Pingos of Tuk

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The Mackenzie Delta, on the Arctic coast of northwest Canada, lies in deep permafrost country and is justly famous for its splendid pingos. The Inuit settlement of Tuktoyaktuk (known locally as Tuk, for obvious reasons) stands on the shore of the Beaufort Sea, which is a part of the Arctic Ocean. The summer terrain is a wetland wilderness of lakes, rivers and peat bogs (Fig. 1), with islands of tundra and just a few isolated hills (the winter terrain is snow and ice). In the Inuit language the boglands are muskeg and the hills are pingos. All the hills in the Mackenzie Delta are ice-cored mounds, and geomorphology has borrowed the word pingo as a generic term for this distinctive arctic landform.

Fig. 1. Wetlands of the Mackenzie Delta, with the buildings of Tuk just visible beyond Split Hill Pingo, seen from the aeroplane in from Inuvik.

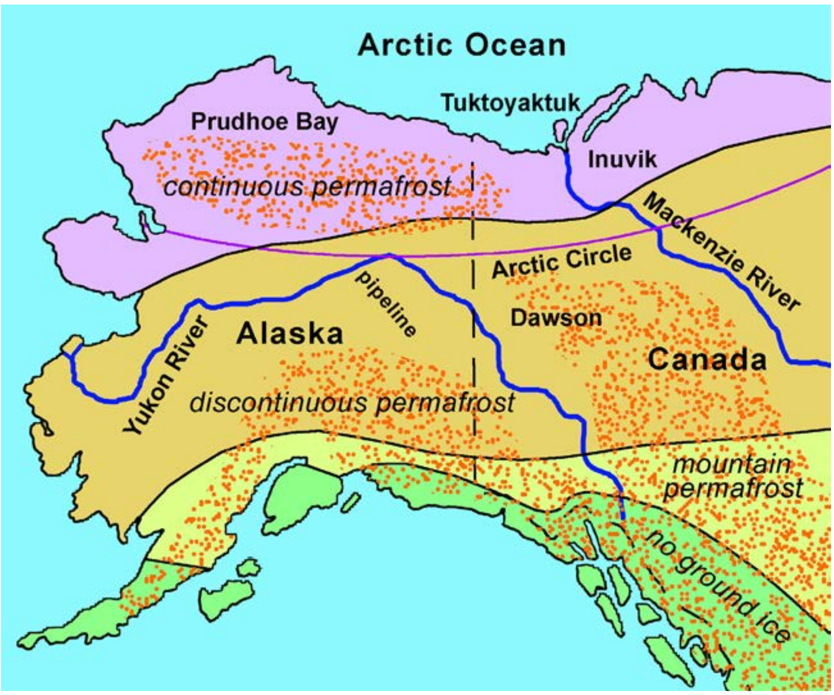

Fig. 2. The extent of permafrost in Alaska and northwest Canada, with Tuk located well into the zone of continuous permafrost.

Tuk's climate is awesome. Only three months in summer have their mean temperatures above freezing, while for five months of every winter the daily maximum stays below -20 °C. When the winter wind blows strong, the chill factor is such that nobody goes outside. Annual precipitation is, however, only 130 mm; Tuk lies in an Arctic desert.

The mean annual temperature at Tuk is -11 °C, well below the figure of -8 °C that is necessary for the development of continuous permafrost (Fig. 2). Frozen ground extends to depths of about 350 m; only below that is geothermal heat adequate to overcome the chill that creeps downwards from the atmosphere. Every summer there is some thawing of the ground surface. This creates the active layer of alternate freezing and thawing, which is typically a few metres thick, but only reaches down a few centimetres in much of the lowland around Tuk. Ice wedges expand through cycles of freeze-thaw, especially in fine-grained soils, until they form polygonal networks that are so easily recognizable by their control on the tundra vegetation (Fig. 3). But the mainly granular soils of the Mackenzie Delta are just about ideal for the growth of massive ground ice – and the formation of pingos.

Open-system and closed-system pingos

Nearly all the delta pingos are of the closed-system type, in that they grow from drained thermokarst lakes (Fig. 4). Within a permafrost region, lakes survive through the winter beneath an insulating cap of ice, and then expand during the summer as their water thaws the adjacent ground before it is eroded by wave action. Known as thermokarst lakes or as thaw lakes, each is underlain by a lens of talik ground that stays unfrozen due to the thermal buffering of the lake water. In the shifting drainage patterns of the delta flatlands, a thermokarst lake is easily and often very rapidly drained. The unprotected talik beneath the site then slowly freezes and therefore expands, so that expelled water forms an ice dome in the core of a new pingo.

Open-system pingos grow where unfrozen water rises through ground that has discontinuous layers of permafrost and unfrozen talik. The rising water then freezes just below the surface to form the ice within an active pingo. Commonly controlled by soil drainage within slopes, there are few pingos of this type in the Mackenzie Delta.

Tuktoyakyuk and its pingos

There are however more than 1350 closed-system pingos recorded in the delta. Those near Tuk benefit by their accessibility – though this is not easy. Inuvik, the regional Inuit capital, is reached by the Dempster Highway from Dawson, a gravel road open in all weather except for breaks during autumn freeze-up and

Fig. 3. Ice-wedge polygons splendidly revealed by the vegetation growing on the sediments of an old lake bed amid the tundra of the Mackenzie Delta.

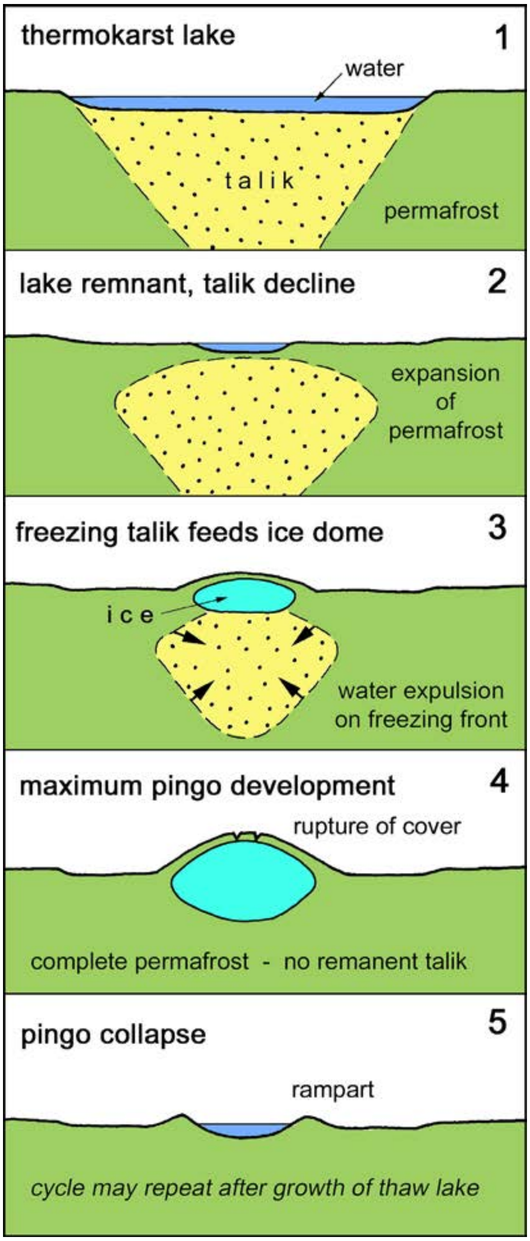

Fig. 4 (left). Sequence of stages in the evolution of a closed-system pingo.

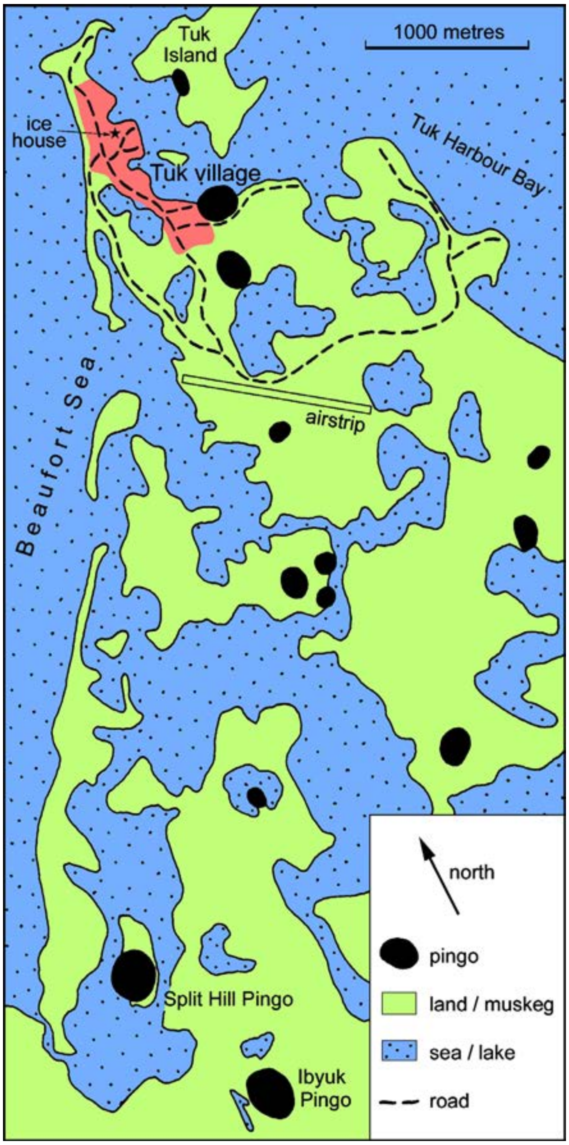

Fig. 5 (right). Map of the pingos and main landforms around Tuktoyaktuk.

Fig. 6. Thaw lakes and river channels in the delta region just inland of Tuk.

spring thaw when the river crossings have neither ferries nor ice-bridges. From Inuvik to Tuk it is a short flight by scheduled light plane, as the summer muskeg is almost uncrossable. Once in Tuk, there is a small hotel – and opportunity for some bracing walks. In winter there is an ice-road along the frozen river, but winter is not the best time to visit!

The village of Tuk is built on a peninsula of glaciofluvial sands (Fig. 5) with a hinterland that is more than half occupied by inlets and thermokarst lakes (Fig. 6). A pingo starts to grow as soon as its ancestral lake is drained. It immediately has the full width of the ex-lake, but initially has little height, and some sites remain as low domes that barely warrant being called pingos (Fig. 7). Over hundreds or thousands of years, a pingo grows into a thick lens of pure *ice* (Fig. 4) beneath an insulating cap of vegetation and organic soil. It reaches a maximum height when all the underlying groundwater has been frozen.

A pingo goes into terminal decline when its soil and vegetation cap ruptures and slides off, so that the exposed ice is then slowly lost by melting and ablation. Of the two large pingos just southwest of Tuk (Fig. 5), Split Hill has just reached the rupture stage (Fig. 8). Its neighbour, Ibyuk Pingo (Fig. 9), is nearly 50 m high, with 15 m of overburden on a core of solid ice. It is still growing by about 25 mm/year, but it has a complex structure with some elements of collapse and its eastern side (on the left in Fig. 9) is particularly unstable. Dated lacustrine sediments show that Ibyuk's ancestral lake existed at least 8000 years ago, and it is thought to have drained just a few thousand years ago. The final stage in the life of a pingo sees the total loss of its ice core, leaving a hollow surrounded by a rampart of slumped overburden (Fig. 4). This is sometimes known as an ognip, because of the reversal in profile. Tuk has no ognips, but the ramparts of Walton Common in west Norfolk are the remnants of collapsed Pleistocene pingos.

The ground ice of permafrost terrain is normally obscured (and preserved) beneath a veneer of organic soil, but a rare exposure is available in Tuk. The village ice cellar was excavated to store frozen seal and caribou carcasses through the arctic summer. It has a laddered shaft 6 in deep into a short series of galleries and rooms cut in the frozen ground. The ceilings are lined with giant hoar-frost crystals (from visitors' breath), but the walls are beautifully clean exposures of the ground (Fig. 10). Just 20 per cent of this is fine sand; about 80 per cent of the ground is

Fig. 7. The low ice-cored dome is an immature pingo on the eastern edge of Tuk village.

Fig. 8. Split Hill Pingo, as seen through a long lens; it is 40 m high and 250 m across, but lies 3.5 km beyond the houses.

Fig. 9. Ibyuk Pingo as seen from the airstrip at Tuk.

pure ice. The cellar is not in a pingo, for the ground is almost level over it, and this proportion of ice is unusually high in flat ground. The spectacular recumbent folds in the frozen sand layers (Fig. 10) appear to be due to glacial drag, in which case the ground ice predates the late Devensian glaciation when Tuk was last overrun by an ice sheet.

Fig. 10. The wall of the first gallery in the Tuk village ice cellar. Glass-clear ice appears black because it reflects no light at all, and the convoluted white bands are fine quartz sand. Giant hoar frost lines the ceiling where warm air accumulates from visitors' breath, and the floor is covered with fallen ice crystals and sand.

It is a sobering thought that the village of Tuk stands largely on ice. However, the ground ice is stable, and the village does nothing to disturb it. Houses are placed on wooden blocks (Fig. 11) so that cold air can blow beneath and prevent heat from the house escaping into the ground to thaw the foundations. Even in Tuk's frigid weather, conservation of the permafrost is critical to the village's survival. Water pipes and drains cannot be buried, and Tuk has no system of surface pipelines (utilidors). A deep borehole down to an unfrozen talik aquifer beneath the permafrost supplies water that is trucked in an insulated tanker to heated tanks inside each house. A second tanker (also with a thick plastic foam jacket) does the rounds to take sewage from each house to a nearby dumpsite. Such are the joys of living on frozen ground – but the views of the pingos are a definite plus for Tuk.

For geologists and geomorphologists with a leaning to the bizarre, Tuk is well worth a visit. As an adventurous extension to a trip to the Klondike goldfields (now almost on the tourist trail), drive the Dempster Highway north from Dawson and then fly in from Inuvik. The key to the ice cellar is available on request from the village admin office.

Suggestions for further reading

French, H.M., 1996. *The Periglacial Environment.* Longman, Harlow.

French, H.M. & Heginbottom, J.A., 1983. *Guidebook to Permafrost and Related Features of the Northern Yukon Territory and Mackenzie Delta, Canada.* Alaska Division of Geological and Geophysical Surveys, Fairbanks.

Mackay, J.R., 1979. Pingos of the Tuktoyaktuk Peninsula area, Northwest Territories. *Geographic physique et Onaternaire,* v.33, pp.3-61.

Fig. 11. A typical house in Tuk, raised on wooden blocks to ensure that no escaping heat thaws the permafrost foundations.