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Faunal and Archaeological Remains as Evidence of Climate Change in Freezing Caverns, Yukon Territory, Canada

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ABSTRACT. Animal and plant remains, some associated with prehistoric artefacts, were collected in freezing caverns (*glacières*) of northern Yukon Territory. Radiocarbon dates show that the oldest remains are Middle Wisconsinan (ca. 38 000 BP). The absence of material of Late Wisconsinan age likely indicates that the caves were infilled by ice during this cold period. Climate warming and ice melting during the Holocene allowed animals and prehistoric hunters to regularly visit these caves. Ice plugs were evidently smaller during the early Holocene than they are now.

Key words: Yukon Territory, Porcupine River, Ogilvie Mountains, caves, *glacières*, karst, biotic remains, prehistoric remains, limestone mountains

RÉSUMÉ. Des restes d'animaux et de plantes, parfois associés à des vestiges préhistoriques, ont été récoltés dans des glacières du nord du Territoire du Yukon. Leur âge radiocarbone indique que les plus anciens vestiges datent du Wisconsinien moyen (v. 38 000 BP). L'absence de matériel contemporain du Wisconsinien supérieur semble indiquer que pendant cette période froide les cavernes étaient comblées par de la glace. Au cours de l'Holocène, le réchauffement du climat et la fonte subséquente des glaces ont permis aux animaux et aux chasseurs préhistoriques de visiter les cavernes sur une base régulière. Les bouchons de glace étaient de toute évidence moins développés au début de l'Holocène qu'ils ne le sont aujourd'hui.

Mots clés: Territoire du Yukon, rivière Porcupine, monts Ogilvie, cavernes, glacières, karst, restes d'origine organique, restes préhistoriques, monts calcaires

INTRODUCTION

Karst responds with great sensitivity to environmental change and preserves associated records more faithfully than most other geological settings (Cogeoenvironment [IUGS] Working Group on Geoindicators, 1996). Features such as caves, rock shelters, and sinkholes are important repositories that contain much scientific information about past terrestrial environments (Ford and Williams, 1989; Andrews, 1990; Burney et al., 1997). They often provide unique, productive, and extensive field sites that yield substantial clues to past climatic events over a variety of time scales (Cogeoenvironment [IUGS] Working Group on Geoindicators, 1996). Sporadically functioning as sediment traps, these features accumulate throughout their geologic life large and complex combinations of clastic, chemical, and organic debris derived from the natural environment (Miskovsky, 1987). Since caves are used as shelters by animals, including predators and scavengers, they often contain the remains of these animals and their food, and hence fossil evidence of past animal populations (Burke and Cinq-Mars, 1996; Heaton et al., 1996). Through the combination of these and other contributing factors, cave sedimentation can lead to the formation of some of the richest and best-preserved deposits in continental environments. For example, the Bluefish Caves (northern Yukon) have yielded archaeological evidence of a full to late ice age human occupation, and have provided the largest in situ vertebrate fauna for eastern Beringia (Cinq-Mars, 1979, 1990).

Here we report animal and plant remains found in "freezing caverns" or "*glacières*" (*sensu* Balch, 1900) in northern Yukon Territory (Fig. 1), particularly in Tsi-tche-Han Cave (Figs. 1, 2a, 3). Balch (1900) introduced these terms to characterize caves *containing* ice deposits but developed in rocks, to distinguish them from caves *developed* in glacier ice. Our results add to those of Schroeder (1972, 1977) and Scotter and Simmons (1976) to help identify the main periods of incorporation of macrobiotic remains in *glacières*. Furthermore, our investigation of faunal and archaeological remains complements the climate and stable isotope data from cave ice in

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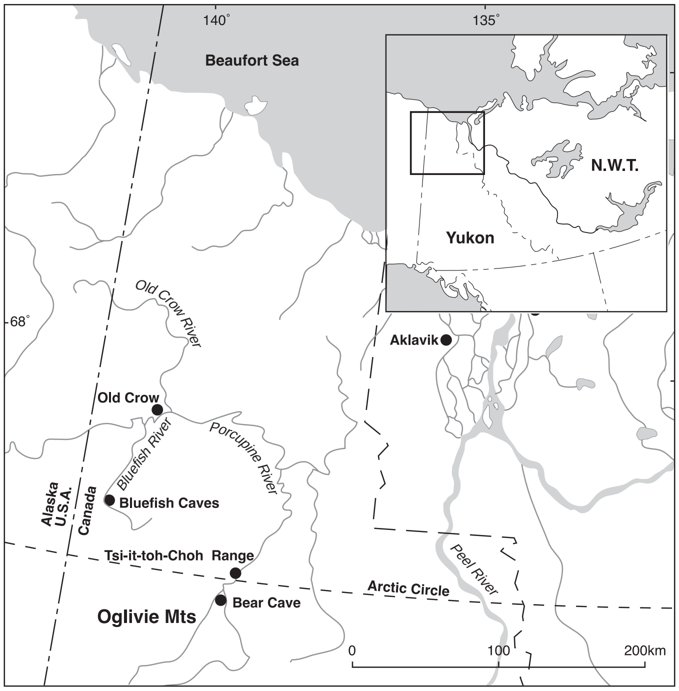

FIG. 1. Map of northern Yukon Territory, showing location of caves mentioned in text. Tsi-tche-Han Cave, the Grande Caverne Glacée, the Grotte des Méandres, the Caverne de la Chèvre, and Caverne Glacée 85 are within the Tsi-it-toh-Choh Range.

Yukon Territory (Clark and Lauriol, 1992; Lauriol and Clark, 1993; Lauriol et al., 1995).

Tsi-tche-Han Cave

Caves of northern Yukon Territory are mainly developed in Devonian limestone beds of the Gossage and Ogilvie formations (Norris, 1978), which were deformed by the Laramide Orogenesis some 60M years ago (Gabrielse, 1975). The major caves known to date were formed near the end of the Tertiary period, when permafrost was absent (Lauriol et al., 1997). Absence of glacial erosion in the area during the Quaternary (Dyke and Prest, 1987) allowed caves to persist until today.

Tsi-tche-Han Cave (Figs. 1, 2a, 3) is located at 66˚49′N, 139˚20′ W and 800 m elevation in the Tsi-it-toh-Choh Range, an extensive karstland (Lauriol et al., 1988, 1997; Thibaudeau, 1988). Its outer, entrance chamber is 10 m long, 5 m wide, and 8 m high; a passageway 10 m long connects to a second, inner chamber, which is lower in height than the outer one (Fig. 3). The cave floor is composed of silt, or of ice over silt deposits. Calcite speleothems cover the walls, mainly in the inner chamber; some of these formations have a Uranium-series age of 80 000 years (Lauriol et al., 1997).

Temperatures recorded inside Tsi-tche-Han Cave yielded a mean annual amplitude that contrasts (Fig. 4) with that shown in Environment Canada (1982) records for Old Crow village, located 120 km to the northwest. While temperature varies on average by 44.3˚C during a year in Old Crow (Environment Canada, 1982), it varies by less than 21.5˚C in the cave (our data). Air temperature inside the cave is warmer during winter (-15.5˚C in January) and cooler during summer (1.5˚C in July) than the outside air. The contrast in temperature also varies within the cave (Figs. 3, 4): the temperature logger placed in the passageway (Tsi-4) recorded a smaller temperature amplitude than the one placed in the first chamber (Tsi-3). These measurements were recorded between July 1997 and July 1998.

METHODS

The faunal and archaeological remains were either collected from the silty and icy floors of Tsi-tche-Han Cave and other caverns or extracted from fossil ice plugs. The only reported visit to caves in the area before our investigation is that of Otto Geist (1953), who visited Bear Cave with a group of Old Crow Natives during the 1952 summer. Therefore, the material collected is considered in situ, with probable minor disturbance by natural processes.

During the field season, the samples were stored in plastic or cotton bags in sealed plastic boxes in a large cooler. They were kept cool until identification or shipment for radiocarbon dating. Samples for radiocarbon dating were cleaned using a 5% HCl solution. Wood identification was done by preparing thin slides and examining cell anatomy. The remains of small rodents were identified with a Wild-Leitz M5 binocular microscope, using the reference collection at the Canadian Museum of Civilization.

Tree trunks (fossil *Picea* logs) collected inside the cave were analyzed for ring width. They were compared with six living *Picea* trees cut on the rocky slope near the entrance of Tsi-tche-Han Cave, where silt deposits allow their growth (the slope itself is presently barren of trees). Cross-sections were taken along the main stems of the dead and living trees. Sections were finely sanded until wood cells became clearly visible. Annual rings were counted under a lens microscope (40×), and ring widths were measured on each sample with a Velmex micrometer (precision ± 0.002 mm) interfaced with a computer. Two opposite radii were measured on every disk, and average ring-width curves were produced from these measurements.

Tree Trunks and Prehistoric Remains

In Tsi-tche-Han Cave, a small rock wall at the entrance of the passageway (Fig. 3) was probably erected by prehistoric hunters. Five logs sitting on this wall, each 3 to 4 m long, were too big to have been introduced to the cave by animals. A piece of one of these trunks was dated at 800 ± 150 BP (UQ-1766; Table 1). The mean (398 μm) and median (349 μm) ring widths of fossil logs are smaller than those of trees living near the entrance of the cave (Table 2), suggesting that the climate was drier or colder 800 years ago than at present.

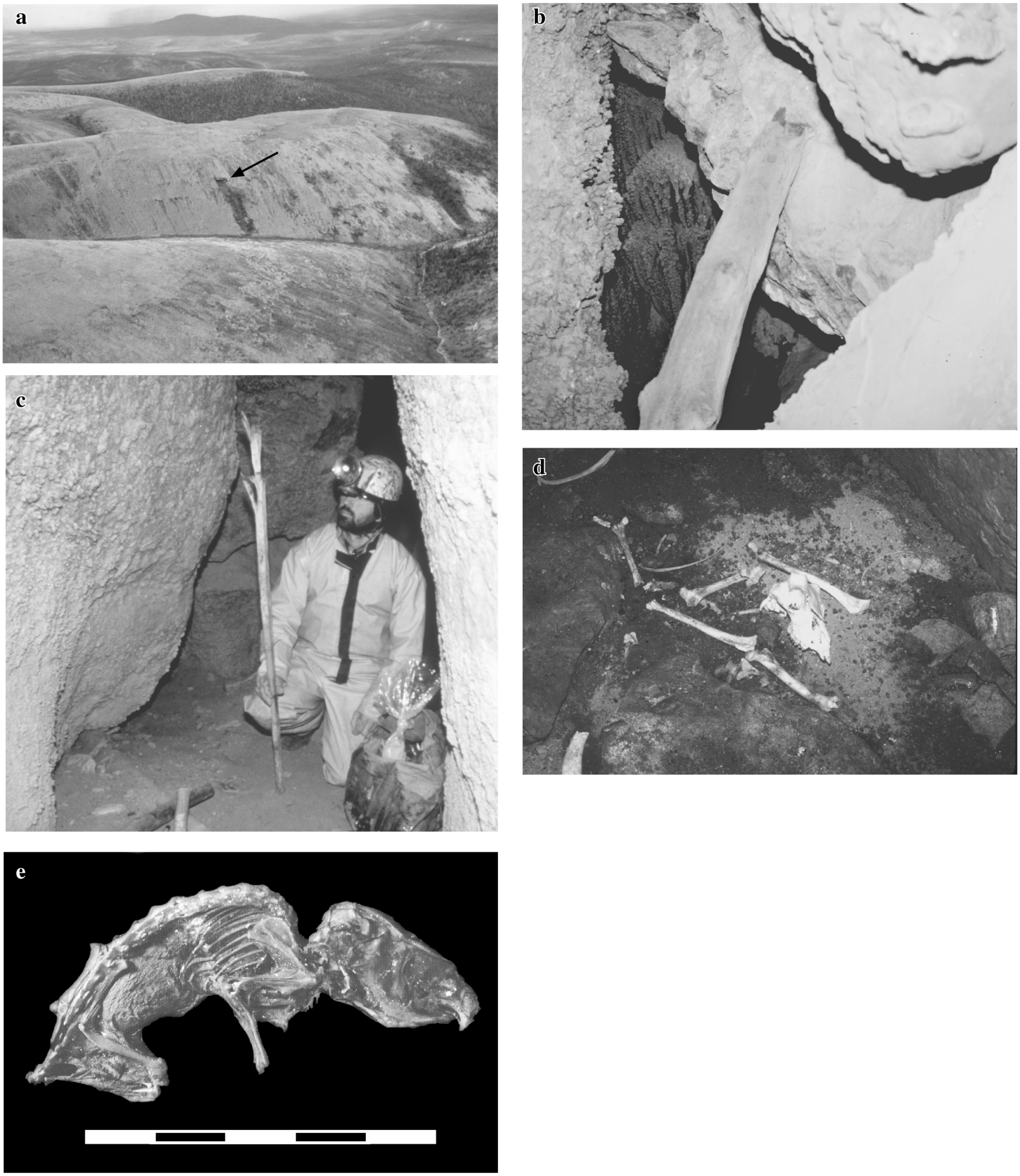

FIG. 2. a: Site of Tsi-tche-Han Cave (entrance is shown by black arrow); b: Early Holocene (8440 ± 90; TO-7013; Table 1) *Populus* tree trunk introduced into Bear Cave by hunters (diameter: 17 cm); c: Modern torch (19th century?) in a passageway of Bear Cave; d: Remains of a Dall's sheep in the Caverne de la Chèvre, Tsi-it-toh-Choh Range; e: Mummified *Microtus pennsylvanicus* collected in the Caverne des Méandres (scale bar = 1 cm).

Fossil logs were also found in Bear Cave, the largest known cave in the region, with 250 m of passageways and rooms (Lauriol et al., 1997). More than 30 large pieces of *Picea* and *Populus* were collected inside this cave. Some

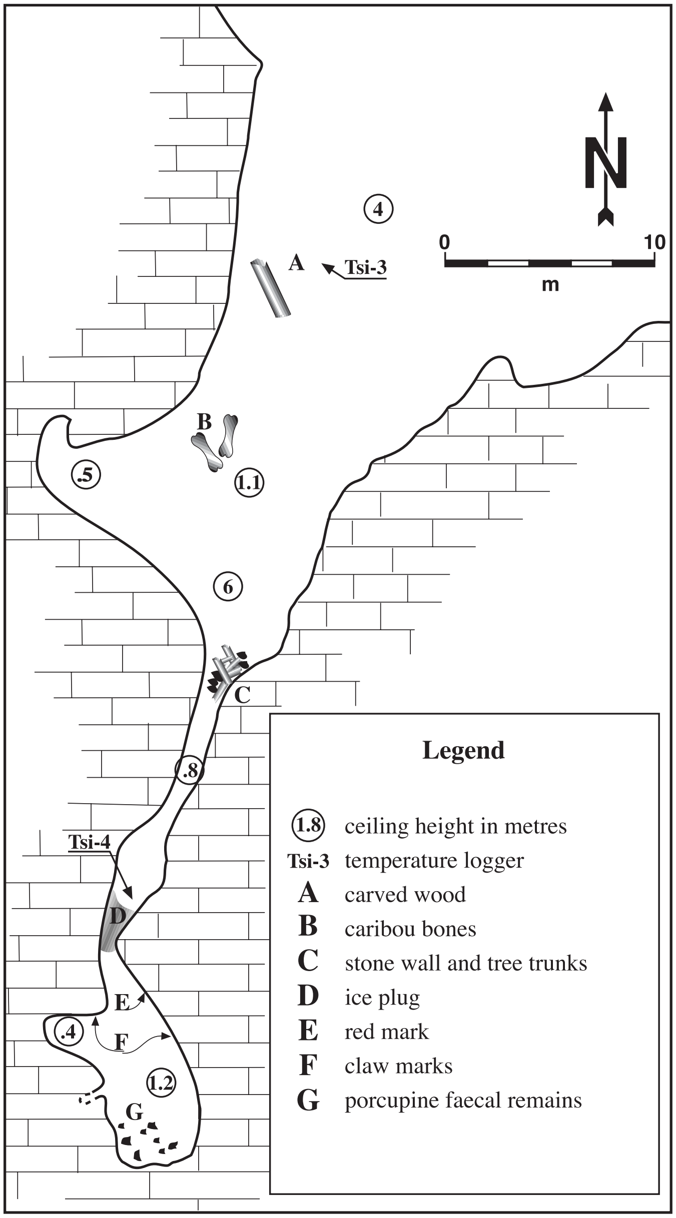

FIG. 3. Plan view of Tsi-tche-Han Cave, showing the location of biotic and prehistoric remains and the two temperature loggers.

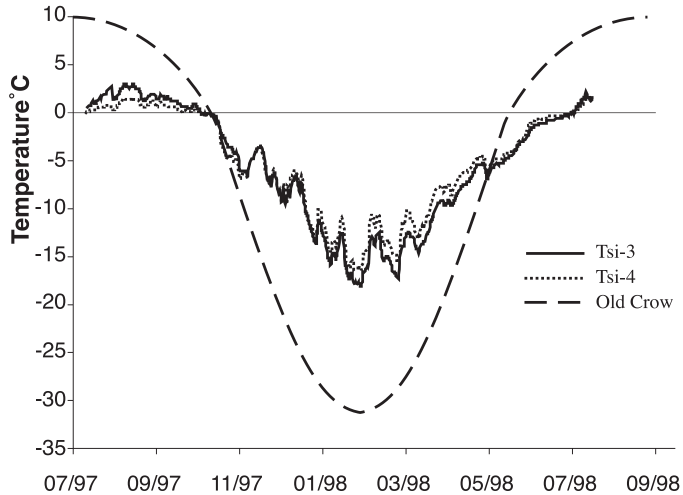

FIG. 4. Temperature data from Tsi-tche-Han Cave (from July 97 to July 98) and Old Crow village, Yukon Territory.

Populus have diameters much larger (17 cm, Fig. 2b) than any now growing near the entrance (5–10 cm). Two specimens (Table 1) yielded radiocarbon ages of 8130 ± 90 (TO-7012) and 8440 ± 90 BP (TO-7013), and thus are contemporary with the warmest period that prevailed in the Yukon during the Holocene, when the poplar habitat extended north to the Beaufort Sea coast (Nelson, 1987). As the trunks were found far inside Bear Cave, and were too large to have been carried by animals, they indicate that the cave was visited by humans at times during the early Holocene. Use of Bear Cave by humans is also indicated by charcoal on the floors of several passageways, which constitutes evidence of fire ignited in the cave with the probable aim of hunting grizzly bears. The large tree trunks found in Bear Cave may thus have served as firewood, or as rudimentary support devices to carry the killed animals. Nowadays, the Yukon caves are no longer used for hunting or for ritual purposes, nor were they so used during most of the 20th century (C.P. Charlie and C. Thomas, pers. comm. 1987 and 1992).

Fossil logs have also been found in other Yukon caves. For example, a well-preserved piece of spruce (*Picea* sp.) was collected by coring 5 m inside an ice plug in the Grande Caverne Glacée, a cave 100 m long × 5 m wide described by Lauriol et al. (1995). The wood was dated at 7350 ± 70 BP (TO-3508; Table 1). Its age indicates that the ice plug was further within the cave around 7000 years ago. This dating is in accordance with the findings of Marshall and Brown (1974), who concluded that ice plugs in Coulthard Cave (Alberta) formed after the mid-Holocene warm period.

Use of Tsi-tche-Han Cave by humans is also revealed by a torch found on the silt near the entrance. The torch consisted of a stick of *Picea* 90 cm long that served as a support for flammable material. The torch was not dated, but as it showed evidence of carving by an iron tool, it is certainly no older than the 19th century. A torch showing similar marks of iron tool carving was also found in Bear Cave (Fig. 2c). These torches indicate that ritual hunting was a common practice during the 19th century, a conclusion confirmed by the oral tradition in Old Crow village.

Large Mammals

Large mammal remains are rare in Tsi-tche-Han Cave: we found only two femora of caribou (*Rangifer tarandus*) lying on the silt in the outer room (Fig. 3). Faecal remains of porcupine (*Erethizon dorsatum*) are common, with abundant droppings in the second room, where permafrost prevents their decomposition. A sample collected at random yielded a radiocarbon age of 4270 ± 70 BP (UL-257; Table 1).

Caverns are not recognized as usual hibernation sites for bears in Canada, the limestone mountains of the upper

TABLE 1. Radiocarbon dates from freezing caverns, Ogilvie Mountains, Yukon Territory. The Borden numbers are MeVj-1 for Tsi-tche-Han Cave, and McVj-1 for Bear Cave. Bear Cave is located on Bear Cave Mountain; all other caves are within the Tsi-it-toh-Choh Range.

Age	Lab Number	Remains	Location and References
70 ± 50	TO-2210	*Marmota* sp. carcass	Grande Caverne Glacée (GCG)
800 ± 150	UQ-1766	*Picea* sp.	Tsi-tche-Han Cave
860 ± 100	UQ-1584	*C. tetragona / D. octopetala*	Small, unnamed cave
1300 ± 100	UQ-1282	*C. tetragona / D. octopetala*	Caverne Glacée 85 (Lauriol et al., 1988)
4270 ± 70	UL-257	*Erethizon* faecal remains	Tsi-tche-Han Cave
7350 ± 70	TO-3508	*Picea* sp.	GCG (Lauriol et al., 1995)
8130 ± 90	TO-7012	*Populus* sp.	Bear Cave
8440 ± 90	TO-7013	*Populus* sp.	Bear Cave
37940 ± 460	TO-2211	cf. *Arctodus*? faecal remains	Caverne des Méandres

Porcupine River being the exception. In fact, resting nests, tracks and faecal remains on the floors, and claw marks on the walls, are usually present a few metres inside cave entrances. Bear droppings were abundant well beyond the reach of daylight in the Grotte des Méandres, under an ice plug 25 m long that starts 35 m inside the cave (Fig. 5). A crawl under this ice plug allowed collection of numerous freeze-dried bear droppings dated at 37 940 ± 460 BP (TO-2211; Table 1), which are interpreted as evidence of a milder climate at that particular time. However, all other ^{14}C dates obtained in our study are much younger (Holocene), and therefore the TO-2211 date stands alone. It is also close to the generally accepted limit for ^{14}C ages. This implies that the bear droppings could, in fact, be much older than ca. 38 000 BP. These faecal remains were located in a small depression (1 m diameter) dug directly into the silty floor. The bear den was different from those observed nowadays in the area, in that it did not contain any of the large fragments of wood that these animals usually lay down inside their shelters. Pollen and macrofossil analyses conducted on the bear faecal remains revealed a diet composed primarily of *Juniperus* spp. This plant is abundant in the valleys, at the base of the south-facing slopes. What is intriguing, however, is that modern bears do not feed on *Juniperus*, as it is toxic to them (J.V. Matthews, GSC, pers. comm. 1995). Therefore, the faecal remains are thought to belong to the extinct short-faced bear (*Arctodus simus*), which disappeared from Beringia at the end of the Pleistocene (Matheus, 1995; Harington, 1996).

Mountain goats (*Oreamnos americanus*) and Dall's sheep (*Ovis dalli*) are the only other large mammals known to wander inside caverns. Geist (1971) noted that mountain sheep commonly seek shelter in caves during severe weather periods. He also reported (pers. comm. to Scotter and Simmons, 1976) Stone's sheep (*Ovis dalli stonei*) making extensive use of a cave, especially from January to late March; however, from late March onward the cave was used less frequently. During the winter, a trapper from Pelly Crossing saw a cave entrance full of sheep near the Tatonduk Mountains (southern Ogilvie Range) (D. Vanbibber, pers. comm. 1999). In our study area, an entire, undisturbed, skeleton of a Dall's sheep was found about 20 m inside the Caverne de la Chèvre in a crouched position, indicating that it likely died of natural causes (Fig. 2d).

TABLE 2. Width of rings (μm) from modern (living) and fossil (dead) trees, Tsi-tche-Han Cave and vicinity, Yukon Territory.

	Modern Ring Width		Fossil Ring Width	
	Mean	Median	Mean	Median
All Years of Growth Combined	449.4	424.0	398.2	349.1
First 60 Years of Growth	490.4	524.0	427.1	378.8

Small Mammals and Birds

Tsi-tche-Han Cave yielded many remains of small mammals near its entrance, as did other caverns in the area. These remains are mainly those of microtine rodents. Among these are the northern red-backed vole (*Clethrionomys rutilus*), the brown lemming (*Lemmus sibiricus*), the yellow-cheeked vole (*Microtus xanthognathus*), and the meadow vole (*M. pennsylvanicus*, Fig.2e), all of which may be found living within the area today (Morlan, 1984). The rodent remains generally displayed fractures and corrosion marks, which are typical signs of predation (see Andrews, 1990, for discussion). Deep in the caverns mice are generally mummified by the cold and dry air, or are preserved frozen in the perennial ice.

Remains of marmots (*Marmota* sp., bones and skin) are also common in northern Yukon caves, and one entire carcass collected from the Grande Caverne Glacée yielded a modern age of 70 ± 50 BP (TO-2210; Table 1). Marmot remains were always found near nests composed entirely of *Dryas octopetala* and *Cassiope tetragona*. One of the nests found in Caverne Glacée 85 (described in Lauriol et al., 1988) was dated at 1300 ± 100 BP (UQ-1282; Table 1), while a second one found in a small, unnamed cavern was dated at 860 ± 100 BP (UQ-1584; Table 1). All nests had been built on ice floors and were overlying ice mounds. Their elevated position was caused by the thermal protection induced by the *Dryas* and *Cassiope* deposits, which prevented the ice mounds from melting. Difference in elevation between the ice floors and the top of the ice mounds was generally ~20 cm, but it even reached 85 cm

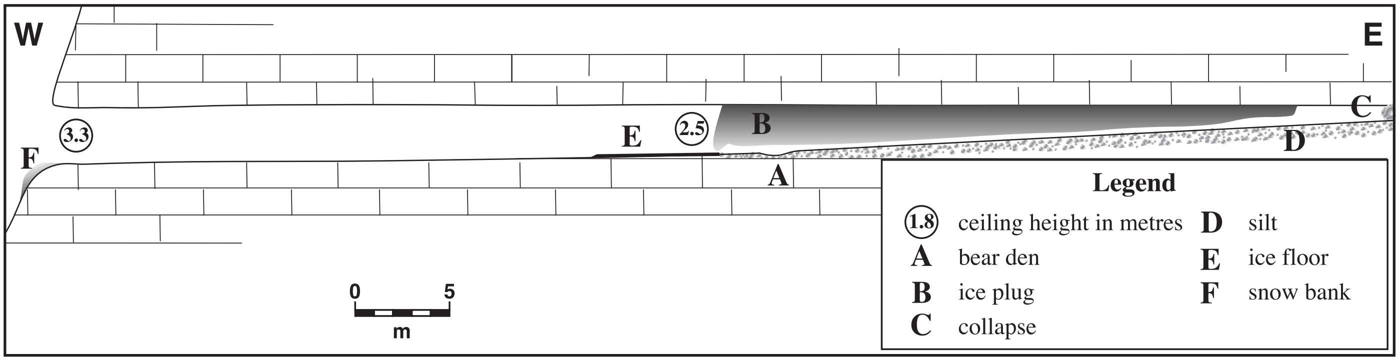

FIG. 5. Cross-section of the Caverne des Méandres, showing location of bear den containing faecal remains dated at 37 940 ± 460 BP (TO-2211; Table 1). Caribou bones and mummified mice were also collected in this cave.

in Caverne Glacée 85. The nest and ice mound combinations provide strong evidence that the ice floors were much thicker in the caves at 1.3 and 0.8 ka BP.

Cave entrances in general are known to be favoured nesting, resting, and feeding places for a variety of birds. During the Late Wisconsinan, birds were also common in the northern Yukon Territory, as may be seen from the investigation of Balkwill and Cinq-Mars (1998) in the nearby Bluefish Caves, where at least 18 species of birds were recovered and identified. The remains of a sparrow (not yet dated) were retrieved from the ice floor of the Grande Caverne Glacée, some 80 m from the entrance. The sparrow was likely introduced into the cave by scavengers, as we never saw nests located beyond the reach of daylight in the caverns.

CONCLUSIONS

Animal and plant remains in caves of the northern Yukon Territory are generally well preserved. The oldest remains yet found (bear faeces) are of Middle Wisconsinan age. A mild climate characterized this time period in eastern Beringia (Hughes et al., 1981). No Late Wisconsinan material was collected deep inside the caves; its absence may be explained by blockage of the cave entrances by ice plugs during this colder period. During the Early Holocene, the ice plugs partly melted or receded, which allowed introduction of large tree trunks by prehistoric hunters. Analyses (radiocarbon, size, and ring width) of these fossil logs suggest that the climate was warmer 8000 years ago, and colder 800 years ago, than the modern climate. These results are in accordance with the radiocarbon dating of a piece of *Picea* found in an ice plug deep inside the Grande Caverne Glacée, and of *Dryas/Cassiope* marmot nests overlying ice mounds. These respectively indicate that perennial ice was less abundant in the northern Yukon caverns around 7400 years ago, and more extensive between 1300 and 800 years ago.

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