Late Pleistocene and Holocene Beringia vegetation dynamic reconstructions based on a yedoma exposure, Itkillik (Alaska)

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1. Introduction

The late Pleistocene environment of Beringia is characterized by an arid and cold climate, favorable to active eolian sedimentation. As a result, yedoma was formed and remains one of the most prevalent features of the periglacial environment in the Arctic[9]. The Itkillik exposure located in far north Alaska results from the accumulation of ground ice and the growth of syngenetic permafrost, which was formed synchronously with sedimentation. This type of sediment is often undisturbed and could offer a unique opportunity to examine a long term vegetation sequence in a high latitude environment. Knowing that Beringia has acted as a refugium for boreal trees and shrubs during the Pleistocene, many questions remain about the environmental history of North-Eastern Beringia, especially the extent and dynamics of the now extinct tundra-steppe biome. This paleoenvironment is characterized by both tundra and steppe elements, and its climate is strongly continental with xeric and cold conditions. This open landscape without actual analogue is also characterized by dominant periglacial herbaceous types of vegetation[8].

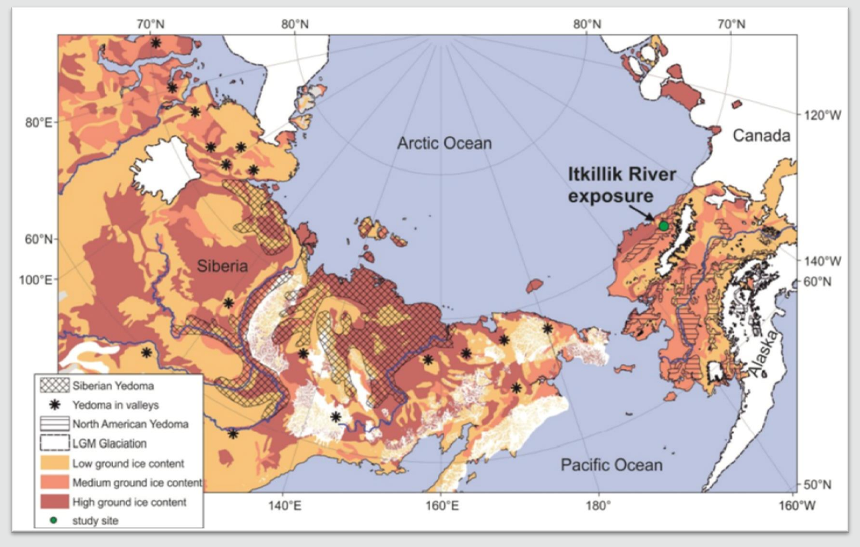
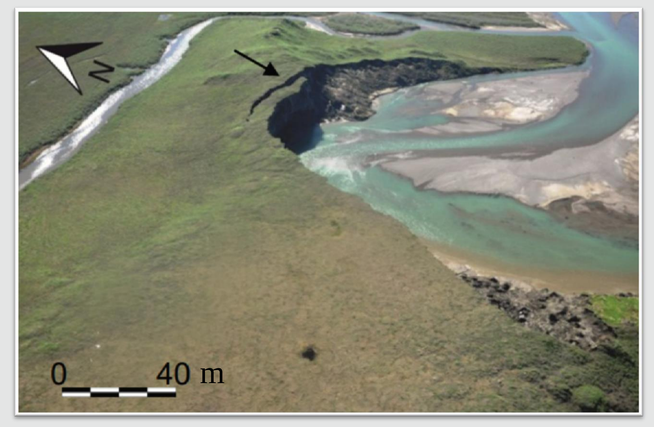


Figure 1. Location of the Itkillik River exposure and the potential area of yedoma in (sub-) arctic lowlands of late Pleistocene Beringia. Map initially published in Strauss & al. (2012).

2. Study site

The study site is located at the boundary of the Arctic Coastal Plain and the Arctic Foothills in the Itkillik river area in Alaska (69°34′ N, 150°52′W). The 33-m-high Itkillik river exposure (Figure 2.1 and 2.2), formed over the late Pleistocene / early Holocene (48,000 to 5,000 14C yrs BP), was revealed by active river erosion. The total length of the exposed face exceeds 400 m. The sequence consists of organic poor eolian silt. The chronology of the Itkillik yedoma used is based on 10 radiocarbon dates.



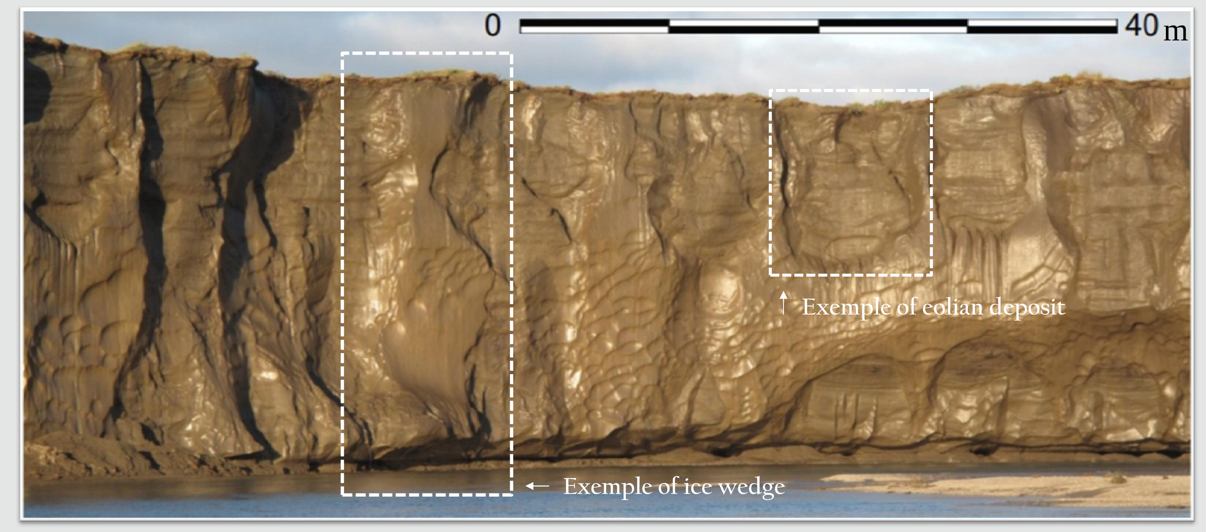


Figure 2.1 and 2.2. Location of the study site in Alaska from Strauss, J. (2012). The Itkillik exposure pictures were taken by Kanevskiy, M. in august 2012 and 2011.

3. Methods

Figure 3. density separation step with sodium polytungstate

In the field, the sampling was carried out by rappelling along the wall. The surface was first cleaned, then we used a drill corer (5 cm diameter, 2-3 cm deep) to extract samples, placed in sealed bags. In the laboratory, samples were weighed and their volume was measured by liquid displacement. For pollen extraction, instead of a classical hydrofluoric acid treatment (to digest silicate minerals), we used an extraction method based on heavy-liquid separation because of the very low concentration of pollen in the sediments and their poor state of preservation.

This treatment involves acid digestion of carbonate (hydrochloric acid (HCL)), organic matter deflocculation (potassium hydroxide (KOH)), a heavy liquid density separation (sodium polytungstate (SPT)) and acetolysis. Sodium polytungstate brings a number of advantages as it is non-toxic, nonflammable, non-odorous and reusable. Also, density may be regulated with water (1,1-3,1 g/cm^3). Initially, the technique, largely unpublished, was developed for processing pollen samples from very poor archaeological sites. At least 1000 eucalyptus grains (contaminant) per level were identified when the samples were very poor (1 933-11 586 pollen grains/cm^3). Species were not always reported because of some poor pollen preservation.

4. Results

Figure 4. Yedoma exposure pollen frequencies (%) plotted against depth and age axes. Species names in red represent the major taxa used to reconstruct the vegetation dynamics according to the three zones of late Pleistocene Beringia vegetation (herbs zone, *Betula* zone and *Picea-Alnus* zone) from Livingston (1955). The 14C dates are not calibrated and plotted on a depth axis. The stratigraphy section shows cryostratigraphic units of the Itkillik yedoma (ice wedges width not to scale) and the radiocarbon age of deposits (14C yr BP) based on a previous study conducted at the Itkillik site (Kanevskiy, 2011).

5. Results summary

A. - The three identified zones of late Pleistocene Beringia vegetation : Herbs zone, *Betula* zone and *Picea-Alnus* zone[10] are not as clear in the Itkillik exposure recording as they are in studies with higher temporal resolution[1-2-3-4-5-6] .
- From approximately 15 000 14C yrs BP, we observed increases in the presence of *Picea* (7-9%) and *Alnus* (2-5%) consistent with a decrease in herbaceous taxa, concordant with the warmer and moister climate of the Holocene . This age is much more older than others sites from the same region[1-2-3-4-5-6], and may be due to some form of contamination during sampling or local cryoturbation.
- We observed that the subzone *Populus*[1], often associated with the *Betula* zone, is absent from the study site. This may reflect the limited dispersion and poor conservation of *Populus* pollen grains[7], coupled with the high exposure location of the study site.

B. - Overall, *Cyperaceae* and *Gramineae* are by far the dominant taxa in the sequence. The local conditions of the study site may have favored the presence and conservation of an herbaceous cover.

C. - No samples could be retrieved for the zone included between approximately 25 000 and 28 000 BP because of technical difficulties associated with the difficult sampling conditions.

D - Sedimentation seems to be slower when there is a thick ice wedges regime. It could be possible that low accumulation rates are due to less windy conditions or to sedimentary sources that are more humid and/or vegetated, which decreases wind erosion and transportation.

6. Discussions & Conclusion

To our knowledge, this is the first pollen-based vegetation reconstruction from a yedoma permafrost sequence in North America. The Beringia landscape over the late-Pleistocene and early Holocene is considered a patchwork of tundra vegetation types, where the local flora was determined by local conditions[2]. The colder and arid climate associated to the far northern position of the Itkillik exposure could have slowed down the transition from grassy tundra-steppe to shrub tundra[10]. The slight dominance of *Cyperaceae* on *Gramineae* could be explained by a thin active layer or by the specific sampling location at the center of the ice wedges, which could have locally improved water availability for plant growth.

Most other studies from East Beringia did not investigate vegetation assemblages after 40,000 yrs BP due to coring and pollen extraction problems[5]. We succeeded in extracting pollen from the deeper parts of the profile (› 40,000 yrs BP) by using an alternative method, which has helped to concentrate the pollen without affecting the preservation of the already corroded pollen grains that remained in the sediments. The assembly of herbs and low concentration reflect a spread open landscape, close to a polar desert.

Because yedoma is a form of permafrost formed synchronously with eolian deposition, it's possible that erosion and cryoturbations have altered the sediment sequence. Despite the low temporal resolution of the reconstructions due to the difficult sampling conditions, the result are in line with reconstructions from lakes located in the same region[1-2-3-4-5-6]. Future work will focus on higher resolution reconstructions with better chronology.

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