Pollen, trace elements and stable isotope plots of Late Pleistocene ice wedges of Seyaha yedoma, Eastern Yamal Peninsula

A.C. Vasil'chuk[1], Yu.K. Vasil'chuk[1], N. A. Budantseva[1], J.Yu. Vasil'chuk[1]

[1]*Department of Geography, Lomonosov Moscow State University, Moscow, Russia, e-mail: alla-vasilch@yandex.ru*

Abstract

The Seyaha yedoma is located in eastern coast of Yamal Peninsula (70°10'00" N, 72°30'30" E). This sequence (height 22-24 m) is especially valuable for paleotemperature reconstruction because its accumulation was nearly continuous: from 30 to 11 ka BP and because of abundant syngenetic ice wedges. The previous oxygen isotope and radiocarbon results allowed aging the ice-wedge formation from 21 to 11 ka BP. The pollen plot of the large ice wedge represents three units corresponding to changes in taxa composition and their abundance. There are two trends in $\delta^{18}O$ values; from +12 to +14.2 m a.s.l. the range in $\delta^{18}O$ values is about 1.5‰, from –24.18 to –25.75 ‰, from +14.2 to +15.8 m a.s.l. there is clear upward increase in $\delta^{18}O$ values from –25.75 to –23.15 ‰. New isotope data reveal that the average January temperature was –34 to –40 °C from 23 to 15-18 ka BP. The tendency to upward increase in $\delta^{18}O$ values may be explained by increase in average winter and average January temperatures during the final stages of ice-wedge formation. There are 3 maxima of trace element content in the upper part of the ice wedge as follows: at a height of 14.6-15.2 m for Fe, Si, Mn, P, Ba, Sr, Zn, Ni, Cu, Cd, Mo, Sb, Pb; at a height of 13.5-13.8 m for Fe, Si, Mn, Zn, Ba, Sr; and at a height of 12 m for Sb, Cd, Mo, Pb.

Keywords: ice wedges, stable isotopes, Yamal Peninsula, pollen, trace elements.

Introduction

The Seyaha yedoma is located near Settlement Seyaha (Fig. 1) in eastern coast of Yamal Peninsula (70°10'00" N, 72°30'30" E). The site investigated in 2016.

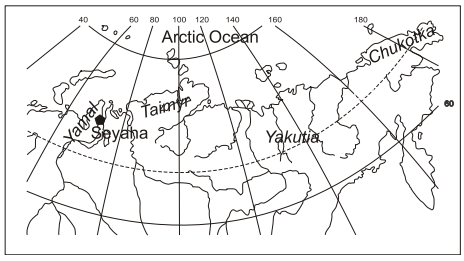

Figure 1. Location of the Seyaha yedoma.

This sequence (height 22-24 m) is especially valuable for paleotemperature reconstruction because its accumulation was nearly continuous during 20 ka: from 30 to 11 ka BP (Vasil'chuk *et al.*, 2000; Vasil'chuk *et al.*, 2005) and because of abundant syngenetic ice wedges.

Results

^{14}C age

The previous oxygen isotope and radiocarbon results allowed dating the formation of ice-wedges from 21 to 11 ka BP (Vasil'chuk *et al.*, 2000). ^{14}C ages without inversions from the bottom part of the exposure are shown in Table 1.

Table 1. New radiocarbon ages of sediment samples.

Sample ID	Heigth, m.a.s.l.	Conventional 14C age, yr BP	Lab ID
YuV-16S/ 76	+5.0	23300 ± 640	Le-11406
YuV-16S/ 77	+3.0	24100 ± 300	Le-11407
YuV-16S/ 78	+2.0	25200 ± 420	Le-11408

Pollen

Pollen extraction using heavy-liquid separation was performed for 25 samples obtained from the main sampling profile of large ice wedge. The pollen plot was subdivided into three units corresponding to changes in taxa composition and abundance (Fig. 2). The profile is dominated by herbaceous and shrub taxa. The lower part of ice wedges (6.8-8.8 m a.s.l.) is notable for having high concentration of pollen, predominance of Betula sect. Nanae, abundance and high diversity of herb taxa. Middle part (8.8-11.1 m a.s.l.) is characterized by a low pollen concentration and high diversity of herbaceous taxa. Spores of typical tundra taxa *Lycopodium lagopus (Laest.) Zinserl. ex Kuzen* were found here. The top part of ice wedge (11.1-13.6 m a.s.l.) shows increase in percentage of boreal tree taxa (*Picea, Pinus*), maximum percentages of Poaceae and Cyperaceae, *Artemisia* and finding of *Diphasium alpinum (L.) Rothm. Lycopodiella*

innundata (L.) Holub). There is a maximum of reworked pollen at this interval. It may be supposed that some part of boreal tree pollen is reworked.

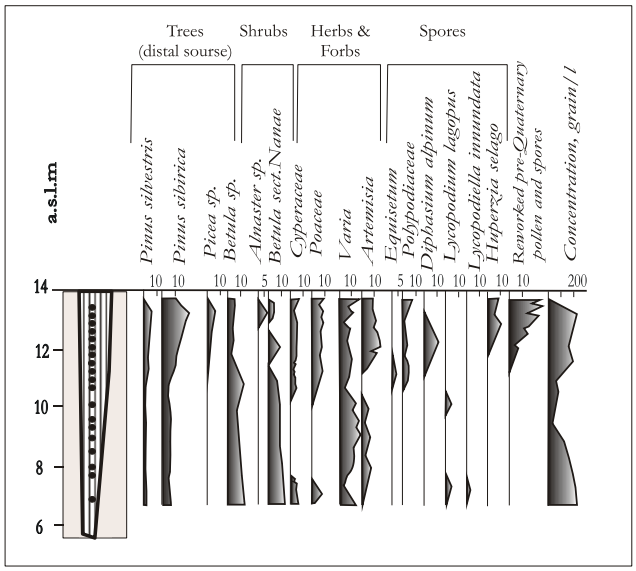

Figure 2. Selected components of pollen spectra from ice-wedge ice of Seyaha yedoma.

Table 2. Stable isotope ($\delta^{18}O$ and $\delta^{2}H$) minimum, mean, and maximum values in ice wedges of the Seyaha yedoma.

Sampl. (n)	$\delta^{18}O$, ‰			$\delta^{2}H$, ‰		
	min.	mean.	max.	min.	mean.	max.
IW profile №1 (№11-58), depth 2.2-6.0 m (12-15.8 m a.s.l.)						
8	–25.75	–24.7	–23.15	–197.5	–192.0	–171.9
IW profile №2 (№63-74), depth 12.0 m (6.0 m a.s.l.)						
59	–26.63	–24.9	–23.41	–203.9	–201.0	–178.9

Stable isotopes

$\delta^{18}O$ values vary from –25.75 to –23.15 ‰ in the upper part of the ice wedge (Table 2). There are two trends in $\delta^{18}O$ values; at the height from +12 to +14.2 m a.s.l. the range in $\delta^{18}O$ values is about 1.5‰, from –24.18 to –25.75 ‰, at the height from +14.2 to +15.8 m a.s.l. there is clear upward increase in $\delta^{18}O$ values from –25.75 to –23.15 ‰. The range in $\delta^{18}O$ values at +15.2 m a.s.l. is 1.49‰, from –23.41 to –24.9 ‰. The basal part of ice wedge at +6 m, is characterized by larger range in $\delta^{18}O$ values than the upper part: from –23.41 to –26.63 ‰. New isotope data reveal that the average January temperature was from –34 to –40ºC from 23 to 18 ka BP, according to the conversion equation proposed by Vasil'chuk (1991). The tendency to upward increase in $\delta^{18}O$ values may be explained by the increase of average winter and average January temperatures during the final of the ice wedge formation.

Chemical composition

There are 3 maxima of trace elements content in the upper part of ice wedge as follows: at a height of 14.6-15.2 m – for Fe, Si, Mn, P, Ba, Sr, Zn, Ni, Cu, Cd, Mo, Sb, Pb; at a height of 13.5-13.8 m for Fe, Si, Mn, Zn, Ba, Sr; and at a height of 12 m for Sb, Cd, Mo, Pb (Table 3).

Table 3. Trace element values in ice wedges of the Seyaha yedoma. Number of samples = 7.

Element	min.	mean.	max.
Si	3251.4	2514.9	3251.4
P	884.1	629.2	884.1
Mn	1620.8	983.7	1620.8
Fe	7048.2	3707.2	7048.2
Ni	40.6	30.7	40.6
Cu	38.4	25.9	38.4
Zn	131.9	90.4	131.9
As	9.23	5.1	9.23
Sr	111	92.1	111
Zr	2.23	1.6	2.23
Mo	0.46	0.23	0.46
Cd	0.45	0.25	0.45
Sb	0.11	0.10	0.11
Ba	183	152.6	183
Pb	20.1	13.0	20.1

The lower part of ice wedge is characterized by low element concentrations except for Fe, Ba, Zn; their stable concentrations both in the lower and upper parts (Table 3) is obviously due to containing in clay minerals and coming from aeolian dust inputs.

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Bâtiment « Pôle Montagne »
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Editors

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