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GEOGRAPHY

Last Glaciation in the Northern Part of the Eastern Chukchi Peninsula and Paleoceanography of the North Pacific

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The Last Glaciation covered limited areas in the northeastern Asia. Even in the Kamchatka Peninsula, where valley glaciers were more than 100 km long, the névé line is located at the altitude of 700–800 m on the Kronotskii Peninsula and 1000–1700 m 150–180 km in the western area. The north Yakutian (i.e., cirque type) mechanism of the Sartan Glaciation is assumed for the Chukchi Peninsula [1 and others]. Few researchers [2] assume that valley glaciers in this area are up to 15–20 km long (50 km in rare cases). In this connection, the wide distribution of fresh glacial relief in our map of the Vakarem lowland [3] seems unusual (Fig. 1).

Three ridges of recessional terminal moraines (Fig. 1, ridges I–III) are most prominent. In the western part of the lowland (north of ridge III), the section was studied in a series of mines (27, 28, 94, and others). The moraine rampart of ridge III overlies the main moraine of ridge II, which rests on the lacustrine–glacial silt of ridge I. The underlying alluvium yielded a ^{14}C age of 40.1–39.3 ka. Hence, all three overlying moraines are younger than 39 ka. The lacustrine–glacial silt yielded palynospectra of the Arctic tundra, whereas the underlying alluvium yielded spectra of the underbrush tundra and alder forests, i.e., more thermophilic vegetation as compared to present-day vegetation (grass tundra). According to calculations made by Klimanov (see [4]), July temperatures exceeded present-day temperatures by 2–5 to 6°C in the Karginskian time (alluvium). During the first stage of glaciation (ridge I), summer temperatures were close to present-day ones and winter temperatures were lower by 2°C. However, the total annual precipitation exceeded the present-day value by 100–150 mm, resulting in expansion of glaciers into the lowland. The age of the lower moraine (ridge I) is suggested by the following facts. The core of borehole 19 includes artifacts (Fig. 1) estimated at ~30 ka B.P. [5]. In borehole 19, this moraine is underlain and overlain by sediments of the late Karginskian [6] ingression, which penetrated along the ancient Kymyneiveem valley. Hence, the age of three moraines of sheet glaciation in foothills on the lowland has been determined reliably. The first stage is marked by the Konoshchel cooling in the Karginskian (middle Würm and middle Wisconsin) time. The second and third stages proceeded in the Sartan (late Würm and late Wisconsin) time.

Let us analyze the scenario of climate variation in the Northern Hemisphere in the second half of the Late Pleistocene and glaciation environment in the northern Chukchi Peninsula. Figure 2 illustrates the beginning, end, and duration of warming and cooling episodes for the last 50–60 ka from Greenland to the Chukchi Peninsula. Naturally, these events showed up differently in various regions depending on the latitude, relief, and other factors. Hence, let us discuss the most general schemes for major regions from the Arctic zone to 42° N (Fig. 2). In the ice core of the Summit area, we can roughly outline 8 (or 11) warming and 8 (or 9) cooling episodes. The peaks of the oxygen isotope curve for this core are correlated up to central Europe [7]. Let us trace them further eastward starting from the middle warming episode, since the first half of the middle Würm is not so important for the problem under discussion.

The Middle Warming episode was shorter in Europe, longer in West Siberia (6–7 ka), and the longest (up to 10 ka) in central Siberia and southeastern part of northern Asia. It reduced to 5.5–6 ka in northeastern

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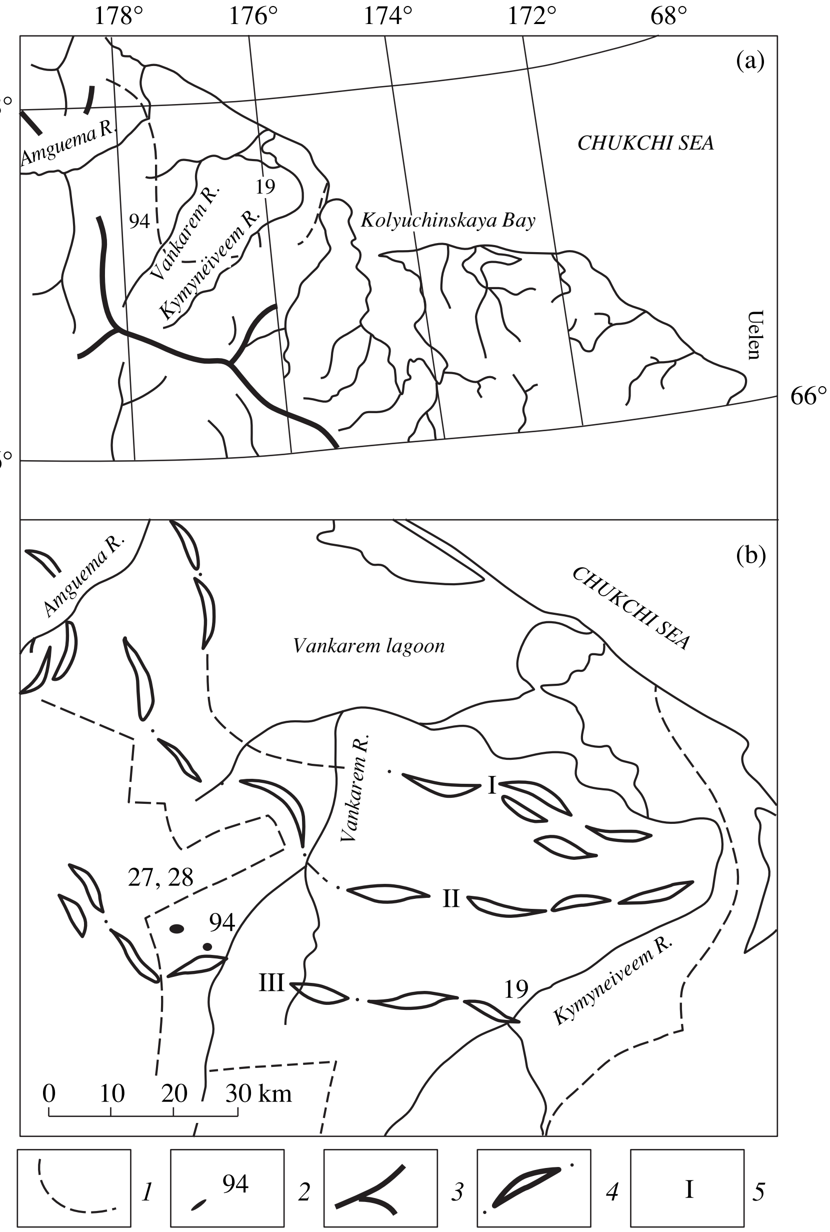

Fig. 1. Location of (a) the Vankarem lowland in the northern Chukchi Peninsula and (b) moraine ridges of the Last Glaciation on this lowland. (*1*) Boundary: (a) Vankarem lowland, (b) Vankarem depression; (*2*) Location of mines 27, 28, 94 and borehole 19 in (a) and (b); (*3*) major mountain ranges in (a); (*4*) moraine ridges of stages 1–3 of the Last Glaciation on the Vankarem lowland in (b); (*5*) see text for numbers of moraine ridges in (b).

Asia. In Greenland, more than three cooling and three warming episodes are distinguished within the interval of 44–35 ka B.P. In Eastern Europe, they correlate with two warming and one (or two?) cooling events. This warming episode in northern Asia was not interrupted by cooling events. In central Siberia and in easterly regions, the warming episode was optimal in the middle Würm. In the northern part of West Siberia, the maximum of the Karginskian transgression with thermophilic and abundant foraminifer fauna coincides with this warming [13]. In the northern Chukchi Peninsula, sea ingression along the ancient Kymyneiveem valley was also likely to be maximal. In borehole 19, diatoms have been found in pra-Kymyneiveem layers [6].

The next cooling event has a complicated structure in Greenland and Europe. Cooling episodes at 33–32 and 31–30.5 ka B.P. were separated by warming episode IS6. In eastern Europe, this cooling ceased 32–31 ka B.P. Estimation of its beginning varies from 33 ka B.P. [11], to 33.5 ka B.P. [8], and 36 ka B.P. [10]. On the Russian Plain, the Denecamp warming episode (35–33 ka B.P.) correlates with the Mikhailov (36–32 ka B.P.) cooling event [10]. In West Siberia, an intense cooling

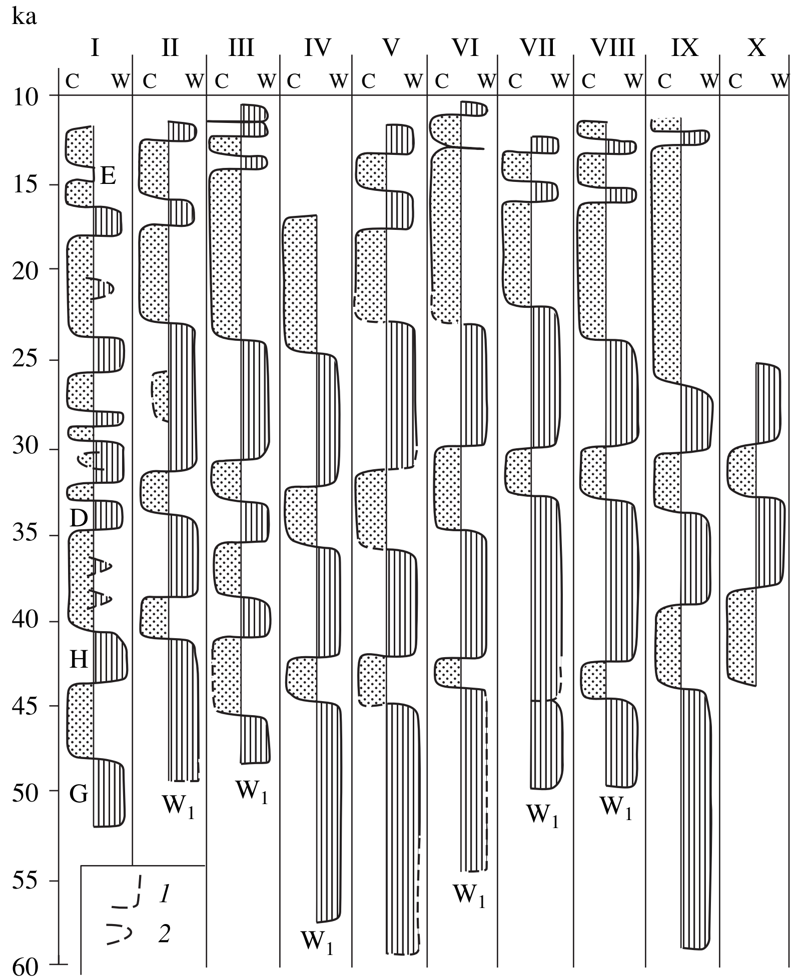

Fig. 2. Scheme of the beginning, duration, and cessation of warming and cooling episodes in the second half of the Late Pleistocene in temperate and Arctic zones of the Northern Hemisphere. (C) Cooling episodes, (W) warming episodes; (W_1) early Würm–Wisconsin Glaciation; (*1*) inferred warming (cooling), (*2*) major warming (cooling) within the cooling (warming) interval; (B) Belling, (D) Denecamp, (H) Hengelo, (G) Glinde [7]; (I–X) major regions of the Northern Hemisphere: (I) Summit area in Greenland correlated with Central Europe [7], (II) central and northern regions of the Russian Plain [8], (III) Russian Plain [11], (IV) Russian Plain [10], (V) West Siberian Plain [13], (VI) West Siberian Plain [12], (VII) central Siberia [9], (VIII) southeastern part of northern Asia (based on A.M. Korotkii in [14]), (IX) northeastern Asia [14], (X) basin at the upper course of the Kolyma River [15].

event is recorded at 35–31 (30) ka B.P. [12, 13]. This cooling is recorded at the same time interval (33–30 ka B.P.) in central Siberia and easterly regions [9, 14, 15]. In some areas of the Verkhoyansk Ridge, the development of mountain–valley glaciers of the Zhigansk Stage (33–31 ka B.P.) was maximal in the Pleistocene [9 and others]. The cooling event of 33–30 ka B.P. was also intense in continental regions of eastern Asia [14]. Therefore, it is not surprising that glaciers were so widespread on the Vankarem lowland ~30 ka B.P. (moraine ridge I). The last warming episode of the middle Würm began and ended earlier in Europe.

Let us discuss what paleogeographic factors could determine the development of glaciation in the latest middle–late Würm on the Vankarem lowland.

The north Yakutian type of the Last Glaciation was caused by the lack of sufficient moisture for the formation of large continental glaciers, because the northern shelf was drained over 300–700 km north of the Chukchi Peninsula in eastern Asia and over 600–850 km south of the peninsula in the Bering Sea. However, even this maximum regression was characterized by a wide range. In the course of regression, the sea retreated gradually and the drained shelf reached its maximal dimensions over a long time. Let us discuss the effect of regression on currents of the North Pacific.

At present, the northern Chukchi Peninsula is washed by branches of the West Arctic cold current (Fig. 3). The North Pacific warm current passes into the Alaskan Current in the south and the Aleutian Current in the west. After penetrating between the Aleutian Islands, waters of these currents form the Transverse, Laurentian, Tanaga, and Ottu warm currents in the Bering Sea. Upon approaching the Chukchi Peninsula,

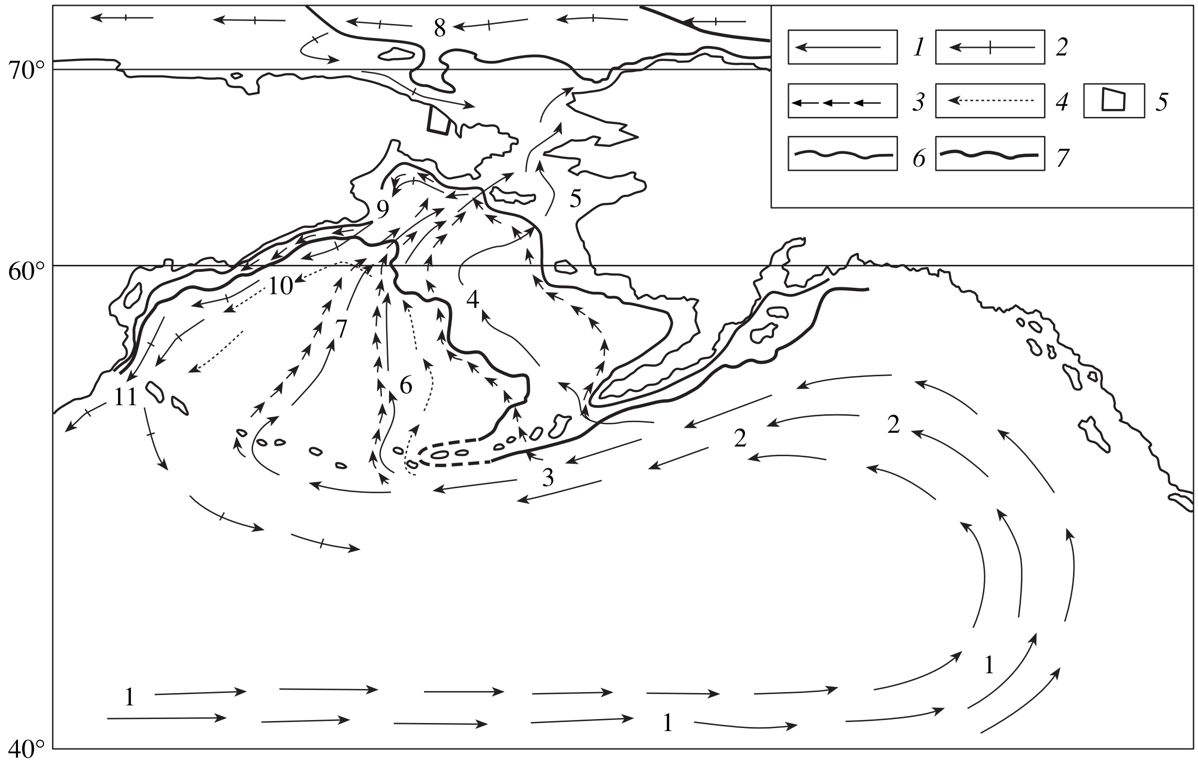

Fig. 3. Scheme of present-day and Würm–Wisconsin currents in the Bering Sea. (*1*) Warm (1–7) and (*2*) cold (8–11) present-day currents: (1) North Pacific, (2) Alaska, (3) Aleutian, (4) Transversal, (5) Laurentian, (6) Tanaga, (7) Ottu, (8) West Arctic, (9) Anadyr, (10) Kamchatka, (11) Oya Siwo; (*3*) currents during the highest (–50 m) sea level in the middle Würm–Wisconsin [15]; (*4*) currents during the lowest (–100 m) sea level (regression in the Last Glaciation Maximum); (*5*) location of the Vankarem lowland; (*6*) coastline at a sea level of –50 m [15]; (*7*) coastline at a sea level of –100 m.

these waters cool down and return to the Pacific along the western coast of the sea as the Anadyr, Kamchatka, and Oya Siwo cold currents. It is believed that the Bering Bridge blocked all these currents south of Saint Lawrence Island and the Chukchi Peninsula throughout the Würm (Wisconsin) time. The highest water level in the Bering Sea in the middle Würm was 50 m lower than at present [15]. Therefore, we can suppose that the maximal water level in the Bering Sea coincided in time with the warmest Middle Warming episode in the eastern part of northern Asia, i.e., 40–33 ka B.P. At that time, the Alaska and Aleutian currents did not pass northward as at present, but surrounded the Chukchi Peninsula on the south (Fig. 3) and could bring sufficient moisture for the formation of glaciers of the Koryak–Kamchatka type in mountains of the Chukchi Peninsula. This situation promoted the maximal propagation of glaciers into the Vankarem lowland about 30 ka B.P. However, at the beginning of the late Würm, wet winds from the Pacific still could bring enough moisture in summer into the Chukchi Peninsula for the formation of glaciers on the lowland. The first and second moraines in the southern Vankarem lowland mark regression stages from –50 to –100 m. Only after the late Würm Maximum could the glaciation of the Chukchi Peninsula develop according to the north Yakutian type. Hence, the first stage of the Last Glaciation on the Vankarem lowland (moraine ridge I) marks the beginning of a cooling episode during the minimal regression in the Würm of Beringia. The second and third stages mark the gradual reduction phases of the regression from –50 to –100 m at the beginning of the late Würm (Wisconsin).

The subsequent late Würm regression shifted the southern coast of Beringia nearly to the Navorin Cape in the south and nearly by 300 km north of the present-day coast of the Chukchi Peninsula. At that time, the high-pressure area shifted from Siberia to the Arctic region. This process was undoubtedly responsible for the formation of submeridional monsoons and, hence, variations in the system of surface currents in the North Pacific.

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