

# BURIED SNOWBANK ICE IN THE CENTRAL AND NORTHERN YUKON TERRITORY

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## INTRODUCTION

The aims of this paper are twofold: (1) to describe the range of stratigraphic and petrographic characteristics for ground ice derived from the burial and preservation of snowbanks in the Klondike and Yukon Coastal Plain areas of the northern Yukon Territory, and (2) to demonstrate how petrographic and stratigraphic analyses can be used to interpret ground ice genesis.

Ground ice is an important component of frozen ground and contributes significantly to the evolution and modification of periglacial landscapes (Harry 1988). It is also an important factor influencing the design and construction of many engineering projects in areas underlain by permafrost (French and Pollard 1986). The term ground ice is used to describe all forms of frozen moisture occurring beneath the surface of the ground (Mackay 1972). However, ground ice displays a complexity of forms. In recent years, the genetic classification proposed by Mackay (1972), which modified earlier Soviet classifications (e.g. Shumskii and Vtyurin 1966, Shumskii 1964) has gained widespread acceptance in North America. The absence of buried surface ice from this classification (i.e. glacier, sea, river, lake, icing and snowbank ice) is the major difference between it and Soviet classifications. To date, most ground ice research has been concerned with the origin and distribution of various forms of epigenetic ground ice, as reflected by the most widely used ground ice classifications. However, in recent years the tentative identification of buried glacier ice in permafrost has raised several questions concerning the significance of buried surface ice in ground ice studies. This paper describes the stratigraphic and petrographic characteristics of ground ice formed by the burial of snowbanks. Examples are taken from the Klondike Plateau near Dawson City and two locations on the Yukon Coastal Plain (Figure 1). These sites reflect both unglaciated and recently glaciated environments.

## STUDY AREA

This study is concerned with massive ground ice documented in (1) the lower Hunker Creek area of the Klondike Plateau 10 km east of Dawson City, and (2) the Yukon Coastal Plain between Sabine Point and King Point. The Dawson City area is within the zone of widespread discontinuous permafrost, which occurs to depths up to 60 m (Judge 1973). The mean annual air temperature at Dawson airport is  $-4.7^{\circ}\text{C}$ . The area is characterised by a subarctic continental climate, with very cold winters and warm summers, mean daily January and July temperatures are  $-28.6^{\circ}\text{C}$  and  $+15.5^{\circ}\text{C}$  respectively. Throughout the Quaternary, the Klondike Plateau remained unglaciated and permafrost aggraded to depths much greater than is possible under current climatic conditions. Numerous faunal remains preserved within the permafrost indicate that it was part of the southeastern Bering Refugium. Although the Klondike remained unglaciated during Quaternary time, pre-Reid glaciations provided source materials for the Klondike gravels and windblown silt that later became incorporated into ice-rich muck deposits covering valley sides and floors. Ground ice is a common constituent of frozen muck deposits; this is evident in placer mine operations like the "Mayes Claim" on the lower part of Hunker Creek.

The Yukon Coastal Plain forms a narrow band of dissected and hilly tundra between the Beaufort Sea and the Barn and British Mountains. It is located within the zone of continuous permafrost, which is at least 300 m deep. The mean annual air temperature is approximately  $-11.0^{\circ}\text{C}$ , with mean daily January and July temperatures of  $-29.0^{\circ}\text{C}$  and  $+7.2^{\circ}\text{C}$  respectively. Most of the coastal plain east of the Firth River was glaciated by an ice sheet moving west from the Mackenzie Valley during the Buckland Glaciation (early Wisconsin). West of the Firth River the coastal plain remained unglaciated. During deglaciation a major stillstand or readvance, termed the Sabine Phase of the Buckland Glaciation, occurred and constructed a moraine-outwash complex parallel to the coast. Massive bodies of ground ice and large ice wedges are common in fine-grained sediments that form the moraine.

## CRYOSTRATIGRAPHY

The buried snowbank ice at King and Sabine Points occurred in similar stratigraphic settings. The King Point site is described in Pollard and Dallimore (1988). It occurred as a layer of opaque whitish to pale-brown ice, 1-2 m thick, exposed in the headwall of polycyclic retrogressive thaw slumps. These ice units usually occurred high in the sections in diamicton or mudflow deposits. The ice bodies were unconformably overlain by 1-1.4 m of diamicton and peat. The upper contacts were abrupt and irregular, in places blocks of sediment or peat were incorporated into the upper part of the ice. The lower contacts were also abrupt and unconformable, but more regular in nature. The ice bodies were underlain by 0.4 - 2.0 m of mudflow deposits, which was sometimes underlain thick massive ground ice. Radiocarbon dates for peat and detrital wood from beneath the snowbank ice at King Point indicate that it was 100-120 year old. This evidence suggests that active thermokarst approximately 100 years ago buried a series of snowbanks situated either at the base of the headwall or on the floor of retrogressive thaw slumps. They were buried by a sufficient volume of peat and sediment that permafrost could aggrade upward into the new deposit. A cooling of climate could have also contributed to their preservation. The absence of layering suggests that these are probably not perennial snowbanks, but a single season's accumulation.

At Hunker Creek, the buried snowbank ice occurred much deeper in the stratigraphic sequence, approximately 10-15 m below the ground surface (French and Pollard 1986). Vertical sections produced by placer mining of low-level terraces exposed ice-rich muck and gravel sequences. At the Mayes Claim, a 30 m section consisted of a lower bedrock unit overlain by 2-3 m of coarse fluvial sand and gravel and 4-5 m of icy silt and dirty ice. This unit was overlain by 2-3 m of massive, relatively clean ice which is interpreted as buried snowbank ice. The icy silt and dirty ice graded upward into a massive ice unit. The remainder of the exposure consisted of muck deposits 10-15 m thick and a surface unit of interbedded sand, gravel and peat. Ice wedges occurred in an upper muck unit. In this section, the buried snowbank ice represents a thick perennial snowbank that occurred at the base steep valley slopes that were subsequently buried by slumping muck deposits. A long period of colluvial activity covered the ice with several metres of muck containing large blocks of peat and faunal remains that date greater than 40,000 yr. BP.

## GROUND ICE

Massive ice refers to large ice bodies ( $> 1\text{ m}$  thick), having a gravimetric ice content exceeding 250% (on an ice-to-dry soil weight basis). A recent article by J.R. Mackay (1989), concerned with the field identification of ground ice, divides massive ground ice into two general categories: (1) buried ice and, (2) in situ ice. In situ forms of ice are further

defined as either epigenetic or syngenetic and include wedge ice, intrusive ice, aggradational ice and various forms of segregated ice. Buried ice includes various forms of surface ice (i.e. sea, lake, river, icing, snowbank or glacial ice) occurring in permafrost areas that have been either buried in place or transported, deposited as part of a depositional sequence and then preserved as the permafrost table moves into the new materials. The burial of surface ice is quite common, but its preservation is somewhat problematic. The recognition of massive ground ice formed by the burial of snowbanks adds a new perspective on this problem. Previously, buried glacier ice occurring as ice-cored moraine was the only commonly-recognized form of buried ice in the North American Arctic. In the Soviet Union, buried glacier ice from the Wisconsinan glaciation has been proposed as a source of massive ground ice in permafrost in western Siberia for a long time. In recent years, a similar interpretation has been proposed for locations in the Canadian Arctic.

### ICE CHARACTERISTICS

Massive ground ice formed by the burial of snowbanks occurred as irregularly-shaped, horizontally-foliated bodies or layers of opaque white or pale-brown ice (Figure 2). The layered appearance is the result of alternating bands of bubble-rich ice and thin sediment layers. The ice from Hunker Creek contained a fine suspension of randomly distributed organic and silt particles. Snowbank ice from Kay Point contained fragments of arctic willow and small amounts of pollen. The internal layering was parallel to the lower contact. The shape and extent of the ice mass is determined by the topographic setting of the original snowbank and the mechanism of its burial. Upper and lower contacts are both unconformable and often reflect a zone of melting and refreezing. The lower contacts observed in both the Klondike and Yukon Coastal Plain dipped upward into the ice face at angles from 7° to 11° and are believed to reflect the side valley slope or the slope of the thaw slump floor.

### PETROGRAPHY

The stratigraphic position of the ice, together with the age of the enclosing sediments, indicate that the buried snowbank ice along the Yukon coast is considerably younger than in the Dawson City area. The snowbank ice at King Point and Sabine Point was composed of very small crystals averaging 1-3 mm long, with maximum lengths of 305 mm. Crystals were elongated in a vertical to sub-vertical direction. This reflects the influence of heatflow and percolation of water during recrystallization. Crystals were euhedral to subhedral with short straight boundaries. Crystal size was constant through the ice unit, with no change at either contacts or at sediment bands. Gas and sediment inclusions were predominantly intercrystalline. Gas inclusions ranged from small spherical and flat bubbles (< 1 mm in diameter) to thin tubular bubbles up to 25 mm long. The long axes of these bubbles were aligned roughly normal to sediment layering. The primary ice fabric was characterized by a random pattern of c-axes with weak secondary maxima (6-7%) oriented normal to the internal layering. These textures and fabrics are believed to reflect the crystalline characteristics of the original snowbank. The horizontal layering, suspended sediment, occasional leaf or twig fragment and contact characteristics illustrate the depositional nature of the snowbank and the accumulation of wind-blown detritus. The vertically-oriented bubbles and secondary c-axis maxima suggest post-depositional modification probably due to compaction and recrystallization.

By comparison, the Klondike snowbank ice was composed of elongated crystals averaging 25 mm long with average lengths of 6 mm and oriented

roughly parallel to the steeply-dipping layering. Crystal size and shape were constant through the unit. Gas inclusions formed two distinct patterns: (1) small spherical bubbles (< 10 mm in diameter) dispersed randomly through the ice body with slightly higher concentrations near sediment bands, and (2) long (up to 15 mm), vertically-oriented tubular bubbles that cut across the steeply-dipping sediment bands. Sediment inclusions occurred as thin discontinuous bands of fine organic silt and a fine suspension through the entire unit. Fabrics were characterised by a vertical to steeply-dipping maxima and a secondary maximum forming a loose girdle inclined 20-30 .

## DISCUSSION

The buried snowbank ice documented in this study occurred as irregularly-shaped bodies of horizontally-layered white to pale-brown bubble-rich ice. The upper and lower contacts of the ice body were abrupt and unconformable. The lower contact reflected the slope upon which the snowbanks were deposited. In the Hunker Creek area they formed near the base of valley sides; at King and Sabine Points, the snowbanks were deposited at the base of retreating headwalls in retrogressive thaw slumps. The upper contact reflected the burial process and a period of melting. The ice is composed of medium to fine-grained equigranular subhedral to euhedral crystals. The older and stratigraphically deeper ice bodies of the Klondike tend to have larger vertically-elongated crystals. They also displayed stress induced structures, like curved crystal boundaries, dislocations and vertically-oriented tubular bubbles. Younger ice bodies were fine-grained with distinct banding. Crystal c-axis orientations ranged from random or weak vertically-oriented girdles in young snowbank ice to strong vertical to sub-vertical maxima for older bodies. The latter also develop secondary maxima associated with thermal or stress histories. Buried snowbanks may provide useful paleoenvironmental information and, if widespread, may be recognized as cryostratigraphic markers.

The results of this study will contribute to the development of a petrographic classification of ground ice types (Pollard, 1989).

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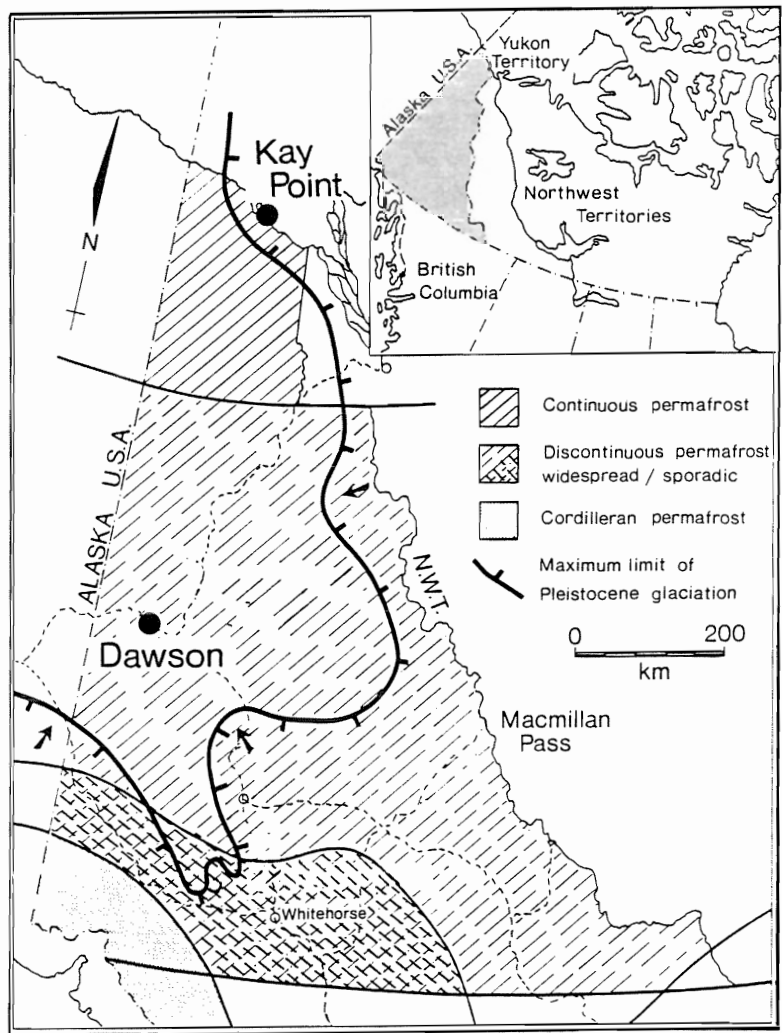
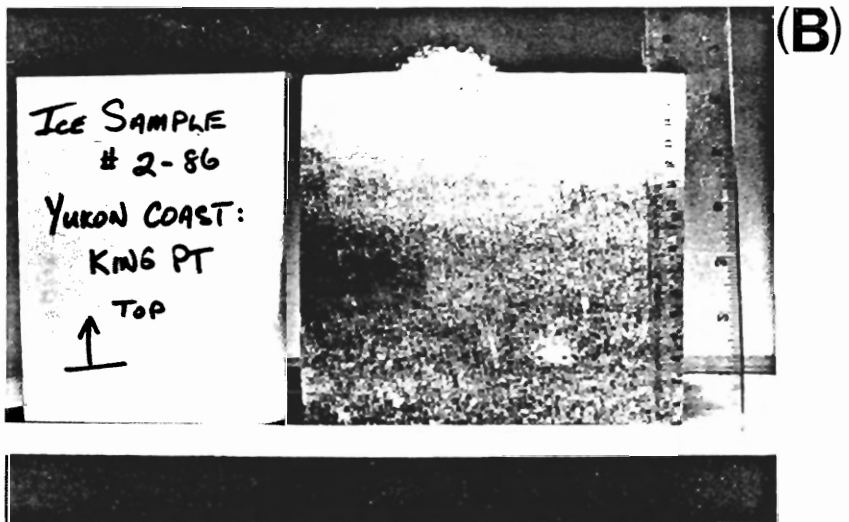


Figure 1: Study Area map showing the approximate limits of glaciation and the distribution of permafrost.



(A)



(B)

Figure 2: (a) Buried Snowbank ice near Kay Point, and  
(b) an oriented block sample from the Kay Point Section  
(July 1986)