allowed for faster transmission, but it also ensured that there would be no degradation in the resolution and dynamic range of the data.

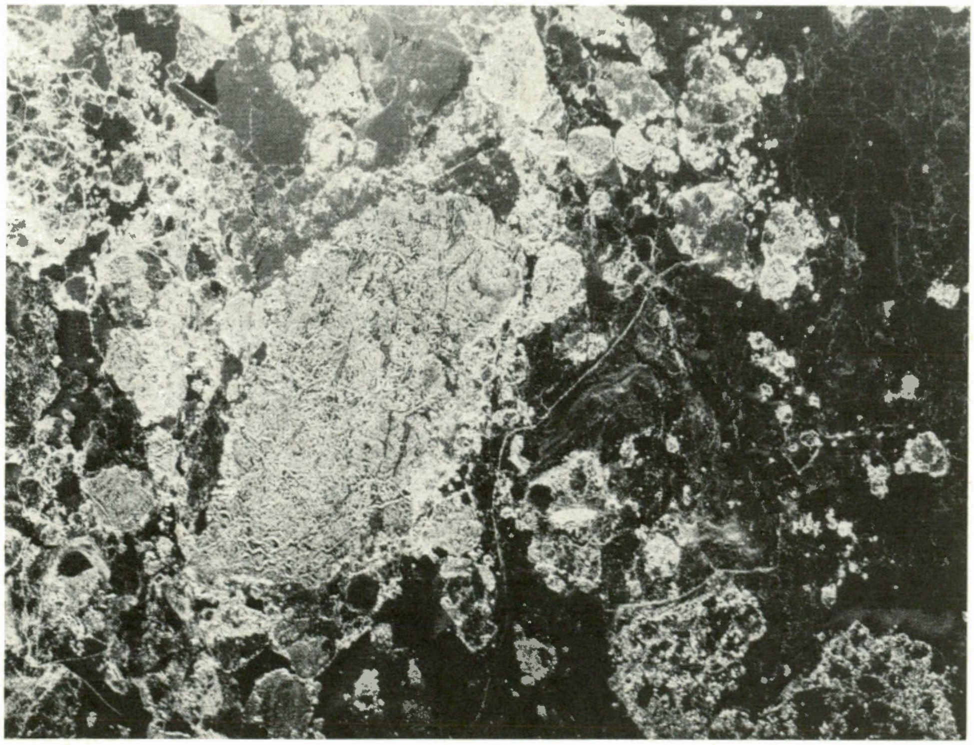

Figure 5. *SAR X band (3 cm wavelength) imagery showing a variety of ice types in the Beaufort Sea. The fine bright line in the centre of the image is the track of an icebreaker as it changed path to avoid old ice floes. The small bright feature at the end of the track is a reflection of the icebreaker in a first year floe*

Image obtenue par radar à ouverture synthétique en bande X (3 cm) montrant différents types de glace dans la mer de Beaufort. La mince ligne brillante qui apparaît au centre de l'image est la trace laissée par un brise-glacé qui a changé de direction pour éviter des banquises

The development of a full resolution downlink is a key factor in converting the pilot project nature of the first year into an operational service. The SAR aircraft was again sent to Inuvik in early October and began operations successfully immediately upon arrival. Unfortunately, the old ice of the permanent pack had already moved into close proximity of the drilling locations and drilling activity had to be suspended early in October. SAR again proved useful for providing graphic imagery of ice conditions. It assisted in prolonging drilling as long as practical and in the return of the drilling fleet to winter storage.

This past year, airborne SAR and other side looking radar systems became an operational tool of the Beaufort drilling operations for the entire drilling season. Technology and systems are still being developed to improve the utilization of the information provided by SAR.

INTERA and INTERTECH have developed along with the techniques. The parent company was formed in 1973. Its original half dozen employee-owners in Calgary and Houston decided from the beginning to emphasize high technology rather than the magnetometer and airphoto studies of conventional survey companies. It now has 250 employees in several companies, with additional offices in Ottawa, Washington D.C., Denver, Austin, and soon in Denmark. Its strength is not in numbers, but in expertise in modelling, in the areas of environmental management, hazardous wastes, biophysical resource inventory and analysis, ice and icebergs, and meteorological consulting. Remote sensing often provides the input for these models.

Through the cooperation of industry and government, Canada has pioneered a new technology in a new frontier. Because of the vast and hostile Arctic environment, there is a need for techniques that obtain timely information without costly investment for conventional survey procedures. Remote sensing provides a practical alternative, and the combined effort and continued co-operation between agencies have provided incentives within the private sector.

These efforts have caught the attention of organizations in the United States and Europe. INTERTECH was asked to undertake a number of international projects this year, including contracts with major U.S. oil companies in Alaska and a SAR project for the European Space Agency in Europe. Through the transfer to industry program, Canadian industry has gained internationally recognized expertise in the most advanced applications of remote sensing technology.□

Nous vous transmettons, ici, deux points de vue sur un sujet d'importance cruciale pour l'aménagement du Nord: la télédétection des glaces de l'Arctique. L'un des articles s'inspire des travaux effectués par les scientifiques d'ÉMR; il aborde la question sous l'angle de la recherche. L'autre article porte sur la façon dont une société privée, INTERTECH Remote Sensing Limited, a utilisé ces découvertes dans le domaine pratique.

Remote sensing with aircraft radars helps spot, distinguish and delineate ice hazards to Arctic operations even in darkness and bad weather.

Cont'd from page 5

radar antenna after a time interval proportional to the distance of the terrain feature from the aircraft. A continuing sequence of this reflected signal 'across track', and the motion of the aircraft 'along track', generates an image which shows the geographic distribution of variations in the terrain backscatter.

If, as is most frequently the case, sea ice reflects radiation much more than open water, then the backscatter image can be easily interpreted to give an accurate picture of ice extent, concentration, etc. However, in order to design ice reconnaissance radars to give more usefully informative images, we must know how backscatter variations from different ice conditions affect these images. For instance, ice imagery can change with temperature, snow cover, ice type and roughness. And radar parameters like frequency, incidence angles, resolution and polarization can all be optimized.

CCRS uses two different radars on a Convair 580 aircraft to investigate how sea ice backscatter varies with environmental and radar parameters. One is a unique, versatile, high resolution 'side looking' radar, operating at wavelengths of 3, 6 and 23 cm and in different configurations. With this we can simulate, for example, steep satellite radar geometry, or more shallow geometry used by an ice reconnaissance aircraft. This CCRS radar, called synthetic aperture radar, or SAR, uses a recording and processing technique giving final image resolution of approximately 3 m, independent of range from aircraft. It was initially developed by the Environmental Research Institute of Michigan (ERIM) and has been improved by CCRS since its installation in the Convair 580 as a cooperative ERIM-CCRS venture in 1978.

The other airborne radar, a 'scatterometer', is calibrated to measure the backscattering coefficient of terrain as a function of both incidence angle and the antenna transmitting and receiving electrical configuration, known as polarization. Figure 1 also shows the scatterometer fan beam extending fore and aft of the aircraft. This radar, operating at 2.3 cm wavelength, does not create an image, but when its signals are processed, can measure accurately the backscatter characteristic of 20 m × 20 m footprints in a line beneath the aircraft.

SAR and scatterometer are both useful tools. Scatterometer is valuable in designing satellite radar systems for ice detection, but because of its narrow swath is not used more operationally. In this article we will emphasize the results gained from SAR images.

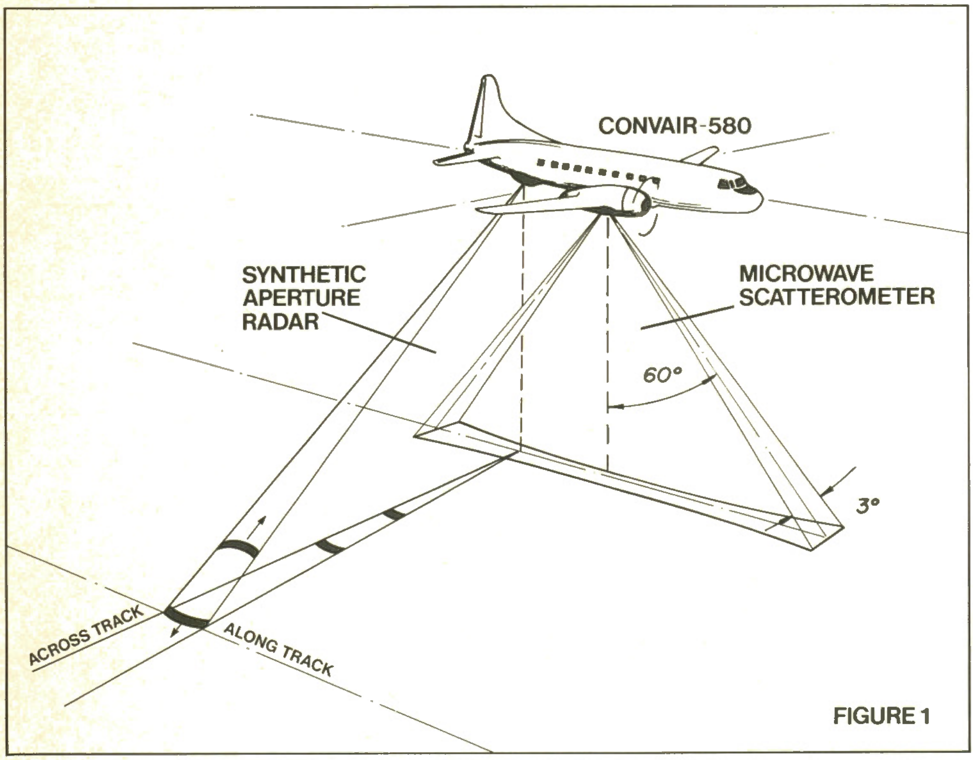

FIGURE 1

Ice Mapping with SAR

Figure 2 shows some of the capabilities of SAR ice mapping. The top picture is the familiar visual image taken by a vertical-looking mapping camera and the lower image is the backscatter image from the short wavelength (3 cm), X band channel of the SAR. In it the whiter tones reflect higher backscatter values. The white ice in the upper photograph is snow-covered and thick, and the grey ice, recently formed, is relatively thin (10-20 cm). Under cold conditions the radar, unlike photography which 'sees' just the top surface, penetrates through dry snow and into the top few centimetres of ice. By detailed comparison of radar and visible images, as in figure 2, we can see that SAR delineates the old ice floes which have survived one or more summer melt seasons.

Entrapped, concentrated sea water or brine pockets in first-year ice drain downwards during the summer melt season, letting microwaves penetrate further. In addition, air bubbles and the recrystallized ice structure in the upper layers of the old ice normally produce larger values for short wavelength backscatter. As well as creating the characteristic backscatter, the lower brine concentration and ice structure changes in old floes make them stronger.

It is important to be able to distinguish these tough old floes, which may be a few to many metres thick, from thinner and weaker first-year ice. SAR is the most reliable way of identifying them.

The graph in Figure 2 gives the results from the scatterometer and a microwave radiometer operating at 1.8 cm wavelength. The dotted line shows variation in backscatter at 45° to vertical for the narrow inner swath marked on the right of the photograph. The solid line indicates radiometer measurement of naturally emitted microwave radiation along the same narrow swath of sea ice. Comparing the variations in height of the two lines with the corresponding locations in the adjacent photographs, we see that backscatter increases where natural 1.8 cm radiation decreases.

Results from both these systems help us understand how microwaves are scattered, reflected and emitted by sea ice. Combining radar and radiometer data improves our ability to distinguish sea ice types and conditions.

Because it is impossible to build a radiometer to operate from an aircraft or satellite and have both high resolution and wide swath, side looking radars, especially SAR's, are potentially much more important than microwave radiometers. However, low resolution imaging radiometers may contribute information too.

Does the ability to identify old ice floes depend on local ice conditions like roughness? With heavily ridged or broken first-year ice, for instance against an island, we need more detail to interpret the high and confusing backscatter created. But generally, the answer to the question is no. We compared scatterometer and radiometer results for a continuous 100-mile-long flight line in the Beaufort Sea in March 1979. The sea contained mostly old or first-year ice with varying degrees of surface roughness. The distribution functions from backscatter measurements clearly showed two peaks. Correlated with ice photography, this in our opinion convincingly indicates that improved airborne SAR systems can distinguish old ice floes from other sea ice even with differing roughness.

Figure 3 shows imagery from four SAR channels plus a photograph covering the upper two-thirds of the four radar images. The two upper radar images are the like- and cross-polarized short wavelength results which show the old ice as bright, well defined floes. The lower images from the long wavelength (23 cm) channels do not show the old ice floes as clearly. Certainly, L band image brightness cannot be used to identify the old ice floes; rather ridging and large scale roughness appears to dictate image brightness much more than ice type. Some image detail, like ridging patterns and ridging around old floes, does help with L band image interpretation. Based on analysis of such imagery we conclude that the shorter wavelength 3 cm channel is more useful than the long wavelength 23 cm channel and the cross-polarized X(HV) channel shows the best contrast.

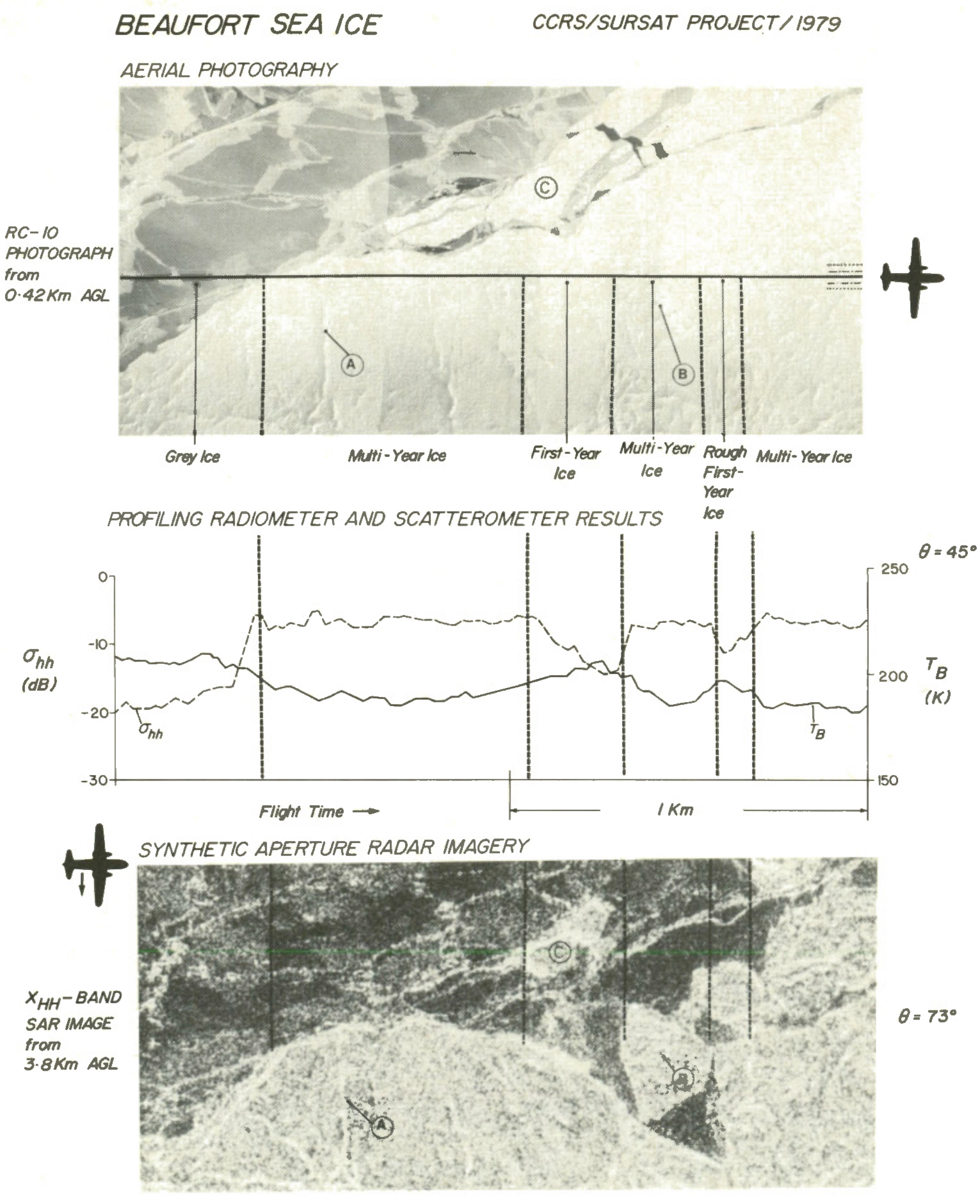

Figure 2

During the summer melt period, it is much more difficult to distinguish old floes from melting and rotting first-year ice with radar images. Image contrast is gone because, when wet, the ice surface layer dictates backscatter levels. Again, the shorter 3 cm channel seems to do a better job. As the snow and then the ice surface melts, channels and ponds form on the ice and a skilled interpreter can sometimes identify some of the old floes. But in general, radar distinguishes ice from open water in the summer, but does not reliably identify different ice types.

Radar Geometry and Resolution

Research shows that the radar geometry affects contrasts on the final image, and consequently its usefulness. When, at low altitudes, grazing angles less than about 5°-8° are created, then bright regions on short wavelength radar imagery indicate large scale roughness like ridging and ice edges. It is similar to L band imagery taken at larger grazing angles and consequently less useful for detecting old ice floes. For wide swath coverage to identify old ice floes in an ice pack under cold conditions, grazing angles greater than about 8° at the far edge of the swath are better. This can also improve the radar signal-to-noise ratio, as the ice backscatter increases significantly as the grazing angles increase in this range.

A high degree of resolution is not always needed. For instance, if the ice is 200 miles from an Arctic operation, then the approximate position of the ice edge, indicated by a cheaper, low resolution radar would be enough. However, we must design our surveillance systems as well as our off-shore installations to cope with extreme conditions. For example, the Ward Hunt Ice Shelf on Ellesmere Island occasionally calves large pieces of freshwater ice island which are very strong and thick. Figure 3 shows part of ice island called T3, which has drifted around the Arctic Ocean for over 30 years. It is 25 to 30 m in thickness!

These ice islands are rare, but they represent a serious threat for safe off-shore operations and we need to differentiate them and smaller ice island fragments from old floes and other ice. At the moment all we can say with certainty is that low resolution, low cost radars will not perform well for this job. Only a short antenna and a high bandwidth pulse maximize the amount of information given by side-looking radar. CCRS uses this kind of radar and we believe that research, development and applications research using SAR is a necessary step to good operational ice reconnaissance systems. Ultimately, it appears that the SAR technique will be necessary to recognize the more serious hazards more reliably.

Use in the Eastern Arctic

Almost all the CCRS work has been done in the Beaufort Sea. In the eastern Arctic ice conditions are more dynamic. Moreover, icebergs, the most serious hazard to off-shore rigs, add another new dimension to the reconnaissance problem. Oil and LNG tankers, going through the northwest passage and south to the Atlantic seaboard, will also need to know about the smaller 'bergy bits' and 'growlers'.

Marine-type radars are used now on ships and drill ships to monitor the position of relatively close ice and icebergs, but should be complemented by ice and iceberg forecasts to give, for instance, a ship's captain more time to change course to avoid heavy ice and icebergs.

Our research shows that aircraft radars, unlike satellite radars, can successfully detect icebergs. In Figure 4 an L band radar image is superimposed on a simultaneous oblique colour photograph. The bright backscatter returns from small pieces of broken ice in the radar image, just visible in the photograph, are clear. The three icebergs are clearly identifiable. Under these conditions, radar could do a good job of mapping icebergs and even smaller bergy bits. Backscatter from icebergs is much greater than from the ocean, and the shape of the bright returns helps to identify them.

We need more study of detectability of icebergs in very rough seas and in rough sea ice where the difference in backscatter or radar contrast between iceberg and background is substantially reduced. It is hard to detect smaller icebergs in the size range 10-50 m, especially in sea ice. Again, by optimizing the radar parameters, we can improve detection. We find that the radar contrast between iceberg and surroundings depends on the radar grazing angle and in these conditions angles less than approximately 10° are best. The reason seems to be that as the grazing angle decreases, the backscatter from sea ice decreases faster than that from icebergs. The contrast and therefore the detectability increases. Satellite SAR's cannot operate at low grazing angles. This is the major reason aircraft radars will be better for iceberg detection. For aircraft and satellite radars the detectability will be better if the iceberg is surrounded by open water rather than sea ice.

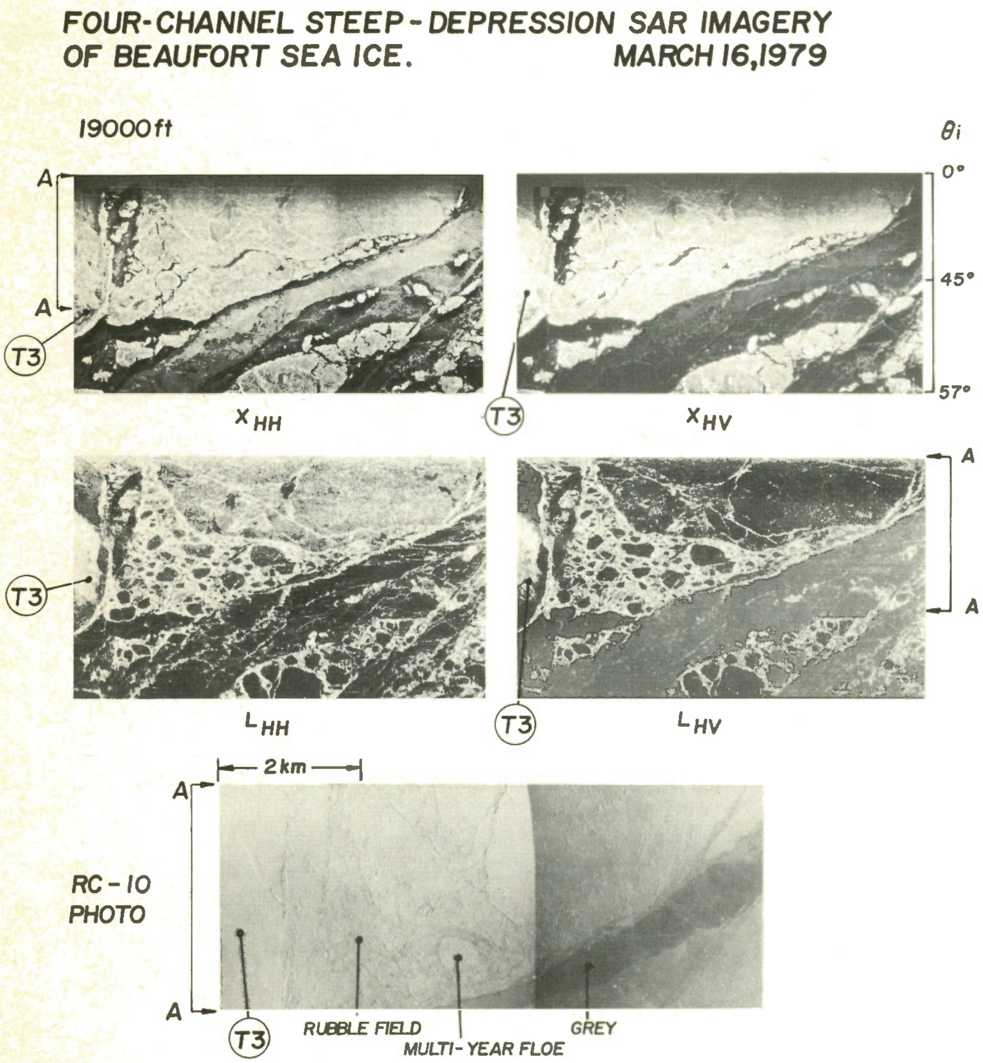

Figure 3

RADARSAT

The results obtained from CCRS radar are also being used to help in the Radarsat program, to develop a Canadian satellite-borne SAR. Specifications for this satellite, to be launched in 1990/91, are based on engineering evaluations and on recent and future experiments and experience with the Convair 580 aircraft and its radar sensors. Experience gained through the development of this world-leading microwave remote sensing facility demonstrates the need for and will aid the design of a Canadian radar satellite to help safe and efficient Arctic development.□

Geology of the Top of the World

CONCEPTS CHANGE as Exploration Advances

By R.L. Christie

To English mariners of the 14th and 15th centuries searching for riches of the Orient, each gulf, bay, or channel to the west promised an easy route. Gradually the idea of a Northwest Passage grew. Discovery advanced ever north and westward: John Davis to Davis Strait in 1586 and 1587; Henry Hudson into Hudson Bay in 1610; William Baffin and Robert Bylot to Smith, Jones and Lancaster Sounds in 1616, and Samuel Hearne overland from Churchill to the mouth of the Coppermine River in 1770-71.

The first Arctic navigators sailed centuries before the framework of modern geology was developed. They described the geology in terms obsolete today, and it is a fascinating exploration in itself to turn to the early accounts and find when a term was first used and what was meant by it.

In the early 1800's, when John Ross made a voyage to the Islands and confirmed Baffin's discoveries, the new science of geology was blossoming. Ross' 1818 voyage heralded a period of vigorous exploration and prodigious increase in geographical knowledge.

Next year, Edward Parry led the first expedition to winter and make overland journeys. Rocks and fossils seemed to suggest a progressive decrease in age of rocks from the southeastern to the northwestern parts of the archipelago — a generalization that still holds. The ages assigned were 'primary' for what we now call the Precambrian Canadian Shield and 'secondary' for rocks of Ordovician to Jurassic ages. These were terms of Abraham Gottlob Werner, one of the world's great teachers of geology and founder of the 'Neptunist School' of geology. He believed that the layered rocks, including those we now know were molten, were precipitated from a universal ocean.

Parry's descriptions of the Canadian Arcitc's immense channels and numerous islands fired the enthusiasm of the British, who sent out a series of expeditions. Parry returned to search for a passage further south and John Ross in 1829 took the paddle steamer *Victory*, the first steam-powered ship in the Arctic, to Boothia Peninsula. Ross was unlucky; although the Eskimos described Bellot Strait to him, he passed it twice without discovering it. Unable to extricate the *Victory* from its icebound winter harbour, the explorers eventually sailed homeward in small boats and were picked up by whalers.

In 1845, Sir John Franklin joined the search. Tragically, his two ships and entire party of 129 men disappeared, almost without a trace. But as a consequence of the catastrophe, a great part of the archipelago was explored over the next 12 years as the British searched it for their lost countrymen.

The geological model envisaged for the Arctic Islands in the mid-1800s shows the

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Dr. Robert Christie has travelled widely in the Arctic by dog sled, pack dogs, motor toboggan, canoes, backpacking and aircraft. His GSC career began in 1944 when he was a student assistant on one of the 'horse parties' then mapping the western Cordillera. During and after his studies in geology at the Universities of British Columbia and Toronto, he worked for the Survey in B.C., Yukon Territory, and the Arctic Islands, and in northern Greenland for the Geological Survey of Greenland. He joined GSC's Institute of Sedimentary and Petroleum Geology in Calgary in 1968. Recently, Bob has taken up a new field of study: sedimentary phosphate rocks, the source rocks for much of the fertilizer used in agriculture.

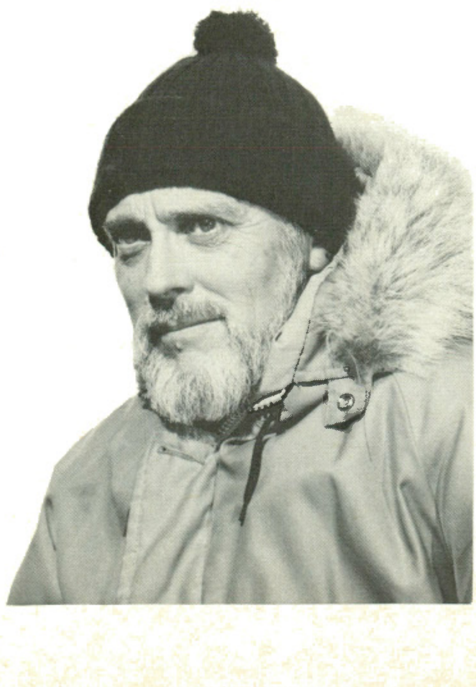
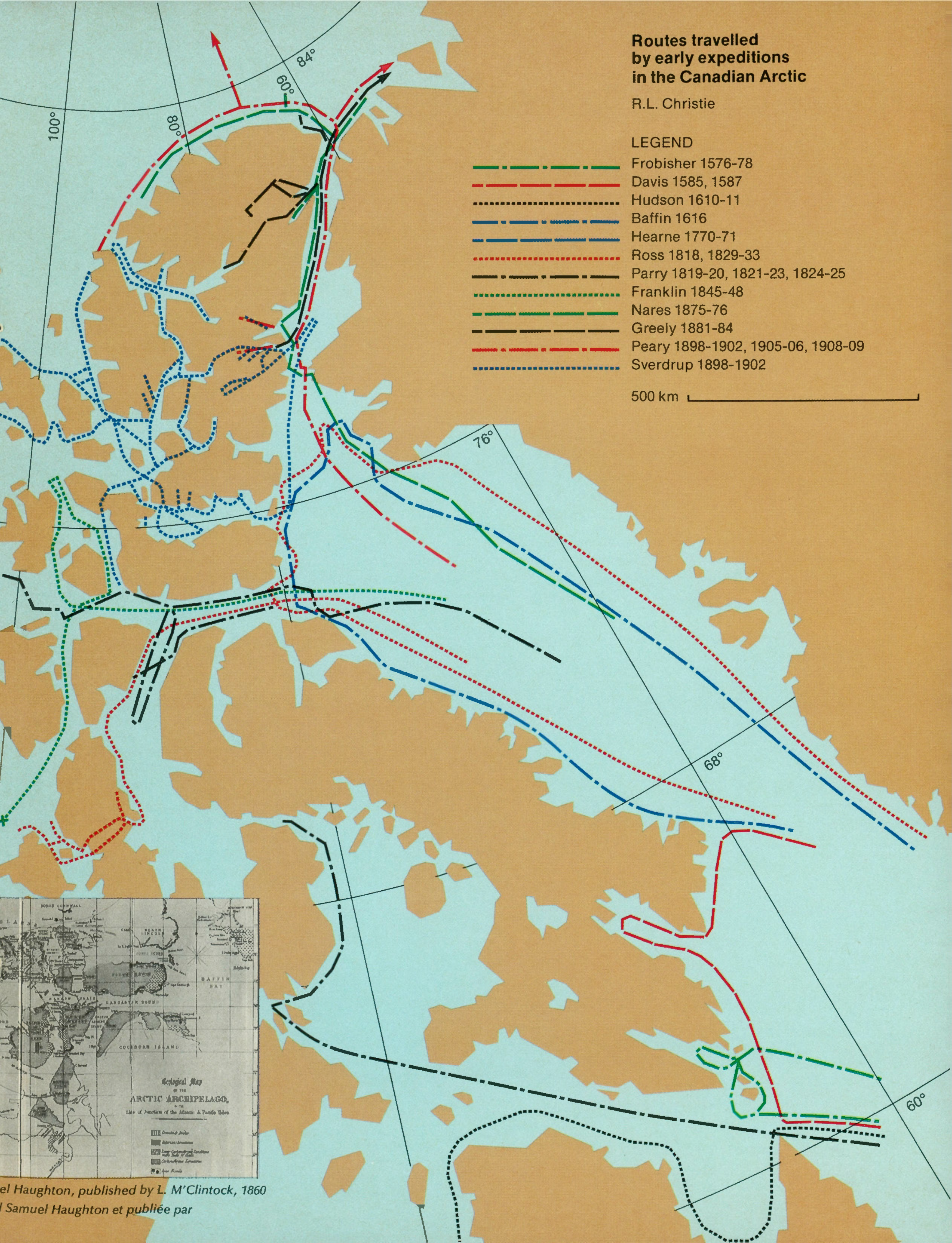


Figure 1. *Map by Rev. Sam*

Carte établie par le révérer
L. M'Clintock en 1860



el Haughton, published by L. M'Clintock, 1860
l Samuel Haughton et publiée par

influence of British geology. Devonian sandy and silty formations that lie between the Silurian limestones and the edge of the Sverdrup Basin on Bathurst and Melville Islands were assumed to be Carboniferous – as in England, where similar sandstones of Carboniferous age underlie Carboniferous limestone (Fig. 1). This assumption held for about 100 years until field work by Tim Tozer of the Geological Survey of Canada (GSC) revealed the mis-identity.

Geosynclines

American geologists like Henry D. and William B. Rogers, James Hall, James D. Dana, and Joseph Le Conte evolved the concept of geosynclines, linear sedimentary basins at the edges of continental masses and destined to become mountain chains. Hall tentatively formulated the theory of trough or synclinal areas of sedimentation in his presidential address on *The Geological History of the North American Continent* before the American Association for the Advancement of Science at Montreal in 1857. Hall's theory lay more or less dormant until 1873, when Dana introduced the term 'geosynclinal' (later to become 'geosyncline') for what Hall had called a 'syncline'. American geologists thought that geosynclines were characterized by great thicknesses of shallow water sediments. By 1900, Emile Haug, in France, influenced by the tectonics of the Mediterranean area, had modified the concept and included among geosynclines deep, elongate troughs in which great thicknesses of bathyal facies sediments accumulated. These were deep-water, but not abyssal sediments. Haug and other European geologists also supposed that geosynclines typically lay between two continents.

These novel theories on sedimentation and mountain building were based on syntheses of the geology of vast, newly explored areas such as Arctic North America. Expeditions of the late 1800s and the turn of the century contributed to the new understanding of these major features.

In 1875, The British government sent out its last Arctic expedition; Captain George S. Nares of the Royal Navy sailed in H.M.S. *Discovery* and *Alert* to northern Ellesmere Island. H.W. Feilden, the expedition naturalist, made an outstanding study of the coasts of Ellesmere Island and Greenland. His map and report, written with C.E. De Rance, were the first on Arctic geology by a geologist from his own field work.

Lieutenant Adolphus W. Greely of the U.S. Army and Commander Robert E. Peary of the U.S. Navy carried out scientific and geographic exploration in northern Ellesmere Island in 1881-83 and 1898-1909, respectively. Greely's expedition was one of twelve polar expeditions fielded simultaneously for the 'International Polar Year' (1881-83), and represents the first systematic study of the physics of the high latitudes. The expedition ended in tragedy; Greely and his men were forced to retreat southward in small boats. They spent a long winter under an overturned boat with starvation rations and only six of the party of 26 survived. Peary travelled some of the same region as Greely, but he focussed mainly on geographical discovery and reaching the North Pole.

Otto Sverdrup took the famous north-pole ship, *Fram* into the Arctic Islands in 1898. Using dogs and skis, the rugged Scandinavian crew made prodigious journeys along the shores of Ellesmere, Axel Heiberg, and other islands. Sverdrup and his party discovered 'new land' almost wherever they went during the period of four years. More than any other, this expedition, with its geologist Per Schei, advanced the geological understanding of the Islands.

> Vigorous exploration and a prodigious increase in geological knowledge came just at the time the new science of geology was blossoming.

The general geological nature of the Canadian Arctic began to emerge as succeeding expeditions returned with rock specimens and field notes. The American Charles Schuchert incorporated this information in his new scheme for geosynclines based on characteristics of the North American sedimentary basins. He named the northern marginal sedimentary belt the Franklinian Geosyncline, and proposed a former landmass, Pearya, based on specimens of crystalline rocks from northern Ellesmere Island returned by the Nares and Peary expeditions (Fig. 2). Geosynclinal theory now had evolved to recognize several types of mountain-chain basins, and Haug's Mediterranean-type geosynclines were considered a special type, not comparable to other geosynclines. Schuchert described the Franklinian Geosyncline variously as existing into the Mesozioc (Upper Cambrian to Triassic) and being 'blotted out' by a Permian orogeny.

Hans Stille of Germany further refined the geosynclinal concept in the period 1936-40. He introduced a scheme based on study of European and western North and South American mountain chains. It included the terms, orthogeosyncline ('true' geosyncline, with Alpinotype orogeny), eugeosyncline (part of the geosyncline with volcanic and intrusive rocks), and miogeosyncline (lacking or hardly any geosynclinal vulcanism).

What of the platform part of the Canadian Arctic, south of the Franklinian Geosyncline? Edward Suess of Austria, in 1906, reviewed the geology of the archipelago in the course of his greater work 'The Face of the Earth', and in a succinct way described what I will call the 'Suess model': . . .the several sedimentary formations . . .are so arranged that they strike east or northeast, and become progressively more recent as they are traced toward the pole. This and his other deductions were perceptive and daring thoughts on high Arctic geology. Writers of the early 1900s followed the British model for the ages of the succession of rocks and the Suess model for the simple structural style in which successively younger strata onlap onto a Laurientian shield. An example of this is the description by G.A. Young in the first edition, 1909, of GSC's *Geology and Economic Minerals of Canada*, a review of the geology of Canada generally known as *EG-1*.

Explorer-Geologists

Ice-strengthened ships and long-range aircraft made the North more accessible in the 20th century. Geologists carrying out their own exploration rather than as a small part of a large expedition, covered the farthest reaches of the Canadian Arctic and Greenland.

A Danish geologist, Lauge Koch, explored northern Greenland and touched on Ellesmere Island between 1916 and 1923. He recognized Schuchert's Franklinian Geosyncline but called it the Smith Sound geosyncline in Greenland. J.C. Troelsen, another Dane, travelled parts of Ellesmere and Axel Heiberg Islands and referred to both names for the geosyncline, and also to Pearya, the 'hypothetical borderland'. In field work overlapping the beginning of World War II, Troelsen noted downwarping of a 'Permian basin of deposition' but referred to the upper Paleozoic and Mesozoic beds as a 'wedge'. The concept of the Sverdrup Basin, a deep depression containing upper Paleozoic and younger sediments, began to take shape; Troelsen recognized the importance of the sub-Pennsylvanian unconformity and returned to a key locality, man-hauling his gear and travelling alone. In his published results in 1950 and 1952, he reintroduced the name Franklinian Geosyncline in Arctic literature after a lapse of 27 years!

Yves O. Fortier, later GSC Director-General, accompanied RCAF Canso flights into the Arctic Islands from 1947 to 1949, and in 1950 Fortier and Raymond

Thorsteinsson began a survey of Cornwallis Island. These projects mark the beginning of systematic study by the Survey of the Canadian Arctic Archipelago, a study that continues today, carried out by geologists now too numerous to name in this brief account.

Survey publications describe the results of the systematic field studies in the Islands and from time to time synthesize the geological structure and stratigraphy. Each synthesis refines or advances the concepts of the past. The earlier, 'Suess model' interpretation of the western Arctic Archipelago as a stable shield overlain by essentially flat-lying sedimentary rocks was at last discarded when Fortier and Thorsteinsson delineated and named several 'fold belts' in 1953.

The detective game continues to discover who used what term. If a scientist used a certain label, presumably he supported that concept. If he avoided it, he probably had his doubts. Yves Fortier, later Director General of the Geological Survey of Canada, introduced the term Innuitian in 1954, meaning a large tectonic region in which lie various structural units and sedimentary basins. 'Eugeosynclinal' and 'miogeosynclinal' fold belts were shown on a map although the Franklinian Geosyncline itself was not mentioned. The 'Sverdrup Area' was noted, and it was tentatively suggested that the 'Eureka Sound Fold Belt' is a 'later, superimposed geosyncline'. In this 1954 compilation a huge area of Melville and Bathurst Islands is shown as 'Pu', or 'probably mainly Permo-Carboniferous and Devonian', thus following, for the last time, British assumptions.

The concept of a Sverdrup Basin, in which Pennsylvanian and younger rocks form a basinal, conformable sequence that unconformably overlies folded lower Paleozoic rocks, finally was established in 1955 during GSC's helicopter-supported 'Operation Franklin'. The epic account of Operation Franklin by Fortier and others appeared after many delays, in 1963. This thick volume with masses of stratigraphic, structural, and geomorphological data at last defined the Sverdrup Basin and included it in the Innuitian Region. In the same year, a petroleum-oriented synthesis of all northern Canada was published by Robert J.W. Douglas, D.K. Norris, Thorsteinsson and Tozer. This paper named the assorted fold belts, the Franklinian Geosyncline and the Sverdrup Basin, but not Innuitian. All three terms appeared, together at last, in 1970 in the most recent, the fifth, edition of EG-1, in a synthesis by Thorsteinsson and Tozer. To make the detective story complete, the mio-and eu-components of the Franklinian Geosyncline also appear.

More recent papers, especially those of H.P. Trettin and J. William Kerr, reveal more refinements. The Franklinian Eugeosyncline appeared with all colours flying in the title of a 1968 paper by Trettin and a 'magmatic belt' at the edge of the eugeosyncline was distinguished. These authors named other basinal or arch features about this time: the Thule Basin and Bache Peninsula Arch and the 'Pearya Geanticline' and 'Hazen Trough'. The Pearya Geanticline may be the final form of the concept that began with Schuchert's borderland 'Pearya'.

J.F. Dewey and J.M. Bird had fully elaborated the 'new global tectonics'. The basins, arches, geanticlines, and the plethora of paralia- epieu-, and other -geosynclines proposed by Kay in 1944 and 1947 seemed to fit into a scheme, perhaps with some exceptions. Argument still flourishes over these recent concepts, but data from the Canadian Arctic will continue to flow and to help us understand the grand features and the small of our fascinating globe.□

British ships wintering in Wellington Channel during their search for the lost Sir John Franklin expedition

Les navires britanniques hivernent dans la passe de Wellington; ils sont à la recherche des membres de l'expédition Sir John Franklin portés disparus

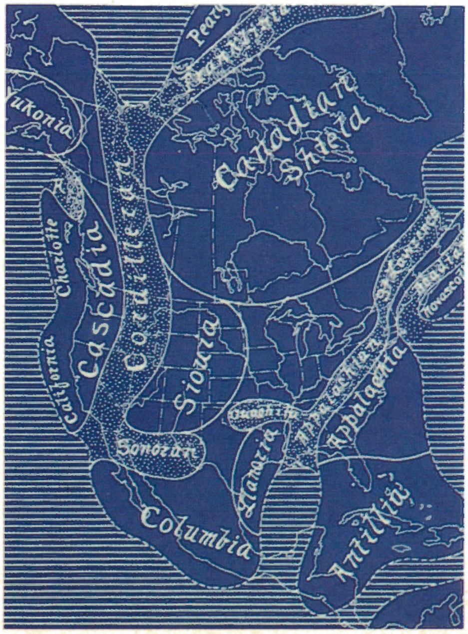


Figure 2. *Charles Schuchert's map figure, 1923*

Illustration de la carte que Charles Schuchert a établie en 1923

Au début du XIX[e] siècle, à l'époque où le marin britannique John Ross explora les îles de l'Arctique et confirma les découvertes de William Baffin, la géologie était en plein essor. L'exploration intensive de l'Arctique et une extraordinaire augmentation des connaissances géographiques sont allées de pair avec l'évolution des concepts géologiques. La participation de géologues britanniques, américains, scandinaves, allemands et autrichiens à de nombreuses missions de recherches a permis de mieux comprendre le milieu arctique, que la Commission géologique du Canada commença à étudier systématiquement en 1950. Depuis ce temps-là, chaque synthèse améliore ou fait progresser les concepts établis dans le passé.

LES SATELLITES
à la rescousse de la cartographie

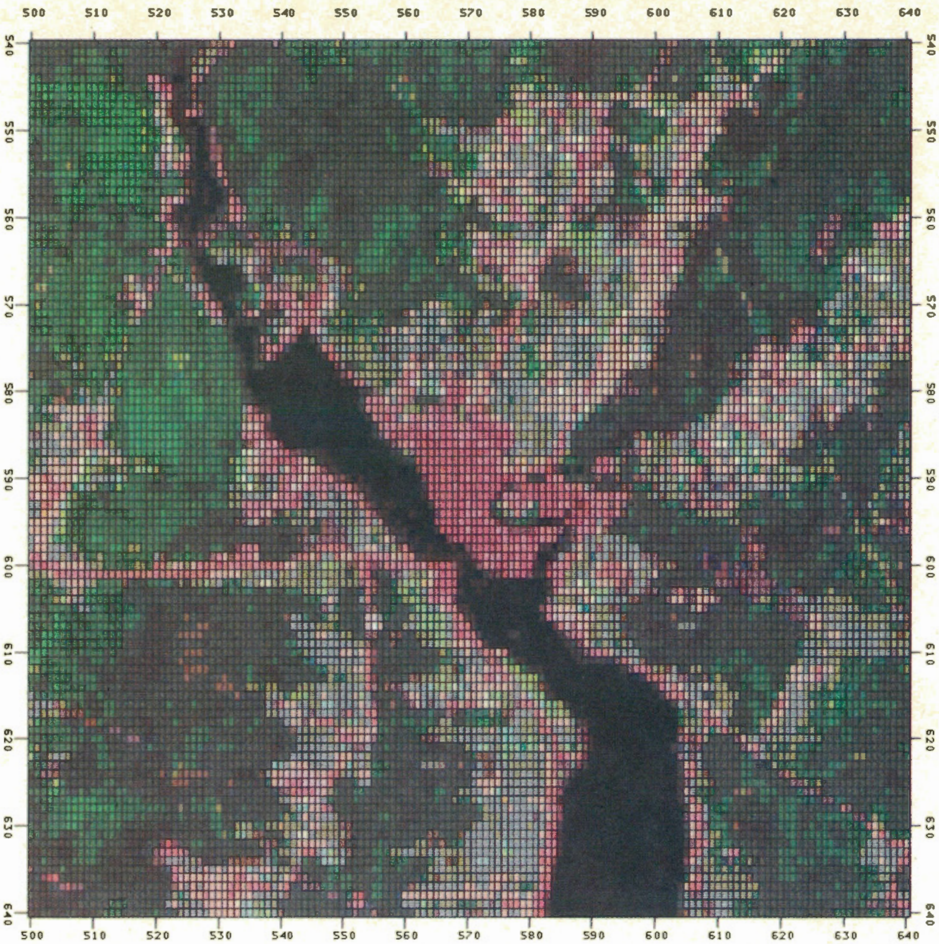


Figure 1. *Identification des pixels. Chaque pixel encadré en noir correspond à une parcelle de terrain de 57 × 79 m*

Pixel identification map. Each black rectangle corresponds to a pixel measuring 57 × 79 m

Par Robert Bélanger

Face au besoin pressant d'une cartographie sur une grande échelle du Nord canadien et aux problèmes qu'entraînent les méthodes traditionnelles de cartographie, la Commission géologique du Canada a élaboré un projet visant à mettre au point un nouveau procédé de production de cartes géologiques adaptées au contexte nordique en se servant d'images provenant de satellites.

Au moment où cet article allait sous presse, M. Robert Bélanger défendait sa thèse de doctorat en géographie à l'Université de Strasbourg en France. Il s'est spécialisé en télédétection à cet endroit et également lors des études pour une maîtrise qu'il a poursuivies à l'Université d'Ottawa. Il a quitté la France pour effectuer en Mauritanie un stage de deux mois à titre de conseiller de la banque des données de l'ONU. Il reviendra ensuite à la Division de la science des terrains de la CGC où il a déjà oeuvré depuis 1969 dans différents secteurs de la cartographie réalisée au moyen de l'informatique et de la télédétection.

Les images de satellites.

En 1972, la NASA procédait au lancement d'un satellite appelé ERTS (Earth Resources Technology Satellite) pour obtenir de façon continue des images de la terre. Pour atteindre cet objectif, on plaça le satellite sur un orbite quasi-polaire et synchronisé avec le soleil; c'est à dire qu'au cours de sa trajectoire nord-sud, le satellite se trouve du côté éclairé du globe, alors que sa trajectoire sud-nord s'effectue du côté obscur. Par suite du mouvement de rotation de la terre, le satellite peut photographier la surface terrestre par tranches successives chaque fois qu'il effectue une courbe descendante.

On trouve à bord du satellite deux systèmes de caméra: un premier, formé de trois Vidicons à retour de faisceaux ou RBV (Return Beam Vidicon), fonctionnant selon le même principe que des caméras de télévision, fournit des instantanés sur trois longueurs d'onde (vert, rouge et proche infrarouge) à intervalles réguliers et couvrant une superficie de 185 km par 185 km. Ces données sont enregistrées sur ruban vidéo sous forme analogique puis reproduites sur pellicules photographiques comme des photographies aériennes. Le second système est formé de balayeurs multispectraux ou MSS (Multi Spectral Scanners) enregistrant la réflectance des objets sur quatre longueurs d'onde (vert, rouge et deux proches infrarouges). Contrairement au système RBV, les capteurs MSS balayent continuellement la surface de la terre sur une largeur de 186 km formant ainsi une image continue, ligne par ligne, durant toute la trajectoire nord-sud. Les don-

CLASSIFICATION NON SUPERVISEE
SUPERFICIE MINIMUM DES CLASSES: 2X2 PIXELS
SCENE MSS DE LANDSAT DU 29 JUILLET 1973

LAC KAMINAK T.N.O.

27 %	EAU
2 %	ROCHE EN PLACE, BLOCS, ESKERS
5 %	BLOCS(FELSENMEER), TILL GROSSIER
21 %	TILL MINCE/ROC
23 %	TILL 1
8 %	TILL 2
5 %	TILL 3
.5 %	SEDIMENTS MARINS
3 %	ALLUVIONS

Figure 2

La CGC se tourne vers la télédétection pour cartographier le Grand nord

nées de réflectance sont enregistrées et transmises sur la terre sous forme digitale puis enregistrées sur rubans magnétiques ordinolingues.

Bien que le lancement du satellite ERTS ait été effectué à titre purement expérimental, la qualité exceptionnelle des images qu'il fournissait a poussé la NASA, avec la collaboration de plusieurs pays dont le Canada, à placer en orbite deux autres satellites du même type; on baptisa ces trois satellites LANDSAT 1, 2 et 3.

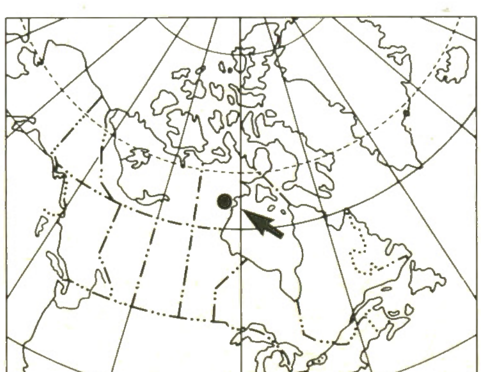
Le traitement des images.
Les images fournies par le système RBV sont généralement reproduites sous forme de photographies aériennes classiques en fausses couleurs. On utilise le terme fausse couleur parce que les couleurs sur la photo ne correspondent pas aux couleurs des ondes captées par les détecteurs; le bleu, le vert et le rouge des photographies correspondent respectivement au vert, au rouge et à l'infrarouge des capteurs RBV. En plus de couvrir une très grande surface, ces images ont l'avantage d'être continuellement mises à jour. Chaque satellite peut en effet photographier la terre en entier tous les dix-huit jours. En raison de la distance des capteurs de la surface terrestre, la résolution spatiale des images n'est que de 40 m par 40 m; bien que cette résolution soit quelque peu grossière, elle n'affecte en rien la netteté de l'image jusqu'à des échelles dépassant le 1:200 000.

Le traitement des scènes MSS, pour sa part, est différent à cause de la nature digitale de l'enregistrement des données de réflectance. L'enregistrement de la scène s'effectue ligne par ligne; chacune d'elle d'une longueur de 186 km est subdivisée en 3 200 unités représentant une parcelle de terrain de 57 × 79 m appelée Pixel (picture element) (*figure 1*); l'ensemble des caractéristiques spectrales de chaque pixel porte le nom de signature spectrale du pixel. La reproduction des scènes MSS peut se faire soit de la même façon que dans le cas des scènes RBV en convertissant les valeurs numériques de réflectance en signaux analogiques, soit par le traitement informatique des valeurs digitales. La sortie cartographique des images peut se pratiquer sur écran cathodique ou à l'aide de traceurs monochromes ou polychromes.

La cartographie thématique.
La cartographie thématique, c'est à dire celle qui porte sur un sujet unique, pose certains problèmes en télédétection, parce que la discriminiation spectrale ne varie pas nécessairement selon des catégories voulues par l'analyste. En effet, lorsque les capteurs MSS balayent la surface de la terre, ils enregistrent la signature spectrale de tous les objets perçus, sans distinction quant à leur signification. Le travail de l'interprète consiste donc à extraire de cette masse d'information, celle reliée aux thèmes qu'il désire traiter.

L'interprète, dans le cas des photos de type classique, identifie les objets à partir des différentes teintes (textures) et formes (structures) de l'image, puis rattache ces phénomènes au thème qu'il désire traiter, en se fondant sur l'expérience acquise sur le terrain. La télédétection, fondées sur les données MSS de LANDSAT, permet de pousser plus loin l'interprétation des paysages spectraux, grâce au format digital des signaux et à l'information supplémentaire fournie par des longueurs d'ondes non visibles à l'oeil humain. En effet, l'enregistrement sous forme digitale permet une identification plus précise des signatures, permet d'accentuer certains contrastes entre les phénomènes, grâce à un traitement mathématique des données, en plus de quantifier les différentes composantes du paysage. Grâce à l'apport de l'infrarouge, il est possible de détecter certaines variations entre les objets qui autrement pourraient passer inaperçus. L'analyse des scènes MSS exige donc une approche quelque peu différente de celle qui est utilisée pour interpréter les photos de type classique ainsi que de nouvelles techniques cartographiques pour reproduire toutes les subtilités des signatures spectrales.

La cartographie du Nord canadien.
Certaines difficultés risquent de surgir lorsqu'on effectue la cartographie des formations géologiques superficielles au moyen de la télédétection. C'est ce qui se produit lorsque le sol est bien développé et recouvert d'une végétation bien établie, comme c'est généralement le cas à moyenne ou à basse latitude. Le Nord canadien offre cependant un milieu privilégié pour la cartographie géologique, étant donné que le climat froid et semi-aride ralentit le développement des sols et lie étroitement la végétation à la nature des dépôts, facilitant ainsi leur identification.



Lac Kaminak

A titre d'exemple d'interprétation d'une scène LANDSAT, on donne dans *la figure 2* une carte chromatique, produite par ordinateur, de la région du lac Kaminak, située près de la côte de la baie d'Hudson. Cette carte a été produite en se servant des canaux MSS 4, 5 et 7 auxquels on a fait correspondre respectivement les couleurs primaires bleu, jaune et rouge. L'intensité de chaque couleur primaire est proportionnelle à la réflectance des objets perçus par les capteurs MSS afin de reproduire de façon analogique les signatures spectrales enregistrées de façon numérique. Il s'agit dans ce cas d'une classification non supervisée des signatures individuelles, car elles sont regroupées en classes correspondant à leur ressemblance spectrale et non à partir de catégories basées sur des données de terrain. Cette façon de procéder permet à l'interprète de rattacher les classes au thème qu'il désire traiter comme dans le cas de l'interprétation de la photo de type classique plutôt que de l'obliger à utiliser des classes définies à l'avance, risquant de n'avoir aucun équivalent en ce qui concerne la discrimination spectrale. La légende accompagnant cette carte donne une interprétation des principales classes ainsi que de la superficie couverte par chacune d'elles. Elle fait abstraction des classes mineures (superficie .5%), car il s'agit généralement de classes transitoires entre les classes principales et leur signification est souvent très aléatoire à cause de leur imprécision.

En utilisant une approche analogique dans la reproduction des classes spectrales, il est possible d'établir un parallèle entre l'évolution des signatures et leur signification sur le terrain. On peut remarquer, sur la carte interprétée, l'influence de la production de chlorophylle par les plantes sur la réflectance de l'infrarouge de la façon suivante: les affleurements rocheux, complètement dénudés, apparaissent en rouge (forte réflectance), puis au fur et à mesure que la végétation devient plus dense, soit dans les champs de blocs, sur le till mince et enfin sur le till épais, les teintes passent de l'orange au brun-rouge et à différentes teintes de vert. *La figure 3* explique plus en détail la légende de la carte en établissant un parallèle entre la classe spectrale, le type de dépôt, le drainage, la végétation et la fragilité du dépôt. Dans l'analyse d'une scène LANDSAT, ou toute autre image provenant de la télédétection, il est nécessaire d'utiliser une légende très élaborée, même si celle-ci dépasse les cadres du thème traité, car les classes spectrales répondent à une foule

Figure 3. Interprétation de la légende de la carte.

CLASSE	DESCRIPTION	VÉGÉTATION
Roche en place, blocs, eskers	Roche en place ou gravier et blocs dénudés. Habituellement en saillie dans le relief. Bon drainage. Dépôt stable.	Aucune, lichens
Blocs (felsenmeer), till grossier	Champs de blocs dérivés de la roche locale en place; till grossier recouvert de blocs de 0,5 à 3 m de diamètres. Bon drainage. Dépôt stable.	Aucune, lichens, mousses entre les blocs
Till mince sur roche en place	Dépôt non consolidé de 1 m d'épaisseur, 10-30 % d'affleurements rocheux. Bon drainage. Drainage moyen ou pauvre. La probabilité de dégradation augmente avec l'épaisseur des dépôts.	Lichens et mousses clairsemés, herbes, arbustes nains
Till	Dépôt non consolidé formé de silt, de sable et de cailloux, généralement inférieur à 30 cm de diamètre. Le pergélisol se situe en moyenne à 1 m de la surface mais peut être de 70 cm sous une couverture de mousses et de 2 m lorsque la végétation est absente. Les tills 1, 2 et 3 se différencient par la couverture végétale, maintenue par la composition granulométrique (susceptibilité à retenir l'eau) et le drainage.	
Till 1	Texture grossière en surface; bon drainage. Matière souvent active (osioles et solifluction) et très sensible à la dégradation consécutive à la présence humaine.	Lichens, mousses, arbustes nains. Couverture non continue.
Till 2	Texture et drainage moyens. Nature et comportement du dépôt se situant entre les till 1 et 3.	Mousses, herbes et graminées. Présence d'arbustes nains.
Till 3	Texture de fine à moyenne; drainage, de moyen à pauvre. Matière généralement humide selon le relief ou la propension à retenir l'eau. La stabilité du dépôt est assurée par la présence de la végétation à Thermokarst et formation de nappes d'eau si la végétation est enlevée.	Mousses (sphaigne), herbes, graminées, arbustes nains. Végétation dense.
Sédiments marins	Argile et silt; drainage de moyen à pauvre. Très sensible à l'érosion (thermokarst, ravinement, glissement, etc.) lorsque la végétation est enlevée.	Herbes (tussak), broussailles dans les endroits protégés, arbustes nains. Végétation dense.
Alluvions	Silt, sable et gravier récents; dépôt fluviatile ou délavé par la mer avant le soulèvement isostatique. Drainage de moyen à pauvre dû principalement au relief. Sujet à l'érosion (éolienne et ravinement) lorsque la végétation est enlevée.	Mousses, herbes, sphaigne. Végétation dense.

de phénomènes composant le milieu naturel et non à un facteur unique. D'ailleurs cette taxonomie inhérente à la télédétection est souvent bénéfique parce qu'elle permet de saisir certaines relations qui existent entre les différentes composantes de l'environnement naturel, telles que la flore, la géologie, le relief, etc; celles-ci pourraient passer inaperçues si on utilisait des moyens traditionels d'interprétation. La légende présentée ici constitue un exemple d'interprétation des classes spectrales; ce type de légende est cependant beaucoup plus élaboré dans le cas d'une étude approfondie.

Bien que la résolution des capteurs des LANDSAT soit encore très grossière et que la signature spectrale soit limitée à quelques longueurs d'onde, les scènes MSS demeurent un moyen très efficace pour dresser l'inventaire des ressources naturelles et de l'environnement biophysique du Nord canadien. Les images de satellite jouent un rôle d'autant plus important qu'elles sont constamment mises à jour, ce qui permet de suivre l'évolution de l'environnement. Elles ne nécessitent aucun investissement supplémentaire lors de chaque nouvelle couverture photographique comme ce serait le cas pour les systèmes aéroportés. Les LANDSAT 1 et 2 ont cessé de fonctionner en 1978 et 1980 respectivement. Le succès de cette première génération de satellites à encouragé les pays qui participaient au projet à mettre au point de nouveaux satellites équipés de capteurs plus perfectionnés, afin d'améliorer la qualité des images au niveau de la précision des signatures et de la résolution spatiale. Il est donc permis de croire que la télédétection, effectuée à partir de vaisseaux spatiaux, est appelée à jouer un rôle de plus en plus important et que dans un avenir rapproché on pourra l'utiliser dans un grand nombre de domaines.□

Faced with a pressing need for large scale geological maps of the Canadian north, and with problems of isolation and short mapping season, the Geological Survey of Canada has developed a new procedure for map production, using satellite images.

Over the Arctic, these images, from Landsat satellites 1, 2 and 3, are especially useful. In the cold, dry climate, vegetation is sparce, and related closely to mineral composition of the rocks. The identification of deposits is thus made easier.

The author analyses an image of Lake Kaminak area, near the west shore of Hudson Bay, to abstract information about and the inter relationship of environmental factors, including vegetation, geology, relief, etc.

Arctic Corrosion

By G.J. Biefer

What does the Arctic climate do to machinery, tools and other structured metals prone to corrosion? Until 1977, no hard data were available, and travellers' observations conflicted.

Canada Centre for Mineral and Energy Technology (CANMET) studied the problem from July 1, 1978 to July 1, 1979. Researchers developed a light, compact, inexpensive corrosion specimen made of a length of clean, mild steel wire, wound into the threads of a vertically mounted nylon bolt (Fig. 1). Exposure corrosion rates could be calculated from the loss in weight of the derusted wires.

Dr. Greg Biefer has been a research scientist in the Corrosion Section of CANMET's Physical Metalurgy Research Labs since 1960, and engaged in atmospheric corrosion studies since 1969. He first worked on the effect of alloying additions to steel, but from 1975 has been constructing an atmospheric corrosion map of Canada's Arctic. At present he is studying 'stepwise cracking,' a form of hydrogen sulphide induced damage suffered by gas transmission pipelines. A McGill graduate, he was with the RCAF, duPont USA, and Atomic Energy of Canada Limited before coming to CANMET.

Steel corrosion rates decrease from south to north and east to west. Higher rates in the Arctic were almost always close to the sea.

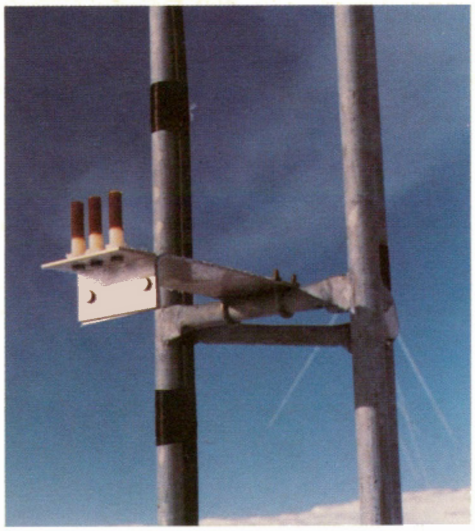


Figure I. *Mild steel corrosion specimens*

Eprouvettes servant à l'étude de la corrosion de l'acier doux

Three specimens were installed at each test site. Environment Canada personnel stationed from Alert, NWT to Moosonee installed most of them in isolated Arctic posts. The Canadian Gas Association helped with comparative tests in southern Canada.

In general, the highest corrosion rates reported at each location decreased from south to north and east to west (Fig. 2). Very low rates of less than five micrometres a year (µm/a) showed inland in the continental Northwest Territories and in the High Arctic Islands. Relatively high rates of over 20 µm/a, equal to those in industrially polluted areas of southern Ontario and Quebec, were also observed at isolated places in the Arctic and sub-Arctic. The high levels were almost always found close to the sea and were attributed to chloride contamination. The highest was 34 µm/a, at Inouedjouac, P.Q., on the eastern shore of Hudson Bay. The moderate corrosion rate of 15 µm/a at Yellowknife seems to have been caused by industrial pollution.

Compared with results in other countries, none of the atmospheric corrosion rates are more than moderately high. However, they do show that in some restricted and industrial environments in the North, corrosion will be a problem and anti-corrosion measures are advisable.□

Entre le 1er juillet 1977 et le 1er juillet 1978, le Centre canadien de la technologie des minéraux et de l'énergie (CANMET) a comparé les taux de corrosion relevés dans l'Arctique à ceux qui ont été observés dans le Sud du Canada. Afin de mesurer la corrosion, il a mis au point une éprouvette légère, compacte et peu coûteuse qui est constituée d'un fil propre en acier doux que l'on a enroulé dans les filets d'un écrou de nylon monté verticalement. Les taux de corrosion signalés diminuaient du sud au nord et d'est en ouest, les plus faibles se situant à l'intérieur des terres et dans les îles du Haut-Arctique. Dans l'Arctique, les taux les plus élevés ont presque toujours été observés à proximité de la mer.

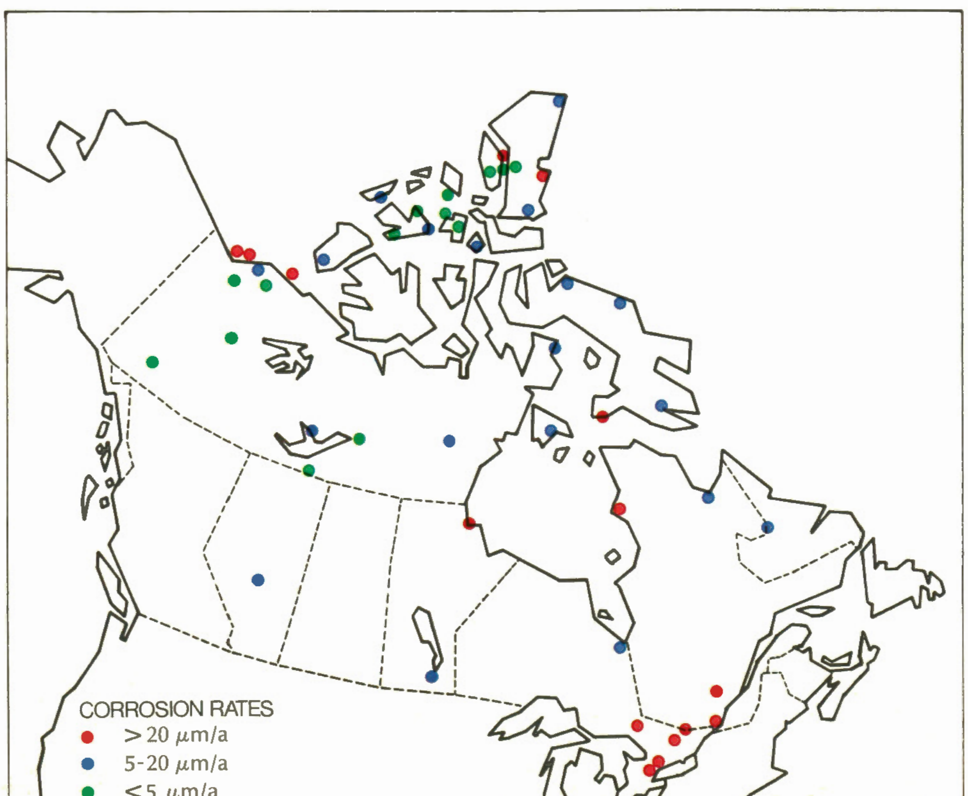
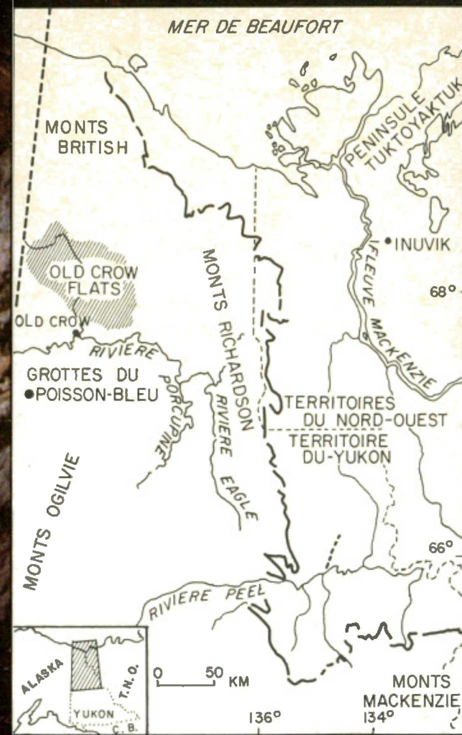


Figure 2. *Highest atmospheric corrosion rates recorded for mild steel, July 1, 1978 to July 1, 1979*

Taux élevés de corrosion atmosphérique de l'acier doux, relevés entre le 1er juillet 1978 et le 1er juillet 1979

Des preuves nouvelles viennent appuyer la thèse voulant que des chasseurs aient vécu au Yukon à l 'âge glaciaire.



L'auteur et un assistant au début du sondage 1979, à l'intérieur de la grotte I

The author and an assistant begin excavation inside cave I in 1979

LES GROTTES du poisson-bleu

Par Jacques Cinq-Mars

Les grottes du Poisson-Bleu ont livré aux archéologues, pour la première fois dans l'histoire de la recherche béringienne, une série de gisements non-remaniés, fournissant un éventail complexe de données paléoenvironnementales, associées à des vestiges culturels datant d'avant 12 000 ans B P (Before present — avant maintenant). Ces données ouvrent une fenêtre sur un monde en transformation, en voie d'extinction, sur un paysage sévère, à la limite des terres non-glaciées, où pendant plus de 5 000 ans au moins, des groupes humains ont réussi à développer divers modes d'adaptation qui, peut-être, tirent leur origine d'expériences plus anciennes dans la même région et qui, possiblement, ont été d'une grande utilité lorsqu'il s'est agi pour certains parmi eux ou leurs descendants de pénétrer plus profondément au coeur du continent nord-américain.

La Béringie orientale correspond à ces vastes espaces non glaciés d'Alaska et du Yukon septentrional qui, plusieurs fois au cours du Pléistocène, se trouvèrent relativement isolés, biologiquement parlant, du reste de l'Amérique du Nord par les avancées conjuguées des glaciers de la Cordillère et de l'inlandsis continental dans les régions environnantes. À ces phénomènes répétés de coupures biogéographiques vers le sud-est correspondait cependant une ouverture vers l'Asie du nord-est, résultant des abaissements du niveau de la mer qui transformèrent en isthme l'actuel détroit de Béring.

C'est au cours de telles périodes, et ce dans un paysage qu'on croit avoir été caractérisé par un climat froid et sec, par une disparition momentanée de la forêt boréale et par une toundra relativement aride, riche en plantes herbacées, très différente de celle qu'on connaît aujourd'hui, que se sont effectués de nombreux échanges biologiques entre l'Asie et l'Amérique.

En partie à cause de cette proximité géographique et même de ce raccordement continental, on a depuis longtemps émis l'hypothèse que des populations humaines d'origine asiatique ont dû à un moment donné participer activement à certains de ces échanges. Il semble fort probable que cela se soit produit durant la dernière grande période glaciaire, dite wisconsinienne; en effet, les régions centrales et méridionales de l'Amérique étaient déjà occupées par de nombreux groupes humains à la toute fin du Pléistocène, il y a plus de 10 000 ans.

Afin de mieux comprendre l'origine de ces premières manifestations culturelles dans le Nouveau-Monde, on a effectué au cours des dernières années, en Alaska et surtout au Yukon septentrional, dans le bassin de la rivière Porcupine, de nombreux travaux de recherches interdisciplinaires portant sur le milieu béringien du Pléistocène supérieur et sur les vestiges culturels des premiers humains qui s'y sont adaptés.

Alors qu'une bonne partie de ces travaux a été orientée vers le décodage des don-

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nées très anciennes, issues des sédiments lacustres du bassin d'Old Crow (voir GEOS: Hiver 1978, p.2-5), d'autres ont consisté à examiner les vestiges de manifestations préhistoriques que l'on retrouve sur le pourtour de tels bassins ainsi qu'à proximité, en région de plateaux et en montagne.

Les grottes du Poisson-Bleu

C'est dans ce contexte qu'ont été découvertes accidentellement, en 1975, à 54 km au sud-ouest du village d'Old Crow, les trois grottes du Poisson-Bleu. Situées au pied d'un excarpement rocheux surplombant d'environ 250 m la rive droite de la rivière Bluefish (Poisson-Bleu), un affluent de la rivière Porcupine, elles semblent s'être formées, au cours des temps, par dissolution et par gélifraction d'anciennes brèches calcaires peu homogènes. Ces dernières sont assez communes dans cette région de massifs calcaires, correspondant à la partie nord-ouest des contreforts des monts Ogilvie. On y a d'ailleurs récemment découvert, en 1981, un certain nombre d'autres grottes ainsi que quelques dolines, signes indubitables de l'existence d'un réseau karstique encore mal connu.

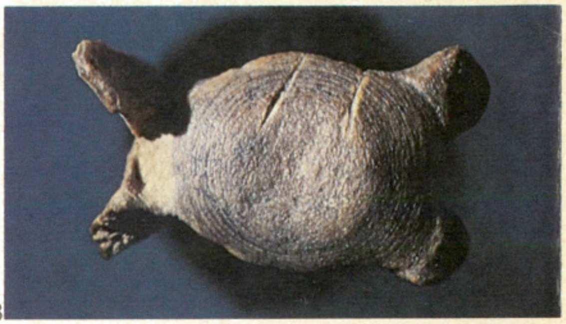
Pour des raisons d'ordre logistique, les grottes du Poisson-Bleu ne purent être sérieusement examinées qu'à partir de 1977 lorsqu'on y effectua un sondage très préliminaire de la grotte I. Les résultats de ce sondage ayant alors révélé la présence dans le gisement de matériel paléontologique d'âge possiblement Pléistocène, on décida d'entreprendre des travaux de fouille poussés; ce qui fut fait au cours des étés 1978, 1979 et 1981 avec la participation de spécialistes en palynologie, en sédimentologie, en paléontologie et en archéologie.

À ce jour, les trois grottes ont été étudiées et toutes trois ont fourni des données qui enrichissent énormément notre connaissance du milieu béringien tardiglaciaire et qui révèlent, sans l'ombre d'un doute, que des groupes humains ont été témoins, sinon participants, de la vague d'extinction qui déferla sur la faune à grands mammifères durant les derniers millénaires du Pléistocène.

Ces grottes consistent en de petites cavités de faibles dimensions, c'est-à-dire de trois à cinq mètres de profondeur et environ trois à quatre mètres de largeur; on pourrait en fait les qualifier d'abris. Les sondages et les fouilles effectués aussi bien à l'intérieur qu'à l'extérieur, sur les replats en face des abris, suggèrent une séquence de remplissage relativement simple, caractérisée en premier lieu par un apport de sédiments allochtones suivie d'un développement autochtone. Schématiquement, la stratigraphie peut se décrire comme suit. De bas en haut on trouve:

1

2



3

4

1 *Illustration des fouilles effectuées à l'intérieur et en face de la grotte I, en 1979. On peut y voir, en premier plan, une énorme concentration d'ossements de grands et moyens mammifères*

Diggings inside and in front of cave I, in 1979. In the foreground, a huge concentration of bones from large and medium-sized mammals

2 *Petit burin d'angle sur lame tronquée, fait de silex gris-bleu. Cet outil, trouvé dans la partie supérieure de la couche de loess, a probablement servi à travailler l'os ou le bois de caribou ou de wapiti*

Small angled chisel with truncated blade, made from grey blue flintstone. This tool, discovered in the upper loess, was probably used on cariboo or elk bones or horns

3 *Vertèbre caudale d'un mammifère de dimension moyenne portant des incisions dues à un travail de désarticulation*

Caudal vertebra of a medium-sized mammal bearing incision marks due to disarticulation

4 *Extrémité distale d'un métatarse de caribou, portant une série d'incisions faites avec un outil tranchant*

Distal end of a cariboo's metatarsus with a series of incisions made with a sharp tool

5 *Vue aérienne de l'extrémité ouest de la crête du Poisson-Bleu*

Aerial view of the western tip of the Bluefish ridge

- la roche en place plus ou moins concassée ou gélifractée, recouverte d'une épaisseur variable de
- loess incorporant un cailloutis constitué de fragments calcaires gélifractés, recouvert lui-même par
- un humus à cailloutis, lui aussi d'épaisseur variable et, enfin, par
- le tapis végétal actuel.

Les données palynologiques obtenues d'échantillons provenant des grottes I et II indiquent qu'au cours de l'épisode sédimentaire éolien (loess), la région semble avoir été caractérisée par une toundra riche en herbes qui se transforma lentement par l'addition du bouleau. Cela fut suivi, à un niveau correspondant à la zone de transition loess/humus, par une augmentation importante de l'influx pollinique de l'épinette, résultat de la réapparition graduelle dans le nord-ouest boréal d'un couvert forestier semblable à celui que l'on retrouve tout au long de l'Holocène et aujourd'hui. Cette reconstitution de l'évolution tardiglaciaire du couvert végétal des grottes du Poisson-

Bleu se compare bien à la description d'autres régions du Yukon et d'Alaska, et où l'on a pu dater l'apparition du bouleau à environ 14 — 13 000 ans B P et celle de l'épinette à environ 10 000 ans B P.

Les données paléontologiques concordent parfaitement avec cette chronologie basée sur la paléobotanique. En effet, les nombreux vestiges de la faune à grands mammifères ne se retrouvent que dans cette portion du remplissage qui est d'origine éolienne, tandis que l'humus à cailloutis n'a fourni que quelques vestiges épars d'une faune de type moderne, c'est-à-dire appauvrie, caractérisée par le caribou et peut-être par le mouflon. Quant à elle, la faune du loess, qu'on peut qualifier de tardiglaciaire, est composée d'un cheval de petite taille, de mouflons, de bisons, de mammouths, de wapitis ou grands cerfs, de boeufs musqués, de caribous, de loups, d'un ursidé ainsi que d'un bon nombre de moyens et petits carnivores. Ces mêmes couches ont aussi fourni de nombreux vestiges de petits rongeurs, d'oiseaux et de poissons.

Les datations au radiocarbone obtenues à partir du collagène extrait des ossements de quelques grands mammifères confirment et précisent cette séquence chronologique, et nous permettent de suggérer que la partie pléistocène du remplissage s'est effectuée entre 17 000 et 12 000 B P. C'est donc au cours d'une période d'environ cinq millénaires que se sont accumulés, autour des escarpements calcaires, sur les espaces de toundra herbacée, ces sédiments transportés par le vent. On croit savoir qu'ils provenaient en partie de la bordure des grands lacs proglaciaires qui occupaient alors les vastes plaines d'Old Crow et de Bluefish situées plus au nord. Et c'est au cours de ces mêmes millénaires que vécurent et moururent au pied des falaises du Poisson-Bleu ces centaines d'animaux dont les ossements tapissent aujourd'hui les gisements.

Si ces derniers permettent de mieux percevoir le milieu naturel béringien à la fin du Pléistocène, ils fournissent en plus des indications précieuses sur une ancienne présence humaine qui est encore bien mal comprise. Il ne fait pas de doute qu'une partie des données extraites de ces sites témoignent d'activités culturelles contemporaines de la faune tardiglaciaire.

Ces données archéologiques recueillies en cours de fouilles consistent, en premier lieu, en une série de petits éclats de chert ou de silex — essentiellement des déchets résultant de la taille ou du réaffûtage de couteaux ou de racloirs de pierre, de quelques galets, d'un burin — outil de pierre taillée servant à travailler l'os ou l'andouiller — d'un petit nucléus à microlames — objet de pierre taillée dont on a extrait de minces lamelles — d'une microlame et, enfin, de deux outils de fortune en os qui semblent avoir été utilisés pour le traitement des peaux. À l'exception de deux ou trois spécimens, tous ces objets proviennent des zones excavées des grottes I et II et ont été recueillis à différents niveaux dans la couche de loess.

Même si ces objets façonnés indiquent clairement que le site des grottes a été utilisé par des groupes humains au cours de la partie pléistocène de son histoire, ils ne permettent pas encore, à cause de leur rareté, de bien saisir la nature et la durée de ces manifestations culturelles.

Cependant, des indications en ce sens sont fournies par d'autres genres de données qui permettent d'associer directement certains aspects des manifestations culturelles avec de multiples éléments de la faune tardiglaciaire. Il s'agit de traces de débitage et de décarnisation — entailles, incisions, raclures, etc. —, causées par le tranchant d'outils en pierre, et que l'on retrouve sur de nombreux ossements de grands et moyens mammifères. En fait, il semble que des éléments représentatifs de tous les grands mammifères mentionnés plus haut soient porteurs de quelques-uns de ces signes d'altération culturelle. On les retrouve, en plus, sur le matériel provenant des trois grottes, ce qui permet de supposer qu'une fraction importante de l'accumulation faunique du Poisson-Bleu résulte d'activités reliées à la chasse ou, tout au moins, au traitement systématique de nombreuses carcasses animales.

Enfin, une conclusion similaire est aussi suggérée par la présence dans quelques zones des gisements de certains modes d'accumulation, de répartition des os qui peuvent difficilement s'expliquer comme étant le résultat de phénomènes naturels, d'ordre géologique ou biologique. Il faut bien admettre cependant, que ces derniers ont eu au cours des millénaires, un rôle important à jouer dans la transformation des dépôts archéologiques originaux. C'est d'ailleurs la raison pour laquelle ceux-ci posent souvent d'immenses problèmes d'interprétation. Pour ne citer que quelques exemples, notons en passant que ce qu'on croit pouvoir être un charnier ou un dépotoir d'ossements d'origine culturelle, peut très bien avoir été transformé par une combinaison d'apports ou de retraits causés par l'action du gel ou par l'activité de certains carnivores. De la même façon, des problèmes d'interprétation des signes de débitage et de décarnisation mentionnés plus haut résultent fréquemment du fait que ces mêmes carnivores ont pu machouiller, ronger et fracturer de nombreux ossements.

Comme on peut le voir, l'analyse complète des données paléoenvironnementales et archéologiques provenant des grottes du Poisson-Bleu reste à faire. Les travaux de laboratoire, actuellement en cours, ainsi que des fouilles additionnelles permettront, espérons-le, d'en arriver à un décodage plus complet de ces gisements géo-archéologiques. Il sera ainsi possible d'en arriver à une meilleure caractérisation des manifestations culturelles, pour le moment encore très floues, et à une chronologie plus précise.□

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The Bluefish Caves site, located in the Porcupine basin of the northern Yukon interior has yielded a variety of *in situ*, late Pleistocene faunal and archaeological materials indicating that between 17 000 and 12 000 years ago human groups had developed means of adapting themselves to what must have been a fairly severe periglacial climate. This paper describes some of these finds and some of their implications for future research.