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GEOGRAPHY

Paleoclimates and Chronology of the Middle Würm Megainterstadial on the West Siberian Plain

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Three warming and two cooling episodes distinguished in the middle Würm (Karginskian in Siberia, 50–24 ka B.P.) are traced virtually everywhere and, in general, synchronously in northern Asia [1–4 and many others]. The amplitude of warming episodes is of importance for the status of this fragment of geological history. In Western Europe and North America, the warming episodes did not reach the parameters of the present-day climate, and the middle Würm–Wisconsinian is considered an interstadial virtually everywhere. According to most researchers [1, 3–7, and others], climate during the optimum warming in Siberia reached present-day parameters or was warmer (and/or milder) than the recent climate. Some researchers called this time interval megainterstadial because of its complicated paleoclimatic structure. Principal sections with the interglacial-type climate in the Karginskian are located in West Siberia, where paleoclimates were mainly reconstructed on paleobotanic data. The layers comprising these data were assigned to the Karginskian based on ^{14}C data in the 1960s–1970s. Part of the data appeared doubtful even at that time [6]. Arkhipov [7] considered that such data are pseudofinite. However, the main data array was accepted as valid. Stratotypes for layers of the Karginskian Horizon were distinguished at the same time. For western Siberia, the following stratotypes were identified [3]: the Shuryshkar warming (50–44 ka B.P.), the Kir'yas cooling (43–42 ka B.P.), the Zolotoi Mys warming (41–35 ka B.P.), the Lokhpodgor cooling (34–30 ka B.P.), the upper Lobanov warming (29–24 ka B.P.) and eponymous layers of the Karginskian Horizon. To work out in detail the paleoclimatic reconstructions and refine the chronology of these stages, we studied stratotypes and key sections of layers of the Karginskian Horizon. Of greatest interest are materials from the Zolotoi Mys and Kir'yas outcrops, which expose Section III of the terrace above the floodplain of the Ob River in its lower and middle course, respectively.

We studied the Kir'yas outcrop on the Ob left bank (approximately 60°51′ N, 75°45′ E) in two strippings spaced 1 km apart. Beds 1–5 were studied in the second stripping; beds 5–14, in the first stripping (bed numbers are given from top to bottom). They include the following units (figure): (1) recent humus horizon, 0–0.1 m; (2) gray layered loam, 0.1–2.3 m; (3) ash gray loam, 2.3–4.68 m; (4) peat, 4.68–4.85 m; (5) bluish gray loam with peat lenses (reference horizons), 4.85–6.2 m; (6) gray loam, 6.2–7.6 m; (7) light gray loam, 7.6–9.4 m; (8) fine alternation of loam and silt, 9.4–9.9 m; (9) peat, 9.9–10.0 m; (10) blue-gray loam, 10.0–10.9 m; (11) whitish silt, 10.9–11.9 m; (12) peat bog, 11.9–12.9; (13) gray heavy loam, 12.9–13.9 m; (14) alternation of yellow sand and bluish gray loam, 13.9–16.3 m.

Arkhipov [4, 6, 8, and others] compiled a rough correlation of all beds throughout the whole outcrop (including our two strippings). Therefore, we united the two strippings in one section. The scope of this paper does not allow us to correlate the beds identified by Arkhipov with the beds described in our work. Therefore, we shall compare our beds with sequences [6]: Beds 1–3, the upper (cover) sequence; Beds 4–12, the middle sequence; Beds 13–14, the lower (Kazantsevian–Zyryanian) sequence, which makes up the terrace base. ^{14}C datings yielded the following values for the middle sequence [6]: 27.5–36.3 ka B.P. for sediments located above the whitish silt (Bed 11); 38.7–44.7 ka

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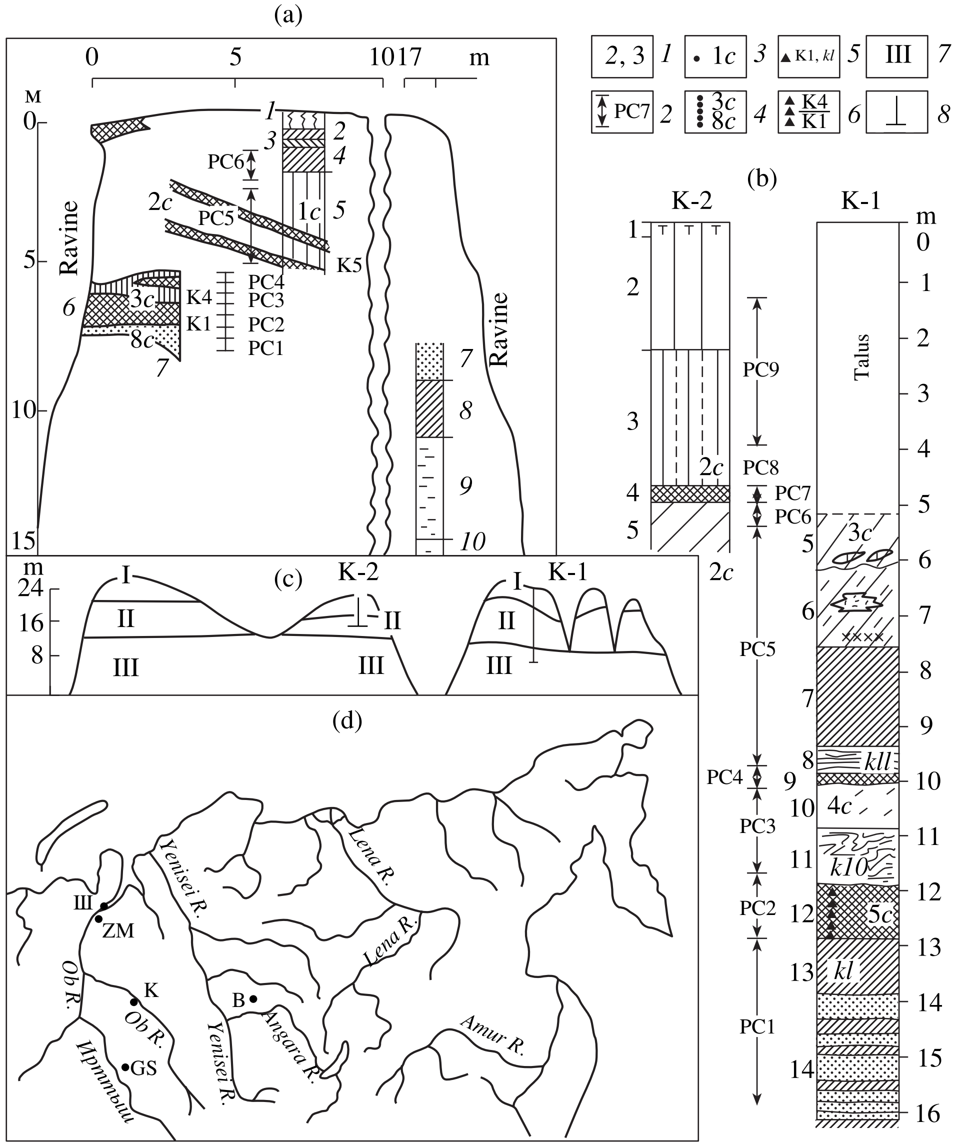

Strippings in the outcrops: (a) Zolotoi Mys, (b) Kir'yas 1 and Kir'yas 2. Location of Kir'yas 1 and Kir'yas 2 strippings in the Kir'yas outcrop is shown in the (b) correlation scheme of basic sequences (after [7, 10]). (d) Location of outcrops mentioned in this work: (ZM) Zolotoi Mys, (Sh) Shuryshkar, (GS) Gornaya Subbota, (K) Kir'yas 1 and Kir'yas 2, (B) Bedoba. (*1–6*) for a and b: (*1*) bed numbers (italics for a, Roman type for b), see text for description; (*2*) intervals and numbers of palynocomplexes; (*3*) ^{14}C dates obtained by the authors in outcrops: Zolotoi Mys: (*1c*) LU-5096A and B, (*2c*) LU-5110A, (*3c*) LU-5112A, (*4c*) LU-5123A, (*5c*) LU-5116B, (*6c*) LU-5122B, (*7c*) LU-5121A and B, (*8c*) LU-5120B; Kir'yas 1, Kir'yas 2: (*1c*) LU-5095, (*2c*) LU-5115, (*3c*) LU-5094, (*4c*) LU-5109, (*5c*) LU-5119; (*4*) series of ^{14}C dates (series of numbers); (*5*) carpology sample and its number (italics for b, Roman type for a); (*6*) series of carpology samples (series of numbers); (*7, 8*) for b: (*7*) numbers of members and boundaries between them, (*8*) location of strippings: (K-1) Kir'yas 1, (K-2) Kir'yas 2.

B.P. for peat bog (Bed 12). What part of the dated interval represents a stratotype for the Kir'yas Beds is still unclear from publications.

We obtained the following dates (figure): 27 800 ± 210 yr (LU-5095) for Bed 4 at a depth of 4.8 m; 31 880 ± 290 yr (LU-5115) for Bed 5 at 5 m and 32 600 ± 200 yr (LU-5094) at 6.1 m; 46 350 ± 1590 yr (LU-5109) for Bed 9 at 9.95 m; and ≥60 700 yr (LU-5119) for Bed 12 at 11.95 m. Hence, Bed 12 is older than the Karginskian Horizon. This is also confirmed by abundant macroflora from the peat bog, which is characteristic of the early Valdai (Zyryanian) Interstadial.

Palynospectra of 71 samples from Beds 2–14 (figure) are united into nine palynocomplexes (PC). PC1 (Beds 13, 14) and PC2 (Bed 12) are older than the Karginskian time. Palynospectra of Bed 10 reflect periglacial herb–glass associations with xerophyte groups and tundra plants: cloudberry, whitlow grass, and others. Spectra of Bed 11 reflect sparse growth of birch and dwarf Arctic birch transitional from the taiga of PC2;

i.e., Beds 11 and 10 (PC3) accumulated at the end of the Zyryanian Glaciation.

The peat bog of Bed 9 (PC4) formed 47.9–44.7 ka B.P. and completely matches the "Shuryshkar warming." Judging from the macroflora, the peat bog accumulated in a shallow-water basin surrounded by forest-tundra and tundra landscapes. Palynospectra correspond to sparse growth of larch. PC5 (Beds 8–5) reflects herb–grass meadows and green-moss bogs. Small areas of sparse birch growth with larch and spruce in some places could exist in valleys. The climate was much colder as compared to the contemporary climate. Slight changes in vegetation are noticed against this background. Traces of relative cooling are established in Bed 8. Judging from the stratigraphic position and the composition of palynospectra, Bed 8 could be the stratotype of Kir'yas Beds. Spectra at the bottom of Bed 7 reflect a slight expansion of north taiga sparse growth of spruce. Spectra from the top of Bed 7 exhibit the expansion of the dwarf Arctic birch, which was again replaced by sparse spruce growth during accumulation of Bed 6. Palynospectra of Beds 6 and 7 correspond to the "Zolotoi-Mys warming" with two peaks of relative warming and a slight cooling at the middle of this stage. PC6 from the bottom of Bed 5 (32.6–31.8 ka B.P.) corresponds to the Lokhpodgor cooling [3, 4, 7] and reflects the prevalence of herb–grass meadows and an increase in the dwarf Arctic birch area, which again decreased by the end of accumulation of Bed 5 (PC7). The upper Lobanov warming showed up in PC8. For example, the abundance and diversity of herbs decreased in peat bog of Bed 4 (~27.8 ka B.P.). The north taiga sparse growth with larch, birch, and spruce was developed in valleys. PC9 from Beds 3 and 2 are characteristic of open periglacial landscapes of the Sartan Glaciation.

Thus, within the interval of 48–27 ka B.P. (LU-5109–5095), which embraces nearly the whole Karginskian, palynospectra of the Kir'yas section record three warming episodes (Beds 9, 7, 6, 4) and two cooling episodes (Beds 8 and 5). During cooling episodes, grass and dwarf Arctic birch tundra extended up to the Surgut region in the Ob River basin. The extension of vegetation zones southward exceeded 800 km during cooling events and could reach 600–300 km during warming events. The Karginskian climate in the Surgut region (Ob basin) differed from present-day parameters, because the Kir'yas section lacks any palynospectra even slightly resembling the middle taiga spectra found in the subrecent surface and Holocene samples. However, no traces of substantial washout and/or stratigraphic hiatus are found in the middle member of this section. Therefore, we can hardly find the Karginskian beds, which formed under climatic conditions close to the present-day (or milder) climate.

The Zolotoi Mys outcrop is located on the right bank of the Ob River (~64°52′ N, 65°34′ E). Thirty years ago, the bank was regularly washed out, and the outcrop was studied down to the Ob shoreline [4, 5]. By 2003, a beach 9–12 m high near the rear suture zone had formed at the outcrop. Correspondingly, the groundwater level rose, and we could study only the upper half of the section, while the lower portion (15–17 m) described in [4, 5] was inaccessible. However, this could not affect basic inferences. We stripped the following beds from top to bottom (figure): (1) 0–0.55 m, humus horizon of present-day soil; (2) 0.55–0.65 m, peaty loam; (3) 0.65–1.0 m, light gray sandy loam; (4) 1.0–1.8 m, bluish gray loam; (5) 1.8–5.2 m, brownish gray loam (horizontally layered at the top), dark gray with a boggy smell from the depth of 3.8 m (two interlayers of brownish red peat dipping southward occur at the depth of 4 and 5 m); (6) 5.2–7.0 m, brownish red leaf peat bog with loam and silt interlayers (alternation is deformed); (7) 7.0–9.0 m, yellow silt; (8) 9.0–11.05 m, greenish gray loam; (9) 11.05–14.58 m, grayish blue clay with sand interlayers; (10) 14.58–14.93 m, bluish gray clay. Since the distance between the strippings is only 5 and 9 m, we could trace all the beds between the strippings. However, the sediments are very loose, and we failed to make a continuous stripping throughout the outcrop. The strippings are deep (see figure). Therefore, they did not crumble and we could document the beds in detail and compile a general scheme of the section.

The comparison with the description presented in [4, 5] showed that the section above the buried peat bog (Bed 6) is more complicated in our strippings. For example, peat is underlain by eolian loam (1.8 m) in [5]. In our strippings, only Bed 3 can be assigned to loam, which is underlain by floodplain and bayou alluvium (Beds 4, 5). Further down the section, beds in our strippings and [5] are identical both in their thickness and genesis: Bed 6, peat of the former riverbed alluvium; Bed 7, silt of floodplain alluvium; fluvioglacial [4] or limnoglacial [5] loam and clay (2.5 m); upper moraine (with limnoglacial sediments in some places) including Bed 6 in [5] and Beds 9–10 in our strippings. We did not strip the further underlying section; however, according to [5], the upper moraine is sequentially underlain by Zolotoi-Mys (alluvial and lacustrine–alluvial) stratotype beds and the lower moraine. Detailed lithofacies study (microscopic inclusive) of both moraines [5] confirmed their morainic origin. Arkhipov et al. [5] obtained 29.5 ka B.P. for the peat bog (our Bed 6), whereas intermoraine beds are estimated at 39.1–40.8 and >45 ka B.P.; i.e., the age of the Zolotoi Mys Beds in the stratotype range from >45 to 39.1 ka B.P. [5] (in the present-day scheme, 41–35 ka B.P. [3]). Palynospectra of these beds are characteristic of vegetation similar to a recent or slightly more thermophilic variety [4, 5].

We obtained the following dates: Bed 5—35 000 ± 990 yr (LU-5096) and 33 500 ± 260 yr (LU-5096B) for the upper peat interlayer and 36250 ± 550 yr (LU-5110A) for the lower interlayer; buried peat bog of Bed 6—40 100 ± 520 (LU-5112A), 42 540 ± 1420 (LU-5123A), 40900 ± 830 (LU-5116B), 48900 ± 2800 (LU-5122B), ≥46500 (LU-5121A), 47200 ± 1460 (LU-5121B), and ≥46800 yr (LU-5120B) for samples from the depth of 5.85–5.96, 5.95–6.05, 6.05–6.15, 6.3–6.4, and 6.8–6.86 m, respectively. Letter designations are as follows: (A) coarse fraction (>0.5 mm), (B) fine fraction (≤0.5 mm) soluble in the 2% NaOH solution. Thus, peat from the base of Bed 6 encompasses almost the whole Karginskian interval from 47.2 to 33 (35?) ka B.P. Dates obtained in the 1970s [5] should be considered pseudofinite [7] values, and deposits identified as the stratotype of the Zoloti Mys Beds [3, 5, 7] should be considered pre-Karginskian sediments. Macroflora from Bed 5 (lower part) and Bed 6 is characteristic of forest-tundra, the southern boundary of which lies 100–130 km north of the Zolotoi Mys outcrop. Palynology suggests a more complicated picture: spectra from Bed 7 are characteristic of larch forests with birch, spruce, and fir; spectra from lower parts of Bed 6 (below the dated LU-5121) are typical of cedar–larch forests of the northern part of the northern taiga; spectra from the middle part of Bed 6 (LU-5121–5116) are characteristic of forest-tundra; spectra extending from LU-5123 to the upper part of Bed 6 are typical of cedar–birch forests of northern taiga; spectra from the lower half of Bed 5 are typical of forest-tundra; and spectra from the upper half of Bed 5 and almost entire Bed 4 are characteristic of larch forests with cedar, spruce, and birch. Thus, Beds 6–4 reflect three warming episodes (including northern taiga) separated by two cooling episodes when the forest-tundra was growing near Zolotoi Mys. Unfortunately, we could not obtain the U/Th date for the Zolotoi Mys peat bog because of its high mineralization. The Kir'yas peat bog was older than the Karginskian bog. Therefore, it could not be dated by the U/Th method. The dating of both outcrops was made only by the advanced ^{14}C method [9]. We dated simultaneously the Bedoba [11] and Shuryshkar outcrops by the U/Th and advanced ^{14}C methods [10].

The stratotype of the Shuryshkar Beds, the Shuryshkar peat bog in the lower course of the Ob River (figure), yielded a ^{14}C age of 42 ka B.P. and several dates beyond the reasonable limit [5]. It comprises abundant macroflora and palynospectra [5, 10] of more thermophilic vegetation as compared to present-day vegetation. The Shuryshkar warming episode was recognized as the main optimum of the Karginskian [3]. U/Th dates obtained for this peat bog by the leaching method (113 ± 14 ka B.P.) and complete dilution (141.1 ± 11.7 ka B.P.) match the Kazantsevian time [10]. Vegetation of the Shuryshkar time (50–44 ka B.P.) was studied in the peat bog of Bed 9 (^{14}C age 46.3 ka B.P.) in the Kir'yas section. The peat bog in the Bedoba section on the Irkineeva River (the northern Angara River region) appeared to be of Kazantsevian age as well. Until very recently, this section was regarded as the reference one for the Karginskian Horizon of central Siberia, because its datings in the 1960s–1970s yielded 11 successive ^{14}C dates ranging from 47 to 24 ka B.P. This section also includes macro- and microflora characteristic of a climate slightly milder than the recent climate. The U/Th date for the peat bog from this section is 120 ± 13 ka B.P. [11]. A repeated ^{14}C dating of this peat bog yielded values beyond the reasonable limit.

The U/Th dating yielded the Kazantsevian age for the Shuryshkar and Bedoba peat bogs with abundant macroflora. The comparison of these macrofloras with the Kazantsevian macroflora of the Gornaya Subbota peat bog in the lower course of the Irtysh River yielded interesting results. In particular, three floras found therein belonged to the Kazantsevian [12]. It is important for the problem discussed in this work that 70% of the species of the macroflora from intermoraine beds in the Zolotoi Mys outcrop (the stratotype of Zolotoi Mys Beds) are common with the Gornaya Subbota macroflora [12]. The Zolotoi Mys outcrop is not only the stratotype of the Zolotoi Mys Beds but also the reference section of the Lokhpodgor Beds (the upper moraine in this outcrop). Hence, if the Lokhpodgor Beds overlie the Kazantsevian Horizon and, in turn, are successively overlain by fluvioglacial (limnoglacial?) sediments and the early Karginskian alluvium, we can refer the Lokhpodgor Beds to the Zyrianian (early Würm–early Wisconsin) Horizon. Thus, the identification of stratotypes of the Shuryshkar and Zolotoi Mys Beds (and, hence, the beds as well) is invalid. Hence, the identification of the Lokhpodgor Beds within the Karginskian Horizon is doubtful, and the stratotype of these beds requires revision.

The Karginskian time is also characterized by another specific feature: general cooling at that time was less intensive in the north than in the south (Zolotoi Mys is located 4° north of Kir'yas) both during warming and cooling episodes as compared to the recent climate. It is likely to be related to the Karginskian warm ingression [13] into the lower course of the Ob region, the effect of which did not show up in southerly regions.

Thus, the revision of ^{14}C dates obtained in the 1960s–1970s showed the invalidity of the main stratotypes of the Karginskian Beds in the West Siberian Plain. The Karginskian time for this part of Siberia has the status of an interstadial. We may infer the interstadial status of the Karginskian time for other Siberian regions as well. Therefore, the revision of "warm" beds of the Karginskian Horizon is necessary for these regions as well. One should not rule out that the Karginskian paleoclimate could be similar or milder than the recent climate. However, the local development of such a paleoclimate is most likely, for instance, in refugia (individual depressions in mountain regions, fragments of valleys of large rivers running from the south to north, and so on).

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