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AMS^{14}C dating and stable isotope plots of Late Pleistocene ice-wedge ice

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Abstract

Strategy for AMS^{14}C dating of organic micro inclusions from syngenetic ice-wedge ice is considered. AMS^{14}C dates are interpreted in terms of fictitious aging of ice-wedge and permafrost sediments due to high concentration of allochthonous organic material. The dating of organic material from small sample, gives the reliable ^{14}C age. The ^{14}C dates from syngenetic ice-wedges are compared with the dates of the host sediments surrounding syngenetic ice wedges. AMS^{14}C dating of small samples of ice-wedge ice yields to set δ^{18}O plots from ice-wedges to the time scale and to correlate them with ice core δ^{18}O record.

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1. Introduction

Long safety of organic material and possibility of its repeated deposition in permafrost conditions complicates ^{14}C dating of permafrost sediments. Re-deposited ancient material is found not only in Late Pleistocene fluvial sediments, but also in Holocene high moor peat [1,2]. The discrepancies of age setting are a rule in permafrost area. Applying AMS techniques for ^{14}C dating is allowed to obtain direct age of ice-wedge ice.

Strategy of radiocarbon dating of Late Pleistocene syngenetic ice-wedges includes as follows: (1) increase the probability to collect autochthonous organic material by optimal volume of sample; (2) interpretation of ^{14}C AMS dates taking into account fictitious aging due to admixture of allochthonous organic material; (3). Comparison and verification ^{14}C dates of syngenetic ice-wedges with dates of the host sediments surrounding syngenetic ice-wedges.

2. Regional setting

Cross-section of Duvanny Yar ice-wedge complex is located in Lower Kolyma River (68°37′N, 159°08′E). Cross-section of Plakhinski

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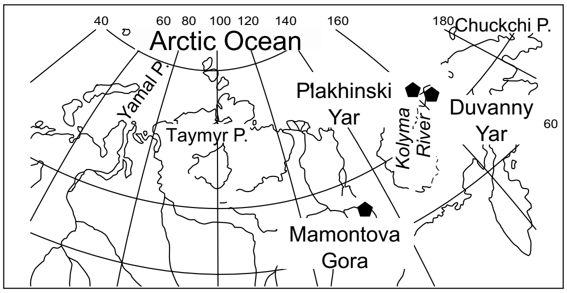

Fig. 1. Location map of Duvanny Yar, Plakhinski Yar Mamontova Gora ice-wedge complexes in Yakutia.

Yar ice-wedge complex is located on the left bank of Stadukhinskaya stream of Lower Kolyma River (68°38′N, 160°55′E). Cross-section Mamontova Gora ice-wedge complex is located in the left bank of Aldan River (63°N, 134°E) (Fig. 1).

3. Methods

At the first stage we have indirect ^{14}C dating of organic material from host sediments surrounding ground ice [1] to set oxygen isotope plots from syngenetic ice-wedges. Later, we have collected large samples more than 60 kg of ice (in Seyaha cross-section, Yamal Peninsula, age 14 000–21 000 yr BP) [3,4]. The ice thawed and 1 kg of enriched residue was used for dating. Decrease of initial weight of ice sample up to 30 kg (Bison cross-section on Kolyma River valley, age 26 000–33 000 yr BP) has allowed to gain satisfactory results too.

High sensitivity of AMS^{14}C dating makes possible to date small samples of melt water from ice-wedges (about 40 ml, the organic impurity not less than 0.5–1 mg). These samples were collected from 1983 to 1985 in Yakutian cross-sections such as: Duvanny Yar & Plakhinski Yar in Lower Kolyma River valley and Mamontova Gora in Aldan River valley. The samples were preserved in a refrigerator. The measurements of small samples have shown the possibility of dating an ice-wedge ice and also stable isotope plots from the ice.

4. Results

Progress in pretreatment and sensitivity of AMS techniques allowed dating less than 1 mg of carbon and it makes possible to use small samples of the ice from ice-wedges. These samples are from cross-sections in Lower Kolyma River valley (Duvanny Yar [5,6], Plakhinski Yar [7]) and one cross-section is on Aldan River valley, (Mamontova Gora ice-wedge complex [7]).

Duvanny Yar ice-wedge complex (Fig. 2(a and b)): Large syngenetic ice-wedges occurred in 55 m loamy thickness. They are wide in the bottom of the cross-section (width up to 3–3.5 m), and narrow in the upper part (up to 1.0–1.5 m). On the base of more than 50 ^{14}C conventional dates of the host sediments we have concluded that, time of ice-wedge formation is from 37 000 up to 17 000 yr BP [8]. Relatively young age of the beginning of sediments accumulation has been confirmed by ^{14}C dates 31 200 and 25 000 yr BP from ice-wedge ice at height about 6 m above see level (Fig. 2(b)).

Plakhinski Yar ice-wedge complex (Fig. 2(c)): Height of exposure is about 14 m, composed by sandy loam with plant remains scattered throughout sediments. The width of ice-wedges is 1–1.5 m, the distance between them is 3–4 m. According to dates from host sediments it was possible to suppose the formation of the seen part of ice-wedges to 30 000–16 000 yr BP [7,9]. The AMS^{14}C dates 17 390 and 11 490 yr BP from upper part of ice-wedge (Fig. 2(c)) are specified the time of ice-wedge formation.

Mamontova Gora ice-wedge complex (Fig. 2(d)): There are 5 m ice wedges in the top part of 50–60 m terrace in the 12 m lens (inset) of lacustrine-marsh gray loam. According to dates from wood fragments from 35 000 up to 46 000 yr BP it was commonly supposed that the age of lacustrine loam and ice-wedges is older than 30 000 yr BP [10,11]. We also have two dates on wood at depth 2.6 m 35 ka BP, and at the depth 8.0 m 38.4 ka BP, and at the depth 2 m autochthonous peat layer was dated 4.8 ka BP.

So we supposed wood as re-deposited and assumed most likely Holocene age of ice-wedge [7]. However, the δ^{18}O values of ice were more negative (−28.5‰), than Holocene or modern ones.

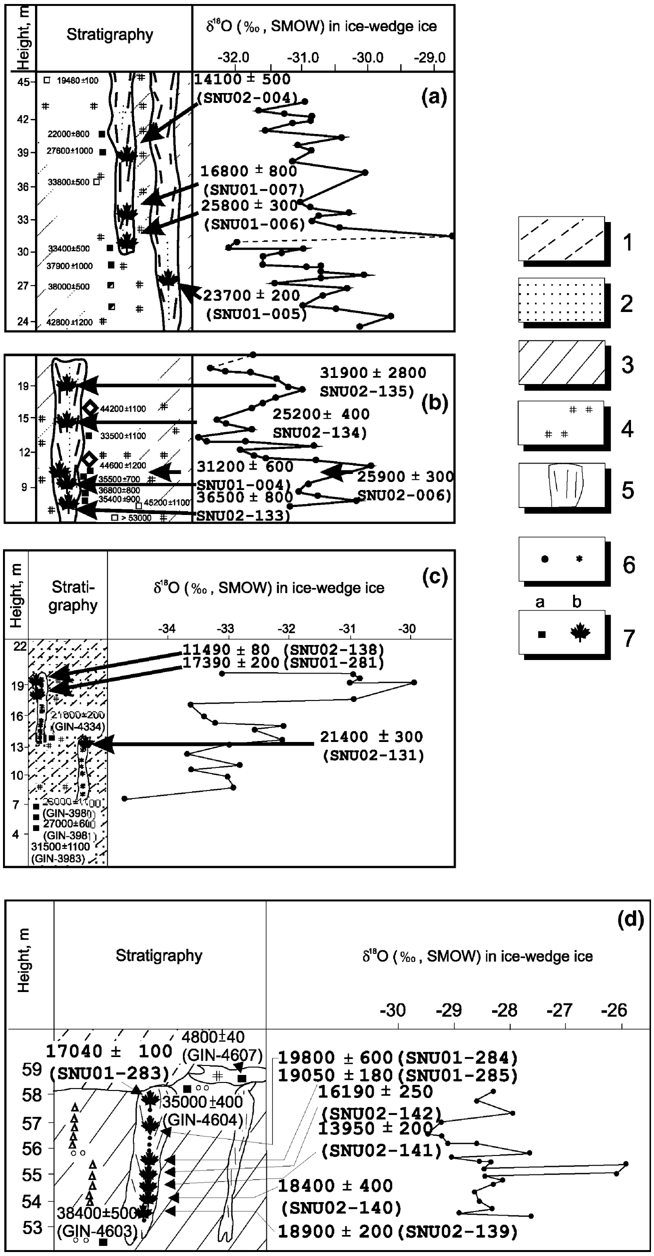

Fig. 2. Oxygen isotope plot, radiocarbon dating of organic material in host sediments surrounding ice-wedge and AMS-dating of ice: In Duvanny Yar Late Pleistocene syngenetic ice-wedge ice in Lower Kolyma River valley in north–east of Yakutia ((a) – top half of section, (b) – bottom half of the cross-section) and oxygen isotope plots on samples from large ice-wedge ice; in Plakhinski Yar (c) Late Pleistocene ice-wedge ice on left coast of Stadukhinskaya stream at lower Kolyma River valley in northeast of Yakutia (the selection of samples for oxygen isotope analyses and radiocarbon dating) in Mamontova Gora (d) ice-wedge complex on Aldan River valley and oxygen isotope plot of ice-wedge ice 1 – sandy-loam; 2 – sand; 3 – loam; 4 – rootlets and allochthonous peat; 5 – Late Pleistocene syngenetic ice-wedge ice; 6 – sampling points for the oxygen isotope analysis from ice-wedge ice; 7 – sampling points for the radiocarbon analysis (a) – from host sediments surrounding ice wedge; (b) – from ice-wedge ice and AMS^{14}C dates of micro inclusions of organic material, the Seoul National University.

The tails of ice wedges are characterized by very high values of $\delta^{18}O$ up to −16.5‰, but also high concentration of continental salts – more 400 mg per liter that evidenced some fractionation as a result of evaporation. On Aldan flood-plain $\delta^{18}O$ of modern ice-wedges (veinlets) ranges from −26.3‰ to −25.1‰.

5. Discussion and conclusions

The measurements of so small samples, have shown the opportunities of using radiocarbon dating for ground ice study, even if the impurity of micro organic inclusions is insignificant, i.e. practically every form of ground ice such as: ice-wedge ice or massive ice, or even structure forming (thin lenses – (schlieren) ice can be rather authentically dated with AMS techniques).

The very fast oscillation of $\delta^{18}O$ is observed in the upper part of Plakhinski Yar ice-wedge ice which is ^{14}C dated 30 000–16 000 yr BP. Positive shift of $\delta^{18}O$ values almost by 4‰ and then negative one by 3.5‰ from 4.5 to 1.5 m depths (dated about 15–11.5 ka BP) in ice-wedge ice corresponds to similar oscillation in GRIP as follow: at the depth 1300–1100 m – the positive shift almost by 6‰ (Bølling) and negative shift by the same values (Allerød). The ice-wedge ice isotope data could be compared also with data from tropical glaciers, because they characterized by close $\delta^{18}O$ values and changes of $\delta^{18}O$ have the same magnitude. It is interesting to compare Plakhinski Yar ice-wedge plot to the data, obtained from of 132 m ice core of Sajama Glacier in Bolivia [12,13]. Comparison of contemporaneous interval from 11 000 to 25 000 yr BP of Sajama and Plakhinski Yar shows similar character of the curves. The range of $\delta^{18}O$ of Plakhinski Yar is 4‰ (from −34‰ to −30‰) and of Sajama also 4‰ (from −18 to −14‰). There is correspondence between minor and major events.

Direct AMS radiocarbon dating of Mamontova Gora ice-wedge ice from 19 up to 13 ka BP allowed comparing isotope record of this cross-section with some part of GRIP ice core. The positive shift of $\delta^{18}O$ values in Mamontova Gora ice-wedge ice by on 3‰ between 15 000 up to 13 000 yr BP (at the height 54–55 m), and then negative shift of $\delta^{18}O$ values by 3.5‰ (at the height 55–58 m) is observed. The similar oscillations in core GRIP at the depth 1745–1755 m (presumably dated from 14 560 up to 14 360 yr BP) from −41‰ up to −35‰ and higher up to −40‰ are marked [14].

Results of radiocarbon AMS-dating of ice samples from Late Pleistocene syngenetic ice-wedges allows to set stable isotope plots to a geochronological scale. Also these results have shown an opportunity exact dating and comparison of cross-sections with ice-wedges with ice core isotope record.

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References

[1] Yu.K. Vasil'chuk, in: Theoretical Problems, Vols. 1–2, Department of the Russian Academy of Sciences and Moscow University Publications, Moscow, 1992 (Vol. 1, 420 pp, Vol. 2, 264 pp).
[2] Yu.K. Vasil'chuk, H. Jungner, A.C. Vasil'chuk, Radiocarbon 43 (2) (2001) 485.
[3] Yu.K. Vasil'chuk, J. van der Plicht, H. Jungner, A.C. Vasil'chuk, Nucl. Instr. and Meth. B 172 (2000) 637.
[4] Yu.K. Vasil'chuk, H. van der Plicht, H. Jungner, E. Sonninen, A.C. Vasil'chuk, Earth Planet. Sci. Lett. 179 (2) (2000) 237.
[5] Yu.K. Vasil'chuk, R.A. Vaikmae, J.-M.K. Punning, M.O. Leibman, Trans. (Doklady) USSR Academy of Sciences, Earth Sci. Sec. 292 (5) (1988) 69.
[6] Yu.K. Vasil'chuk, A.C. Vasil'chuk, Permafrost and Periglacial Processes. 8 (3) (1997) 335.
[7] Yu.K. Vasil'chuk, Trans. (Doclady) USSR Acad. Sci., Earth Sci. Sec. 298 (1) (1988) 56.
[8] Yu.K. Vasil'chuk, A.C. Vasil'chuk, D. Rank, W. Kutschera, J.C. Kim, Radiocarbon 43 (2) (2001) 503.
[9] M. Fukuda, D. Nagaoka, K. Saijyo, T. Nakamura, in: Reports of Institute of Low Temperature Science, Hokkaido University, Sapporo, 1997, p. 17.
[10] K.K. Markov (Ed.), Cross-section of the newest sediments Mamontova Gora, Moscow University Press, 1973, p. 198.

[11] T.L. Pewe, A. Journaux, Professional Paper, N1262, 1983, p. 1.
[12] L.G. Thompson, E. Mosley-Thompson, K.A. Henderson, J. Quaternary Sci. 15 (4) (2000) 377.
[13] L.G. Thompson, in: L.C. Gerhard, W.E. Harrison, B.M. Hanson (Eds.), Geological Perspectives of Global Climate Change, American Association of Petroleum Geologists, Studies in Geology N47, Tulsa, OK, 2001, p. 99.
[14] W. Dansgaard, S.J. Johnsen, H.B. Clausen, D. Dahl-Jensen, N.S. Gundestrup, C.U. Hammer, C.S. Hvidberg, J.P. Steffensen, A.E. Sveinbjornsdottir, J. Jouzel, G. Bond, Nature 364 (6434) (1993) 218.