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Kwäday Dän Ts'ìnchí, the first ancient body of a man from a North American glacier: reconstructing his last days by intestinal and biomolecular analyses

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A HOLOCENE FAST-TRACK REPORT

Abstract: We report on scientific analyses of the only well-preserved ancient human body ever recovered from a North American glacier. The body was found high in the mountains of northwest British Columbia at about 80 km from the nearest point of the strongly indented coast of southern Alaska. The geographical location suggests that the young man, aged about 20 years, could have lived either on the mild coast or in the continental interior. Preliminary environmental scanning electron microscopy (ESEM) and light microscope studies of the contents of the digestive tract reveal pollen of an intertidal salt-marsh plant and pieces of a marine crustacean. Remains of coastal zone plants (a fruit of a flowering plant and a needle of a coniferous tree) had adhered to the deceased's robe. Stable isotope analyses of bone and muscle show that more than 90% of the dietary protein was from marine sources. We conclude that this individual had strong coastal connections during his life and had been on the coast shortly before he died about 550 to 600 years ago.

Key words: Ancient frozen body, isotopes, palynology, macroscopic plant remains, parasitology, ichthyology, carcinology, palaeodiet, late Holocene, British Columbia.

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Introduction

Numerous remains of plants and animals have been found associated with Kwäday Dän Ts'ìnchí (Long Ago Person Found) whose corpse was the first ancient body to be discovered in a melting North American glacier (Beattie *et al.*, 2000; Pringle, 2002). Some 80 km from the nearest point of the strongly indented sea coast, and located at the southeastern end of the Saint Elias Mountains in the Tatshenshini-Alsek Park, British Columbia, Canada, the discovery site lies at an elevation of approximately 1600 m (Figure 1). The surrounding terrain is rugged with mountains reaching over 2500 m with massive glaciers. The human remains and associated artifacts were found at the melting margin of the glacier about 200 m west of the valley divide (Beattie *et al.*, 2000). They were on a ridge-like feature (Figure 2) that has been visible on air photographs for the past 50 years. Three nunataks have become exposed since 1999, suggesting that the ice is melting in accord with the regional warming trend of more than 1°C for the western Arctic over the past 30 years (Washington and Meehl, 1996).

The man may have lived as much as 550–600 years ago and died at an age of about 20 years. Radiocarbon dating of the hat, fur robe and a wooden projectile found with the body provide calibrated ages ranging from AD 1400 to 1490 (Beattie *et al.*, 2000). A similar ancient male body, Ötzi, from 5200 years ago, was discovered in melting glacier ice in the Tyrolean Alps in 1991 (Dickson *et al.*, 2003; Müller *et al.*, 2003).

Because they died while actively pursuing daily life and their remains had not been prepared for burial, Ötzi and Kwäday Dän Ts'ìnchí pose questions different from those arising from frozen burials such as those of the Inuit, sacrificed Andean children or the Siberian Pazyryks. What had these men been doing, had they travelled far, what were the events immediately before and after death, who were their kin and where was their home? Did Kwäday Dän Ts'ìnchí belong to a coastal people, such as the Tlingit, or an interior group, such as the Champagne and Aishihik First Nations within whose traditional territory the body was found? Because ancient bodies from glaciers can have intact alimentary canals retaining chyme (stomach contents), food residues from the lower intestines and faeces, the meals consumed during the last few days before death can be investigated and the results compared with isotopic evidence for diet. Stable isotope measurements of collagen extracts from archaeological tissues indicate past diet, too (Chisholm *et al.*, 1982; Schoeninger *et al.*, 1983; Schwarcz and Schoeninger, 1991; Richards *et al.*, 2000). Specifically, the $\delta^{13}C$ and $\delta^{15}N$ values indicate the source of dietary protein of lifetime diets (Ambrose and Norr, 1993).

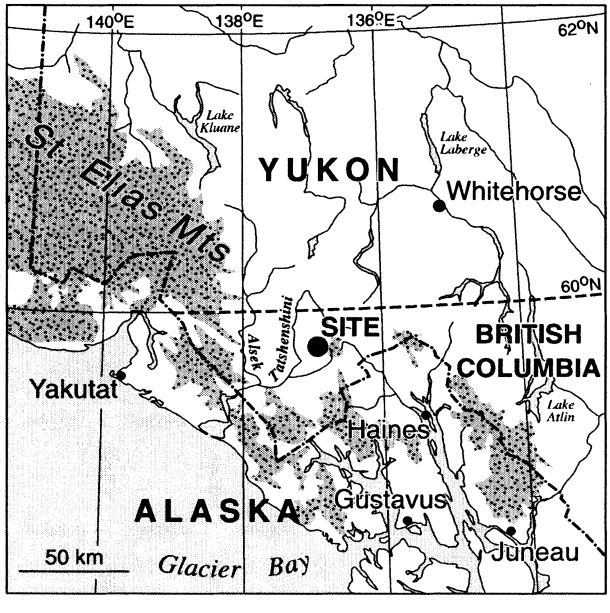

Figure 1 Location of the site in northernmost British Columbia.

Figure 2 Looking west down from a rock outcrop towards the site. Note the parked helicopter close to the ice, a little right of centre. The three recently emerged nunataks can be seen in the mid-distance. The arrow indicates the approximate position of the site; there has been considerable icemelt since August 1999 when the frozen body was found. (Photograph by PJM, 9 August 2002.)

The nature and style of artifacts and clothing discovered with the young man's body show that he was an aboriginal (Beattie *et al.*, 2000); DNA analysis confirms this (Monsalve *et al.*, 2002). Under the body was a robe of sewn pelts of arctic ground squirrel [*Spermophilus paryii plesius* (Osgood 1900)], a garment of interior type (Mackie, 2002). Near the body was a coniferous root hat of coastal design. Two pieces of fish with scales were found near the body, and numerous fish scales adhered to the robe.

The human body was incomplete, with the back of the thorax showing much development of adipocere (so called 'grave-wax' consisting mainly of fatty acids), which forms under wet, oxygen-poor conditions; in this respect there is a marked contrast with Ötzi, whose intact body contained only very small amounts (Spindler, 1994; Bereuter *et al.*, 1996). However, the autopsies revealed that the alimentary canal of Kwäday Dän Ts'ìnchí was well preserved and, chyme being present, that death must have occurred only a few hours after the last meal. The chyme was totally removed and small samples of residues from the lower intestines were taken, as well as faeces from the rectum. These samples represent a time sequence covering the last few days of the man's life. Their study by microscopy, combined with isotopic assays of bone and hair and the identification of any plant remains adhering to clothing, reveals not just diet but potentially also the man's last itinerary.

Methods and results

Palynology (Figure 3a)

The preparation of a chyme subsample and a faecal sample for pollen analyses by light microscopy was by standard methods (Faegri and Iversen, 1989). Two other chyme subsamples were prepared using the acetolysis method of Oeggl (2000). For environmental scanning electron microscopy, the pollen residue was suspended in a drop of distilled water, mounted

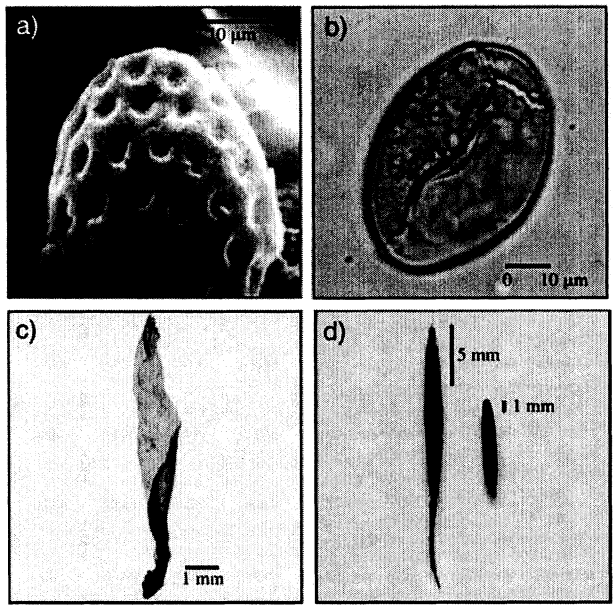

Figure 3 (a) ESEM of glasswort pollen grain from the stomach. (b) An egg (about 60 µm long axis) of the tapeworm *Diphyllobothrium* from the faecal smear. (c) A 12 mm long piece of endophragmal skeleton of a large decapod crustacean, from the stomach. (d) Left, the half schizocarp of mountain sweet-cicely; right, needle of mountain hemlock.

on an aluminum SEM stub, and air-dried in a fume hood before coating with carbon. The coated stubs were scanned with a KeV of 17 and magnification of ×500. Ten to 15 grains of each species were imaged at magnifications of about ×5000 and ×13000.

The three standard pollen counts from chyme subsamples all have as the largest component Chenopodiaceae (about 25%). ESEM was used to identify glasswort pollen in one stomach subsample and one robe sample. Abundant chenopod pollen also occurs on the robe. Pollen from the faecal sample included chenopods and a smear revealed a fragment of conifer charcoal, plant fibres and other tissues, as yet unidentified.

Glasswort Salicornia perennis *Miller, Chenopodiaceae*
Four species of *Salicornia* have been recorded in the study area: there are two intertidal salt-marsh perennials, *S. perennis* and *S. pacifica* Standley, an intertidal annual *S. europaea* L., which is known north to Anchorage, and the inland alkali flat annual, *S. rubra* A. Nels., which occurs at several localities close to Whitehorse, Yukon. The glasswort pollen from the stomach and the robe resembles that of *S. perennis* and *S. pacifica* (Mudie, 1975) rather than pollen of the other species or related genera of salt-marsh Chenopodiaceae (Mudie *et al.*, unpublished data). *S. perennis* has scattered localities in the Juneau/Glacier Bay area but *S. pacifica* is known only further south.

Macroscopic plant remains (Figure 3d)

Plant macroremains were picked or washed with jets of distilled water from the surface of the robe and were compared with herbarium specimens and recently field-gathered ones.

Mountain sweet-cicely Osmorhiza berteroi *DC, Apiaceae*
There are three species of this perennial herb genus in the relevant area (Cody, 2000; Hultén, 1968). The ripe fruits of these species are dark to black, long and narrow and taper gradually to the lower end. They have sparse, downward directed, brittle hairs that are an adaptation for briefly clinging to fur. One half of a schizocarp, 22 mm long, was removed from near the lower left-hand corner of the robe. Having the correct, overall morphology, it is complete at the lower end; however, part of the upper end has broken off and the hairs are lacking, though their bases can be seen. The length, in excess of 20 mm, excludes all species but *berteroi* (Douglas *et al.*, 1998).

Mountain hemlock Tsuga mertensiana *(Bong.) Carr., Pinaceae*
There are two species of coniferous hemlock trees in the relevant area which can be readily separated on needle form (Viereck and Little, 1972). In *T. mertensiana* the needles are 6–25 mm long and keeled below, whereas in *T. heterophylla* (Bong.) Sarg. they are 6–22 mm long and flat. One needle was removed from the robe; it is 8 mm long and keeled.

Animal remains (Figure 3, b and c)

Fish tapeworm Diphyllobothrium *sp.*
Eggs of this fish tapeworm were found in large numbers in the small intestine and in smaller numbers in the descending colon and the rectum. Five species of *Diphyllobothrium* are known to infect humans in Alaska at present. The eggs could not be identified beyond the genus level on the basis of available material (Rausch and Hilliard, 1970). There are a large number of possible fish host species including several species of Pacific salmon. These tapeworms are common in fish-eating birds and mammals including humans, and some species grow to 10 m in length. Humans are infected by eating uncooked fish that are infected with the juvenile plerocercoid stage of the tapeworm. This stage may be found in the musculature or encysted on the viscera of the fish.

Marine crustacean
Five pieces of endophragmal skeleton (10–12 mm long) and a segment of abdominal exoskeleton (10 mm) of a decapod crustacean were among the stomach contents. They were compared to Dungeness crab and lobster. The large size of these pieces show that the crustacean must have been marine, as no terrestrial crustaceans of this size are found in the region, nor freshwater crayfish north of southernmost British Columbia (Hamr, 1998). No more precise identification is yet available. A piece of exoskeleton, 14 mm long, was found in the lower intestines.

Chum salmon Oncorhynchus keta *(Walbaum 1792)*
No fewer than five species of salmon inhabit the Alsek/Tatshenshini system: sockeye, coho, chinook, chum and pink. The two pieces of fish with scales weighed 5.9 g and numerous scales belong to chum salmon. The species identification was made by comparison with museum specimens and use of dichotomous keys (Bilton *et al.*, 1964; Koo, 1962). A total of 116 cycloid scales were removed from both pieces of fish and proved to be from four-year-old chum salmon. Multivariate analysis suggests that all the scales belonged to a single fish. The lack of developed circuli near the focus of the scales suggests that the fish had spent only a short time growing in a freshwater environment before entering the ocean at an early age. The lower intestines contained fish bones that may be chum salmon, but no precise identification has been possible.

Isotopes

We undertook isotopic analysis on two bone samples, one muscle sample and two hair samples from this individual.

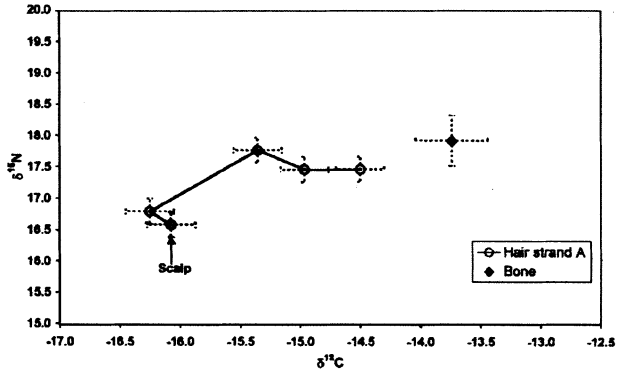

Figure 4 Bone collagen and hair $\delta^{13}C$ and $\delta^{15}N$ values from Kwäday Dän Ts'ìnchí. Each hair segment was 1.5 cm long and reflects approximately 1–2 months of diet while the bone reflects long-term (e.g., 5–10 years) dietary averages.

Two aliquots of bone were used, one given a chloroform: methanol pretreatment to remove possible lipid constituents. Protein extraction was undertaken on the two bone samples and one muscle sample using standard collagen extraction methods (Brown *et al.*, 1988). The samples were then demineralized in 0.5 M HCl at 5°C for two days, and the resultant solids gelatinized in sealed tubes with pH3 HCl at 70°C for 24 hours. The resulting gelatin was then filtered through 30 kD ultrafilters and the >30 kD fraction lyophilized. Modern bone is approximately 20% collagen by mass, and the two bone samples yielded 18.7% and 19.2% collagen-type material, and the muscle sample yielded 3.7% proteinaceous material. The C:N ratios are as follows: bone 1 (NaOH pretreatment) 3.1, bone 2 (no NaOH pretreatment) 3.4 and muscle 3.4. These ratios of the extracted collagen-like material from the bone samples are within the range observed for well-preserved 'collagen' (DeNiro, 1985). There is no statistical difference between the stable isotope values and C and N contents for the two aliquots of bone. The hair samples were pretreated with 2:1 chloroform:methanol for 12 hours then sectioned into 1.5 cm sections for isotope measurement. The results are given in Figure 4.

Discussion

The very high proportion of Chenopodiaceae pollen from the stomach samples is a completely unexpected finding because this family is but a minute element of the plant cover in this area of North America and is absent from local high mountain vegetation. In coastal northwestern North America, chenopod pollen occurs in high proportions only in surface and pollen trap samples from upper intertidal plant communities (Mudie, 1975; Hebda, 1977). The ESEM studies show that the *Salicornia* species is probably *S. perennis*, which appears to have its present northern limit at the south end of Glacier Bay where it grows on mudflats inundated by seawater with a salinity of about 30‰ (Mudie *et al.*, unpublished data).

So far, no organism from either the gut or the robe is unequivocally indicative of an inland source in the Yukon or British Columbia to the north and east of the site, whereas there are two plants that grow only in the coastal zone: mountain sweet-cicely and mountain hemlock. Both these plants are confined to the coastal vegetation in a zone of heavy annual precipitation – a climate contrasting greatly with that of the much drier and colder interior, which supports a different flora and vegetation. They do not occur in the Yukon (Cody, 2000; Burns and Honkala, 1990). Mountain hemlock is 'characteristic of maritime subalpine forests' (Klinka *et al.*, 1989: 236). For mountain sweet-cicely, Hultén (1968: 697) plots the maritime distribution and merely states 'woods'; but, along the Alaskan coast from Glacier Bay (Gustavus and Pleasant Island) at least as far north as Yakutat, it grows at altitudes close to sea level by woodland edges and track sides (JHD and PJM, personal observations). To brush through a stand of *Osmorhiza* plants is to inadvertently gather on your clothing many fruits, most of which are soon knocked or shaken off.

As for diet, it is clear that Kwäday Dän Ts'ìnchí consumed chum salmon and could have been infected with the tapeworm by eating uncooked fish. Significantly, and unlike most other salmon species, chum salmon spawn only in the lower reaches of the rivers in the area, a further indication of coastal connection.

Fossil and archaeological deposits and ethnographic observations provide a good record from 6500 BP to the present for the consumption of intertidal shellfish, nearshore fish, salmonids, sea mammals and sea birds by coastal aboriginals (Hebda and Frederick, 1990). That marine crustaceans were a component of the diet is well documented. Dmytryshyn and Crowhart-Vaughan, 1976: 36) quote the 1817–32 reports of Khlebnikov, who was based in Sitka, Alaska: 'Among shellfish, there are large crabs here, shrimp, and various sorts of mollusks... All these types of shellfish are used as food...' . Krause (1885: 107) stated of the Tlingit that 'The principal dish of the day is always fish, boiled, roasted, dried, but never raw. Next in importance is the meat of land and sea mammals, fowl, crabs, squid, shellfish, sea urchins...' . There are well-documented ethnographic accounts of ancient trade routes between the coast and the interior (Emmons, 1991).

Kwäday Dän Ts'ìnchí's bone and muscle tissue $\delta^{13}C$ values indicate a diet in which >90% of dietary protein was from marine sources. The $\delta^{15}N$ value also indicates consumption of higher trophic level marine protein, such as piscivorous fish and marine mammals (Ambrose and Norr, 1983; Peterson *et al.*, 1985; Peterson and Fry, 1987; Richards *et al.*, 2000).

The hair isotope data contrast with the bone data (Figure 4), showing an increasingly terrestrial isotope signal along the lengths of the two hair samples. One centimetre of hair reflects approximately one month of growth (Richards and Hedges, 1999) and this isotope data indicates that Kwäday Dän Ts'ìnchí had spent time inland for a few months before he died. Previous human isotopic palaeodietary studies in coastal British Columbia contexts also found a heavily marine-based diet, but marine food consumption, as might be expected, was much less at inland sites (Richards and Hedges, 1999).

Conclusions

The isotopic evidence of a mainly marine-based diet for Kwäday Dän Ts'ìnchí is very significant, as it indicates that he must have lived near the coast most of his life and moved inland less than one year before he perished and was preserved in the glacier.

The physical evidence of the gut contents and plants from the robe lead to the working hypothesis that Kwäday Dän Ts'ìnchí was in the coastal zone shortly before his death, either travelling overland between coastal fjords or walking from coast to interior, not *vice versa*.

In the few days just before their deaths, both Ötzi and Kwäday Dän Ts'ìnchí must have travelled across vegetation types changing markedly with altitude. These journeys are recorded to some degree in their intestinal contents. The continuation of even more detailed examinations of the chyme

and the lower intestinal contents is extremely important because pollen and other types of analyses may enable the deduction not just of approximate itineraries but also of relative timetables. If such results can be achieved, then it will be a first in archaeology and forensic science. For the last days of Kwäday Dän Ts'ìnchí's life it is very clear that he had carried seafood, which he must have eaten well away from the coast, probably at high altitude.

Most human corpses found in melting glaciers are only a few decades old and may be in a fragmentary state because of differential ice movements (Ambach *et al.*, 1991; Spindler, 1994). With glaciers the world over in retreat, it can be anticipated that more ancient bodies will be found; however, very few, if any, can be expected to be both as old and as intact as Ötzi, whose corpse had moved only a matter of metres (Oeggl, 2003). Prior to the discovery of Kwäday Dän Ts'ìnchí, there were two very fragmentary bodies, which were a few centuries old, both from glaciers in Switzerland. One was a woman who is thought to have lived some time in the sixteenth to eighteenth centuries (Kaufmann, 1996), and the other was a man who had lived in the late sixteenth century (Meyer, 1992). There may prove to be few such bodies that are even as old as Kwäday Dän Ts'ìnchí. Nonetheless, all ancient bodies from glaciers, albeit fragmentary and only centuries rather than millennia old, are worthy of scientific investigation, especially if they have intact digestive tracts retaining food residues.

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