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GEOGRAPHY

The AMS Radiocarbon Dating of Pollen Concentrate from the Late Pleistocene Ice Wedge of the Bison Section, Kolyma Region

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The object of this work is to correlate new results of the AMS radiocarbon dating of spore-and-pollen concentrate extracted from the Late Pleistocene syngenetic reformed ice wedge (hereafter, ice wedge) of the Bison section with palynological data on the same samples and results of the AMS radiocarbon dating of two other organic fractions obtained earlier in the same samples from ice [1]. The degree of reliability of dating different organic fractions is also considered.

The Late Pleistocene Bison ice wedge is situated on the right bank of the Kolyma River, in the mouth of the Lakeevskaya Channel, 15 km downstream of the Duvannyi Yar (69° N, 158° E).

The Bison section, more than 15 m thick, exposes perennially frozen sandy loams with interlayers of organic material (OM) (lenses up to 0.5 m thick). The section includes several stages of syngenetic ice wedge with a vertical thickness up to 9 m and width in the upper part up to 2–2.5 m (Fig. 1).

We dated this ice wedge complex earlier on the basis of OM microinclusions extracted from the Late Pleistocene ice wedge and the alkaline extract from this organic material. Samples were collected from three ice stages in two adjacent fragments of the exposure. Wedges 1 and 2 are located on the native wall, whereas Wedge 3 is situated on the "baidzherakhi" (hillocks left after deglaciation) massif transformed by thermoerosion. Seven samples of this section were analyzed by J. Van der Plicht at the Center for Isotope Research, Radiocarbon Laboratory (Groningen University), and seven pairs of datings were obtained within the interval from 26 to 38 ka ago [1]. Each pair included a dating based on microinclusions obtained by screening the ice with organic suspension through the electronic sieve (hole diameter 200 μm) and another dating based on the alkaline extract obtained from the same sample prior to screening.

The spore-and-pollen concentrate was obtained in four samples dated on the basis of microorganic material and alkaline extract applying the procedure of spore-and-pollen extraction from ice wedge specially elaborated by A. Vasil'chuk for the AMS radiocarbon dating [2, 3]. The treatment and dating of the samples was carried out in the AMS Laboratory of Seoul National University.

Six new radiocarbon dates ranging from 43.6 to 26.2 ka were obtained for the pollen concentrate from Bison ice wedge (Table 1).

It is expedient to consider the obtained dates within each of the three studied ice wedges (Fig. 2). Wedge 1 yielded 31.4 ka. Previously, we dated a composite OM sample taken from ice wedge near Wedge 1 and obtained 26.4 and 27.7 ka for microinclusions and alkaline extract, respectively. These datings are rather close and their reliability is probably high. The pollen age obtained for the neighbor sample seems to be slightly overestimated. The spore-and-pollen spectrum of this sample is characterized by a very high content of the

Table 1. Direct AMS radiocarbon dating of spores and pollen from ice wedge of the Bison section in lower reaches of the Kolyma River, northern Yakutia

Field no.	Abs. height/depth, m	^{14}C age, yr	Lab. no.
Wedge 1			
378-YuV/195	+18.0/2.6	31400 ± 500	SNU02-128
Wedge 2			
378-YuV/90	+16.6/4.0	26200 ± 300	SNU02-147
378-YuV/100	+13.0/7.6	28200 ± 600	SNU02-150
378-YuV/102	+13.0/7.6	35600 ± 800	SNU02-124
Wedge 3			
378-YuV/144	+12.5/8.1	36900 ± 1000	SNU02-127
378-YuV/146	+9.6/11.0	43600 ± 1100	SNU02-125

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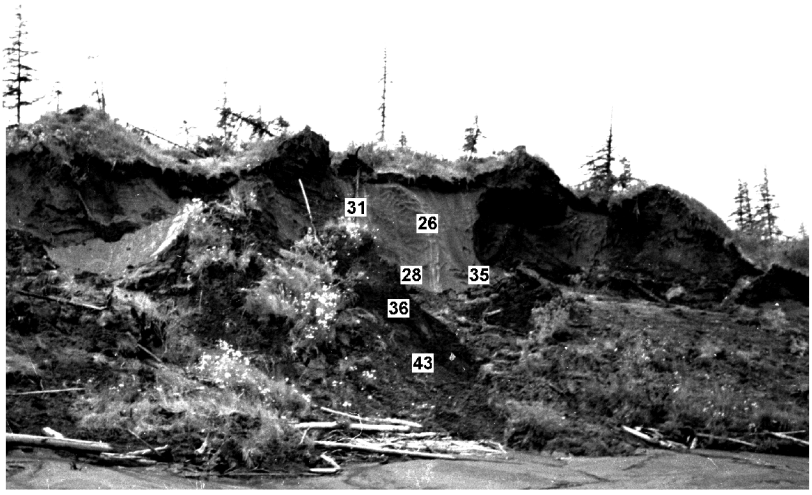

Fig. 1. General view of the exposure of the Late Pleistocene syngenetic reformed ice wedge in the Bison section and locations of six new ^{14}C-datings (ka) of the spore-and-pollen concentrate in three wedges.

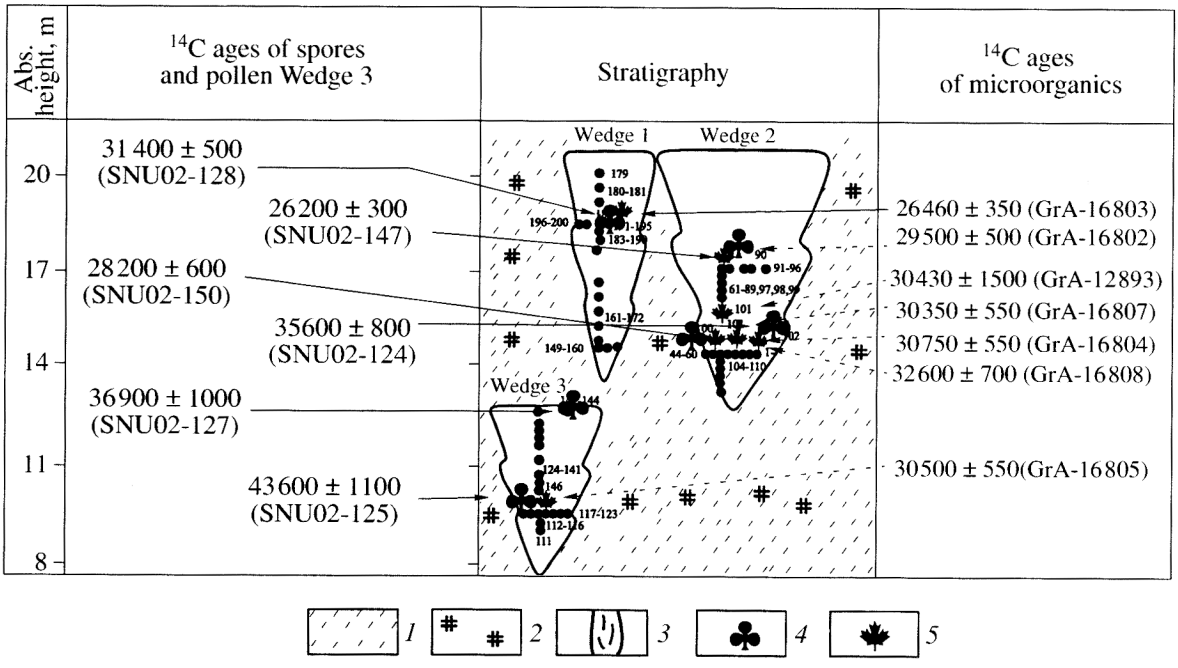

Fig. 2. Radiocarbon dating of the pollen, spores, and microorganic inclusions from the Late Pleistocene syngenetic ice wedge in the Bison section. (*1*) Sandy loam; (*2*) allochthonous peat; (*3*) ice wedge; (*4, 5*) sites of ice wedge sampling for AMS radiocarbon dating: (*4*) spore-and-pollen concentrate, (*5*) microorganics of the >200-μm fraction.

pollen of *Pinus pumila* (up to 42%) (Table 2) and the presence of the arboreal pollen (>4%), including rare ecdemic pollen of *Pinus silvestris* and *Pinus sibirica*. A noticeable amount of spores of *Lycopodium* in the ice wedge spectrum is indicative of their input with dust from the surface of mineral grounds that are virtually bare in winter. Since the spore-and-pollen content is rather low and the composition of this pollen spectrum corresponds to local landscapes in the northern belt of typical tundra, the presence of arboreal pollen and Japanese stone pine (*Pinus pumila*) presumably indicates the presence of redeposited elements in the spectrum (the *Pinus pumila* content here is anomalously high and reaches 42% against the background value of 5–8%).

Such redeposition is probably related to the eolian transportation of exposed sediments that predated the ice wedge by 10–15 ka, since the spectra lack exotic forms and *a priori* ancient pre-Pleistocene pollen (only

Table 2. Contents of spores and pollen and correlation of AMS radiocarbon dates based on different fractions of organic material extracted from the same ice wedge samples (Bison section, the lower course of the Kolyma River)

Pollen, spores	Sample 378-YuV/195	Sample 378-YuV/90t	Sample 378-YuV/100	Sample 378-YuV/102	Sample 378-YuV/144	Sample 378-YuV/146
Arboreal pollen	4.8	–	–	0.8	1.2	5.0
Frutescent pollen	14.4	28.6	40.8	8.7	26.1	26.3
Herbaceous pollen	21.6	50.7	46.8	56.5	42.1	33.8
Spores	20.4	22.1	10.6	34.8	32.4	33.8
Pinus silvestris	1.2	–	–	–	–	–
Pinus sibirica	1.2	–	–	–	–	–
Betula sect. Albae	2.4	–	–	0.8	0.6	1.9
Larix	–	–	–	–	0.6	3.1
Pinus pumila	42.0	10.4	–	1.6	2.7	5.6
Betula sect. Nanae	8.4	15.6	38.4	4.0	23.4	16.9
Alnaster	–	–	–	1.6	–	2.5
Salix	3.6	2.6	2.4	1.6	–	1.3
Poaceae (small)	1.2	–	–	1.6	6.4	4.4
Poaceae (large)	–	–	–	5.6	–	–
Cyperaceae (type Carex)	14.4	23.8	25.2	20.5	21.6	6.9
Cyperaceae (type Eriophorum)	2.4	10.0	–	3.2	–	0.6
Ericaceae	–	1.3	–	0.8	–	1.9
Artemisia	–	–	–	1.6	–	–
Compositae	–	–	–	–	1.8	–
Varia	3.6	6.5	18.0	19.4	7.2	13.1
Chenopodiaceae	–	–	0.9	1.6	–	–
Polygonaceae	–	–	–	–	0.9	0.6
Polemoniaceae	–	–	–	–		1.3
Rosaceae	–	–	–	–	2.7	1.9
Dryas sp.	–	–	3.6	–	–	1.3
Brassicaceae	–	–	–	0.8	–	–
Draba sp.	–	–	–	–	–	0.6
Saxifragaceae	–	–	–	–	–	1.9
Liliaceae	–	1.3	–	–	–	0.6
Juniperus	–	1.3	–	–	0.9	–
Bryales	3.6	11.7	6.0	25.2	14.4	13.1
Sphagnum sp.	–	–	–	3.2	1.8	0.6
Polypodiaceae	1.2	–	–	0.8	4.5	0.6
Equisetum	–	10.4	4.8	–	4.5	1.3
Selaginella sibirica	15.6	–	–	1.4	6.3	21.9
Specimens per 1 l	164	156	164	382	228	481
Redeposited palynomorphs	0.2 % (Riccia)	–	1 % (Ulmus, Diervilla)	–	0.4 % (Quercus sibirica, Pinaceae)	1 % (Sporites durabilis, Trudopollis sp., Shchizaceae, Leotriletes sp.)

single *Riccia* spores were found). The appreciably high content of fine particles in the ice sample also indicates the eolian input of spores and pollen. The age of the pollen concentrate from this sample is most likely unreliable and overestimated by 4–5 ka.

The situation in spectra of three samples from Wedge 2 is quite different. Judging from the spectra composition, their autochthonous nature is almost beyond question. The same conclusion follows from the dating of the pollen concentrate, which yielded a noninversion series of dates ranging from 26 to 35 ka. The uppermost sample is characterized by the tundra-type pollen spectrum. It should be noted that the pollen concentrate yielded the youngest age of 26.2 ka, which is 3 ka younger than the date of the same sample based on organic microinclusions (they are extremely rare, because the pollen are better preserved and more adapted to multiple redeposition from older deposits to younger ones). In the uppermost section, the pollen of *Pinus pumila* and *Salix* are common and the pollen of Cyperaceae and *Eriophorum* and spores of *Equisetum* are abundant. Therefore, we can reconstruct local hydromorphic landscapes in the northern belt of typical tundra that existed in lower reaches of the Kolyma River 26 ka ago. The dating of the pollen concentrate is most likely reliable, because traces of spore-and-pollen are absent here and practically all palynomorphs are well preserved.

Two lower samples were collected from a wedge at the same height (7.6 m), but their ages differ by 7 ka. This suggests that the 28-ka-old ice wedge (Sample 378-YuV/100) intruded an older ice wedge that was formed approximately 30–37 ka ago (based on the dating of OM microinclusions in the ice fragment). The pollen spectrum obtained from this sample (378-YuV/102) is characterized by a high concentration of palynomorphs with different degrees of preservation. Probably, the pollen of *Betula, Pinus pumila*, and *Artemisia* did not simultaneously enter the ice wedge. The herbage pollen (~20%), represented here by at least eight families, are generally well preserved. They are aggregated into clay particles, indicating a sufficiently high water level in the basin and inundation of the polygonal area. It is likely that ice wedges developed 30–30.7 ka ago under conditions of an inundated low floodplain or beach with abundant herbaceous vegetation. The value of 35.6 ka obtained for the pollen concentrate from this sample indicates the presence of variable-age palynomorphs in the pollen spectrum (OM microinclusions in the sample yielded the value of 30.7 ka). Overestimation of the pollen concentrate dating is confirmed by the presence of carbonized pollen grains and coal particles of the pollen grain dimension in the spectrum. Coal particles account for 15.2% of the total amount of spores and pollen. Hence, the dating of the pollen concentrate from this sample is unreliable and considerably overestimated, since the pollen spectrum displays apparent signs of the spore-and-pollen redeposition.

Sample 378-YuV/100 yielded the pollen concentrate age of 28.2 ka. Its pollen spectrum is very poor. Moreover, coal particles and carbonized palynomorphs are absent. The regional component, i.e., the pollen of *Betula nana,* dominates in the spectrum (38.4%). Therefore, it is likely that the AMS date of the pollen concentrate corresponds to the timing of the ice wedge. The dating of the pollen concentrate from this sample is probably reliable, since no signs of spore-and-pollen redeposition were found and practically all palynomorphs are well preserved.

Pollen spectra from Wedge 3 reflect a different stage in the evolution of vegetation and a different regime of the ice wedge formation. Redeposited pollen grains of *Quercus sibirica* Pan. and fragments of the pollen of Coniferae were found in the spectrum of the upper sample from this wedge. The content of pollen-sized coal particles makes up 9.9%, whereas the content of redeposited forms is 0.4%. Signs of the redeposition of spores and pollen in the pollen spectrum are vague. Nevertheless, the younger age of the microorganic material obtained from the same wedge suggests different ages of pollen spectrum components. Hence, the date of the pollen concentrate from this sample is unreliable. There are signs of redeposition of organic material, and the palynomorphs are differently preserved.

The lower sample from ice wedge, which yielded the pollen concentrate age of 43.6 ka, contains the pollen of *Larix* that commonly suggests the participation of the larch pollen in the vegetation cover since it rarely endures redeposition. This sample has the highest concentration of spores and pollen. The composition of herbage pollen is also very diverse. Based on microorganic inclusions, the sample yielded a significantly younger age (30.5 ka), and the alkaline extract yielded an anomalous value. This sample is marked by the presence of pollen grains with primary forms. However, they are opaque and black in the transmitted light under a microscope (these forms are not included in the number of calculated palynomorphs, but they account for 25% of the total sum). Redeposited elements of the spectrum (1%) include *Sporites durabilis, Trudopollis* sp., and *Leotriletes* sp. It is likely that mainly particles of the pollen-sized fraction (black palynomorphs subjected to diagenesis) were redeposited. Hence, the dating of the pollen concentrate from this sample is unreliable. Signs of the redeposition of spores and pollen are obvious in the pollen spectrum, although the palynomorphs are well preserved. This pollen spectrum can be more precisely dated only after a repeat study.

Thus, both samples from the lower Wedge 3 is most likely contaminated with the asynchronous material to ice formation. This issue can be elucidated only after supplementary study of the section. As was noted in [1], the dating of this wedge is complicated by a possible postgenetic subsidence of the whole frozen massif.

When comparing dates of the pollen concentrate, microorganic inclusions, and alkaline extract with

regard for the composition of spore-and-pollen spectra, one can distinguish the fraction with the more reliable dating. In some cases, the spore-and-pollen concentrate yields the more reliable date. However, more often the 200-μm fraction of the compound microorganic material is more reliable owing to the good preservation of spores and pollen and their multiple redeposition from older deposits. An important point is that the pollen and spores extracted from the ice wedge characterize a regional pollen fallout; i.e., practically all the determined pollen belongs to regional and subregional components. Therefore, the adequate reconstruction and timing of landscape dynamics in the regional scale is possible on the basis of dated extracts of pollen and spores from the ice wedge.

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