Geological Features of the Mackenzie Delta Region, N.W.T.

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Contents

Foreword

This is the first in what the Science Institute hopes will be a series of Reports on a variety of northern, scientific topics. Each is to be aimed at a general readership with an interest in the results of research in the Northwest Territories. The Institute is thus attempting to increase the public's awareness of science while informing the research community of developments across a broad range of disciplines.

This first Report focuses on the geology of the Mackenzie Delta area, as seen on the land surface near Inuvik, and on the permafrost features called pingos in the Tuktoyaktuk area. While each of the papers in this report were written by respected scientists they are aimed at an audience that may have no special scientific knowledge.

Dr. J. Ross Mackay has been the pre-eminent permafrost researcher in the Mackenzie Delta and Beaufort Coast regions for many years. In 1963 he published the standard reference work on the physical geography of the Mackenzie Delta and has subsequently authored a large number of research reports dealing with his research on hydrologic and permafrost phenomena in the Western Arctic.

Dr. Larry Dyke is an associate professor with Queen's University in Kingston, Ontario. The paper included in this report developed as a result of a sabbatical stay at the Inuvik Research Centre during 1988 and 1989. Originally prepared for the Inuvik Elderhostel program, the present paper has been expanded and updated. Dr. Dyke is continuing his geological studies in the outer Mackenzie Delta.

The Institute expresses its appreciation to Mr. Gary White, the Manager of the Inuvik Research Centre, for work in preparing this publication. He worked with the authors to standardize the reports, collected materials from the authors and struggled to eliminate the many minor problems which plague the start-up of a new report series.

The Institute welcomes any comments that readers may have on this report. Suggestions for new report topics are of particular interest. The offer to author additional reports would be especially appreciated!

David Sherstone,
Director, Scientific Services
Yellowknife, November 1990

Guidebook to Geological Localities in the Vicinity of Inuvik, N.W.T.

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on behalf of
The Science Institute
of the Northwest Territories

SCIENCE INSTITUTE
OF THE NORTHWEST TERRITORIES

Geology – Not just the study of rocks!

Imagine a hot day, wandering up a creek bottom on a hike, your eyes idly casting about, hoping to find something worth taking home. The mosquitoes are so thick that... hey, a slab of shale lies freshly broken open and you recognize the imprint of leaves and plant stems. You have found a fossil, the remains of something buried long ago. Maybe your find isn't glamorous but you still have something that gives you a glimpse into the past, something that tells you what the Earth was like when those plants were buried.

You'll often hear geology defined as the study of rocks. This definition is correct but leaves out the most interesting part of the subject. Really, geology is the study of the Earth's history. Events during this history are recorded by the formation or alteration of rocks.

The history of the Earth is filled with action, if you believe that an earthquake or the spring break-up of the Mackenzie River is action. Events like these form or change rocks. We must be aware of these events if we are to learn how to interpret rocks and piece together this history. We also need to know if any of these events will happen in the future so we can stay out of the way.

You are lucky if you first became interested in geology in Inuvik. If you drive out along the Dempster Highway and walk to the places described in this guidebook, you can explore preserved intervals of the Earth's history. With a little study you can see that the present rolling hills near Inuvik, the Mackenzie Delta and the Aklavik Range in the distance are all the result of many episodes of uplift, erosion into mountains, filling in by large rivers, and scouring by glacial ice. In this guidebook you will find introductions to places in the Inuvik area where little pieces of this history can be seen. You have to use your imagination though. The rocks hold only clues to what happened in the past. You must try to put life back into everything you see if you are to understand what the Earth was like when the rocks were formed.

Inuvik's oldest rocks (Map 1, Site 1)

If you hike along the north shore of Airport Lake, you will see the oldest rocks within 100 kilometres of Inuvik. The road that leads to the gravel pit west of the airport also runs down to the lake and here you can see these old rocks in cliffs along the shore. The rock is argillite and it is about one billion years old. Argillite is the geologic equivalent of porcelain, clay with some quartz that has been baked by the heat of deep burial. One billion years has been enough time for the mud of a tidal flat to be buried under kilometres of sediment settling from the water, squeezed into chevron-like folds, raised, eroded, and buried by completely different rocks that you will see at other places. Geologists call this kind of rock "the basement" meaning rock from the deepest level, rock that has seen the most complicated history. (This rock is shown on the time chart, Figure 1.)

These ancient rocks form the core of an elongated dome that may have begun growing hundreds of millions of years ago. The dome has gradually been levelled so that the oldest rocks are exposed in the centre and younger, overlying rocks crop out on the flanks. These younger rocks are the Devonian carbonates, which form the highest hills south of the airport and Cretaceous sandstones and shales which are the ancestors of the modern Mackenzie Delta. These will come up later on in the guidebook. The dome is called the Campbell Uplift.

How do we know the rocks are so old? In this case the answer is paleomagnetism. This term refers to the magnetism of the Earth in the past. Many rocks contain magnetic minerals that settle into alignment with the Earth's magnetic field when the rock is formed. Thinking of these minerals as tiny bar magnets, their direction is often found to be very different from the present direction of the Earth's magnetic field. This shows that the magnetic poles

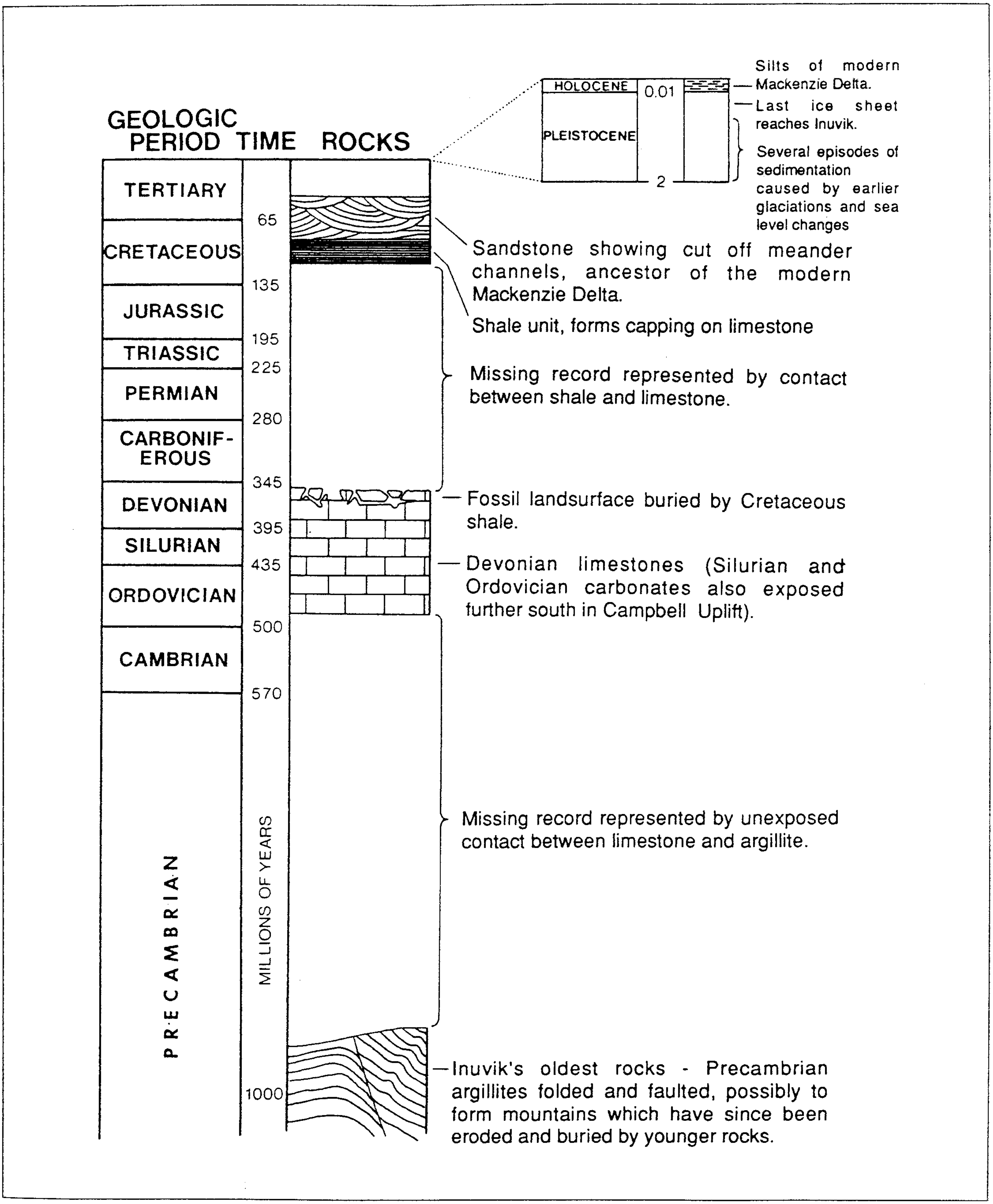
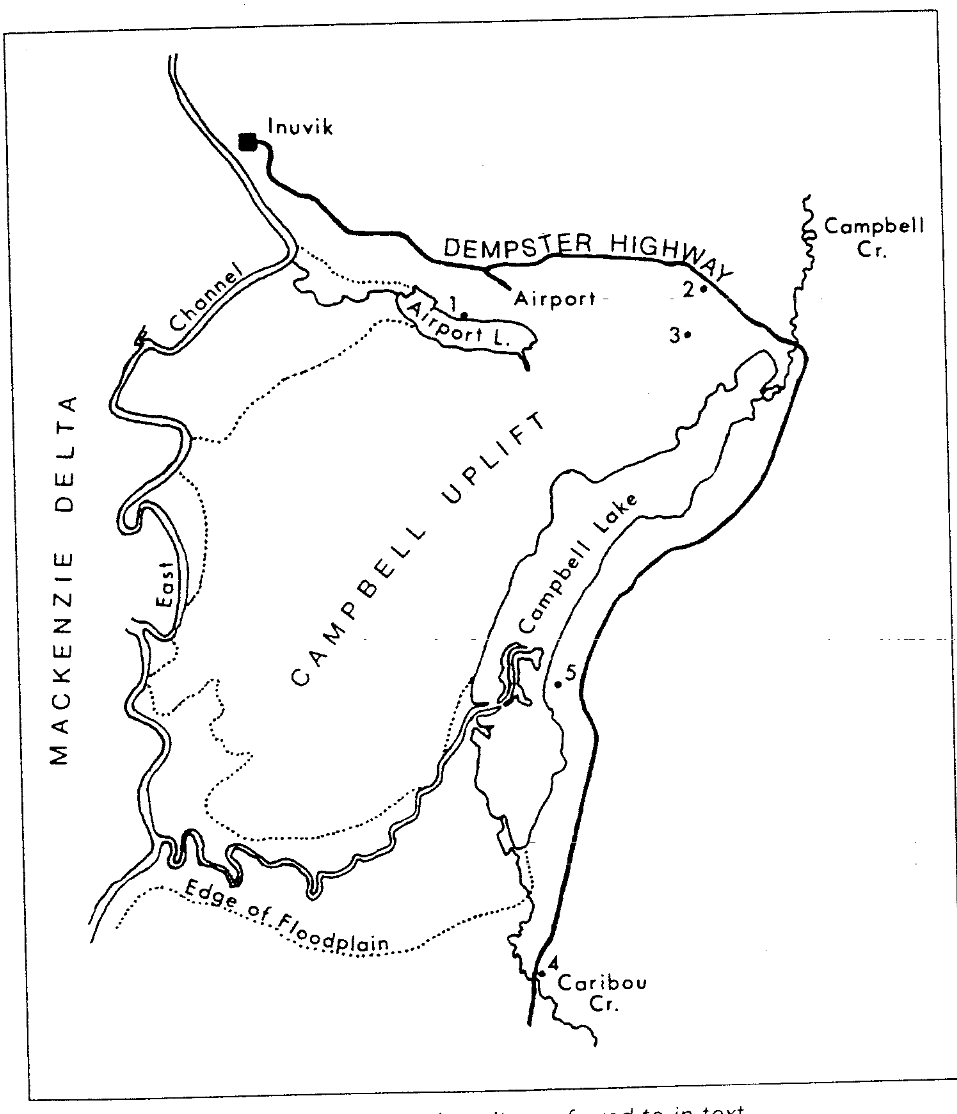


Figure 1. Geological time chart showing the names of the geologic periods and the order of the rocks and geological events of the Inuvik area.

have moved since the rock was formed. Enough determinations of the direction of magnetic minerals have been made to reconstruct magnetic pole wandering. At Airport Lake, no other dating method can be used because there are no fossils and no radioactive elements for measuring the duration of radioactive decay. Instead, there happen to be magnetic minerals in the argillite. Their alignment with the magnetic field at the time the rock was formed has been compared with the magnetic pole history to find the age of the rock.

You will probably notice that the sedimentary layers are folded. These folds are one way rock responds to compression, a way that the rock mass tries to take up less space when squeezed. The size of the folds is often controlled by the thickness of the beds or layers; thin beds produce small folds. In the Ogilvie Mountains of the central Yukon you can see folds at the other end of the scale. There, much thicker limestone beds have been compressed into folds over a kilometre across. Folds also have length. That means you could trace them back into the rock face if you excavated. There is a fold in sedimentary rocks of the Rocky Mountains in Alberta that is about 200 kilometres long.



Map 1. General location map showing sites referred to in text.

If rocks continue to be compressed, they may break to form a fault. It is also possible for rock to behave like plasticine if it is hot enough or if the compressive force is applied gradually enough. Experiment with a piece of toffee. On a cold day it shatters if you try to bend it. On a warm day it easily curls. But if you twist it suddenly you can still break it. Rock acts in the same manner. Of course the times and temperatures are much greater.

If you walk west along the shore of Airport Lake you will come to a fault separating reddish rock from yellowish rock (you may need a boat if the water level is high). You will also notice that the beds of rock against one side of the fault turn into the fault. This is called a drag fold and illustrates how the rock folded before it ruptured to form the fault. By matching colours or distinctive beds across the fault, you can tell which way the rock on either side moved.

Many faults continue to move after they form. Probably the most famous is the San Andreas Fault that runs through southern California. Horizontal movement has occurred along it almost continuously, a few centimetres a year. When the fault stops moving, then suddenly "lets go", you have an earthquake.

There is no evidence to say that the fault at the Airport Lake is active now. However, active faults are not far away. On the west side of the Mackenzie Delta, the Donna River Fault runs the length of the Aklavik Range (shown on map, Figure 2). Although no devastating earthquakes have ever been recorded along this fault, it has produced events up to magnitude 5 on the Richter scale. The disturbances travelling through the Earth from these earthquakes are recorded by seismographs, instruments that detect movement in the Earth. There is a seismograph station, operated by the Federal Department of Energy, Mines and Resources, in the pink building on the east side of the quarry road. The vibration sensor is located in a vault underground to ensure a solid contact with the Earth.

Just before we leave Inuvik's oldest rocks, you are probably wondering how a seismograph really works. The principle is simple. Imagine a cannon ball hanging from a thin steel thread attached to the ceiling of your bedroom. Fastened to the ball is a felt-tip marker. The marker is positioned such that if the ball moves, it will mark on a sheet of recording paper on the floor. If the room moves due to an earthquake, the marker is going to make a line on the paper. That long thread combined with the inertia of the cannon ball mean that for a short time, the room will move independently of the ball. Early seismographs were very similar to this but more modern equipment is much smaller and can detect movement in the Earth's crust that you would not be aware of.

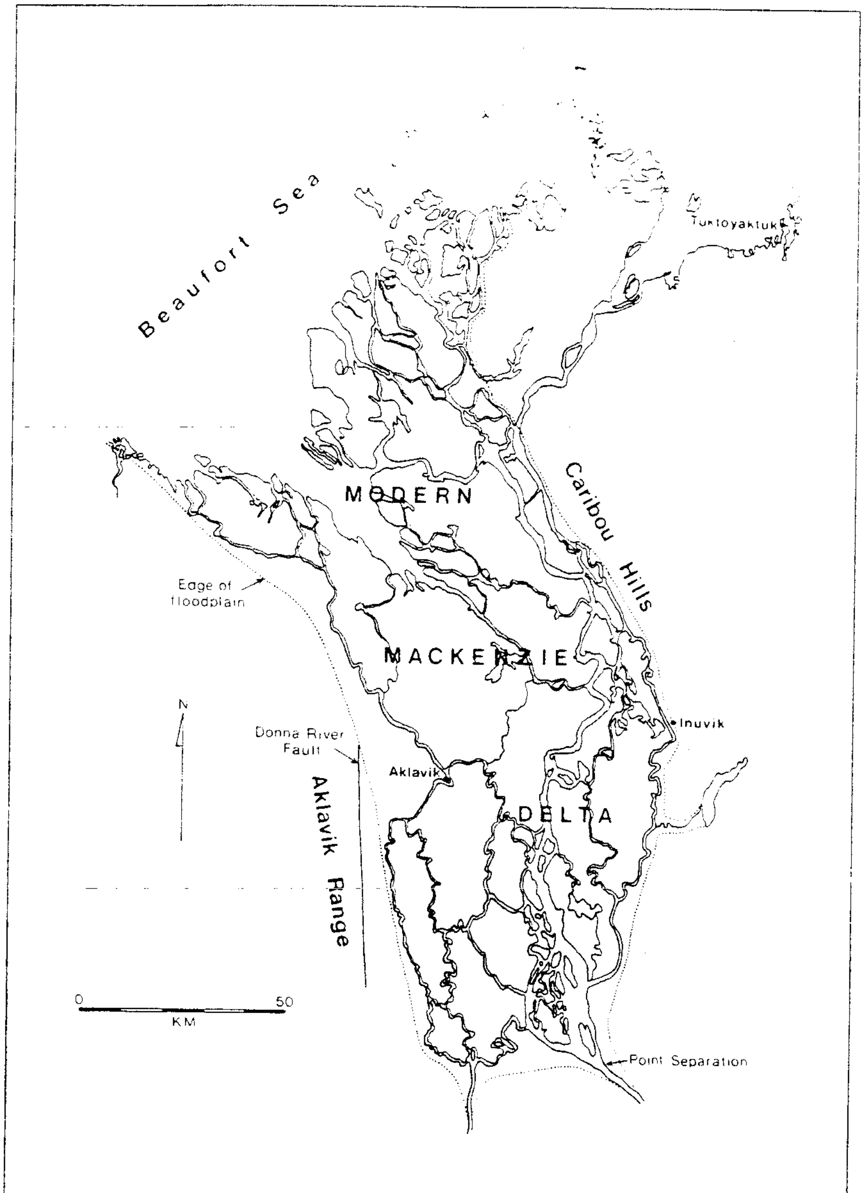
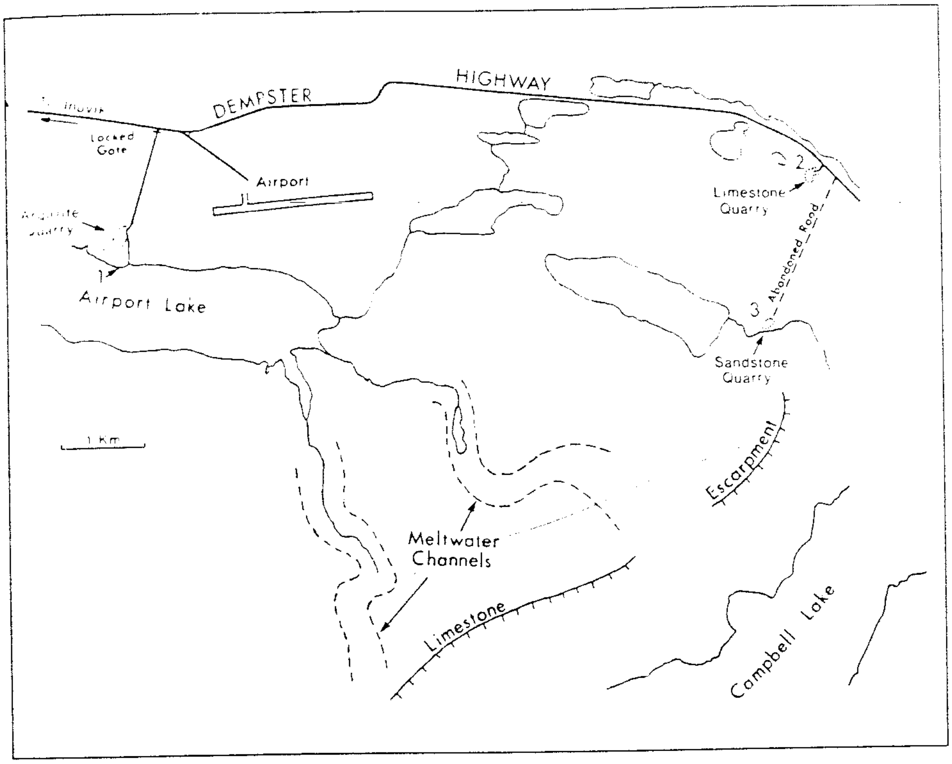


Figure 2. The main channels of the Mackenzie Delta and adjacent features.

Rocks Made from Living Things (Map 2, Sites 2 and 3)

In the Inuvik area the Precambrian rocks are covered by limestone and dolomite (see the cross-section, Figure 3). These are also sedimentary rocks but they are different from argillite because they form from the remains of living things. Sometime between one-half and one billion years ago, soft bodied creatures developed the ability to secrete calcium carbonate as an outer covering or shell. This was part of life; calcium was available in seawater and carbon dioxide was a product of life processes. These were combined by the organism to form calcium carbonate. This material was ideal for preservation because of its resistance to organic decay. As a consequence we get to see what these creatures looked like.

The most convenient place to see limestone is in a quarry on the south side of the Dempster Highway approximately seven kilometres east of the airport turn-off. These rocks form the most rugged terrain in the Inuvik area and are responsible for the cliffs that line both sides of Campbell Lake. The quarry is in a bluff, the first of many that stretch south for about 20 km. You



Map 2. Detailed location map showing sites 1, 2, and 3.

won't have to look long before you'll find shells called brachiopods and maybe even disc-like crinoid segments. Those who are persistent find corals and trilobites. A crinoid is a colonial organism that looks very much like a miniature tree but was really an animal. The stem and branches were easily broken into their component segments once the animal died. What would cause the pieces to scatter? What is your interpretation? Currents caused by waves would be a good answer. That means you could say that the water was probably shallow because wave action dies out quickly in deeper water.

The fossils are contained in a dark, very fine grained crystalline matrix that originated by the accumulation of billions of shells from tiny floating creatures. These shells can often be seen under the microscope but in this case the calcium carbonate of the shells has been temporarily dissolved and recrystallized. All you would see would be countless tiny crystals. Still, all this rock was originally formed from the remains of living things.

These rocks are from the Devonian period or you can say they are "Devonian in age". The Devonian period is that part of the Earth's existence extending from 395 million to 345 million years ago (shown on time chart, Figure 1). The entire history of the Earth during which organisms with hard or shelly parts lived is divided into 12 periods, starting 570 million years ago. But how do you tell the age of a fossil? This is done by correlation. If you can find a particular fossil close to a rock that has been dated by paleomagnetism or radioactive decay, then you can say that the same fossil elsewhere is the same age. About 40 years ago, when methods for determining the absolute age of rocks were developed, geologists began to assign absolute ages to fossils. Before then, ages were relative and you could only say that one rock was older then another but not by how much.

Of course these rocks were deposited in a sea. Carbonate rocks from the Devonian period occur throughout Western Canada, from the Arctic Islands to Alberta. This is an immense volume of organically derived rock and means that a sea, rich in life, existed through this whole area at that time. Coral reefs were common in the Devonian, probably forming islands much like they do now in tropical waters. When these reefs were buried by more sediments, they became excellent reservoirs for oil because of all the spaces amongst the corals and shelly remains. Buried reefs form some of Canada's largest oil reservoirs.

So now we have seen ancient, lifeless Precambrian rocks covered by younger rocks containing evidence of abundant marine life. What about the time in between? Somewhere the two rock units must make contact. They do but no natural exposures of the contact have been found and no bulldozer operator has inadvertently unearthed it. You just have to take it on faith that if the Precambrian argillite and Devonian carbonates are present, the younger must rest on the older. Imagine... Precambrian to Devonian. That means that a span of time 200 million years long is not accounted for in the rock record (see time gap on Figure 1). This sort of gap and the surface where the two rock units contact is called an unconformity. In our case it means that either no rock was deposited during that 200 million years or that rocks were formed but were eroded away before the Devonian sea appeared. We will have to leave this question of the missing rock. Questions about what happened at a particular location often need to be answered by looking over a large area to try and find rocks that fill the missing time gaps.

A Fossil Land Surface (Map 2, Site 2)

The quarry limestones still leave an enormous gap of time unaccounted for. What happened after this time of widespread, perhaps tropical seas? If you look around the quarry rim you will see places where the rock face is interrupted by zones of loose, yellowish soil. Sometime after the limestone formed, it was raised above sea level and became part of a land mass. If you know about limestone caves you will know that limestone can be dissolved by water trickling down from the surface into the rock along fissures or cracks and through pores. This happened to the Devonian limestone. Caves formed through the process of dissolution; the rock was eaten away until the roofs of some caves collapsed to produce pits or sinkholes. Later still, the land surface was buried by more sedimentation and the sinkholes were filled in. The fill material may have become the yellowish soil. This is one way of interpreting the meaning of the yellowish soil. It has been exposed by the excavation of the quarry so you are seeing slices through some of the filled-in pits.

The sediments that buried the limestone have been removed by erosion. It is almost certain that sediments covered the limestones because remnants of the covering are found nearby. The rounded hill that forms that highest land on the skyline south of the airport is one of these remnants (see Figure 3). Glacial scouring probably removed much of this sediment during the Pleistocene ice age. Once the ice worked its way down to the limestone, erosion was slowed by this much harder rock. It is possible that the present rock surface along the rim of the quarry is the same surface that was buried by the shale sediments. This means that we have another unconformity, one that is much easier to appreciate because the filled-in caves are part of it and there for you to see. This unconformity was once the surface of the Earth, buried then uncovered to become part of the surface again.

The Mackenzie Delta Ancestor Replaces the Shallow Sea (Map 2, Site 3)

The remnants of shale that cover the limestones in a few places are a tiny sample of a huge sedimentary basin that is preserved under the Mackenzie Delta. In fact the delta is merely the most recent stage in the accumulation of sediments in this basin. Sediment has been washing into it for at least the last sixty-five million years and has built up to a thickness of about 15 km. This basin is wedge-shaped in cross section, becoming thicker as the Beaufort Sea is approached. These sediments contain all of the gas and oil finds that have been made in the Delta or Beaufort Sea.

Shales are one of a family of rocks known as clastics. These sedimentary rocks formed from the erosional products of other rocks. Sandstones and conglomerates fall into this category. The coarser the fragments composing the rock, the faster must have been the currents moving them. From this knowledge and the distribution of shale, sandstones, and conglomerates, it is possible to interpret the environment at the time these sediments were deposited. Most of what is known about the rocks in the Mackenzie Delta sedimentary basin came from the wells drilled in search of oil and gas. A diamond drill bit makes an annular hole and the rock left in the middle is brought to the surface as core. This is very costly because the entire length of drill rod connecting the bit with the surface must be raised also. This may take several hours if the drill is deep. Therefore, geologists working on the drill rig get cores only when they feel it is very important to examine the structures in the rock. Otherwise they must content themselves with the cuttings (rock chips) that are washed up the hole with the circulating drilling fluid.

It turns out that the structure of the sedimentary basin is quite complicated. It is a large basin that filled with sediment but, simultaneously, mountain-building forces were at work, disturbing the basin. The present delta contains mostly silt laid down by the twisting channels of the Mackenzie River. Below the delta surface the entire range of clastic sediments are found. Conglomerates indicating strong currents were present at the time of sediment deposition. Parts of the basin were raised by compressive forces to form land and streams ran off this land, redepositing sediment that had already been turned to rock. The raising of Campbell Uplift was probably happening at this time because shales that presently cap the uplift would have originated in a deep part of the basin, away from the direct sediment source of a river mouth. Shales that are the same age exist to the west and north of the Campbell Uplift under the Delta. The shales on the Uplift must have had time to be raised high enough so that erosion could expose them.

To observe one of the erosional remnants deposited during the disturbance of the basin, walk 1.5 km south along an old access road that leaves the Dempster Highway, about 100 m east of the limestone quarry. This road leads to a quarry (Site 3) that was abandoned because the quality of the rock turned out to be unsatisfactory for road construction. It turned out that this rock weathers very quickly. It is a sandstone in which the sand grains are only weakly cemented with calcium carbonate or pyrite. Both these minerals are readily dissolved by water percolating through the rock. If this happens the rock loses its strength. Chunks break down into sand so a roadbed constructed of such material gradually collapses. Determining the suitability of rock for construction is part of a separate field called engineering geology.

There is still enough of the quarry to let you see a record of an erosion episode that took place as the Mackenzie Delta sedimentary basin was being disturbed by mountain-building forces. The exposure is a record of a stream channel depositing sand, pebbles, cobbles, and plant remains over a more tranquil setting, perhaps a bog or flood plain. The flood plain layers are thin, less than one cm thick, with much organic material that forms black layers. Over this it seems that sand has suddenly been deposited in curved layers. A stream channel has appeared and would be changing course rapidly, in a matter of days or even hours. Sand would settle out on the stream bed, then the bed would move, perhaps to a place where it had been before, eroding the previous sediments. You can tell this if you follow a sand bed. You'll find that one sequence of beds is cut off or truncated by another, a sign that the stream was changing course and removing sand it had left earlier. Pebbles are spotted throughout, showing that the current must have been rapid. You might also notice that the thin organic beds below are not horizontal but have been compressed or squeezed. The stream washed in sand so quickly that the sediment beneath was still soft enough to collapse a bit under the added weight.

These sediments are tucked away in this low area between two limestone ridges, one to the south and one beside the road you walked in on. It is a protected pocket that survived removal by glacial erosion. Sometimes a small outcrop like this is all that is available for making interpretations of what happened. These rocks are clastic (formed from broken rock fragments), and they must be related to the much larger deposit of clastic rock that is the Delta sedimentary basin. The source of these particular sandstones has long been buried or removed and these pockets remain to give us clues that more than just one continuous building of sediment happened.

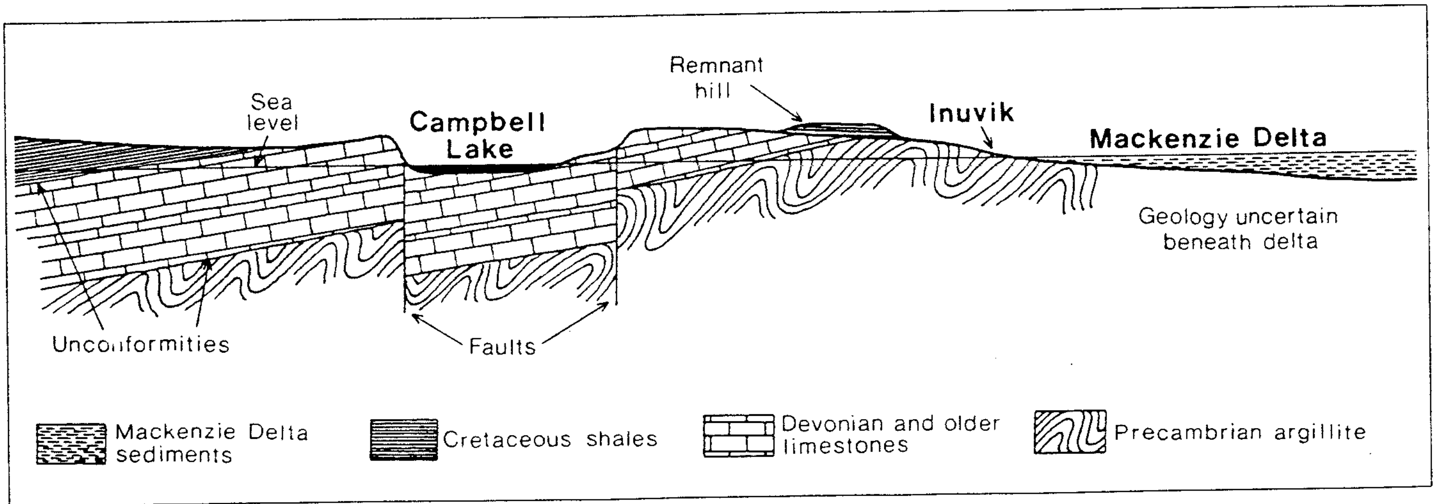


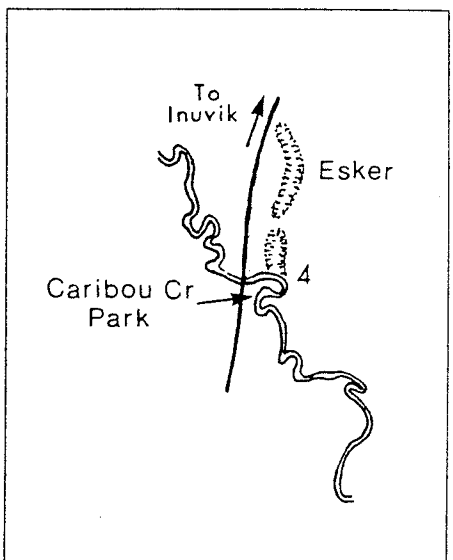
Figure 3. Generalized cross-section showing what a slice of the land would look like moving from Campbell Lake to the Mackenzie Delta.

The Laurentide Ice Sheet Makes It To Inuvik – Just Barely! (Map 3, Site 4 and Map 4, Site 5)

The last major geologic event that actually left the hills and valleys the way we see them today was the Wisconsinan Ice Age. This was the last of several periods of glaciation, each of which covered Canada with ice up to 2 kilometres thick. It was the erosive power of these moving ice masses and the later tremendous volumes of meltwater that scoured, sculpted, and deposited the land forms we see today. The Laurentide ice sheet probably had its source in central Keewatin. It spread out in all directions, just managing to extend northwestward as far as the Tuktoyaktuk Peninsula. This would have been about 18,000 to 20,000 years ago. By 10,000 years ago it had begun to melt and, after dwindling back to Keewatin, was gone by 5,000 years ago.

The ability of the ice to erode the land surface depended on the temperature of the ice sheet base and on its velocity. If the ice sheet was cold enough on the bottom, it would freeze to the land surface. In this condition, not much erosion would take place. If the base of the ice was at the thawing point, it would not be bonded but rather free to slide. Rocks and sand imbedded in the base provided an abrasive or rough surface. In this way the deep fiords of the British Columbia and Alaska coasts were shaped, although much of their form was also caused by the concentration of ice flow into narrow valleys. Around Inuvik the ice advanced as a single sheet and while it did not have the opportunity to carve deep valleys, it still left its mark.

Map 3. Caribou Creek Area



The evidence for glaciation is not striking from the ground at Inuvik. Areas close by show spectacular scouring but you need a boat to reach them. By examining an aerial photograph of the south end of the Campbell Uplift, parallel ridges in the carbonate bedrock left by the ice are visible. These ridges are also very apparent on the ground in that area. Glaciation can leave a rock surface polished to an almost mirror smoothness but on carbonates weathering by the elements keeps the rock rough.

An ice sheet leaves the most complete record of its presence during its retreat. Any glacial deposits such as moraines or eskers, that formed are left intact instead of being destroyed by an advancing ice sheet. It follows that most glacial landforms are therefore the product of the most recent glaciation. Only buried features are able to survive an ice advance. The melting that accompanies a retreat produces enormous volumes of meltwater. Meltwater streams have left many abandoned channels across Canada, valleys that are far too deep and wide to have been formed by the streams now occupying them. Meltwater probably drained across the Campbell Uplift in two valleys that seem to begin and end for no other reason (see Map 2 showing site 1, 2, and 3 for locations). These valleys form two low passes between Campbell Lake and Airport Lake. The edge of the ice sheet may have rested for a while against the cliffs that rise along the west side of Campbell Lake, meltwater would have ran off the glacier, across Campbell Uplift, and into what was to become the modern Mackenzie Delta. When the ice was gone the channels were left with a few ponds and a trickle of water.

The retreating ice also left eskers. These are ridges composed of sand and gravel that are deposited by meltwater streams running beneath the ice. One of these forms a sharp crested ridge about 15-20 metres high that follows the Dempster Highway immediately east of Caribou Creek. In fact the creek cuts into the esker just above the highway culvert crossing (Site 4). This is why the high bank is made of yellowish-brown sand. Elsewhere upstream the sides are rock. If you keep a careful watch, you will see other eskers and related features further north along the highway. Eskers eventually must exit from beneath the ice and when they do a delta is likely to form. You can see a slightly raised, flat sandy area 100 m or so west of the highway about l2 km north of Caribou Creek. Just about any feature on the broad gentle slopes to Campbell Lake that appears as a slight rise and supports tall spruce is likely to be some kind of glacial meltwater deposit. Some of them have been partly removed for use as construction material.

Because the ice sheet that reached the Tuktoyaktuk Peninsula was probably thin compared with the source back in Keewatin, there was little depression of the land from the added weight. Around the shores of Hudson Bay and along the arctic coast east of the Delta area, the land was depressed as much as 300 metres. When the ice disappeared, the land began to return to its former level. The process was rapid at first with sea level dropping as much as 30 cm per year. Soon it slowed down, giving enough time for beaches to form at successively lower levels as the land continued to rise. These raised beaches are one of the most visible and spectacular land forms in the arctic, but they never formed in the Mackenzie Delta area.

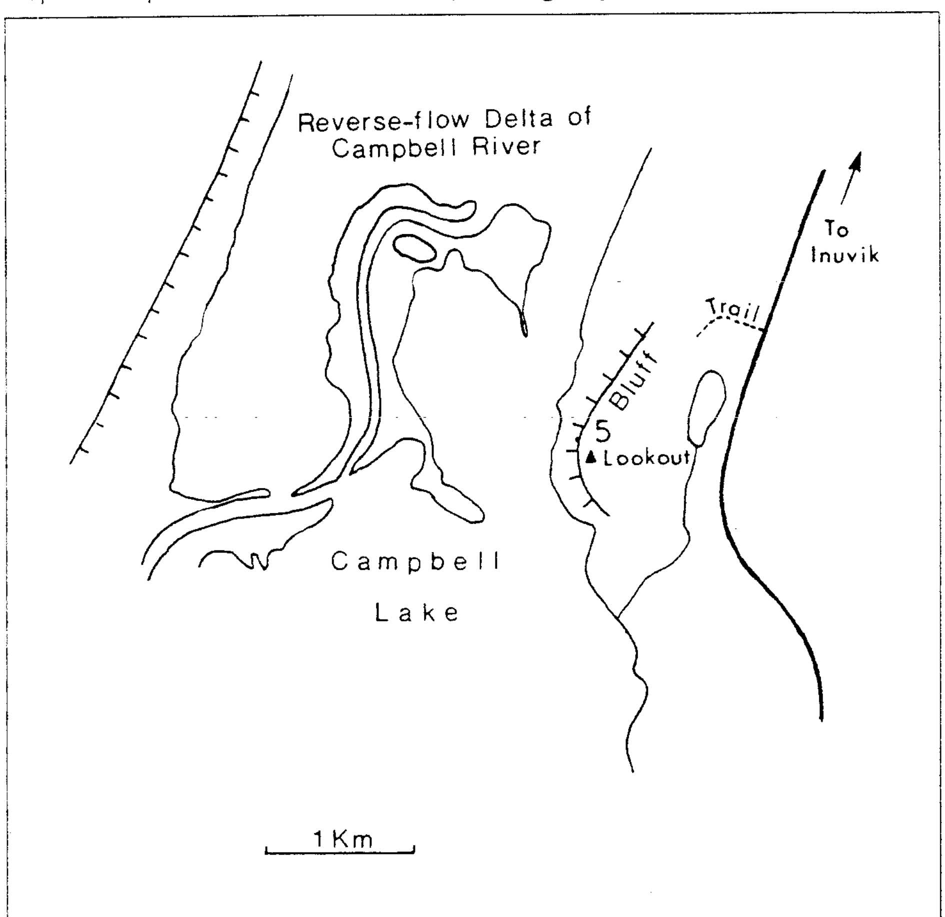
The water that was used to form the continental ice sheet resulted in a drop in sea level. The ice that reached here was simply not thick enough to cause noticeable land depression. The Beaufort Sea withdrew, causing the coast to be as much as 100 kilometres further north than it is now. This new land was exposed for perhaps 50,000 years, long enough for permafrost to form to depths of 700 m. Since then the sea has returned and submerged this permafrost.

The Mackenzie Delta in its present form (the flat alluvial area presently occupied by the channels of the Mackenzie River) developed during the retreat of the Wisconsinan ice sheet. A borehole was drilled in 1961 about 5 km southwest of Inuvik to see how thick the Delta sediments are. The drill hole encountered limestone at 71 m below the surface. This is the same limestone that forms the Campbell Uplift. Everything above the limestone is silt or sand with an occasional pebble layer and even one occurrence of buried wood. This borehole records the building of the Delta. The present Delta fills a broad, shallow valley into which the Beaufort Sea advanced as sea level rose. However, the Mackenzie River existed then and probably had an even greater discharge than at present (it presently reaches maxima near 30,000 cubic metres per second or one cubic kilometre every 10 hours during flood periods). The ancient river filled this valley with sediment, reclaiming the land covered by the sea.

The Delta was built northwards from Point Separation and its evolution has been dynamic. Islands originating as offshore bars at the mouths of channels are constantly enveloped by continued advances of the Delta. Lagoons between the bars and the front of the Delta become landlocked. This process continues throughout the growth of the Delta, thus forming the countless lakes covering the Delta. Channels maintain themselves by building levees or raised banks during spring flood. Sediment spills out from the channels during high water, gradually increasing the height of the levees. Channels are able to maintain themselves separately from the lakes because of this tendency to build levees.

The channel-building tendency is illustrated at the south end of Campbell Lake (Map 4). Here Campbell Creek is building a channel out into the lake. This would seem to be the reverse of what should happen. After all the lake should be draining into the Mackenzie. However, remember that at flood time Campbell Creek backs up, reversing its flow and carries enough silty Mackenzie water into Campbell Lake to build the channel. To see this walk from the Dempster Highway (see Map 4 for location of site 5). The trail soon disappears

Map 4. Campbell Lake Area, near Dempster Highway lookout



but the country is open and you can find your way to the crest of the nearest bluff which reveals a view down onto the lake. The limestone is the same age as the rock at the limestone quarry (Devonian) but the lake lies in a graben. A graben is a structure formed by the down-dropping of a body of rock along two faults. One fault forms the boundary of the bluff and the other forms the cliffs on the far side of Campbell Lake. Try to locate glacial grooves on limestone bedding surfaces as you are hiking to this lookout.

Footnote

The stops described in this report are intended to give you glimpses of geologic history in the Inuvik area. Events over the last one billion years are recorded but you now know that there are large gaps in this history. This is typical of the geology of any area and it is necessary to move further afield to find rocks that fill the gaps. Rocks from the time interval between the Devonian and Cretaceous (missing in the Inuvik area) are present to the west in the Aklavik Range. They may have been present in the Inuvik area but were subsequently eroded. The Earth's history on the largest scale is a sequence of uplifting, eroding, inundation and draining of land masses. The composition and age of the rocks formed tell much about the earlier geography of the Earth. Keep this in mind as you continue your travels in the north.

Acknowledgement

This report was originally written during the summer of 1989 while the author was resident at the Inuvik Research Centre. It is small compensation for the aid and encouragement provided by the Centre to the author's ongoing research. The author is indebted to Gary White, the present manager, for his thorough and competent review of the manuscript.

Pingos of the Western Arctic Coast

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Figure 1 (above): A wave eroded pingo about 100 km (60 miles) northeast of Tuktoyaktuk, N.W.T. The exposed section is about 7 m (22 feet) high. The ice core is pure ice.

Pingo is an Inuit (Eskimo) word for a conical hill. A pingo is an ice-cored hill (Figure 1) that can only grow and persist in a permafrost environment. The world's greatest concentration of pingos, numbering about 1,450 is in the Tuktoyaktuk Peninsula area (Figure 2). Numerous pingo-like features also occur in submarine permafrost at the bottom of the Beaufort Sea. In addition, thousands of circular features resembling collapsed pingos have been found in many non-permafrost areas of the world, such as northwestern Europe, the British Isles, southern Canada and the northern United States. If correctly identified, collapsed pingos in a non-permafrost area prove the former presence of permafrost in that area.

Pingo Origin

A schematic drawing of the origin of the Tuktoyaktuk Peninsula pingos is shown in Figure 3. Permafrost in the region is usually deeper than 300 m (1000 feet). Permafrost is widespread because of the cold mean annual air temperatures which average about -11°C (12°F) at Tuktoyaktuk. However, large lakes maintain unfrozen basins beneath them (Figure 3a). Many of the lakes drain naturally because of erosion of the ice-rich ground at their outlets. When a lake drains, the lake bottom becomes exposed to cold air temperatures so permafrost will start to grow downward on the exposed lake bottom in the first winter (Figure 3b).

Most drained lakes have small residual ponds which slow down the downward growth of permafrost beneath them. Permafrost is therefore thinner beneath the ponds than around them. When water freezes its volume increases by about ten percent. However, when the saturated sand beneath the downward growing permafrost on the lake bottom freezes, some of the water tends to be squeezed out, like water from a sponge. This squeezing out of water, or pore water expulsion, may create a sufficiently high water pressure to cause the permafrost to form a dome at the weakest spot. This is beneath a residual pond; pingo growth has started. The water

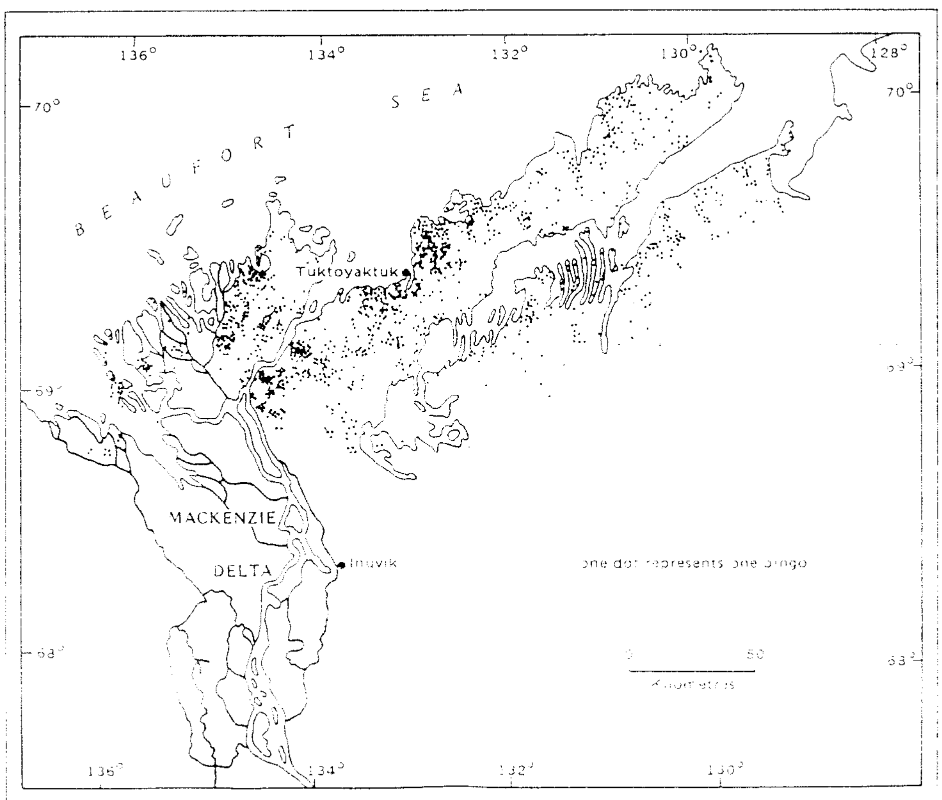

Figure 2 (above): Distribution of pingos.

pressure is often so great that the ice cores of many growing pingos are underlain by water lenses that can be as much as 3 m (10 feet) deep, as shown in Figure 3c.

Pingo Growth

Pingos, like plants and animals, grow most rapidly when young. A few grow nearly 1 m (3 feet) in the first year. The growth rate slows with time until, eventually, growth ceases. Contrary to what might be expected, the age of a pingo cannot be estimated by its size. This is because the diameter of a pingo is established at birth by the shape, depth, and permafrost conditions of the residual pond where growth commenced. A pingo then grows higher but only a little wider. Therefore, a small pingo can be much older than a large pingo, or vice versa. Most of the Tuktoyaktuk area pingos are hundreds to thousands of years old so that the birth of a pingo is a rare event.

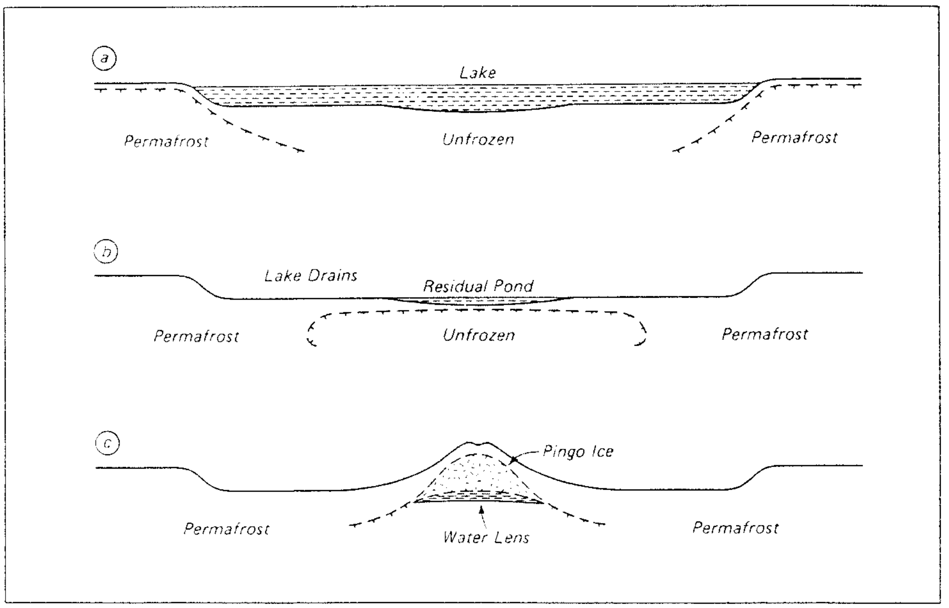

Figure 3: (a) A lake with an unfrozen basin beneath it. (b) Growth of permafrost after lake drainage. (c) Growth of a pingo at the site of a residual pond.

Ibyuk Pingo

Ibyuk Pingo (Figure 4), one of the largest pingos in the world, is just a few kilometres southwest of

Figure 4 (above): Ibyuk Pingo is a few kilometres southwest of Tuktoyaktuk, N.W.T.

Tuktoyaktuk. It is 50 m (160 feet) high and about 300 m (1000 feet) in diameter at the base. The pingo is probably more than 1000 years old. For the 1973 to 1983 period, the summit, as measured by precise surveys of bench marks anchored in permafrost, rose at the steady rate of 2.3 cm (1 inch) a year. The 50 m thick ice core of Ibyuk Pingo is protected from melting by about 15 m (48 feet) of frozen peat and sands.

Ibyuk Pingo can be reached by boat from Tuktoyaktuk or on foot, but it is not advisable to walk to the pingo without a good map or a guide. Hikers should avoid all bare slopes, especially those of loose sand, because frequent disturbance will lead eventually to exposure of the pingo ice and pingo collapse.

Tuktoyaktuk

There are several pingos in the settlement at Tuktoyaktuk. The pingo with the large log house on the side formerly had a tunnel, the so-called "curling rink", excavated into it, although the room was never used for that purpose. The tunnel entrance collapsed in 1979.

Grow your own Miniature Pingo!

With a little patience, a miniature pingo (Figure 5) can be grown in a home freezer with no more equipment than a washbasin filled with sand and a flattish piece of thin rubber, such as that from a large balloon. You can duplicate, in miniature, the natural conditions of pingo growth. First, fill a convenient sized container, such as a plastic washbasin about 50 cm (1 1/2 feet) in diameter with sand. Make a small saucer-sized depression in the centre. Place a circular piece of thin rubber, slightly larger than the depression, over the depression. Put a layer of sand around the circumference of the rubber to hold it down in place. Gently pour water into the sand until there is water under the rubber. Pour a little water over the rubber to make a pool. The container with saturated sand then represents a drained lake; the saucer shape depression is a residual pond; and the rubber is the thin permafrost (i.e. frozen soil) at the bottom of the residual pond that is domed up by pingo growth. Now put the container in a freezer; cover it to prevent it from freezing too rapidly. As the saturated sand in the container freezes inward from the top, bottom, and side, water should ooze up beneath the depression and dome the rubber to grow a miniature pingo with an ice core. A little experimentation will be necessary to adjust freezing conditions to the size of the container, amount of sand, the dimensions of the miniature pond, etc., but with practice, realistic pingos can be grown. Growing miniature pingos can be an interesting project for a science fair. Colour can be added to the water; the shape and the depth of the residual pond can be varied to grow pingos of different sizes and shapes; and a device can be arranged to measure the water pressure.

Figure 5 (below): A miniature "pingo" grown in a home freezer. The marble is about 1.25 cm (half an inch) in diameter.

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