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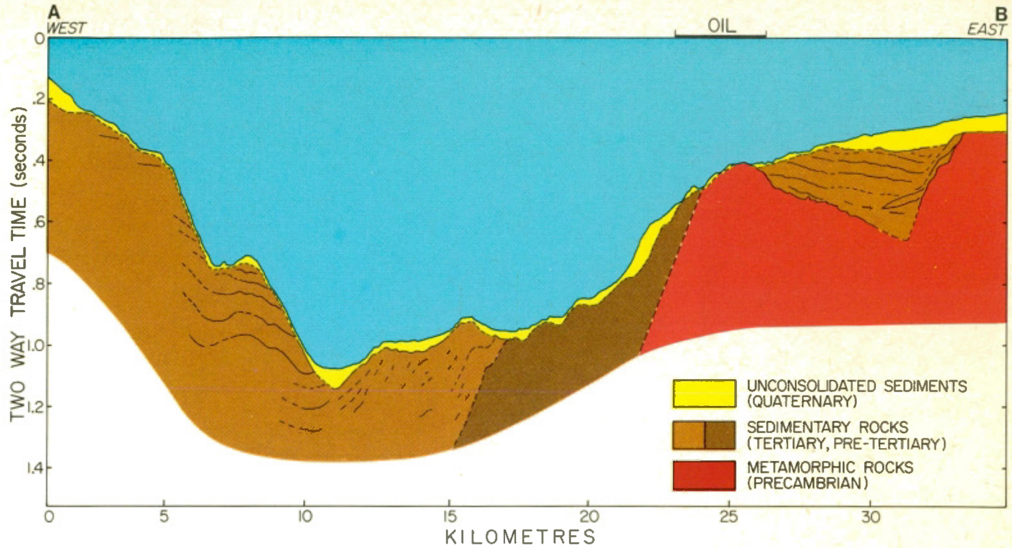
COUVERTURE: *L'artiste s'est ainsi représenté la navette spatiale de la NASA, avec le laboratoire spatial Spacelab; cette navette est évoquée dans l'article "Geologists in Space" (Géologistes dans l'espace) de Kathryn D. Sullivan, une future astronaute de la NASA, actuellement à l'entraînement.*

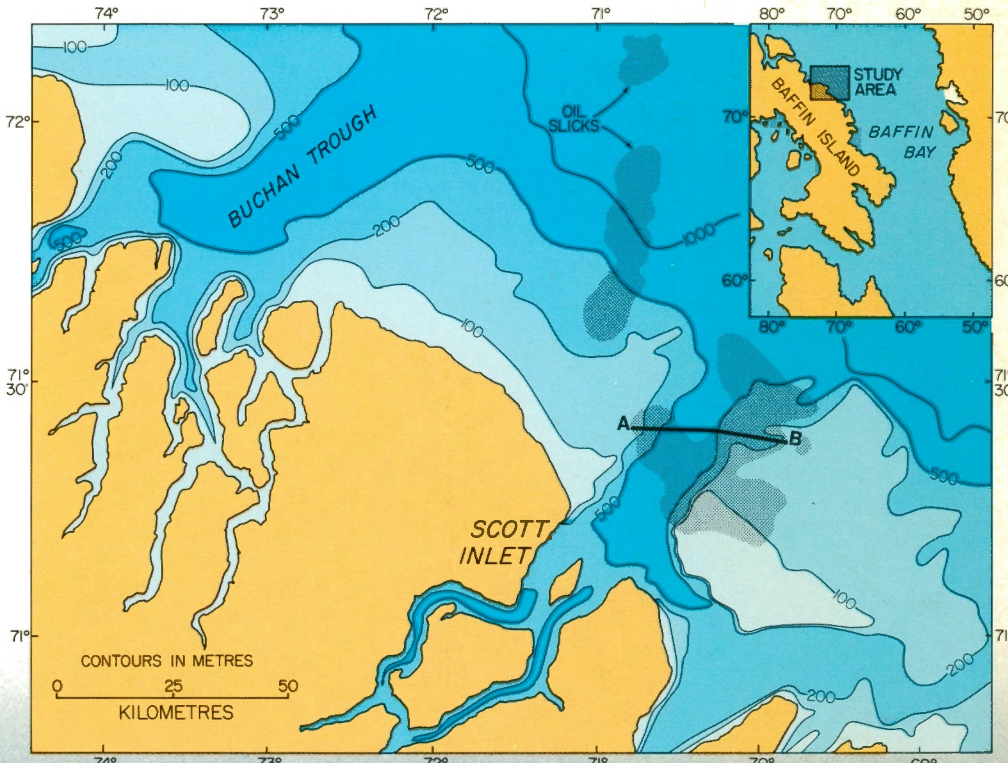
Geological cross section of the Scott Inlet trough, based on seismic reflection data. Oil has several times been seen bubbling to the surface at about 25 km, where the Precambrian rocks come to the surface as a structural high

Coupe géologique transversale du pli synclinal de Scott Inlet; cette coupe est dessinée d'après les renseignements fournis par la réflexion sismique. On a pu à plusieurs reprises observer le pétrole bouillonnant à la surface aux environs du 25 km, à l'endroit où les roches précambriennes affleurent



Traces of oil picked up by polystyrene blocks towed on the surface alongside the CSS Hudson

Traces de pétrole recueillies par des panneaux de polystyrène remorqués en surface le long du CSS Hudson



oil seep in the arctic

By Constance Mungall

In August 1976, crew and scientists engaged in making seismic measurements from the Bedford Institute of Oceanography (BIO) ship *Hudson* sighted an oil slick in Baffin Bay. They were intent on finishing their seismic line, but the slick was significant enough to make them retrace their course during the night for a second look. They found it again at 3:00 a.m. It was easy to see the iridescent sheen of the slick in the Arctic twilight.

"Slowly, wisps of oil appeared on the water," remembers Robin Falconer, chief scientist on the cruise and head of the Eastern Arctic Offshore group at EMR's Atlantic Geoscience Centre, part of the BIO in Dartmouth. "As we went, the traces thickened, the ice was brown along the edges, and the oil flattened the sea. Globs of oil rose to the surface."

The scientists were excited and curious. They speculated that the slick had not been seen before because it was in an area that was usually ice-choked, and therefore out of the regular shipping channel, on the Baffin Shelf, 40 km northeast of Scott Inlet on Baffin Island.

Before leaving, they took samples of the seafloor sediment, water from several depths, and a smear of the light brown surface oil on a bunch of kleenex on a string, for chemical testing in the BIO laboratories back in Dartmouth.

The slick was still there on *Hudson's* return trip to St. John's Newfoundland 25 days later. The area of the slick was about a kilometre wide. Since currents continually flow south (icebergs travel south at a rate of about 25 km a day), a stationary source seemed to be indicated.

Other natural submarine hydrocarbon seeps have been discovered — in the Gulf of Mexico, off California in the Santa Barbara channel, and south of Nome, Alaska. The first two are now active oil drilling areas. Investigations near Nome bring up not oil, but gas.

There are other seeps that are not commercially profitable. For instance, seeps have been known along the west coast of Newfoundland and although oil has been produced, production has been minimal.

The AGC scientists considered three possible sources for their find. It could be natural crude, as in the other known seeps; it could be animal oil, perhaps from a decaying whale; it could be refined oil leaking from a sunken boat, a crashed plane, or even a snowmobile lost through the ice. The size of the slick seemed to argue against the last two sources, and enquiries to the RCMP, other agencies and people in the area revealed no report of any crash or sinking.

If the seep was natural, it could be a signpost for oil — in which case more information was needed about the source, the geology of the area, the chemical composition of the oil. Other scientific disciplines and other agencies would be interested.

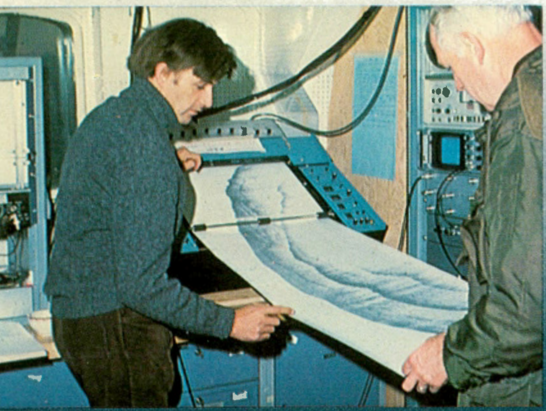
The slick would also provide a natural Arctic laboratory for the study of the effects of oil on marine life, and for Canada's program for the detection and tracking of oil spills in ice-filled waters, conducted by the Canada Centre for Remote Sensing. Environmental authorities restrict deliberate oil spills. Therefore every opportunity to develop understanding and skills for handling the consequences is exploited.

Further examination of the slick area with a wide variety of techniques was included in the cruise program of *CSS Hudson* in 1977 and 1978. From the accumulation of evidence, a model of the geology of the area was constructed that explained the natural seep.

"The structure of the seafloor in the area is probably the key," says Dr. Falconer. "The continental shelf along most of the eastern side of Baffin Island is about 50 km wide and 150 m deep. However at Scott Inlet, glaciers have cut a 20 km-wide channel through the shelf to a depth of 700 m."

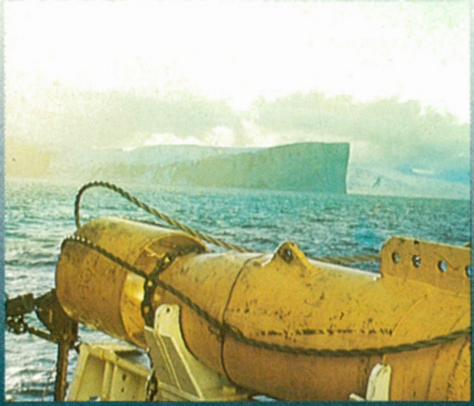
Shallow moraines have been left on either side of the channel, and dozens of icebergs ground on them. The scenery is spectacular.

Constance Mungall is the Editor of GEOS.



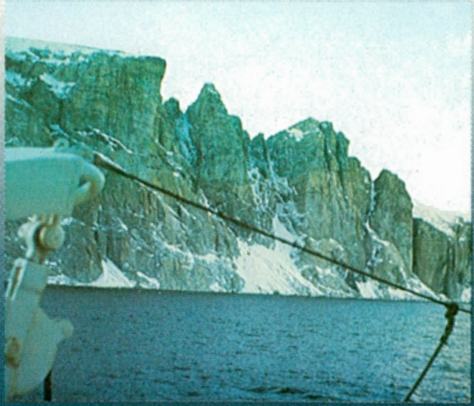
Scientists Robin Falconer, l., and Brian MacLean, r., both of Atlantic Geoscience Centre, examine record being made by the Hudson's *seismic reflection recorder over the oil bubbling site. The seismic record reveals the buried basement high around which the oil seeps*

Les scientifiques Robin Falconer, à gauche, et Brian Maclean, à droite, tous deux du Centre géoscientifique de l'Atlantique, examinent les relevés effectués par l'enregistreuse de réflexion sismique du Hudson. *Les relevés sismiques peuvent révéler les contours du soubassement élevé à travers lequel suinte le pétrole*



Cliffs 450 m high mark the east end of Scott Island, the land nearest the natural oil seep. Foreground, head of a piston corer, one of the instruments used to collect sediment samples, on the CSS Hudson

Falaises de 450 mètres de hauteur à l'extrémité est de l'île Scott, la terre la plus rapprochée du lieu où l'on a détecté le suintement de pétrole. Au premier plan, on peut voir la tête d'une foreuse à piston, à bord du CSS Hudson. *Il s'agit d'un des instruments que l'on utilise pour recueillir des carottes sédimentaires du fond de l'eau*



Cliffs of Scott Island, near oil seep. Most of the land in this area is rugged Precambrian rock with only a small sediment plain at the coast, yet offshore are thick sedimentary troughs, up to 6 km, which may be the oil reservoirs

Falaises de l'île Scott, près du site du suintement de pétrole. Le relief accidenté de cette région est formé en grande partie de roches précambriennes; ce n'est que sur la côte que l'on rencontre une petite plaine sédimentaire; il existe pourtant au large des côtes d'épais plis synclinaux sédimentaires, dont l'épaisseur peut atteindre 6 km, et qui pourraient constituer les réservoirs de pétrole

If it were on land, this deep channel would be like a sheer mountain cliff exposing the sedimentary layers which form most of the shelf. AGC scientists led by geologist Brian MacLean in 1977 and 1978 have been able to take samples of the deeper sections of the shelf by dredging and drilling the walls of the trough. Paleontological studies of the samples show that some sediments in the trough walls are of late Eocene age (40-45 million years). Older sediments are probably present.

At first the scientists thought that the oil was seeping from the exposed ends of beds truncated by the trough, the oil having migrated up from deeper reservoir beds. Geophysical work in 1974 and earlier had shown a deep sedimentary basin in the area. Further research showed the answer was more complex.

"We now know that there is a basement ridge which strikes across the south wall of the trough near its outer end," says Brian MacLean. "The only place that we saw oil coming to the surface in 1976, and again in 1978, was very close to this ridge."

The scientists speculate that the oil does not come from the basement ridge itself, which they believe to be Precambrian, too old for oil. They reason that the oil probably originates in the strata flanking the ridge, migrating to the surface up the bedding planes or along the basement contact.

In the 1977 investigations, the oil slick was not as confined as in 1976, but was seen over hundreds of square kilometres. This suggested either more than one source, or complex current flows.

"They seem too complex for one source to be likely," says Falconer. "There must be current studies done of the area in future years."

During the 1978 season, the *Hudson* spent almost four weeks in the area, with geologists, geophysicists, chemists and biologists all making their own studies. As in the first 1976 sightings, the oil slick was confined to a few square kilometres.

"However I think it's purely a question of weather and light enabling us to see the slicks rather than their actual extent," says Dr. Falconer.

Another possible source is another trough cut by glaciers coming out of Buchan Inlet, across the shelf 100 km north of Scott Inlet. Geophysical and chemical studies of that area in 1978 revealed no slicks, but did show some higher than background concentrations of methane and oil in the water. Sediments cored from the floor of the trough are of late Cretaceous age (80-85 million years), a good age for oil sources.

Analysis of the chemical oceanographers' samples showed the Scott Inlet oil to be a weathered crude oil. When the surface slicks are sampled with wire screens, the concentration of oil is very variable, but frequently several hundred times that of the background level of clean eastern Arctic water. Samples of the water column at various depths usually contain very low concentrations of oil, but an occasional sample will hit high oil concentrations.

"This is what one might expect if oil was sporadically escaping from the seafloor and being carried along by currents at the same time as it was rising to the surface," points out BIO chemist Eric Levy.

The biological studies showed little effect on wildlife although a measurable reduction in feeding by Arctic zooplankton was observed, says Dr. Levy.

Other EMR branches, including Earth Physics and CCRS, made their own studies.

Earthquakes are frequent in the Scott Inlet area, and if commercial development was contemplated, an understanding of the seismic activity would be vital in the design of subsea equipment such as wellheads and pipelines. In 1978, Earth Physics seismologists installed instruments at the Petro-Canada camp near Scott Inlet, at Pond Inlet and at Clyde River. AGC men on the *Hudson* put seismic instruments on the seafloor off the coast for 10 days. Numerous small earthquakes were detected in the region between Scott Inlet and Pond Inlet. Three or four bigger events, one magnitude 3.0, occurred near the coast.

Last summer, CCRS flew their DC3 and their Convair 580 over the area from Clyde River and from Thule, Greenland respectively. Both were equipped with sophisticated sensing equipment. The DC3 laboratory included a laser fluorosensor which can identify oil and which CCRS hopes will soon be ready for commercial production. The mapping of the oil slick was done by conventional cameras, low light level television cameras, and a multi spectral scanner. The Convair 580 carried a dual frequency synthetic aperture radar flown with assistance from the interdepartmental Sursat project.

"After several passes, we found the oil slick close to the bubbling site," says Dr. Robert O'Neil, CCRS project director. "The presence of ice, fresh water from icebergs, and complex current patterns frequently produces an effect on the sea surface that looks like oil, but the instruments do a good job in sorting these out.

"In my opinion, it's going to be difficult to see oil on water with 100 percent ice cover. But we want to determine what the limits of our sensors are. We'll try to see at what level we can detect oil through cracks between ice floes, and the way sensors respond to different ice types."

As a final indication of the significance of the oil seep — there has been renewed interest in the oil potential of Baffin Bay. Imperial Oil and Aquitaine Co. of Canada will drill in Davis Strait further south in 1979. Norlands Petroleum Ltd. and Petro-Canada are expected to drill in Lancaster Sound to the north, pending approval of environmental studies, perhaps in 1980. □

En 1976, des scientifiques qui effectuaient des mesures sismiques à bord du navire *CSS Hudson* de l'Institut d'océanographie de Bedford ont remarqué la présence d'une nappe de pétrole sur l'eau, à 40 km au nord-est de Scott Inlet dans l'île Baffin. Les observations effectuées plus tard au cours de l'année et des deux été suivants ont confirmé que la nappe était créée par un suintement naturel de pétrole. Les scientifiques en sont arrivés à la conjecture que le pétrole provenait de strates disposées à côté d'un soubassement élevé situé sous la paroi sud d'un pli synclinal profond creusé par le déplacement des glaciers sur le plateau continental à Scott Inlet. On connaît l'existence, un peu partout dans le monde, de quelques autres suintements naturels de pétrole sous la mer. Certains se trouvent actuellement dans des régions de forage et peuvent indiquer la présence de pétrole en quantité commerciale. N'ignorant pas l'importance possible du suintement, les géologues, les géophysiciens, les chimistes et les biologistes à l'emploi du gouvernement ont joint leurs efforts pour étudier la région. Le Centre canadien de télédétection s'est également servi des lieux comme laboratoire naturel, afin d'exécuter son programme de détection et d'analyse des suintements de pétrole dans les eaux recouvertes de glaces. Quant aux sociétés pétrolières, elles font preuve d'un intérêt renouvelé pour toute la région de la baie de Baffin.

Cet article est disponible en français

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GEOLOGISTS IN SPACE

New opportunities for synergy between man and machine

Dr. Kathryn D. Sullivan

By Kathryn D. Sullivan

The space shuttle of the U.S. National Aeronautics and Space Administration is scheduled for first launch in November, 1979.

The value to earth scientists of the synoptic view and repetitive coverage available from orbiting spacecraft has already been demonstrated over the past ten years. A wide variety of satellite systems — LANDSAT, TIROS, NIMBUS, to name but a few — have provided us with voluminous data on the nature and dynamics of the solid earth, the oceans and the atmosphere. Recent rapid advances in computer processing of remote sensing data are now opening the way for many new applications of these systems.

The goal of the space shuttle program is routine manned operations in low earth orbit, much like today's commercial airline travel (Fig. 1). This means more frequent flights (as many as 40-60 per year are forecast), larger payloads (a maximum of 65,000 lbs) and lower launch costs (through re-use of vehicle components) than have been available with the expendable launch vehicles used so far.

Several aspects of the shuttle program are particularly interesting to earth scientists. They include many more opportunities to conduct visual observations of the earth; development of a group of astronauts with skills in orbital observations; opportunity for non-astronauts to fly as payload specialists to conduct very specialized projects; a flexible mission profile, i.e., the ability to vary orbital inclinations and altitudes between sorties of four to seven day duration. These and other factors combine to make the shuttle an observational platform of great potential utility to all earth scientists.

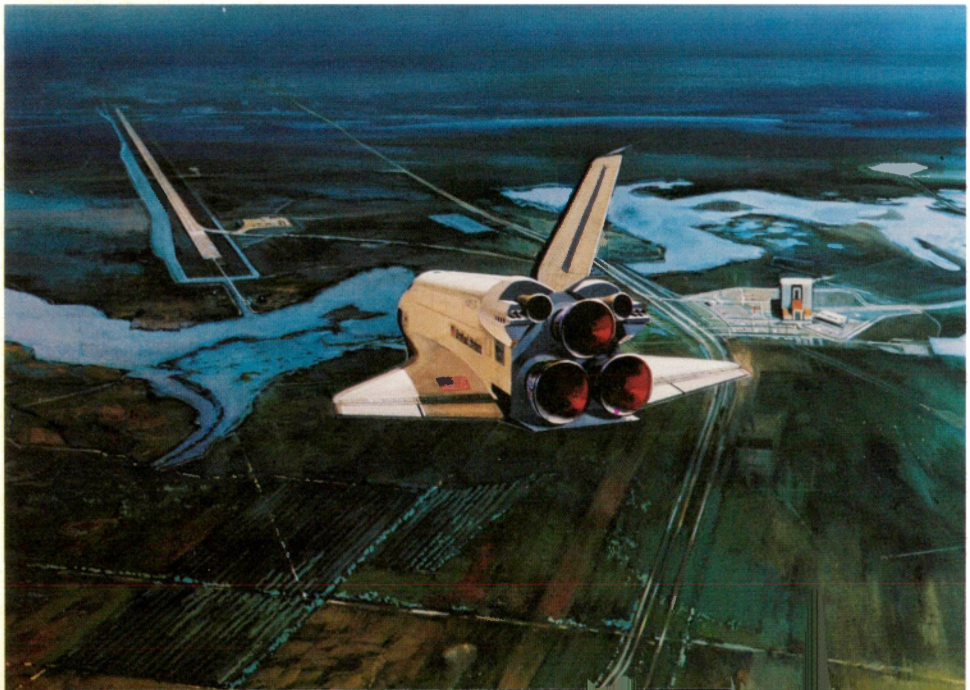
What will a typical shuttle mission be like? Media coverage of last year's landing tests in California left many people with the impression that the shuttle orbiter, a delta-winged spacecraft about the size of a DC-9 jetliner, will be launched from a 747. Actually, the orbiter will be launched like a rocket from either Florida (for orbital inclinations $I = 39° - 57°$) or California ($I = 57° - 104°$) (Fig. 2).

In the launch configuration, the orbiter is attached to a large liquid-propellant tank and two solid propellant boosters. Both solid boosters and the three orbiter main engines are fired at launch, providing about 6.8×10^6 lbs of thrust to lift the 4.5×10^6 lbs of launch vehicle. The solid boosters expend their propellant in about two minutes and are jettisoned, falling back to earth at a pre-selected area in the ocean for recovery and refurbishment. The orbiter main engines continue to burn, drawing propellant from the liquid propellant tank, for about another seven minutes. At this time, the orbiter is at an altitude of about 380 000 feet, travelling at nearly orbital velocity. The main engines are shut down, and the propellant tank is separated from the orbiter and allowed to fall back into a remote part of the Indian or Pacific Ocean. This part of the launch vehicle is not recovered.

Propellant from onboard tanks is then supplied to two smaller orbital maneuvering system engines, which provide the final increment of velocity required to maintain the desired orbit. The shuttle will normally operate at an altitude of approximately 200 nm and will stay on orbit for four to seven days. The main limitation to both mission duration and altitude is the amount of propellant required by the orbital maneuvering engines for on-orbit attitude control and the de-orbit burn. Temporary propellant tanks can be installed in the payload bay to meet specific mission requirements for stay times up to 30 days and altitudes up

Figure 1 *A Space Shuttle Orbiter approaches a landing field at NASA's Kennedy Space Center, Florida, following a flight in space. The Orbiter will be able to land on a conventional runway similar to that used by present day jet aircraft*

Figure 1 *A la fin d'un vol dans l'espace, la navette spatiale Orbiter s'approche du terrain d'atterrissage de la NASA au Centre spatial Kennedy, en Floride. L'Orbiter pourra atterrir sur une piste ordinaire, semblable à celles qui sont utilisées par les réactés modernes*



to 600 nm (with reduced payload weights).

Current models for the development of the program show the shuttle carrying a wide variety of payloads to orbit in the 60-foot long payload bay (a Greyhound bus *could* be accommodated, with room to spare). Possible payloads are of two general types: free-flyers and attached payloads. Both categories offer interesting prospects for earth observations.

Free-flying satellites will be deployed from the payload bay (Fig. 3) using the

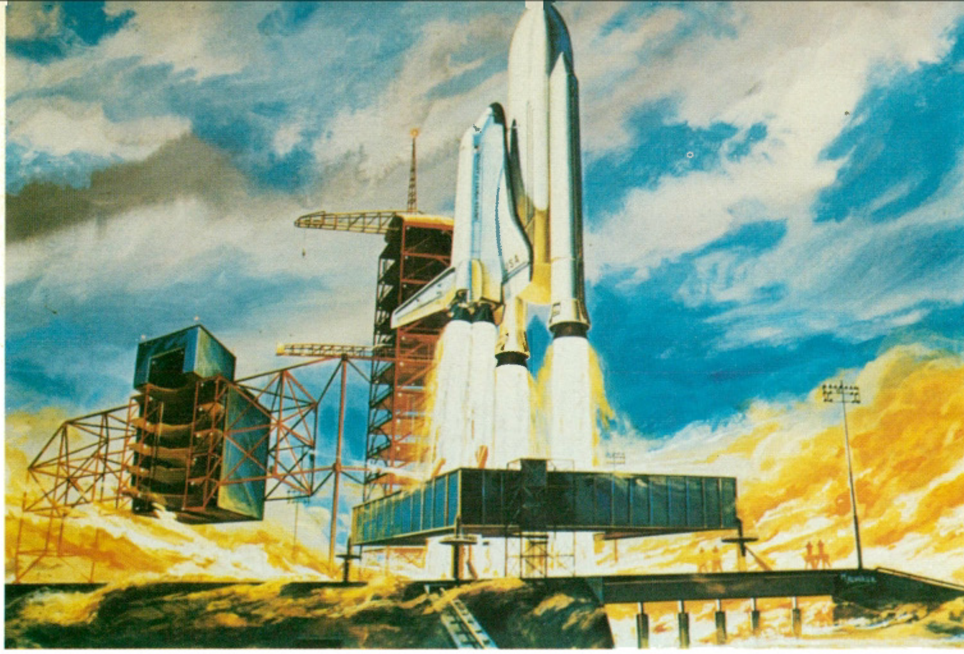


Figure 2 *Artist's concept of a Space Shuttle Orbiter lifting off the launch pad with all engines burning in parallel. Solid fuel rocket boosters (on either side of the large external tank) develop 11 210 000 newtons of thrust as they help push the orbiter into space. Following burnout at about 43.4 kilometres the depleted boosters parachute back to a predetermined site in the ocean, for recovery and use on other missions*

Figure 2 *Conception de l'artiste d'une navette spatiale Orbiter qui quitte la rampe de lancement, après la mise à feu de ses moteurs parallèles. Ses propulseurs d'appoint à carburant solide, (de chaque côté du grand réservoir externe) d'une force d'accélération de 11 210 000 newtons, propulsent la navette dans l'espace. A 43,4 kilomètres de la terre, les propulseurs d'appoint totalement vidés de leur carburant tombent dans l'océan, à un endroit prédéterminé, pour y être récupérés et servir de nouveau lors d'autres missions*

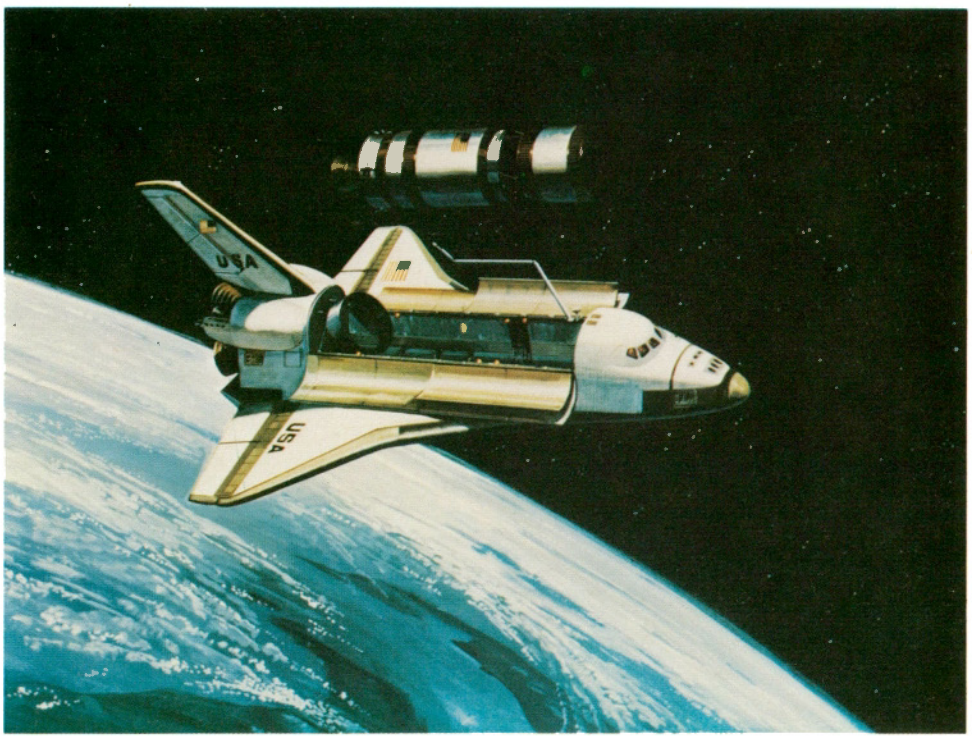


Figure 3 *This artist's concept shows the size of the payload bay, 18 metres long. The Interim Upper Stage is being deployed from the Shuttle Orbiter payload bay. The IUS would be used to place a payload from low earth orbit into geosynchronous orbit, elliptic or planetary orbits*

Figure 3 *L'artiste représente ici la dimension de la soute de 18 mètres de long. L'étage supérieur provisoire est déployé à partir de la soute de la navette Orbiter. Cet étage servirait à placer, d'une orbite terrestre basse à une orbite géostationnaire, elliptique ou planétaire, une charge utile quelconque*

Artist's concepts courtesy NASA/Idées de l'artiste avec la permission de la NASA

KATHRYN D. SULLIVAN

Kathryn Sullivan is a geologist who was chosen last year as one of 35 people in the first selection of new astronauts made by the U.S. National Aeronautics and Space Administration in about a decade. She was the only earth scientist chosen, and one of six women.

Of special interest to Canadian readers is the fact that Kathryn Sullivan, 27, took her PhD in geology at Dalhousie University in Halifax, and worked at the Atlantic Geoscience Centre, GSC, in Dartmouth, as a research student on problems connected with the evolution of the Newfoundland Basin. She sailed on the HUDSON and MARTIN KARLSEN under AGC chief scientists.

A U.S. citizen, Dr. Sullivan received her Bachelor of Science degree from the University of California in Santa Cruz. She did part of her studies as an exchange student at the University of Bergen, Norway. During her doctoral studies at Dalhousie from 1973 to 1978, she took part in oceanographic expeditions with the U.S. Geological Survey and Woods Hole Oceanographic Institute, as well as the Bedford Institute in Dartmouth. She did research on the mid-Atlantic ridge, Newfoundland Basin, and the offshore extent of Southern California faults. Her doctoral thesis was on the structure and evolution of the continental margin and deep seafloor east of the Grand Banks of Newfoundland.

Dr. Sullivan answered an ad in the journal, Science, to apply to train as an astronaut, and was chosen from 8 079 applicants. Dr. Robert Frosch, chief of NASA, said those chosen were judged only on professional qualifications, physical condition, and past records. He called them "the most competent, talented and experienced people available to us today."

Dr. Sullivan began her two-year training and evaluation program in July 1978. She will fly as a mission specialist, comparable to chief scientist on EMR research expeditions. □

50-foot long mechanical arm, called the Remote Manipulator System, being built by Spar Aerospace in Toronto. Satellites that require high orbital altitudes (geosynchronous or sun-synchronous) and interplanetary probes will be boosted from the low altitude shuttle orbit by one of several propulsion stages currently under development. The first such "extra boost" mission will be an earth science payload: the GOES-D satellite (Geosynchronous Orbiting Environmental Satellite) is scheduled for launch on the fourth shuttle flight. These upper stage boosters can also be programmed to bring the satellite back to a low orbit so that the shuttle can retrieve or repair it if necessary; the advantages of lengthening satellite lifetimes in this manner are obvious.

Most of the free-flying satellites in the present mission schedules are commercial satellites, mainly from the communications industry. However, there is one very exciting scientific payload on the schedule which will take advantage of the shuttle's satellite retrieval capabilities and will open exciting new vistas for astronomers. This is the Space Telescope. After deployment from the shuttle, the telescope will be operated real-time (as the observations are actually occurring, as if the operator was present) from control stations on earth. Its position above the earth's atmosphere will allow astronomers to view a volume of space 350 times greater than is possible from earth-based facilities and to conduct studies in several wavelength regions that are blocked by the atmosphere. The shuttle will rendezvous with the space telescope periodically, to allow astronauts on EVA (extravehicular activity) to repair or check out telescope systems.

Attached payloads are carried in the bay on special equipment pallets or, in the case of some Spacelab Experiments, inside a pressurized laboratory module (Fig. 4). This allows scientific research payloads to be assembled in building-block fashion, with a set of standard orbiter-payload interfaces. An example of an attached payload slated for an early shuttle flight is the OSTA-1 pallet. This is an earth observations payload which includes an L-band imaging radar, an ocean-colour scanner, an infrared radiometer, an atmospheric pollutant measuring device and several other experiments. The systems on this pallet are designed to be almost completely automatic; the crew only has to switch on the power at the appropriate time. Full payload automation was required for this flight because the crew will be primarily occupied with testing orbiter systems and operations on the first few flights.

As a minimum, the shuttle will carry three astronauts: two pilots (designated pilot and commander) and one scientist or engineer (the mission specialist). The pilots are responsible for the safety of the flight, for conduct of the launch and reentry phases of the mission and for attitude control and rendezvous while on orbit. The mission specialist, generally a PhD level scientist or engineer as well as a fully trained astronaut, functions as a chief scientist on orbit. I will be a mission specialist. My duties will include: (a) to assist in the monitoring and operation of various orbiter systems; (b) to act as liaison between the ship's crew and the onboard and ground-based investigators; (c) to coordinate and conduct payload operations, such as deployment, retrieval and experiment operation; (d) to conduct EVA sorties as required by payload design or contingency situations.

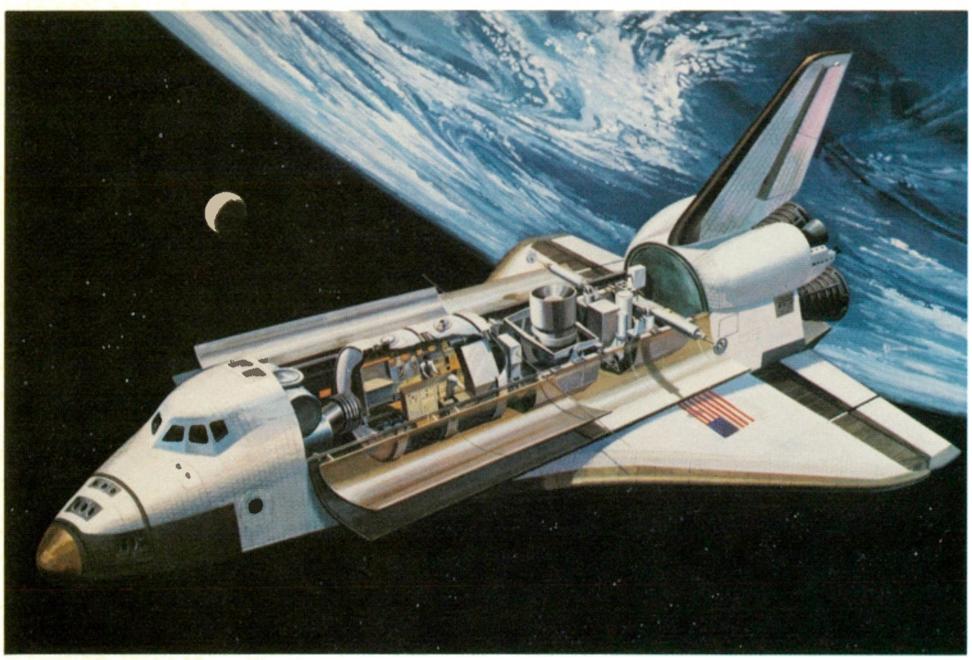


Figure 4 *A major planned payload for Space Shuttle will be Spacelab. Artist shows it tucked in the Space Shuttle Orbiter's payload bay. It will make it possible for scientists to go into space to perform experiments and studies*

Figure 4 *Un des emplois principaux prévus pour la navette sera le laboratoire spatial Spacelab. L'artiste nous le montre dans la soute de la navette spatiale Orbiter. Les scientifiques pourront ainsi aller dans l'espace pour effectuer des expériences et des recherches*

Depending on the mission, there may be as many as four additional people aboard the orbiter. These payload specialists will be responsible for the operation of a single set of experiment systems. In many cases, the payload specialist will be a mission specialist astronaut who has been chosen by NASA and the investigator involved. In cases where no qualified mission specialist is available, or where very highly specialized skills are required to conduct an experiment, non-astronauts will be assigned as payload specialists. The qualifications for this position are nomination by the principal investigator in charge of the project, extensive training on the experiment systems to be flown, good health (subject to NASA Class I medical standards) and completion of a few months of orbiter systems and operations training.

What kind of instrumentation should be onboard for earth science missions? Imagine yourself as the payload specialist on a flight. Your equipment could range from a hand-held camera to a full payload of sensors and a pressurized, shirt-sleeve environment laboratory. Obviously, you want to obtain as much high quality, relevant data as possible in the allotted time. In many cases, the subject you are investigating will be too poorly understood to predict the correct observation targets or the conditions that will exist when you are observing. How do you design your operation to maximize the data return?

The experience of the Skylab astronauts provides some valuable insight on this topic. During the 84-day Skylab IV mission in 1973, astronauts Ed Gibson, Jerry Carr, and Bill Pogue observed both the earth and the sun, obtaining useful and unique data in both cases. Ed Gibson subsequently wrote a monograph entitled "Manned Earth Science Observations," in which he proposes that four things are required to realize the potential available in orbital geology.

First, a flexible initial plan, based on thorough consideration of the scientific objectives and the strengths and weaknesses of the existing data. *Second,* the availability of new and comprehensive data in real-time (while the observations are being made) as a basis for modifying the initial plan. *Third,* rapid and accurate assessment of the real-time data. (This will obviously be a function of the observer's background and preflight training, the types of equipment available to

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support him, etc.) *Fourth,* response by the observer with the correct data acquisition instruments to record the data that have been selected as most significant.

On Skylab, the solar observations program approximated this format, but the two earth-oriented programs fell far short. The automated multispectral sensors on board almost left man out of the picture; the crew simply switched the sensors on and off at pre-scheduled times in the mission. As well, the manned observations program was a rudimentary, last-minute effort that provided only 20 hours of pre-flight crew training and used only hand-held cameras. The fact that extremely valuable data were obtained in spite of these limitations is a testimony to the power and flexibility of the human intellect.

The Skylab example proves my point that the best approach to take in planning orbital earth science missions for the next decade is one that combines the unique human abilities for comprehension, integration, discrimination and interpretation with the capabilities of electronic sensors.

It is impossible to foresee circumstances and results in such a new area while on the ground, before the flight, and a reaction after the ship returns may be too late to be effective.

We must move away from the old stereotypes, in which man in space is seen as a tourist with a simple camera and more sophisticated instrumentation is always fully-automated. The frequent flights and flexible payload capabilities of the space shuttle offer us new opportunities to design orbital earth observation laboratories which make top use of the synergy between the man and the machine. □

Le premier vol de la navette spatiale de la NASA (U.S. National Aeronautics and Space Administration) est prévu pour novembre 1979. La mission de l'équipage de cet appareil est d'exécuter des manœuvres en orbite terrestre basse, manœuvres fort semblables à celles de l'aviation commerciale moderne. Plusieurs aspects du programme de la navette spatiale intéressent particulièrement les spécialistes des sciences de la terre. L'auteur a obtenu un doctorat en géologie de l'université de Dalhousie, à Halifax, et a travaillé au Centre géoscientifique de l'Atlantique, C.G.C.; elle subit présentement, à la NASA, un entraînement comme spécialiste de la mission orbitale, au cours de laquelle elle occupera le poste de scientifique en chef. Elle décrit une mission typique de la navette, le personnel qui l'habite et les aspects que les spécialistes des sciences de la terre jugent importants.

Cet article est disponible en français

IS GEOLOGY FROM SPACE USEFUL?

Comment by L. W. Morley, Director-General Canada Centre for Remote Sensing

For the past seven years Canada, under an agreement with NASA, has been receiving, processing and disseminating satellite images of Canadian terrain to a large number of resource managers. Applications vary from crop and forest mapping to mineral and petroleum exploration, and the data becomes more useful as resource managers become more familiar with methods of analysis.

For geological applications, data collected from space supplements other information which helps an experienced exploration geologist discover new deposits. We have yet to see however if a geologist can improve his effectiveness by actually going into space.

As a contributor to geological knowledge in Canada, Landsat, the NASA satellite from which CCRS receives data, has been disappointing. Landsat's Multispectral Scanner cannot penetrate vegetation and glacial deposits which hide bedrock geology, and it adds little to the geological information Canada already has in maps and aerial photos. It has been useful in arid, little vegetated areas with no glacial deposits and where geology is not well mapped, as in the Middle East and the Sahara.

We have not yet had sufficient experience with the Synthetic Aperture Radar used in Seasat, which was launched by NASA in June and fell silent prematurely in October 1978. The concept was proven — Synthetic Aperture Radar does produce a good useable image from space — but there is a bottleneck in getting the data out. Of 4 000 scenes recorded in Canada, we have managed to see only three so far. Only when we can get those images into the hands of crews on the ground can we tell if they are useful.

As for the value to geologists of manned space flight, I agree with Dr. Sullivan that the big advantage is in the opportunity for real-time decision making. However, that capability is largely in the area of instrument testing. An unmanned automatic satellite needs a five-year lead time to orbit instruments and systems, compared to a year to put an unproven sensor into a manned Spacelab where, if something goes wrong, you can repair or modify it on the spot.

The Seasat case is the perfect example. Because the radar failed, the satellite's usefulness ended after four months, and there will now be no radar in space before 1984. If Seasat had carried a man, he would have had it fixed in a few hours, and back into effective use for the next four years or so.

That is a great advantage, but this real-time capability relates largely to technical decisions regarding instruments, not to scientific decisions or interpretation, which still have to be made on the ground. Take two examples. A scientist can do airborne geophysical work, but he still can't make real-time decisions about, for instance, where to drill for oil or minerals. The data must be recorded, compiled, analyzed, interpreted and compared with other data before decisions can be made, a matter of months or even years.

Another example is in flood management. The mission specialist in the Spacelab makes observations, but again he or she cannot interpret and get full value from the data. The flood manager on the ground has to receive the information and make the decisions.

In terms of time alone, there will be little opportunity for real-time scientific decisions. Suppose the shuttle is up one month, with a staff of four or five. It will bring back hundreds of tapes of data, which will then take a team of 200 scientists one to three years to analyze. Look at Skylab. They haven't completely analyzed data from that, and it went up six years ago!

I see the shuttle program as a test platform for instruments that will later go into automatic satellites. An end objective of scientists in space is *not* in itself legitimate. We must be careful not to oversell the concept of the geologist in space in the same way that enthusiasts oversold remote sensing in the beginning, or indeed in the way that geophysical exploration was oversold 30 years ago. □

LE GLACIEL DU CANIAPISCAU

Depuis 6 000 ans, le glaciel moule le réseau hydrographique

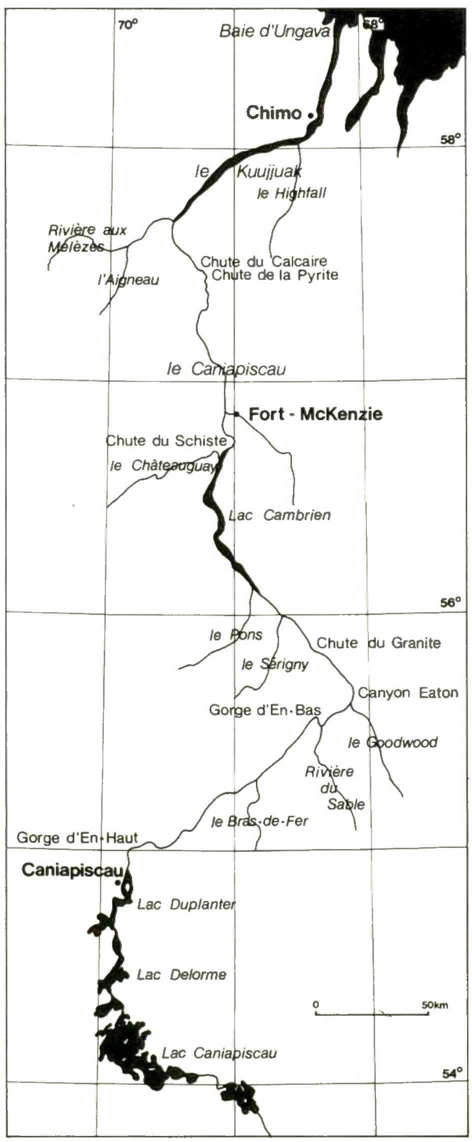
**Par Camille Laverdière
et Pierre Guimont**

Long de 900 km soit depuis sa tête au cœur du Nouveau-Québec jusqu'à son embouchure dans la baie d'Ungava, le Caniapiscau présente deux physionomies très distinctes. Autant sur les hautes-terres du lac Duplanter qui ondulent mollement, prend-il la forme d'une succession de grands lacs à hiérarchie toujours indécise, autant est-il confiné par la suite au centre d'une longue et large vallée qui le mène au Kuujjuak, son estuaire. Ces deux vastes ensembles très différents l'un de l'autre trouvent aussi leurs équivalents dans les activités glacielles du cours d'eau, qui sont faibles à sa tête, au contraire excessives à l'aval. Rappelons-le: le glaciel concerne toutes les manifestations, et leurs résultats, liées à l'action géologique des glaces flottantes.

Le bassin du Caniapiscau est d'abord un vaste domaine lacustre où la débâcle s'exprime par une glace mal entraînée qui pourrit souvent sur place, de la fin de mai au début de juin, dans un dédale d'îles innombrables; c'est ensuite un domaine fluvial où la rivière (devenue en eau courante), augmente continuellement son débit dans un lit où la déclivité se traduit dans de nombreuses et importantes ruptures de pente. Il en résulte au printemps une activité glacielle portée au paroxysme, entre autres dans la construction de hautes levées caillouteuses riveraines. En réalité, le glaciel traduit sa présence de l'engel au dégel; c'est néanmoins au printemps, par l'intermédiaire d'une glace en débâcle, qu'il devient le plus spectaculaire.

A l'emplacement même où la calotte glaciaire de Scheffer (glacier du Nouveau-Québec) fondait sur place entre il y a 1 000 et 6 500 ans, le réseau hydrographique d'une immense surface plus ou moins plane ne pouvait s'organiser que par l'intermédiaire d'une multitude de lacs mal reliés entre eux; ces derniers épousaient étroitement une topographie tant d'érosion que d'accumulation riche de formes à la fois orientées et indécises. Il en est résulté un pays autant lacustre que terrestre où le glaciel devenait fonction d'un tel décor fermé. Autrement dit, des eaux à peine courantes ne pouvaient permettre, par l'intermédiaire de leur glace flottante, l'attaque des berges ou de leur lit.

Au contraire, les composantes d'un milieu fluvial froid libèrent à un moment de l'année le plus fort de leurs énergies, et ne peuvent que permettre au phénomène de la débâcle ses actions les plus significatives. Des eaux et des glaces abondantes, en rétention temporaire et cédant subitement sous les contraintes accumulées, vont par exemple effectuer de puissants râclages jusqu'au haut des berges, et édifier ainsi des digues constituées des matériaux les plus grossiers. Ce sont les résultats de ces manifestations qui demeurent les plus impressionnants, alors que les formes d'érosion ne se traduisent très souvent que par un lit récuré à la roche.



A l'aval du lac Duplanter, les rapides qui marquent le cours supérieur du Caniapiscau, surtout à la gorge d'En-Haut, ont produit au cours de l'automne et de l'hiver d'importantes quantités de frazil, si bien que le lit peut être complètement obstrué par l'agglutination de ce type de glace; les eaux de la rivière, à leur plus faible débit à ce moment de l'année, ne s'écoulent que par un étroit chenal sous la glace de frazil. Cette dernière est constituée d'une multitude d'infimes cristaux produits par une eau en surfusion venue au contact d'un air très froid, comme au droit de rapides; ces cristaux adhéreront fortement entre eux comme à tout objet dans leur parcours.

Nombreuses sont les rivières qui tout au cours de l'hiver produisent une glace de frazil au sein de leurs sections en rapides; les cristaux viennent alors s'accoler en aval sous la glace de surface, à l'emplacement des zones de calme ou à l'intérieur de bassins plus ou moins profonds. A la fin de l'hiver, le couvert de glace ainsi constitué atteint parfois quelques dizaines de mètres d'épais, et s'étend sur plusieurs kilomètres.

Plus encore, les glaces qui comblent ainsi ces bassins réduisent considérablement la section mouillée qui se transforme en une véritable conduite forcée, obligeant alors la masse de glace à se soulever; la croissance du haut vers le bas de ces ponts flottants aura donc coincé des eaux de plus en plus rapides à l'intérieur de minces chenaux, malgré des débits hivernaux de plus en plus faibles. Sous ces obstructions, les niveaux d'eau les plus élevés sont alors atteints en mars, dépassant même celui des crues moyennes. Les glaces se haussent le long de fractures riveraines en même temps que les eaux en surgissent, accroissant ainsi l'épaisseur d'un pied de glace bien accroché aux rives; les poussées glacielles se font toujours peu sentir.

C'est au printemps ou à la fonte nivale, quand les débits se gonflent considérablement, que les crues de débâcle, fortes et subites, font éclater l'ensemble et contribuent à la transformation particulière des berges. Les glaces qui se rompent partent à la dérive et créent des embâcles à l'amont de tout rétrécissement du lit où les eaux vives ont souvent été les premières déglacées. Pressées les unes contre les autres, elles exercent alors sur les rives de fortes poussées qui sont à l'origine de ces imposants bourrelets de cailloux et de blocs perchés au-dessus des eaux de la rivière. Elles s'offrent ainsi de façon pres-

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que ininterrompue du lac Duplanter au canyon Eaton.

La glace à la surface du cours d'eau, avant la débâcle, n'est qu'une mosaïque constituée de milliers de glaçons de toutes formes, accolés lors de l'engel. Des brassages d'automne sur une glace en formation expliquent ce casse-tête de géant dont les teintes passent par tous les blancs, tous les gris et tous les bleus. Mais l'onde de crue du printemps ne laisse pas cette surface intacte; des amoncellements de glace, hauts de plusieurs mètres, dus aux poussées le long de cassures ou à l'avant des rives, des glaçons redressés à la verticale ou empilés les uns sur les autres contribuent à une certaine allure chaotique du milieu.

A l'endroit des berges, au cours d'un processus répétitif et ponctuel, la pression des glaces rajeunit cette forme glacielle majeure qu'est le bourrelet parallèle au rivage, long de plusieurs kilomètres et haut parfois de dix mètres; il peut constituer des flèches lorsqu'il se détache des rives jusqu'à leur conférer un profil en crête de coq. Les glaces agissent en même temps par à-coups, par touches successives et finissent après des dizaines d'années, voire quelques centaines, par conférer aux rives de la rivière un caractère glaciel continu. Pour impressionnantes en hauteur que soient les levées glacielles au-dessus des eaux d'un Caniapiscau de fin d'été, il ne faut pas oublier que ces constructions ont été mises en place en fonction de plans d'eau de crue (ou) fort élevés.

Le Caniapiscau occupe au printemps tous les bras qui lui donnent accès au canyon Eaton, l'un des grands accidents fluviatiles du Québec; les eaux se précipitent alors dans la gorge longue d'un kilomètre, par trois ou quatre chutes hautes de plus de trente mètres dont la principale demeure impressionnante. Toutes les eaux rassemblées rugissent ensuite au fond d'un couloir large de 50 mètres de toute la blancheur de leurs remous et de leur écume. Les glaçons, déjà démantelés, sont réduits sans doute encore plus après leur brassage sur quelques kilomètres dans des eaux déchaînées, sans parler de l'accélération de leur fusion entre autres par libération d'énergie d'une masse en furie qui tombe de plusieurs dizaines de mètres.

De plus, sur toutes les îles du Caniapiscau, dont celles précédant le lac Cambrien, la poussée des glaces est telle qu'à leur face amont s'érigent des levées glacielles arquées qui comptent parmi les plus impressionnantes du cours d'eau, du moins par leur hauteur; elles perdent rapidement de la taille sur les flancs de ces îles, et en sont absentes à la partie aval. Des glaçons épais de plus d'un mètre montent à leur assaut en utilisant la plage comme rampe d'accès, s'attaquent au front raide et vont même jusqu'à débouler le revers des levées et remettre en équilibre instable toute une tranche de matériaux sur lesquels ils fondent lentement au soleil.

Le Caniapiscau s'élargit ensuite pour donner naissance au lac Cambrien, long de 52 km et large de 2,5 km, et s'inscrit verticalement au contact d'un massif appartenant à la fosse du Labrador. Les sommets voisins font, de part et d'autre de la nappe d'eau, profonde de plus de 120 m, jusqu'à 617 m. Partout les glaces tiennent bon jusqu'à pourrir sur place sous forme d'aiguilles, mais le tracé lacustre en baïonnette crée rapidement un étranglement central en eau libre.

De la chute du Schiste à celle du Calcaire, malgré que le Caniapiscau perde de plus en plus d'altitude et gagne en latitude, le cours étroit et rapide du tronçon fluvial est le premier à se débarrasser de ses glaces; et celles-ci partent à la dérive sans trop créer d'embâcles. C'est finalement l'estuaire qui est atteint par le Kuujjuak où le brassage de la marée ne peut que contribuer à accélérer la désagrégation du couvert glaciel.

Né de précipitations qui totalisent annuellement 700 mm d'eau au droit du lac Caniapiscau, mais 525 seulement au lac Cambrien, le Caniapiscau répond aussi et davantage, dans son comportement saisonnier, aux profonds contrastes qui s'établissent surtout lors du passage de l'hiver à l'été. C'est alors qu'outillé d'une glace en rupture pouvant se déplacer et surtout former des embâcles, il se donne des moyens à nuls autres pareils pour édifier, hors de son lit mineur, de puissantes levées glacielles qui constituent l'un de ses aspects riverains les plus exceptionnels. ☐

The Caniapiscau River forms a moderate glacial environment in the Duplanter Lake area. Downstream the river flows into a valley whose banks bear the marks of exceptional ice activity. During the winter, the rapids sections are filled with broken ice. In spring, the swelling current raises these sheets and pushes them against the riverbanks, creating ridges and spits as well as bow-shaped bulges on the upstream side of islands. Jams occur in the narrows, and over time the river area attains glacial features. Although Cambrien Lake retains ice sheets that rot there, elsewhere, from Eaton Canyon downstream, the ice drift is faster and only allows for scattered areas of glacial characteristics.

This article is also available in English

1 *Après un cours resserré et marqué de nombreux rapides à la gorge d'En-Haut, le Caniapiscau retrouve un large couloir tenu par l'embâcle en amont du Bras-de-Fer*

After flowing through narrow banks and forming many rapids at the En-Haut gorge, the Caniapiscau River encounters a wide corridor blocked by the ice jam upstream from Bras-de-Fer

2 *Des poussées glacielles en milieu d'embâcle permettent de telles constructions temporaires où les pièces glacielles déplacent sans peine les blocs rocheux les plus grossiers; rive droite du Caniapiscau à l'amont du Bras-de-Fer*

Even the biggest boulders are pushed aside by the ice; right bank of the Caniapiscau, upstream from Bras-de-Fer

3 *La canyon Eaton, en eau vive même en hiver, rugit en période printanière de toutes ses eaux en crues et voit le Caniapiscau se précipiter au fond de sa gorge étroite par plus d'une chute spectaculaire*

In the Eaton canyon, the Caniapiscau River flows freely even in winter. In springtime, it swells up, becomes tumultuous and plunges to the bottom of the narrow gorge through many spectacular falls

4 *Les mouvements de la nappe de glace expliquent la construction de bourrelets de cailloux et de blocs et leur rajeunissement annuel. Le volume des glacons en mouvement est sans équivoque à la mesure des matériaux glaciels déplacés*

Ice sheet movements explain the formation of pebble and rock bulges. The moving blocks of ice are big enough to displace large volumes of material

5 *Dans le lit du Caniapiscau, près du Pons, îlot ceinturé au trois quarts par une levée de cailloux et de blocs sur laquelle sont venues s'appuyer les glaces printanières*

On the bed of the Caniapiscau, near the Pons, islet almost completely surrounded by a pebble and rock ridge supporting spring ice

6 *L'ampleur de la forme construite comme son imbrication avec les pièces de glace amoncelées, témoignent de l'importance de l'activité glacielle printanière*

The extent of the formation as well as its imbrication with ice blocks shows the importance of springtime ice activity


1


2


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SAND DUNES IN CANADA

Les surfaces couvertes de dunes représentent 0.3 pour cent de la superficie du Canada. On les trouve d'un océan à l'autre. La plupart des dunes sont stabilisées par la végétation; une exception importante est celle de la région du Lac Athabasca où de grandes superficies de sable sont exposées à l'activité éolienne. Les dunes, actives ou stabilisées, sont presque toutes de type parabolique; des dunes transversales sont observées, mais à un seul endroit, dans la partie nord de l'Alberta. La forme parabolique des dunes est due au contexte dans lequel elles se sont développées, c'est-à-dire en milieu non désertique. L'évolution des dunes paraboliques a mené, par endroit, au développement de longues crêtes de dunes qui à l'occasion ont été confondues avec des dunes longitudinales de type «seif» de milieu désertique, des moraines mineures ou même des eskers. Il faut noter également que des dunes paraboliques ont déjà été identifiées comme étant des barkhanes; en vérité, il n'y a aucun exemple de barkhanes au Canada.

Cet article est disponible en français

By Peter David

Few laymen think of sand dunes in Canada, and yet they cover about 26 000 km^2 of the land surface, a little less than 0.3 percent of the total. Moreover, they are widely dispersed from coast to coast — found in every province and territory of the country.

Sand dunes have been neglected, possibly because most of them are far from the major population centres, possibly because at present they offer no commercial potential, except as tourist attractions and as ranch land. Nevertheless, to a dunologist, they are beautiful, they are interesting, and they are one of the most sensitive biophysical units, often in danger of being trampled out of existence. Moreover, they contain the records of local variations in temperature, humidity, wind velocity and direction since the last continental ice sheet receded 5 000 to 15 000 years ago.

In Canada, contiguous dune occurrences range in size from a few tens of square kilometres to over 1 200 km^2. The two largest areas are located along the south side of Lake Athabasca. While the sand in most dune areas is stabilized by vegetation today, there are still large barren surfaces where the wind can shift the sand. The Lake Athabasca region also has the largest such *active* sand surfaces, which extend over an area of 385 km^2.

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Definition. Sand dunes are mounds or ridges of sand piled up by the wind into a variety of forms. They may either be bare or covered to various degrees by vegetation. Active sand dunes are those which still move freely. When they become stabilized by vegetation they cease to move (Fig. 2). Either external morphological or internal structural characteristics will show how they developed.

Regional distribution. Alberta has nearly half the dune area in Canada. It also has the largest single dune occurrence, the Richardson River Sand Hills, one of the four in the Lake Athabasca area. Saskatchewan and Manitoba have 36 percent and 10 percent respectively. All the other provinces also have sand dunes, including many associated with the beautiful Maritime beaches (Fig. 1).

The author arbitrarily selected 25 km^2 as the minimum surface area for inclusion in a recently completed study, because of the large number of smaller dune occurrences. Only the three Maritime provinces do not have dune areas that large.

Formation of dunes. Dunes form where a sandy source deposit, either new or recently stripped of protective vegetation, becomes exposed to wind. The wind transports and piles the sand into low mounds. Once a mound is formed it serves as a trap for further sand movement and builds up to a critical height. It then develops a steep frontal slope called the slipface (Fig. 3). With the appearance of the slipface a dune is formed and begins to migrate downwind. During its migration, reverse and crosswinds will slightly modify its appearance though it always tends to retain its original shape.

Dune types. There are many different types of dunes, but they all classify into two categories: parabolic and desert. Parabolic or wet sand dunes (Fig. 3) have a frontal baseline which is convex downwind and a baseline at the back which is usually also convex. Sand ridges are one subtype of parabolic dunes. Desert, or dry sand dunes include among their subtypes transverse, barchans and longitudinal dunes. Transverse dunes are set across, or at right angles, to the prevailing wind direction. Barchans are in reverse to parabolic dunes, with head downwind, and horns pointing downwind (Fig. 3). Longitudinal dunes are elongate ridges formed parallel with the direction of the wind. The author maintains that there are no barchans nor longitudinal dunes in Canada. Miniature barchans which form on loose sand today disappear in less than a day.

Canadian dunes were originally either parabolic or transverse. In today's grassland and parkland regions the initial dune forms were mostly transverse, but elsewhere they were mostly parabolic. We know of only one region in Canada, in north central Alberta, where there still are a few occurrences of stabilized transverse dunes, and this is the only region with direct evidence that the primary dune forms were transverse.

Eolian environments. The types of initial dune forms and their evolution depend on the character and stability of the prevailing eolian (wind produced) environment. Canadian eolian environments, and therefore dune types, vary from region to region.

Fortunately, we can examine the morphology and structure of sand dunes of a particular region and deduce the initial environment and its changes. This can most easily be done in the present forest zones, where the simplicity of dune forms and structures indicate only one short

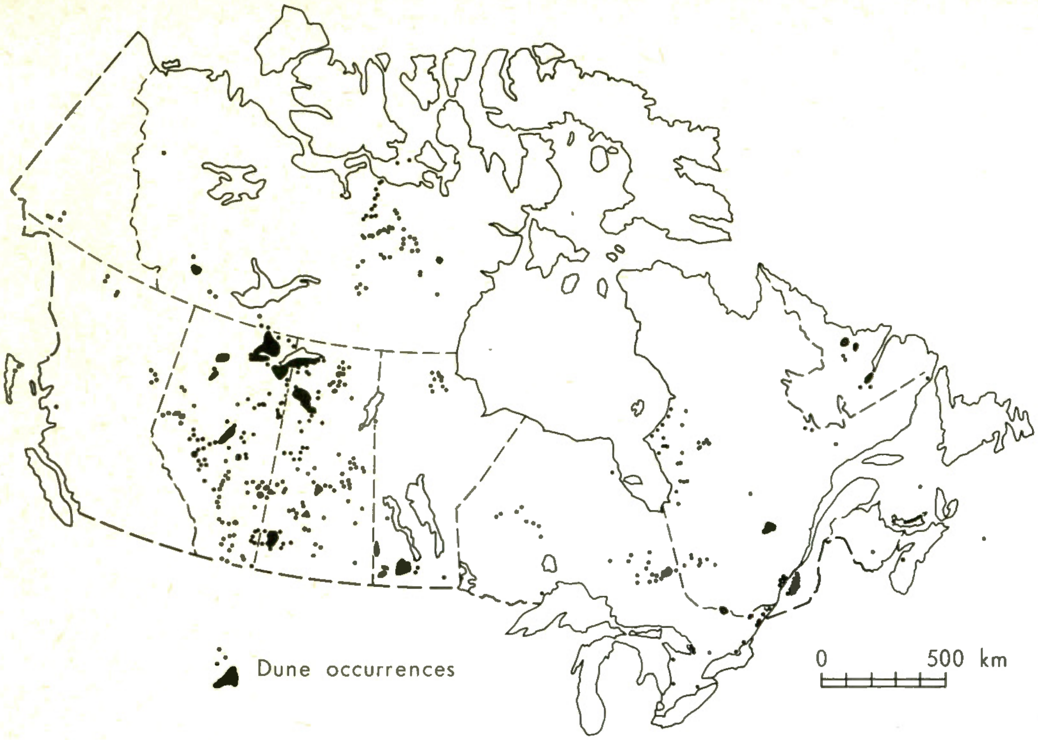

Figure 1 *Sand dune occurrences in Canada. Map includes some areas smaller than 25 km²*
Les dunes au Canada. La carte représente certaines régions de dunes d'une superficie inférieure à 25 km²

period of activity, followed by rapid stabilization. Any sporadic recurrences of activity are only local.

Unraveling the past eolian environments becomes more complex outside the forest regions. Also, while in the south the primary climatic factor favouring eolian activity is low precipitation (Fig. 4), in the north it is low temperature (Fig. 5). Therefore, though similar eolian phenomena may occur in both regions, they may be due to diverse combinations of different environmental factors.

Groundwater is the principal environmental factor determining dune type, and that is a function of the local climate. Only under truly desert environments will the sediments involved in eolian activity be dry and remain dry, otherwise groundwater will be present in some form. The effect of groundwater on dune development may be summarized as follows:

A — Dry source deposits. A/1 — Dry dune sands. If the source deposit is dry, small transverse ridges develop first as a result of wind action. These ridges will grow into larger dunes only if they themselves are also dry and if the source deposit is thick. If the deposit is thin, the non-sandy substratum becomes exposed between the transverse dunes, and the latter will break up into individual barchan dunes. The same phenomenon will occur if the transverse dunes migrate over a non-sandy substratum. There is no evidence that this process ever occurred in Canadian dune areas. Where barchan-like structures do form, as in Saskatchewan, they disappear within a few days (Fig. 6). However, we can look at present day examples in the White Sands National Monument, New Mexico.

A/2 — Wet dune sands. If the sand in the transverse dunes becomes moist, the ridges will break up into parabolic dunes rather than barchans (Fig. 3). This process must have been quite common in the grassland regions of Canada. If moisture arrives only after the barchans have already formed, their growth will be slowed down or arrested by the moisture, they will be joined by other barchans, and will eventually give way to parabolic dunes. This may have occurred in Canada but since there are no stabilized barchans today, there is no proof. The reverse process can also occur; moist parabolic dunes gradually lose their moisture content and become barchans, as in the Moses Lake region of Washington. This process probably never occurred in Canada.

B — Moist source deposits. If the source deposits are moist during dune development, wind has to dry them before the sand can be moved. Consequently, little loose sand is available for wind action, and the sand accumulates in the form of small sporadic mounds instead of transverse ridges. If these mounds become stabilized before any further development occurs, they will be preserved in their original shapes, and will have no slipface. Mounds like these are common in Canada. If, however, the mounds grow in size and acquire slipfaces, their further

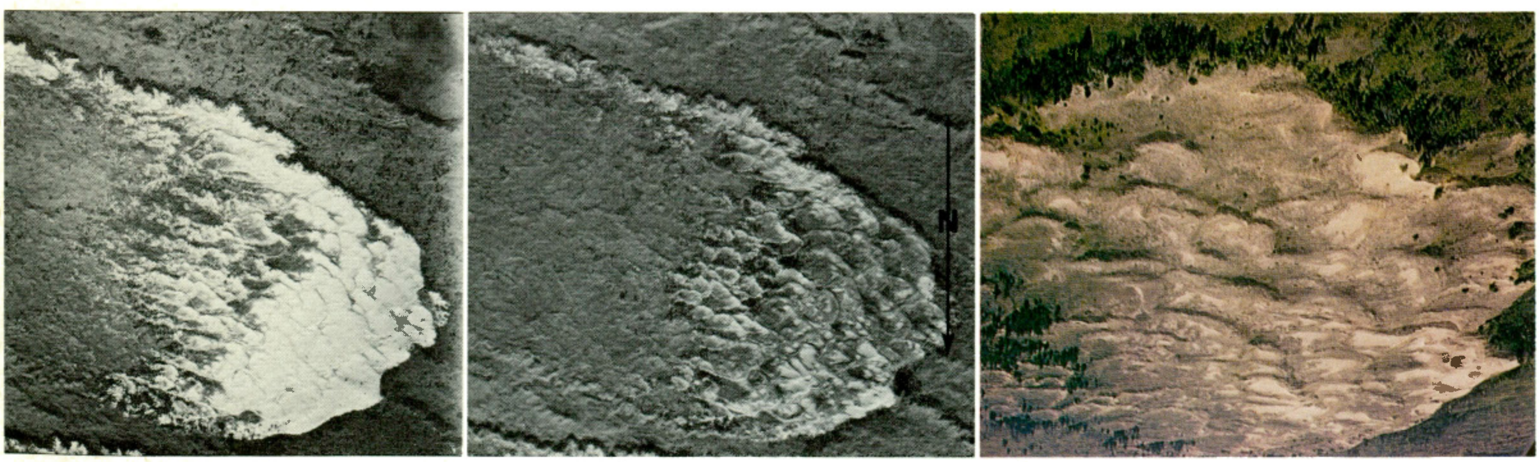

Figure 2 *Sequential aerial photographs of a "dune blanket", a coherent group of dunes advancing over formerly stabilized dunes, in the process of stabilization. Brandon Sand Hills area, Manitoba, left: 1928; centre: 1969 (National Air Photo Library); right: oblique air photo of the same dune in 1967*

Photos aériennes en série d'une «couverture de dunes»; il s'agit d'un groupe cohérent de dunes avançant sur des dunes déjà stabilisées; ce groupe est déjà lui-même en voie de stabilisation. La région de Brandon Sand Hills, au Manitoba, à gauche: 1928; au centre: 1969 (Photothèque Nationale de l'air) à droite: photo aérienne oblique de la même dune en 1967

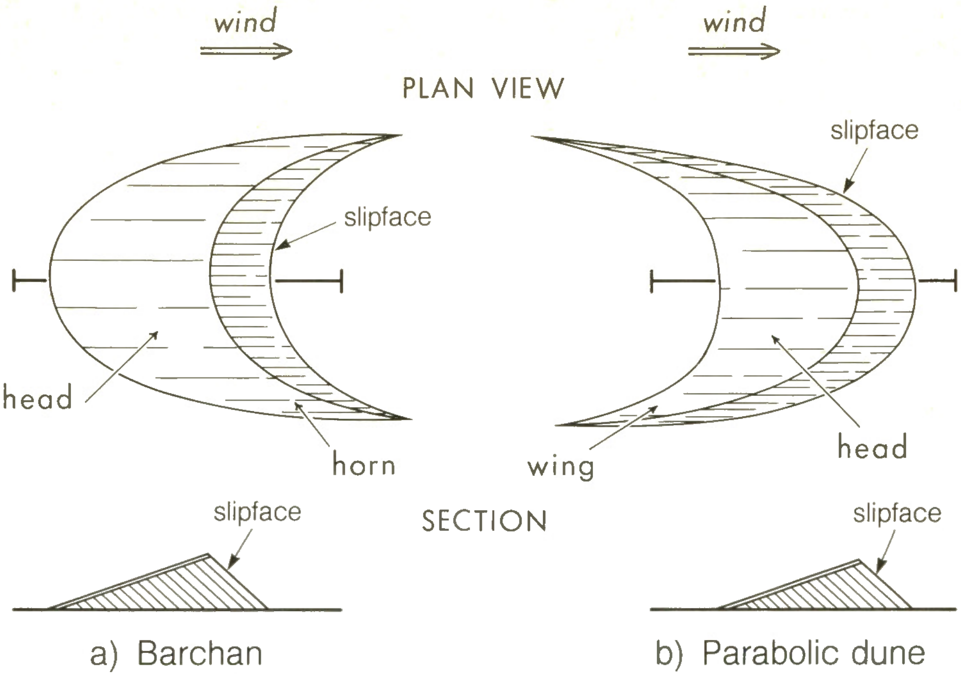

Figure 3 *Comparison of barchan and parabolic dunes. Barchan develops from dry sand; 'horns' point downwind; steep slope is always downwind, on the concave side. Parabolic dune develops from moist sand; 'wings' point upwind; steep slope is on the convex side. Internal structure of both may be same if parabolic dune has advanced far enough*

Comparaison entre les barkhanes et les dunes en parabole. Les barkhanes sont faites de sable sec; les «cornes» pointent vers l'aval; la pente raide est située sur la face concave. Les dunes en parabole sont faites de sable humide; la pente raide est située sur la face convexe. La structure interne des deux types de dunes peut être la même si la dune en parabole a avancé suffisamment loin

Figure 4 *Southern active dune environment: active sand dunes near Brandon, Manitoba. Moisture is just sufficient to allow growth of vegetation behind advancing dunes at the same rate as dunes advance*

Un milieu actif de dunes, dans le Sud: dunes de sable actives près de Brandon, au Manitoba. L'humidité est juste suffisante pour permettre la croissance de la végétation derrière les dunes en mouvement au même rythme d'avance des dunes

Figure 5 *Northern active dune environment: active dune area south of Lake Athabasca, looking south. All the dunes are parabolic despite lack of vegetation. Large active areas develop because the short growing season impedes rapid vegetation growth*

Un milieu actif de dunes, dans le Nord: cette région est située au sud du lac Athabasca, regardant vers le sud. Toutes les dunes sont paraboliques, en dépit de l'absence de végétation. De vastes régions de dunes se créent parce que la courte saison entrave une croissance rapide de la végétation

development depends on whether the sand in them remains dry or becomes wet. If the sand remains dry the mounds develop into barchans (Fig. 6). If it becomes wet they give way to parabolic dunes. This is one way the haphazardly occurring parabolic dunes of the grassland regions must have formed.

There is one more way by which parabolic dunes may form. If vegetation cover becomes disturbed on a sandy deposit, the wind can deflate the sand from the exposed deposit and accumulate it along the edge of the break on the vegetation cover. The resulting dune form is necessarily parabolic. Although this is the most commonly mentioned parabolic dune development, it cannot account for more than a fraction of the total.

Why are dunes parabolic? The parabolic dune form develops in response to the presence of moisture in the sand. While dry sand can be freely moved around by the wind, in moist sand the grains stick to one another as in a sand castle. The sand must be dried before the wind can move the grains. Sand is dried fast and in great quantities where the speed of the wind is highest, where it is funnelled onto the converging arms of the dune. From these depressions the wind removes the dried sand and drops it over the slipface just in front of the depression, providing the rest of the slipface with little or no sand. As the slipface in front of the depression receives more and more sand, it becomes projected further and further ahead in a curved shape, producing the parabolic form.

This hypothesis destroys some popular thinking that Canada's dunes indicate we at one time had local Sahara-like deserts. Rather, the parabolic shape of the dunes shows that moisture was a factor in their evolution.

Dunes or not dunes? Parabolic or not parabolic? In any of the dune occurrences in Canada, all the sand dunes, with the exception of the transverse dunes in north central Alberta, have or have had at some time the basic parabolic form (Fig. 3).

Some of the dunes observed today have evolved to such an extent that the original parabolic form is no longer evident, and it may be difficult to correctly identify them. For instance, dune ridges evolved from ordinary parabolic dunes through a process of dune elongation may result in lengths of as much as eight kilometres. Some of these have been variously, and erroneously, interpreted as ice-crack moraines in northern Saskatchewan, and marine crevasse fillings in the St. Lawrence Lowlands of Quebec. Other groups of deformed parabolic dunes have been mistaken for longitudinal seif dunes of the desert types, or even for eskers. Only with further study will our understanding of these fascinating geological phenomena improve. □

Figure 6 *Small barchan formed of dry sand on top of moist dune which provided the "hard" floor. Due to its size and the changing wind directions, this form disappears in a day or two. Background: right, mound with incipient slipface; left, mound with transverse slipface becoming barchan-like. Everywhere, the loose sand is rippled*

Une petite barkhane formée de sable sec au sommet d'une dune humide qui a formé le plancher «dur». A cause de sa taille et du changement de direction du vent, cette forme disparaît au bout d'un jour ou deux. Arrière-fond: à droite, monticule avec une pente frontale en train de se développer; à gauche, monticule avec une pente frontale transversale ressemblant à une barkhane. Partout, des rides couvrent le sable meuble

Lé deboisement dans les réservoirs

What happens when a large forested area is flooded after a dam is built? Studies carried out in several areas in the province of Quebec conclude that nature adapts itself rapidly to re-establish a good environmental balance. Actions of ice, waves and other natural agents promote the rapid removal and decomposition of trees and vegetation.

This article is also available in English.

Par Hubert Marcotte et Alain Soucy

Lors de la création de réservoirs, de grandes zones forestières sont soumises à l'ennoyage, souvent sans avoir pu être déboisées; qu'advient-il de cette forêt?

Des observations effectuées sur certains réservoirs ont permis de cerner des phénomènes naturels modifiant la végétation forestière ennoyée lors du remplissage des réservoirs, ainsi que les conditions du milieu dans lesquelles ces agents sont actifs.

Les agents naturels reconnus efficaces pour le déboisement des réservoirs sont, premièrement, la glace et, plus particulièrement, l'action combinée du poids du couvert de la glace et du mouvement vertical du plan d'eau sur les arbres. Il semble que le déplacement latéral du couvert de glace sous la force du vent peut avoir un effet sur le renversement des arbres mais cette action ne compte pas comme un impact majeur. Deuxièmement, l'action des vagues sur le littoral boisé aboutit à une érosion permettant le déracinement des arbres. L'importance de cette action des vagues est reliée à l'énergie de celles-ci et au type de rivage. Troisièmement, les sols, saturés d'eau après inondation, deviennent instables et par conséquent sujets à des mouvements de masse ou des glissements. En dernier lieu, l'action de la glace et des vagues devient plus efficace avec le pourrissement des arbres partiellement submergés. Le pourrissement des arbres réduit la résistance des troncs et rend donc les arbres plus vulnérables à l'action des autres agents naturels.

LA GLACE

Les observations effectuées dans les réservoirs visités ont permis de reconnaître que la glace est l'agent naturel qui produit le plus grand impact sur les peuplements forestiers inondés.

De façon générale, l'eau accumulée dans les réservoirs durant l'été est utilisée l'hiver suivant pour la production d'électricité. Le niveau d'eau s'abaisse alors graduellement durant l'hiver jusqu'à la fonte des neiges (des fluctuations existent nécessairement dans le temps et entre les réservoirs). De plus, une couche de glace recouvre les lacs et, de la même façon, les réservoirs. Avec le temps et le froid persistant, cette couche de glace s'épaissit de plus en plus.

Généralement au début de l'hiver, le plan d'eau du réservoir est à son niveau maximum et les arbres sont partiellement submergés. La couche de glace qui se forme graduellement se soude alors aux troncs.

Lorsque le niveau d'eau s'abaisse, les arbres réagissent comme des piliers d'édifice; ils peuvent alors supporter la couche de glace ou éventuellement casser sous la pression exercée par le poids de cette dernière.

Le poids du couvert de glace est fonction de son épaisseur, laquelle est reliée directement à la température de l'air ambiant et aux conditions hydrologiques.

Lorsque le niveau d'eau s'abaisse, la couche de glace flottante s'abaisse parallèlement. Comme cette couche est soudée aux troncs des arbres, la glace exerce alors une pression sur les tiges. Si le couvert de glace est suffisamment épais, les arbres se brisent; dans le cas contraire, le couvert de glace se morcelle et les blocs flottent séparément. Si les peuplements forestiers sont assez denses, il arrive que les arbres supportent des portions du couvert de glace.

La résistance des arbres est fonction de leur essence, du diamètre des tiges et de la densité (nombre de tiges à l'unité de surface) de la végétation. Pour les tiges de diamètre inférieur à 22 cm, la densité est un facteur critique.

Lorsque les arbres atteignent 22 cm et plus en diamètre, le critère de densité n'est plus significatif; la distance du couvert de glace au sol devient le facteur critique pour briser les tiges par flambage.

En même temps que baisse en hiver le niveau d'eau dans les réservoirs, la couche de glace descend avant d'atteindre son épaisseur maximum. La pression verticale est donc réduite au début et s'accentue avec la croissance du couvert de glace. Cela signifie que seulement les arbres de petits diamètres seront cassés au début de la baisse et que généralement, l'action de la glace s'amplifiera jusqu'à la fin de l'hiver.

VAGUE

L'étude des modifications dans les lacs naturels est basée sur des principes géomorphologiques et hydrologiques. Le concept de base repose sur le fait qu'un lac à son état naturel évolue de façon continue par une érosion des berges et une sédimentation dans le bassin.

M. Marcotte est géographe-géomorphologue pour la firme S.A.G.E. Limitée. M. Soucy est chef du Service Environnement de la Société d'Energie de la Baie James.

Ainsi, dans les réservoirs et dans les biefs d'amont, les vagues, par leur action sur les berges, produiront un déboisement des forêts littorales inondées.

L'efficacité des vagues est directement fonction de leur énergie, du type et de la forme des berges, ainsi que de l'épaisseur de la nappe d'eau. L'énergie de la vague est fonction de la vitesse du vent, de sa direction et de l'emprise sur le plan d'eau. Les berges constituées de matériaux non consolidés seront plus sujettes à l'érosion que celles constituées de matériel aggloméré. Enfin, la pente de la berge permettra à l'énergie des vagues d'être concentrée en un point et d'avoir un plus grand impact sur les pentes fortes, alors que cette énergie sera distribuée sur une plus grande surface dans les pentes faibles.

DECOMPOSITION DU BOIS

Les arbres partiellement exposés aux agents atmosphériques et affectés par le pourrissement, voient leur résistance à l'action de la glace et aux autres agents fortement réduite. De plus, ce phénomène s'effectue sur une courte période de temps, voire en 2 ou 3 années.

Il semble possible d'évaluer l'impact de l'inondation sur les diverses espèces d'arbres d'un réservoir. Notons cependant que le taux de pourrissement, dans les réservoirs inondés, est en général rapide pour toutes les espèces (c'est-à-dire dans les deux premières années d'inondation) de sorte que les variations entre espèces n'apparaissent pas significatives. La mort des arbres avant inondation, tout au moins celle résultant du feu ne paraît pas avoir d'influence sur la vitesse de pourrissement après l'inondation. Les observations laissent plutôt prévoir l'inverse.

La décomposition partielle du système radiculaire avant inondation réduit la résistance des arbres au renversement, les rendant ainsi plus sensibles à l'action du vent, de la glace et des autres agents.

PHASES NATURELLES
DE DEBOISEMENT

Les observations effectuées dans les réservoirs recoupent celles d'autres chercheurs: les arbres partiellement submergés ont été, dans la plupart des cas, cassés ou broyés au sol.

Le couvert de glace n'était pas assez épais pour briser cet arbre. Réservoir Manic-5, mars 1976
The ice cover was not thick enough to break this tree trunk. Manic-5 reservoir, March 1976

Erosion des berges par les vagues et accumulation de débris. Réservoir Outardes-4, juillet 1976
Shoreline erosion and debris accumulation in Outardes-4 reservoir, July 1976

Stabilisation à long terme des berges. Réservoir Gouin, mai 1976
Long term slope stabilization in Gouin reservoir. May 1976

Au printemps, des radeaux de glace peuvent être poussés sur les berges. Réservoir Manic-5, juin 1976
In Spring, ice rafts are pushed ashore by winds. Manic-5 reservoir, June 1976

Les processus de déboisement par les agents naturels prennent place en deux phases qui se distinguent par le type d'agents actifs et par l'intensité des processus.

La première phase, appelée phase initiale, est caractérisée par l'action optimale produite par la glace dans la zone de marnage.

Cette action commence dès la première année, au cours de laquelle le niveau d'eau atteint son élévation maximum au début de l'hiver, et se poursuit pendant une période d'environ deux années au cours desquelles la majeure partie du déboisement par la glace est complétée. Il est évident que l'action des vagues lors de tempêtes peut aussi créer un certain impact durant cette période.

La phase d'ajustement se caractérise par l'interaction des agents autres que la glace: soit les vagues, les eaux souterraines, les courants et les agents biologiques tels le pourrissement des arbres. La végétation et les berges sont les éléments les plus affectés par ces agents. Ces processus peuvent être actifs sur une période de 5 à 30 ans.

L'interaction de ces agents durant cette phase produit une modification totale de l'environnement suite à l'action combinée des vagues sur le sol, et de l'impact de la glace sur les arbres. ☐

Le développement du minerai de fer est un facteur clé de la planification de la République populaire de Chine pour doubler sa production d'acier d'ici 1986 et pour créer une nation industrielle moderne avant la fin de ce siècle. Les Chinois se sont adressés aux pays occidentaux pour obtenir leur appui scientifique et technique ainsi que de l'équipement industriel.

Une importante délégation de géologues et d'ingénieurs chinois a visité le Canada en 1977 et l'année suivante, une délégation canadienne de quatre géologues, présidée par l'auteur de cet article, a rendu cette visite. Cet échange a ouvert de plus larges perspectives à la recherche canadienne et a constitué un point de départ pour les échanges scientifiques, le transfert de technologie ainsi que pour l'intensification du commerce des ressources. L'auteur décrit ici les régions visitées par la mission canadienne, ainsi que les discussions entreprises avec les autorités chinoises.

Cet article est disponible en français

CHINA/CANADA EXCHANGE: broader horizons for both

Enlarging our scientific data base benefits Canada directly...

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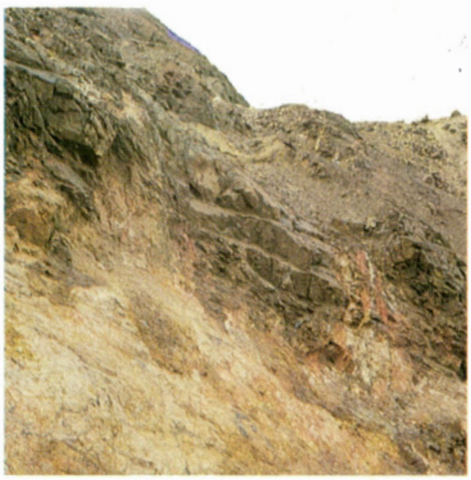

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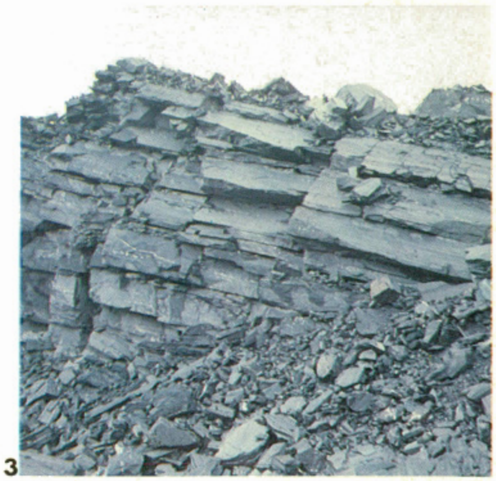

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1 *Canadian iron ore mission with Chinese colleagues on the Great Wall. l. to r. Jacques Gauvin, Ministère des Richesses Naturelles de Quebec; Hsia Hsien-Min, National Bureau of Geology; J.A. Donaldson, Carleton University, Ottawa; H.E. Neal, consulting engineer, Toronto; Shih Ming-hao, National Bureau of Geology; Gordon A. Gross, head of mission*

La mission canadienne sur le minerai de fer avec des collègues chinois sur la Grande Muraille. De gauche à droite, Jacques Gauvin, Ministère des Richesses Naturelles du Québec; Hsia-Hsien-Min, Bureau national de Géologie; J. A. Donaldson, Université de Carleton, Ottawa; H. E. Neal, ingénieur consultant, Toronto; Shih Ming-hao, Bureau national de Géologie; Gordon A. Gross, chef de mission

2 *Granite intrusions in the magnetite orebody at Pingyung in Kwangtung Province*

Injection de granit dans le minerai de magnétite à Pingyung, dans la province de Kwangtung

3 *Typical magnetite iron-formation at Takushan mine, Anshan area*

Une formation typique de magnétite ferreuse dans la mine de Takushan, dans la région d'Anshan

4 *Tayeh iron mines. Deposits are geologically similar to many in southeastern Ontario and Quebec and on Canada's west coast*

Les mines de fer de Tayeh. Les dépôts y sont géologiquement semblables à ceux qu'on trouve dans le sud-est de l'Ontario, au Québec et sur la côte ouest du Canada

5 *Ferry crossing near Kweilin, with striking karst topography of Kwangsi Province beyond*

Le ferry traversant près de Kweilin; on peut voir nettement la topographie karst de la province de Kwangsi au fond

6 *Part of Anshan iron ridge, where the largest iron and steel industry in China is located. Agricultural village in foreground*

Une partie de la crête d'Anshan, où se trouve la plus importante industrie de fer et d'acier en Chine. A l'arrière-plan, un village agricole

7 *Bedded manganese at Laipin Mine, Kwangsi Province*

Dépôts de manganèse dans la mine Laipin, dans la province de Kwangsi

By Gordon A. Gross

Iron ore development is a key factor in the plan of the People's Republic of China to double steel production by 1985 and to create a modern industrial nation before the end of this century. The Chinese have therefore turned to western countries for scientific and technical advice and industrial equipment needed for rapid development and renovation of their resource industries.

Their petroleum industry is expanding, and extensive resources of coking coal have been proven. The location and development of good quality iron ore resources therefore remains critical. Most of the iron ore reserves in China are low grade and consist of metamorphosed iron-formations, as in Canada. The Chinese recognize Canada's advanced mineral exploration methods, major diversified mineral industry, and similar mineral bearing terrain. They have studied GSC's Economic Geology series, used as text books in many countries, and translated large portions of the writer's three volumes on the geology of iron deposits.

Dr. Gross is senior resource geologist, GSC, and an international authority on iron ore resources. He is preparing a technical report on this visit.

In 1977 a party of nine senior geologists and engineers from the National Bureau of Geology in Peking, The China Geological Exploration Company, and the Bureau of Geology in two provinces, Anhwei and Honan, came to Canada for a month to study the geology, exploration methods and technology used for concentrating and processing various kinds of sedimentary iron ores. In return, a Canadian party of four geologists and an interpreter, led by the author, visited some of the main iron mining areas in China in May and June, 1978, to identify principal kinds of iron resources available to industry and to discuss iron ore exploration and evaluation methods.

For the Chinese, the mine visits and industrial and professional contacts have helped evaluate the status and efficiency of their own industry and identify and locate new technology and industrial know-how to renovate and expand their iron ore and steel industry.

On the other hand, the Canadian mission to China opened a broader dimension for our own research by providing access to the geological experience and knowledge of a continent, and a multitude of mineral deposit case histories. Enlarging our scientific data base benefits Canada directly. It improves our techniques of guiding mineral exploration and appraising mineral resources, especially where different kinds of ore deposits can be examined. They may not have been recognized in this country previously or available to us for research. The immediate value of the visit to Canada was in the initial steps made toward scientific exchange, technology transfer, and commerce in the resource industry, and to evaluate China's industrial and trade capabilities. Canadian industrialists are now following with engineering services, equipment sales, and consultation.

On arrival in Peking we were given a general briefing on the different kinds of


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iron resources found in China and the geological factors that control their distribution. Exploration and proving of mineral resources in China is carried out by the Geological Exploration Company, a branch of the National General Bureau of Geology (NGBG) and by the Bureaux of Mines and Geology in a number of the provinces. The Canadian Mission gave lectures and seminar sessions at the Academy of Geology of the NGBG in Peking and for each of the mining groups visited in other parts of the country. Exploration, mining and ore processing methods used in Canada were described and the geology of deposits comparable to those being mined in China was discussed in detail.

The Metals Society of China in Peking is composed of representatives from all engineering and scientific disciplines related to the mineral industry and provides high level policy recommendations to the government. They discussed their development problems and iron ore requirements and enquired about Canadian methods of sampling, drilling and ore testing in proving iron ore reserves, where such work was carried out and who performed it. They asked if we considered geological conditions in China favourable for natural high grade iron ore and how it might be found, pointing out that other countries, India and the Soviet Union, adjacent to China, possess such ore while relatively little has been found in China. Members expressed a keen interest in participation of Canadian geologists and engineers in the exploration, development and rebuilding stages of their iron ore industry.

The largest iron and steel industry is located at Anshan in Liaoning province in northeast China. Metamorphosed magnetite and hematite iron-formations containing about 30 percent iron are mined in three large open pits and the ore is concentrated and sintered to provide about six million tons of processed ore annually for the Anshan blast furnaces. Basic engineering methods and equipment from the Soviet Union advanced the Chinese iron and steel industries after the Revolution, and further modifications and improvements have been made recently. However, the Chinese recognize an urgent need to upgrade standards and operating efficiency. Contracts are currently being given to North American, Japanese and European engineers to renovate and modernize their mines and steel plants.

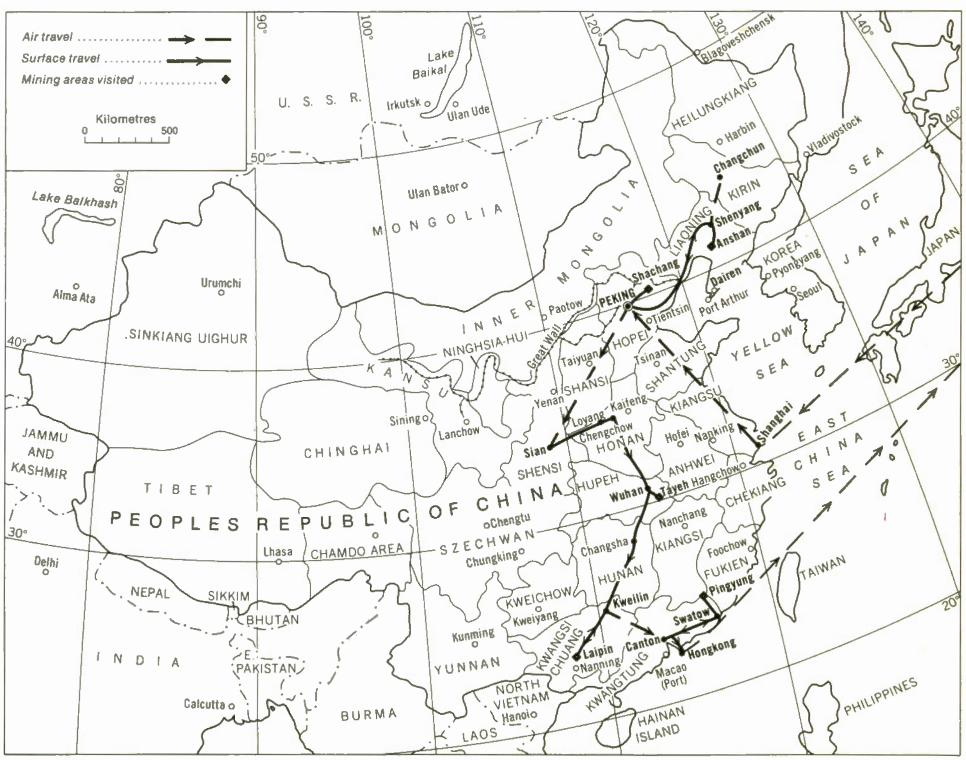
Highly metamorphosed sedimentary iron-formations comparable to iron deposits in northern Ontario and the Wabush Lake area of Labrador are distributed in a broad belt of Precambrian rocks that extends across Inner Mongolia and northeast China. We visited another deposit near Peking which is smaller but similar in type to those mined in Anshan. Important sedimentary ores with more complex mineralogy are mined near Poatow in Inner Mongolia.

Iron deposits visited at Tayeh in Hupeh province supply magnetite ore concentrate to the steel plants at Wuhan on the Yangtze River. These iron deposits are geologically similar to many that occur in southeastern Ontario and Quebec and along the west coast of Canada and are typical of deposits distributed throughout the eastern and southern part of China. Small amounts of copper are recovered from the Tayeh iron ore while deposits visited on the northwest part of Kwangtung province contain appreciable amounts of tin which may be recovered in the processing of this ore. The complex geology and mineralogy of the iron deposits in this part of China creates difficult conditions for mining and processing and ore reserves are not defined accurately.

The manganese mines at Laipin in Kwangsi Province in the southern part of the country are located in the midst of a world famous belt of karst topography. The landscape presents a jagged array of pinnacles, domes, sugar loaf hills and tufted ridges sculptured through the ages by ground water slowly dissolving the less resistant carbonate rocks. A cruise on the river at Kweilin provided a spectacular view of this rugged scenery that has inspired China's artists for millenia and offered a bold demonstration of the processes that formed the Laipin manganese ore. Although the quality and size of the manganese ore beds was not impressive, these deposits are of special significance in contributing to China's self sufficiency in manganese ore, essential for its steel industry.

The Chinese were among the first in ancient times to produce iron tools and implements, and local primitive forges still provide about 15 percent of the iron used. Larger steel plants producing up to one half million tons of steel annually are operated at the provincial level and about 70 percent of the iron and steel is produced from the major national enterprises such as the plants visited at Anshan and Wuhan. Iron ore deposits are widely distributed throughout China and the larger industries are located close to the major iron ore deposits. Resource distribution will be a controlling factor in the location of future industrial areas, to avoid long distance haulage of ore by rail.

Important new discoveries of iron ore have been reported in central and western China as a result of intensive exploration efforts in recent years. Geological conditions are considered favourable for the discovery of new sources of iron ore, particularly in the less developed parts of the country. By revising geological concepts, guidelines and approaches in exploration, the Chinese hope to establish an indigenous supply of raw materials for future industrial expansion. ☐



Canadian Iron Ore Geology Mission led by G.A. Gross, May to June 1978, to the People's Republic of China

La mission géologique canadienne sur le minerai de fer, qui visita de mai à juin 1978 la République populaire de Chine sous la direction de G. A. Gross

The objective of the Department of Energy, Mines and Resources (EMR) is to enhance the discovery, development and use of the country's mineral and energy resources and broaden our knowledge of Canada's landmass for the benefit of all Canadians. To attain this objective the department devises and fosters national policies based on research and data collection in the earth, mineral and metal sciences, and on social and economic analyses.

Le ministère de l'Energie, des Mines et des Ressources (EMR) a comme objectif la mise en valeur de la découverte, du développement et de l'utilisation des ressources minières et énergétiques canadiennes, ainsi que l'accroissement de nos connaissances des richesses naturelles du Canada, au bénéfice de tous les Canadiens. Pour atteindre cet objectif, le Ministère met sur pied et appuie des politiques nationales de recherches et de compilation des données relatives aux sciences de la Terre, des mines et des métaux, ainsi que des résultats d'analyses sociales et économiques.