GEOLOGIJA. 2008. Vol. 50. No. 3(63). P. 176–187
DOI: 10.2478/v10056-008-0043-0

On the palaeoclimatic structure of MIS-5 analogues in the midland part of Siberia (palaeobotanical and U/Th dating data)

Stanislav Laukhin,

Algirdas Gaigalas

Laukhin S., Gaigalas A. On the palaeoclimatic structure of MIS-5 analogues in the midland part of Siberia (palaeobotanical and U/Th dating data). *Geologija*. Vilnius. 2008. Vol. 50. No. 3(63). P 176–187. ISSN 1392-110X

A simultaneous use of ^{14}C, U/Th dating and palaeobotanic researches of the midland part of Western and Middle Siberia (Shurishkary, Gornaya Subbota, Golden Cape, Chembakchino and Bedoba) has allowed to trace a correlation of the palaeoclimatic events detected in these sections with similar events fixed in the ice-core of Greenland (SUMMIT) and MIS-5. The broad confidence intervals of U/Th dates do not allow precisely to date the detected palaeoclimatic events, but allow to establish a clear sequence and amplitudes of these events similar to records in the ice-core of Greenland and MIS-5. In the buried peat bogs of midland sections located about 60° NL and to the north, it is possible to detect analogous climatic events 5e5, 5e1, 5e4, 5c, 5d and to select tracks of events 5e3, 5e2. The main the optimum of the Kazantsovian Interglacial, as well as in the curve of the ice-core of Greenland (SUMMIT), falls in the very outset beginning of MIS-5 (5e5). The temporal inadequacy of palaeoclimatic events detected in peat bogs to analogous events of MIS-5 and the curve of the ice-core of Greenland is selected: the analogous events on the continent are usually exhibited earlier than in the ocean (MIS-5). Such a ratio from MIS-5 is known also for palaeoclimatic events dated by U/Th in the bottom deposits of Baikal. However, because of large confidence intervals of U/Th dates in peat bogs, no reliable regularity in the ratio of the time of development of palaeoclimatic events of MIS-5 and analogous events inside the continent has been traced.

Key words: Kazantsovian time, palaeoclimate, U/Th dating, Siberia, macroflora, palynospectra, vegetation zonality

Received 04 July 2008, accepted 20 July 2008

Stanislav Laukhin. Institute of Northern Development, Siberian Division of Russian Academy of Sciences, 625003 Tyumen, Box 2774, Russia. E-mail: valvolgina@mail.ru; **Algirdas Gaigalas.** M. K. Čiurliono 21, Vilnius University, LT-03101 Vilnius, Lithuania. E-mail: Algirdas.Gaigalas@gf.vu.lt

INTRODUCTION

The conformity of the Kazantsevian Interglacial of Siberia to that of Mikulino of Eastern Europe and to the Eemian of Central-Western Europe raises no doubts any more. However, if for this interglacial of Western Europe three warmings (5e5, 5e3, 5e1) and two coolings (5e4, 5e2) have been selected and compared to records in the ice-core of Greenland (SUMMIT) (Dansgaard et al., 1993), up to the 21st century for the Kazantsevian Interglacial of Siberia sub-global palaeoclimatic events were not selected, though in particular sections of the Kazantsevian Horizon the tracks of large oscillations of climate had been repeatedly noted (Архипов и др., 1977; Гуртовая, Кривоногов, 1988; Волкова и др., 1988; Архипов, Волкова, 1994 etc.). In the beginning of the 21st century, such sub-global events began to be noted also in Siberia. So, V.S. Volkova (Волкова и др., 2003, c. 181) in the Kazantsevian Interglacial of Western Siberia has noted three warmings and two coolings which were correlated, accordingly, with the 5e5–5e1 events, though no reference to the article (Dansgaard et al., 1993) and the relation of these events with events detected in the ice-core of Greenland has been made. Somewhat later, for this interglacial the same authors (Волкова и др., 2005) presented four warmings and three coolings, but neither their absolute age nor conformity with sub-global palaeoclimatic events were indicated. However, the point is that in these publications (Волкова и др., 2003, 2005) do not present the basis on which these events are selected and in which sections of the Siberian Pleistocene they are reflected. The first possibility to judge the age of the palaeoclimatic events appeared on obtaining the first U/Th dates of the buried peat bogs of the Kazantsevian Horizon of Siberia (Velichkevich et al., 2004; Астахов и др., 2005 etc), though these data are not enough for detecting the complete palaeoclimatic structure of this interglacial. The correlation of MIS–5a–d sub-stages with the

Zirianian Horizon was also made in the 20th century (Arkhipov, 1997, etc.), but it was grounded on infrequent TL dates, and U/Th dating in this part of the Late Pleistocene of Siberia allows a certain verification (Laukhin et al., 2007, etc.).

The first U/Th dates obtained from the data of boring the bottom sediments of Baikal (Fig. 1), have shown, respectively, the beginning, middle and end of the Kazantsevian Interglacial of Siberia (Гольдберг и др., 2002): 140–138, 128–122 and 113–100 Ka, but palaeoclimatic events within the limits of this interglacial are not indicated by that dating. The U/Th dating of peat bogs started at the some time showed the Kazantsevian and Zirianian age of some sections earlier referred to the Kazantsevian Horizon (Астахов и др., 2005; Лаухин и др., 2006; Laukhin et al., 2007, etc.). Simultaneously with U/Th, the ^{14}C dating was made. Palaeobotanic studies (Velichkevich et al., 2004; Астахов и др., 2005; Лаухин и др., 2006, 2008, etc.) and analysis of the known palaeobotanic data on these sections (Архипов и др., 1977; Архипов, Волкова, 1994, etc.), as well as of the key sections of the Kazantsevian Horizon (Гуртовая, Кривоногов, 1988; Волкова и др., 1988, 2003, etc.) have shown presence of several climatic optimums in the Kazantsevian Interglacial of Siberia.

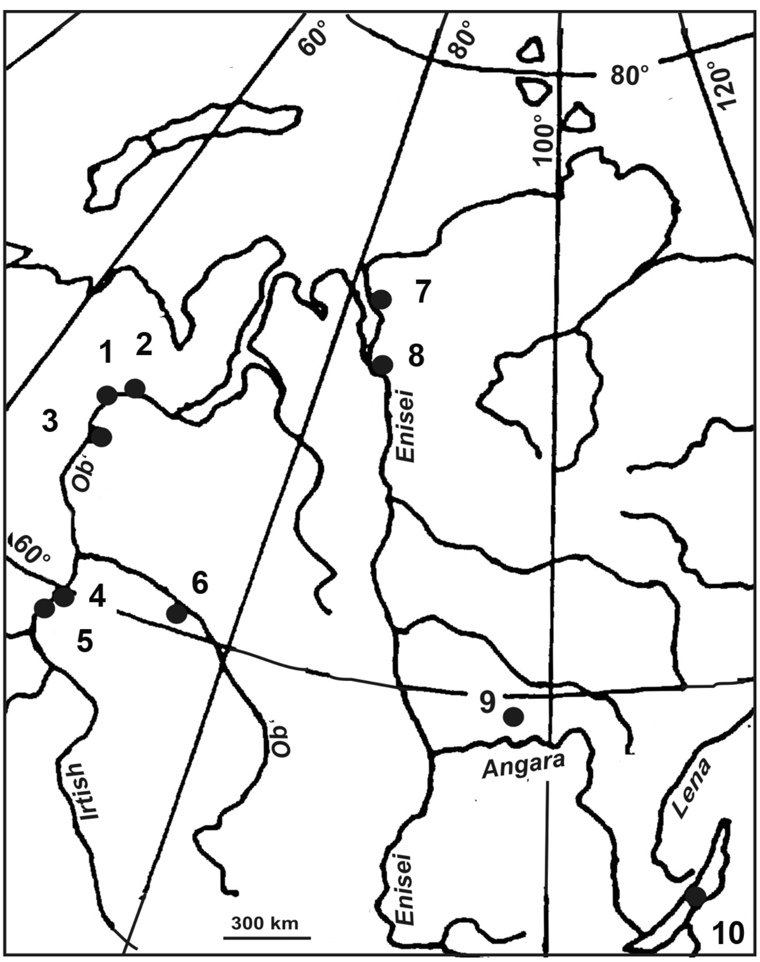

Fig. 1. Location of sections discussed in the article.
1 – Shurishkarian Sor (including Shur 1), *2* – Pyak-Yakh, *3* – Golden Cape, *4* – Chembakchino, *5* – Gornaya Subbota, *6* – Kirias, *7* – Sopochnaya Karga, *8* – Lukovaya Protoka, *9* – Bedoba, *10* – Station 15 on Academian Ridge (Lake Baikal)

1 pav. Straipsnyje minimų pjūvių padėtis

Here, there is no place for discussing the method of U/Th dating (partially it is made in Maksimov et al., 2006; Laukhin et al., 2007). Let's note only that two digits are obtained: L/L – dating by the method of leaching and TSD by the method of full dissolution. The divergence of L/L and TSD dates and, most importantly, the broad confidence interval do not allow a precise dating of a palaeoclimatic event, but the confidence interval of U/Th dates can be essentially limited with the help of palaeobotanic data. So, the low limit of the U/Th, date of the Shur 1 peat bog (see below) is 147–152 Ka. It obviously catches the limits of MIS-6. This stage is glacial, and interglacial vegetation in MIS-6 is eliminated. Therefore, the lower limit of this U/Th date should not be lower than the end of MIS-6. Similarly, also the U/Th date of the Chembakchino peat bog cannot be in the 5d sub-stage, for which (see below) the development of woodless periglacial vegetation has been established. The confidence interval allows to attribute this date to sub-stage 5c or to event 5e1. The first version is eliminated by the development at the Chembakchino latitude during sub-stage 5c of the northern sub-zone of taiga, whereas the palynospectra of the optimum of the Chembakchino peat bog are typical of southern taiga with an admixture of broad-leaved species. Apparently, the climatic optimum of peat bog formation in the Chembakchino section is related to event 5e1 which by the intensity of warming, according to the data of analysis of the ice-core of Greenland, not strongly succumbed to the maximum of warming of sub-stage 5e. Thus, the triangles in Fig. 2 as the first approximation correspond to the real position of U/Th dates in the scale of absolute age, though their diapason is much smaller than the confidence intervals of U/Th dates. U/Th dates have shown a sequence of palaeoclimatic events, and their comparison with the Baikal U/Th dates and palaeoclimatic events reflected the an ice-core of Greenland (Fig. 2) enables also to verify the time of palaeoclimatic events detected in Western and Middle Siberia. The evolution of palaeoclimates was reconstructed on palynological data. Active use was made of macroflora which, except reflecting the palaeoclimates, may promote a correlation of sections remote from each other.

All the peat bogs discussed below occur as lenticles; their structure and the sections containing these lenticles have been described in detail. The main publications containing the description of the sections adduced have been referred to. Therefore, here we do not present the description of the sections, and the position and structure of peat bogs in them is considered only in a minimum indispensable volume.

DISCUSSION OF MATERIALS OBTAINED FOR CONTINENTAL ANALOGUES OF MIS-5E SUB-STAGE

Shur 1, the most northern peat bog from those dated by U/Th, is located in the Lower Ob' River, 66° NL and 65° 30' EL for Shurishkarian Sor near the northern boundary of the northern sub-zone of taiga (Fig. 1). A section of Shurishkarian Sor (sor is a flood plain lake) uncovers the upper part of the depressions of the glacial series and the overlapping interglacial alluvial and lake depositions with two lenticles of peat. The interglacial deposits fill in erosive depressions in the top of depositions of the glacial series. Therefore, the bottom of alluvial and lake layers is observed at the absolute marks from +10 m up to –18 m (Архипов и др., 1977). Later, the Shur 1 section was studied in the same place, also with a buried peat bog (Астахов и др., 2005). The peat bogs studied by S. A. Arkhipov et al. (Архипов и др., 1977) have not quite a legible location. In any case, they are found at a distance of no less than 1–1.5 km to the north from the Shur 1 exposure. Their hypsometric ratio is more definite: the peat bog of the Shur 1 section occurs 6–7 m below the lower of the two peat bogs studied by S. A. Arkhipov, and during its researches the Shur 1 peat bog was below then brink of water in the Ob' River. Thus, in the Surishkarian Sor region there are three (instead of two, as considered by S. A. Arkhipov) levels of peat bogs: the upper and the median, studied by S. A. Arkhipov et al. (Архипов и др., 1977) and the lower studied by V. I. Astakhov et al. (Астахов и др., 2005).

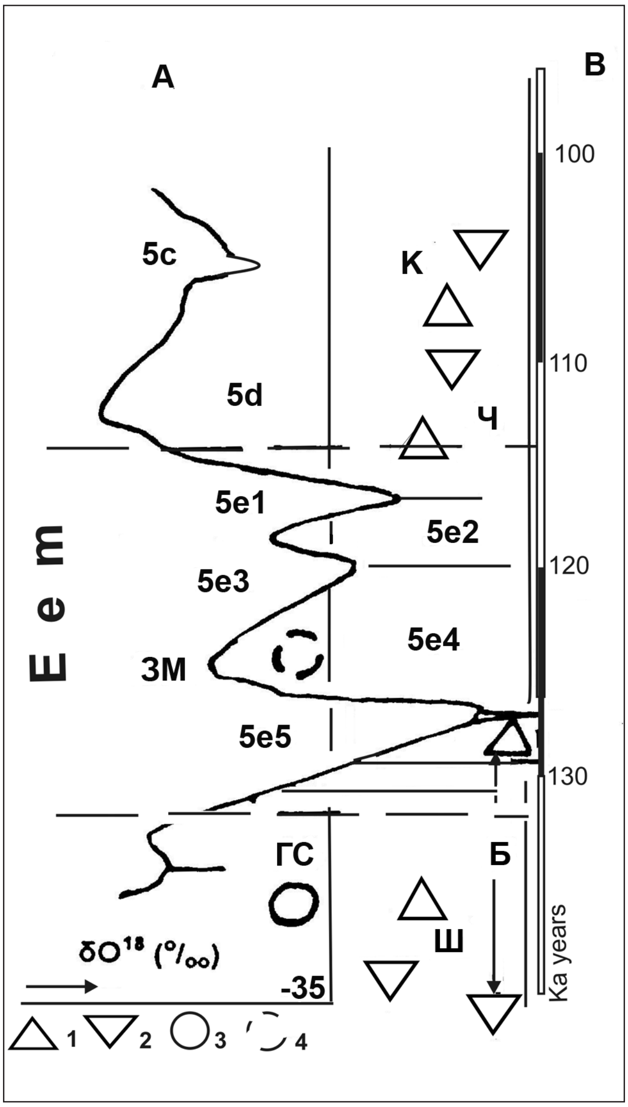

Fig. 2. Comparison of dates obtained for peat bogs of Kazantsevian Horizon of Western and Middle Siberia with palaeoclimatic events documented in the ice-core of Greenland and applied to Central Europe (Dansgaard et al., 1993).

A – part of Fig. 2 for the SUMMIT area from Dansgaard et al., 1993. *B* – time in thousand years related with palaeoclimatic events fixed in the ice-core of SUMMIT area (Dansgaard et al., 1993).

U/Th dates: *1* – TSD, *2* – L/L for peat bogs: K – Kirias, Ч – Chembakchino, Ш – Shur 1, Б – Bedoba; *3* – date of Kazantsevian Interglacial in Gornaya Subbota peat bog (ГС) based on TL date, Blake episode and on palaeobotanical data; *4* – position of intertill peat bog in Golden Cape (ЗМ) section according to palaeobotanical data

2 pav. Vakarų ir Vidurio Sibiro Kazancevo horizonto durpių amžiaus datų sugretinimas su paleoklimato įvykiais, užfiksuotais Grenlandijos ledo kerno mėginiuose SUMMIT plote ir pritaikytais Vidurio Europai (Dansgaard et al., 1993).

A – 2 pav. schemos dalis, skirta SUMMIT plotui (Dansgaard et al., 1993). *B* – amžius tūkstančiais metų sugretintas su paleoklimato įvykiais, fiksuotais ledo kerno mėginiuose SUMMIT plote (Dansgaard et al., 1993).

U/Th datos: *1* – gautos TSD metodu; *2* – L/L durpių: K – Kirias, Ч – Čembakčino, Ш – Šur 1, Б – Bedoba pjūviai; *3* – Kazancevo interglacialo durpių pjūvyje Gornaya Subbota (ГС) amžiaus durpių padėtis pagal TL datą, Bleiko epizodą ir paleobotaninius duomenis; *4* – Golden Cape (ЗМ) pjūvio tarpmoreninių durpių padėtis pagal paleobotaninius duomenis

In the upper and the middle peat bogs, dates beyond the limits of ^{14}C-dating are known, but in upper one there is also one final date – 42000 ± 125 years (SOAH-646); it has allowed S. A. Arkhipov et al. (Архипов и др., 1977) to attribute all the interglacial member to the Karganian Horizon (45–24 Ka), to one of its lower sub-horizons. It was dated so until recently (Архипов, Волкова, 1994; Волкова и др., 2003, etc.), but recently from the lower peat bog in the Shur 1 section a U/Th date on TSD 141.1 ± 11.7 and on L/L 133 ± 14 Ka (Астахов и др., 2005) was obtained. As all three peat bogs occur in a unified member of interglacial depositions, V. I. Astakhov et al. (Астахов и др., 2005) have attributed the whole member to the Kazantsevian Horizon.

For the lower peat bog (Shur 1), palynospectra of southern taiga with an admixture (up to 2%) of broad-leaved species: hornbeam, oak, elm, linden have been studied (Астахов и др., 2005), allowing to reconstruct the displacement to the north of vegetative zones in the west of Western Siberia by at least 600–700 km. In the overlying depositions including the middle and upper peat bogs, palynological data show eight phases of vegetation development (Архипов и др., 1977; Архипов, Волкова, 1994): forest-tundra – northern taiga – south of northern taiga – southern taiga – open woodland – tundra – forest-tundra (in the upper peat bog). V. I. Astakhov et al. (Астахов и др., 2005, c. 97) write that "the course of curves … is similar to the diagram of M. R. Votakh" (Архипов и др., 1977). However, a comparison of the diagrams in these two publications does not confirm this. The ratio of pollen of woody and grassy plants in the peat bog studied by M. R. Votakh (Архипов и др., 1977), is close only to the upper third of the diagram of the Shur 1 section. But also here, Shur 1 contains more fir, birch, Gramineae and less fur-trees, also linden, elm, oak are noted, a lot of pollen of hornbeam not representative of north-taiga and tundra palynospectra in the bottom part of the section analysed by M. R. Votakh. In the lower two thirds of the Shur 1 section, woody pollen usually takes more than 90% (versus 50–70% in the diagram of M. R. Votakh), birch 40–50% (versus 15–20% and rarely up to 50% in the diagram of M. R. Votakh), there is more fur-tree pollen, up to 2% of pollen of broad-leaved species not noted by M. R. Votakh at all. Such differences indicate that the lower peat bog is much older than the middle one. In this case, instead of one optimum and two pessimums detected from palynological data in the upper and the middle peat bogs (Архипов и др., 1977), there is one more, lower, optimum in the Shur 1 section. A sharp difference among the upper palynospectra, characteristic of boreal pine-fur forests with fir and infrequent oak, linden, elm and hazel, in the pollen diagram of Shur 1, from the lower palynospectra representing forest-tundra and tundra, in sections including the middle and the lower peat bogs, implies an interruption in sedimentation (or in studying the section) between the lower peat bog (Shur 1) and the overlying layers of the interglacial member with palynospectra of forest-tundra and tundra in the bottom of this member in which a transition from southern taiga to forest-tundra occurred. Thus, except for the lower – main – optimum in the palynospectra of Shurishkar Sor sections, there is a second optimum timed the middle peat bog, when on 66° NL southern taiga, but this time without an admixture of broad-leaved species (Архипов и др., 1977; Архипов, Волкова, 1994), appeared again. To the same lower optimum seems to belong also the Pyakh-Yakh layers whose palynospectra describing southern taiga were studied in the 60s (Зубаков, Левковская, 1969). The Pyakh-Yakh section is found 40' to the north of the Shur 1 exposure (Fig. 1), and the Kazantsevian age of these layers has been recently confirmed by OSL dates of 133 ± 11 and 138 ± 8 Ka (Астахов и др., 2007).

During the main optimum of the Kazantsevian Interglacial, southern taiga not only reached 66° NL, but also contained various broad-leaved species. In the opinion of S. M. Fotieva (Фотиева, 2005), the southern boundary of permafrost in the northwest of Siberia during the optimum of the Kazantsevian Integlacial was displaced up to 62° NL. It is difficult to suppose broad-leaved species, especially oak and hornbeam, to grow at about 66° NL in the permafrost zone 4° (650–700 km) to the north of its southern boundary. It is more reasonable to suppose that permafrost occurred somewhere to the north of the Polar Circle, but somewhat to the north of the Shurishkar Sor sections then there was the shore line of the marine Kazantsevian transgression.

As already noted, the U/Th date in the peat bog Shur 1 was obtained above then layers with palynospectra of the main optimum, i. e. this optimum was at the very beginning of the MIS- 5e sub-stage. It is known that δO^{18} curves written in the SUMMIT ice-core of Greenland and VOSTOK in the Antarctic Continent essentially differ. Their maximum 5e5 on both curves, reflecting the oscillations of climate for the last 220 Ka in the southern and northern hemispheres, coincide almost completely, as do no any other spikes of these two curves. U/Th date allows to surmise that the main optimum written in the palynospectra of the Shur 1 peat bog, corresponds to the 5e5 event. In this case, the second optimum whose palynospectra in the middle peat bog demonstrate the development of southern taiga, may correspond to event 5e3 in the ice-core of Greenland (Fig. 2), and the bottom of the pollen diagram built by M. R. Votakh (Архипов и др., 1977), and describing the development forest-tundra may be attributed to event 5e4 or to the top of this event.

It is worth noting that at any interpretation of the confidence interval the U/Th date of the peat bog Shur 1 still appears older than the lower boundaries of the Eem on the curve of the ice-core of Greenland (Fig. 2). As noted above, in the core of the bottom depositions of Baikal, the beginning of MIS-5 is dated back to 140–138 Ka (Гольдберг и др., 2002), i. e. too much earlier than the beginning of MIS-5 in the ocean (and in the ice-core of Greenland). For Baikal, such divergence is explained by the "inertness" of the ocean: the δO^{18} curve reflects not the temperature but the total volume of ice on the poles (or the general desalting of the ocean). In these conditions, the mistiming of global temperature rise and its reflection in MIS peaks can reach 5 thousand years (Гольдберг и др., 2002). However, this divergence is shown in the ratio of ocean to the bottom sediments of Baikal. Baikal reaches the depth of 1620 m and has a water volume of 23000 km^3. By water volume, close to it are the Great Lakes (22700 km^3), but their depth is 64–393 m. Apparently, the warming up of water in Baikal also needed time. Its inertness was less than in the world ocean, but it is possible to suppose that overland inside the continent the peak of optimum was exhibited earlier than in Baikal. Besides, the ground-level vegetation most sensitively reacts to temperature variations; diatoms of Baikal could react more slowly. This can explain the mismatch of peaks of the warm stages U/Th dated overland inside the continent and peaks of the curve of the Greenland ice-core (Fig. 2). It is possible that these were not the only factors of such a mismatch.

The interruption of sedimentation between the lower and middle peat bogs of Shurishkar Sor exposures are partially filled by high layers of Gornaya Subbota – the key section of the Kazantsevian Horizon of Western Siberia. Palynospectra of these layers partly fill the interruption in the history of the development of vegetation between the palaeoclimatic events 5e5 and 5e4, noted above.

The Gornaya Subbota section (Fig. 1) is located in the Lower Irtish River (59° 50' NL and 69° 55' EL) near the southern boundary of the middle sub-zone of taiga. This section in different years was dated to the Middle Pleistocene (Волкова, 1965, 1966; Архипов и др., 1970), Kazantsevian (Никитин, 1970; Волкова, Букреева, 1970; Архипов, 1971), Karganian (Волков и др., 1973; Архипов и др., 1973), again Kazantsevian (Зубаков, 1974; Волкова, 1977), again Karganian (Архипов и др., 1980; Архипов, Шелкопляс, 1982) times. And only in the late 1980s (Архипов, 1987; Гуртовая, Кривоногов, 1988) the buried peat bog of Gornaya Subbota was finally recognized as Kazantsevian, and since then for more than 20 years Gornaya Subbota has been the key section of the Kazantsevian Horizon. An attempt to obtain a U/Th date for the Gornaya Subbota peat bog was unsuccessful. A huge (1.3 m) buried peat bog of Kazantsevian age has been studied (Гуртовая, Кривоногов, 1988) in a ravine on the right bank of the Irtish River. We visited this ravine 20 years later. During this time, the ravine has broadened and a considerable portion of the peat bog lenticle was destroyed. Only pinchings out of the lenticle, either with or without aleurite interbeds, but with the mass of peat less than 50 cm, which did not allow U/Th dating. However, in sands above then peat bog, a Blake episode was established (Волкова и др., 2003) with the age of 128 Ka (Поспелова, 2002), and in the interbed of aleurite at the top of the peat bog a TL date of 130 ± 31 Ka (Архипов и др., 1997) was obtained, confirming the Kazantsevian (MIS-5) age of the buried peat bog in the Gornaya Subbota section.

In the lower quarter of the Gornaya Subbota peat bog, palynozones I and II, interpreted (Гуртовая, Кривоногов, 1988; Архипов, Волкова, 1994) as the beginning of the optimum (southern taiga with a restricted participation of broad-leaved species), and the optimum (southern taiga with the participation of linden, elm, oak, hazel) of the Kazantsevian Interglacial were studied. Above, palynozone III of middle taiga and in the upper half of the peat bog palynozone IV of rarefied northern taiga were identified. A comparison of palynospectra of the Kazantsevian Interglacial optimum of the Gornaya Subbota and Shur 1 demonstrated that the latter are characteristic of more thermophilic vegetation, though Shur 1 is located more than 6° to the north of Gornaya Subbota. Apparently, palynozone I of Gornaya Subbota reflects not the beginning of the optimum, but a separate minor cooling within the limits of the optimum. In this case, the peat bog of Gornaya Subbota was formed in the second half of the optimum and after the Interglacial optimum. These data, as well as the character of the burial of the Gornaya Subbota peat bog allow a certain updating of its age.

The peat Gornaya Subbota bog is buried under strata of younger depositions with a thickness of 10 m in a riversite precipice 46 m high. The natural dampness of peat bogs is 500–2000% (Трофимов и др., 2005), i. e. before the burial the Gornaya Subbota peat bog was no less than 6–7 m thick. Besides, for fossil peat bogs are characteristic shrinkage, compressibility, etc., which reduce their thickness even more. Therefore, the initial thickness of the Gornaya Subbota peat bog could be considered to be 6–7 m only as minimum possible. The modern peat bogs of such thickness in Western Siberia take 7–8 thousand years to form (Лисс и др., 2001). Therefore, the lower layers of the Gornaya Subbota peat bog were formed no later than 136 Ka ago and, within the accuracy limit of dating, belong to the palaeoclimatic events 5e5 and 5e4. The TL date 130 ± 31 Ka at the top of the Gornaya Subbota peat bog does not contradict such dating.

The peat bog of Gornaya Subbota has a rich macroflora which somewhat varies upwards (Гуртовая, Кривоногов, 1988). Its comparison with the macroflora of the upper peat bog of Shurishkary (Table) allows to update the history of vegetation in the north of Western Siberia during event 5e4. 55% of taxons of Shurishkary flora was found in the Gornaya Subbota peat bog, practically all of them in the upper half of the peat bog, in palynozone IV (northern taiga), though the location of Shurishkars by 6° to the north stipulated occurrence in its flora of cold-resisting *Selaginella selaginoides* (L) Link., *Ranunculus hyperboreus* Rottb., *Juncus* cf. *arcticus* Willd. etc., missing in the Gornaya Subbota peat bog. Attracts attention the presence in Shurishkary, as well as in Gornya Subbota, such thermophilic species as *Azolla interglacialis* Nikit., *Potamogeton obtusifolius* Mert. et Koch., etc. For specifying the history of vegetation of the north of Western Siberia during the palaeoclimatic event 5e4, significant are palaeobotanic data of the Golden Cape section.

The Golden Cape (Zolotoi mys) section (64° 52' NL and 65° 33' EL) is located in the Lower Ob' River (Fig. 1) in the southern part of the northern sub-zone of taiga. It uncovers two peat bogs: top and bottom. The latter is buried between two tills and is a stratotype of the Zolotomysskian sub-horizon of the Karganian Horizon (Архипов и др., 1977; Волкова и др., 2003). For the upper peat bog, we obtained eight ^{14}C dates from 33.5 up to 48.9 Ka, which practically cover all the Karganian time. We show that the intertill peat bog is of the Kazantsevian age (Лаухин и др., 2006). From the intertill peat bog we collected macroflora in which 70% of the forms common to flora of the Gornaya Subbota peat bog (Table), including more than hundred megasporas of *Azolla interglacialis* Nikit, were determined. These thermophilic species, both in Gornaya Subbota and in Gold Cape was described by V. P. Nikitin (Никитин, 1970) as non-redeposited. In floras of Golden Cape and Gornaya Subbota we determined *Potamogeton obtisifolius* Mert. et Koch., living nowadays in the south of Western Siberia. *Potamogeton vaginatus* Turcz., *Batrachium* spp., *Ranunculus sceleratus* L., *Potentilla* spp., *Hippuris vulgaris* L., *Comarum palustre* L. are present in the Golden Cape flora. In the Gornaya Subbota peat bog they are found mainly in the interval of palynozones I and II (the lower optimum of the Interglacial). Less forms of Golden Cape flora were detected mainly in the palynozone IV interval of Gornaya Subbota (northern taiga): *Myriophillum spicatum* L., *Andromeda polifolia* L., etc. The majority of the general forms are more or less uniformly distributed across the Gornaya Subbota peat bog (Гуртовая, Кривоногов, 1988), and it is difficult to correlate them with palynozones of southern, middle and northern taiga. A comparison of the Golden Cape and Shurishkary floras has shown that the first contains more than 60% of the common forms with the Shurishkary peat bog flora. Almost all forms common in Shurishkary and Gornaya Subbota are present also in the Golden Cape flora. The general forms of Shurishkary and Golden Cape floras, which absent in Gornaya Subbota, comprise only 24%. Among them, notable are *Selaginella selaginoides* (L). Link., *Juncus cf. arcticus* Willd. and *Ranunculus hyperboreus* Rottb. Somewhat more abundant are forms common in Golden Cape and Gornaya Subbota floras, but missing in Shurishkary flora. There is an impression that the flora of Golden Cape is closer to the flora of Gornaya Subbota, though the latter is removed from Golden Cape almost by 6°, and Shurishkary are only 1° to the north of Golden Cape. Probably the flora of Golden Cape by age is closer to the top part of Gornaya Subbota peat bog, than to Surishkary flora.

For a long time the palynospectra of the Golden Cape intertill peat bog had been considered to enhance the course of change of vegetation written in the palynospectra of the middle and upper peat bogs of Shurishkary (Архипов и др., 1977; Архипов, Волкова, 1994, etc.). This opinion was grounded on the final ^{14}C dates of the 1970s: 42 Ka for the upper peat bog Shurishkary and 39–40 Ka for the Golden Cape intertill peat bog. As is shown above, both these peat bogs appeared to be more ancient (Kazantsevian), the indicated ^{14}C-dates being pseudo-final (in the nomenclature of S. A. Arkhipov) and the macroflora of the Golden Cape peat bog being more ancient than the macroflora of the Shurishkary upper peat bog. Therefore, the palynospectra of the Golden Cape intertill peat bog are also more ancient than the palynospectra of the Surishkary upper peat bog and cannot accumulate the latter.

Table. **Composition of largest floras, from the buried peat bogs of appropriate to MIS-5**

Lentelė. **Gausiausios floros sudėtis palaidotose durpėse, kurios priskiriamos MIS-5**

Sections / Taxon	I	II	III	IV	V	VI
Cenococcum graniformae (Sow.) Ferd. et Winge	+	–	–	–	–	–
Nitella sp	M	+	–	–	+	–
*Eqisetum fluviatile**	+	–	–	–	–	–
Equisetum sp.*	+	–	–	–	–	–
Drepanocladus sp.*	+	–	–	–	–	–
*Dryepteris spinulosa**	+	–	–	–	–	–
*Lemna trisulcata**	+	–	–	–	–	–
Chara sp.	M	+	+	–	–	–
Phragmites communis L*	+	–	–	–	–	–
Bryidae	–	M	M	–	–	–
Bryales sp.	–	–	–	+	+	–
*Meesea trifolia**	+	–	–	–	–	–
*Aulacomnium turgidum**	+	–	–	–	–	–
*Mnium affine**	+	–	–	–	–	–
*M. ciclidioides**	+	–	–	–	–	–
*Sphagnum abtusum**	+	–	–	–	–	–
Sphagnum sp.	–	+	+	+	+	–
Azolla interglacialis Nikit.	+	+	–	+	M	–
Salvinia natans All.	–	–	–	–	M	+
Selaginella selaginoides (L.) Liun.	–	–	–	+	+	–
Isoetes lacustris L.	–	M	–	–	+	–
Abies sibirica Ldb.	+	–	–	+	–	–
Picea sect. Eupicea Willk.	M	–	–	–	–	–
Picea sect. Picea Willk.	–	–	–	–	–	M
Larix sibirica Ldb.	M	+	+	–	–	M
Pinus sibirica (Rupr.) Mayer	+	+	+	–	–	+
Pinus sylvestris L.	+	–	–	–	–	–
Sparganium emersum Rehm.	+	+	+	–	–	–
S. cf. angustifolium Michx.	–	+	–	–	–	–
S. glomeratum Laest.	–	+	–	–	–	–
S. microcarpum (Neum.) Raunk.	+	–	–	–	–	–
S. minimum Wallr.	+	+	+	–	–	+
S. hiperboreum Laest.	+	+	–	–	+	+
Sparganium sp.	+	–	–	–	–	–
Eriophorum latifolium Hoppe*	+	–	–	–	–	–
Typha angistifolia L.	–	+	–	–	–	–
T. latifolia L.	–	+	–	–	–	–
Typha sp.	M	M	+	+	+	M
Potamogeton fresii Rupr.	+	–	–	–	–	–
P. filiformis Pers.	–	+	–	–	–	+
P. vaginatus Turcz.	+	M	+	+	+	–
P. gramintus L.	+	+	+	–	–	–
P. natans L.	+	+	+	+	–	–
P. panormitanus Biv.-Bern	+	–	–	–	–	–
P. pectinatus L.	+	+	+	–	–	+
P. rutilus Wolfg.	–	+	–	–	–	–
P. obtusifolius Mert. et Koch.	–	+	–	+	+	–
P. praelongus Wulf.	+	+	+	–	–	–
P. pussilus L.	+	–	–	–	–	+
P. aff. *asiaticus* A.Benn.	–	+	–	–	–	–
P. alpinus Balb.	–	+	+	–	–	+
P. cf. *nodosus* Poir.	–	+	–	–	–	–
P. luceus L.	–	+	–	–	–	–
P. perfoliatus L.	–	–	M	–	–	–
P. cf. *perfoliatus* L.	–	+	–	–	–	–
P. aff. *foliosus* Rat.	–	+	–	–	–	–
P. polygonifolius Pourr.	–	+	–	–	–	–
P. trichoides Cham. Et Schlecht.	+	–	–	–	–	–
P. sibiricus A.Benn	–	–	–	–	–	+
Potamogeton sp.	–	–	–	–	–	+
Zannichelia palustris L.	M	–	–	–	–	–
Najas marina L.	+	–	–	–	–	–
Caulinia flexilis Willd.	+	M	–	–	–	–
C. minor (All.) Coss. et Germ.	–	+	–	–	–	–
C. tenuissima (A. Br.) Tzevel	–	–	+	–	–	–
C. ex gr. *tenuissima* (A. Br.) Tzevel.	+	+	–	–	–	–
Scheuchzeria palustris L.	–	+	+	–	–	–
Alisma planto-aquatica L.	+	–	+	–	–	–
A. cf. *planto-aquatica* L.	–	+	–	–	–	–
Alisma sp.	–	+	–	–	–	–
Sagittaria sp.	–	+	–	–	–	–
Alismataceae gen. et sp. indet.	–	+	+	–	+	–
Hydroharis marsus-ranae L.	–	+	–	–	–	–
Cladus mariscus (L.)*	+	–	–	–	–	–
Damasonium sp.	+	–	–	–	–	–
Scripus sylvaticus L.	+	–	M	–	–	–
S. cf. *sylvaticus* L.	–	+	–	–	–	–
S. radicans Schkuhr.	–	M	–	–	–	–
S. lacustris L.	–	M	+	–	–	–
S. tabernaemontani C. C. Gmell.	–	–	+	–	–	–
S. cf. *tabernaemontani* C. C.Gmell.	–	+	–	–	–	–
S. micronatus L.	–	–	+	–	–	–
S. aff. *micronatus* L.	–	+	–	–	–	–
Scripus sp.	–	+	+	–	–	–
Schoenoplectus lacustris (L.) Palla	+	–	–	–	–	–
Sch. tabernaemontani (C.C.Gmell.) Palla	+	–	–	–	+	–
Eleocharis palustris (L.) Roem. et Schult.	+	M	+	–	–	–
E. ovata (Roth. et Schulf.) Roem.	–	–	+	–	–	–
E. aff. *ovata* (Roth. et Schulf.) Roem.	–	M	–	–	–	–
Sida cristallina Benth*	+	–	–	–	–	–
Gramineae gen. et sp. indet.	–	+	+	+	+	–
Carex diandra Schrank	M	–	–	+	–	+
C. elongata L.	+	–	–	–	–	–
C. paucifloroides Wieliczk.	+	–	–	–	–	–
C. pseudocyperus L.	M	+	–	–	–	M
C. ripara Curt.	+	+	+	+	–	M
C. pauciflora Lightf.	–	–	M	–	–	–
C. cf. *pauciflora* Lightf.	–	M	–	–	–	–
C. rostrata Stokes	–	M	+	–	–	+
C. versicaria L.	M	–	–	–	–	–

Table. **Continued**

Taxon \ Sections	I	II	III	IV	V	VI
C. diodica L.*	+	–	–	–	–	–
C. caespitosa L.*	+	–	–	–	–	–
C. Buxbaumii Whlb.*	+	–	–	–	–	–
C. diandra Schrenk *	+	–	–	–	–	–
C. lasiocarpa Ehrh.*	+	–	–	–	–	–
C. wiluica Meinsh.*	+	–	–	–	–	–
C. subgen. *Vignea* (Beav.) Kirschl.	M	–	–	–	–	M
Carex sp.	M	M	M	M	+	M
Shoeplectus tobirnaemontani (C. C. Gmell.) Palla	–	–	–	–	–	+
Eriophorum vaginatus L	–	–	–	–	–	M
Heliocharis palustris R.Br.	–	–	–	+	+	–
Calla palustris L.	+	+	+	+	–	+
Spirodela polyrhiza (L.) Schleid.	–	+	–	–	–	–
Juncus cf. *arcticus* Willd.	–	–	–	+	+	–
J. cf. *geniculata* Schrenk	–	+	–	–	–	–
Juncus sp.	–	+	–	+	–	–
Luzula sp.	–	–	–	+	–	–
Lemna trisulcata L.	M	–	–	–	–	+
L. gibba L.	–	+	–	–	–	–
Lemna sp.	–	–	+	–	–	–
Salix sp.	–	–	–	+	–	–
Betula sect. *Albae* Rgl.	+	+	+	+	+	+
Betula fruticosae Pall.	+	–	–	–	–	+
B. pendula Ehrh.	+	–	–	–	–	–
B. pubescens Ehrh.	+	–	–	–	–	–
B. humilis Schrank.	+	–	–	–	–	+
B. nana L.	–	–	+	+	+	+
Betula sp.	–	+	–	–	–	–
Alnus hirsute Turcz.	M	–	–	–	–	–
Urtica dioica L.	+	M	+	–	+	+
Atryplex cf. *poluta* L.	–	–	–	–	–	+
Rumex maritimus L.	M	–	–	–	–	–
R. crispus L.	+	–	–	–	–	–
Rumex sp.	+	+	–	–	–	+
Silene cf. *acaulis* (L.) Jacq.	–	–	–	–	–	+
Fallopia convolvulus (L.) A. Love	+	–	–	–	–	–
Oxiria digyna (L.) Hill.	–	–	–	+	–	–
Polygonum viviparum L.	–	–	–	+	–	–
P. lapathifolium L.	+	+	+	–	–	–
Polygonum sp.	+	–	–	–	–	–
Melanodrium sp.	–	–	–	+	–	–
Batrochium sp.	–	+	–	–	–	+
Calla palustris L.	–	–	–	+	–	+
Chenopodium cf. *album* L.	+	–	–	–	–	–
Ch. glaucum L.	–	–	+	–	–	–
Ch. hybridum L.	+	–	–	–	–	–
Ch. polyspermum L.	+	–	–	–	–	–
Ch. rubrum L.	+	–	–	–	–	–
Stellaria cf. *gruminea* L.	–	–	+	–	–	–
Myosoton aquaticum (L.) Moench.	–	+	–	–	–	–
Caryophillim sp.	+	–	–	–	–	–
Caryophillaceae gen. et sp. indet.	+	+	–	+	+	–
Nymphea alba L.	–	+	–	–	–	–
Nuphar pumila (Timm.) DC	+	+	–	–	–	–
N. cf. *lutea* (L.) Smith.	–	+	–	–	–	–
Brasenia sp.	+	–	–	–	–	–
Ceratophyllum demersum L.	+	–	–	–	–	–
C. submersum L.	+	–	–	–	–	–
Batrachium circinatum (Sibth.) Spach.	–	+	–	–	–	–
B. eradicatum (Laest.) Fries.	–	+	–	–	–	–
Batrachium sp.	+	+	+	–	+	–
Ranuncululus acer L.	+	–	–	–	–	–
R. acris L.	–	–	+	–	–	–
R. cf. *repens* L.	+	–	+	+	–	+
R. gmelinii DC	+	–	–	–	–	+
R. sceleratus L.	+	+	+	–	+	+
R. hyperboreus Rottb.	–	–	–	+	+	–
R. pedatifidus Sm.	–	–	–	+	+	–
R. pygmaeus Wahl.	–	–	–	+	+	–
R. reptans L.	–	–	–	+	+	–
R. flamnula L.	–	–	–	–	+	+
R. lingual L.	–	–	–	–	–	M
Ranunculus sp.	–	–	–	–	+	–
Thalictrum flavum L.	–	–	+	–	–	–
Th. cf. *flavium* L.	–	+	–	–	–	–
Th. simplex L.	–	–	–	+	–	–
Th. lucidum L.	–	–	–	–	–	+
Ranunculaceae gen. et indet.	–	–	–	+	–	–
Papaver nudicaule L.	–	–	–	+	+	–
Papaveraceae gen. et indet.	–	–	–	+	–	–
Cruciferae gen. et indet.	–	–	–	+	+	–
Rorippa palustris (L.) Bess.	–	+	+	–	+	–
Brassiaceae gen. et indet.	–	–	+	–	–	–
Centrospermae	–	–	+	–	–	–
Aldrovanda vesiculosa L.	–	+	+	–	–	–
Chelidonium maias L.	+	–	–	–	–	–
Spirea cf. *betulifolia* Pall.	+	–	–	–	–	–
Crataegnus cf. *altaica* Lge.	+	–	–	–	–	–
Comarum palustre L.	+	M	+	+	+	+
Filipendula ulmaria (L.) Maxim.	+	–	–	–	–	–
Potentilla supine L.	–	+	–	+	M	–
P. anserine L.	–	–	–	–	+	–
Potentilla sp.	+	M	+	+	+	+
Ledim palustre L.	–	–	–	–	–	+
Elatine aff. *alsinostrum* L.	–	M	–	–	–	–
El. hidropiper L.	–	+	–	–	–	–
Rubus idaeus L.	+	+	+	–	–	+
R. saxatilis L.	+	–	–	–	–	–
Rubus sp.	+	–	–	–	–	+
Euphorrbia sp.	+	–	–	–	–	–
Emphetrum nigrum L.	+	–	–	–	+	–
Viola cf. *palustris* L.	+	–	–	–	–	+
Viola sp.	+	–	–	+	+	–
Hippuris vulgaris L.	+	+	+	+	+	+

Table. **Continued**

Taxon \ Sections	I	II	III	IV	V	VI
H. cf. *sium latifolium* L.	–	–	–	+	–	–
Myriophyllum spicatum L.	+	+	–	–	+	+
M. verticillatum L.	+	–	+	+	–	–
Sium latifolium L.	–	–	–	–	+	–
Umbelliferae	–	–	–	–	+	–
Cicuta virosa L.	+	+	+	–	–	+
Apiaceae gen. et indet.	+	+		–	–	–
Swida sanguinea (L.) Opiz.	+	–	–	–	–	–
Andromeda polifolia L.	–	M	+	+	+	–
Chamaedaphne calyculata (L.) Moench.	+	+	–	+	–	M
Ericaceae gen. et indet.	–	–	+	–	–	–
Lusimacheae thyrsiflora L.	+	–	–	–	–	+
L. vulgais L.	+	+	–	–	–	–
Naumburgia thyrsiflora (L.) Rchb.	–	+	+	+	–	–
Menyanthes trifoliate L.	+	M	+	+	+	M
Nymphoides peltata (S. G. Gmel.) O. Kutze	–	+	+	–	–	–
Stachys palustris L.	–	–	+	–	–	–
Origanum vulgare L.	–	+	–	–	+	–
Thymus sp.	–	+	–	–	–	–
Scutellaria galericulata L.	+	–	–	–	–	–
Lycopus europaeus L.	+	+	–	–	–	+
Stachys palustris L.	–	–	–	–	–	+
Galeopsis bifida Boenn.	–	–	–	–	–	+
Mentha cf. *orvinsis* L.	–	+	+	–	–	–
M. cf. *spicata* L.	–	+	–	–	–	–
Mentha sp.	+	+	–	–	–	–
Laminaceae gen. et indet.	–	+	+	–	–	+
Scutellaria galericulata L.	–	–	–	–	–	+
Sambucus racemosa L.	+	–	–	–	–	–
Lonicera xylosteum L.	+	–	–	–	–	–
Bidens tripartite L.	+	–	+	–	–	+
Cirsium palustre (L.) Scop.	–	–	–	–	–	+
Asteraceae gen. et indet.	–	–	+	–	–	+
Cardus sp.	+	–	–	–	–	+
Cennococcum grandiformae (Sow.) Ferd et Winge	–	–	–	–	–	M

I – peat bog in Bedoba section, identification of F. Yu. Velichkevich (* supplemented from identification of L. A. Sozinova); II – peat bog in Gornaya Subbota section, identification of V. P. Nikitin (1970); III – peat bog in Gornaya Subbota section (Гуртовая, Кривоногов, 1988); IV – peat bog in Shurishkary section, identification of V. P. Nikitin (Архипов и др., 1977); V – lower (intertill) peat bog in Golden Cape section, identification of V.P.Nikitin (Архипов и др., 1977); VI – lower peat bog in Kirias section, identification of F. Yu. Velichkevich.

+ present, M abundant: by F. Yu. Velichkevich 100 speciments and more (Velichkevich et al., 2004), by E. E. Gurtovaya and S. K. Krivonogov (Гуртовая, Кривоногов, 1988) quantities for M index are not indicated.

Palynospectra of the intertill Golden Cape peat bog reflect forest-tundra, northern taiga and again forest-tundra (Архипов и др., 1977), applicable rather to event 5e4 (Fig. 2) also fill (or partially overlap) the interval of the vegetation development history between the palynospectra of palynozone IV of Gornaya Subbota section and the palynospectra studied by M. R. Votakh (Архипов и др., 1977) below the second optimum recorded in the palynospectra of the middle peat bog of Shurishkary (see above).

The depositions of the late Kazantsevian time were studied by us in the Chembakchino section (Fig. 1) (60° 08' NL and 69° 48' EL) in the middle sub-zone of taiga of the Low Irtish River only 44 km to the north from Gornaya Subbota. The exposure in a riverside precipice of the Irtish River at the Chembakchino village has been known for a long time (Волкова, 1966; Каплянская, Тарноградский, 1974; Архипов и др., 1997, etc.), but its mostly its well denuded upper part had been studied. Six kilometres from Chembakchino, in the forested part of the precipice, we cleared its top, including a buried peat bog and the underlying layers (Лаухин и др., 2008). The macroflora in of the Chembakchino peat bog was studied by F. Yu. Velichkevich. It is quantitatively rich (many forms are presented by more than 1000 speciments), but taxonomically is not expressive and reflects the local conditions of peat formation, therefore here it is not considered. The evolution of the zonal type of vegetation is demonstrated by seven palynocomplexes (PC1-7) with two optimums (PC3 and PC6), separated by PC5 of birch forests with *Betula* comprising up to 74%. The PC1 from sands underlying the peat bog is pre-Kazantsevian. The PC2 from the bottom of the peat bog is characteristic of sparse north taiga, which at the lower optimum (PC3) passes into southern taiga with fur-tree, larch, fir, with birch forests in the plains of rivers, with participation of hazel, oak and elm, their sum of pollen making 1.3–9%. The peat from the PC3 has a U/Th date: TSD 110 ± 6.7/5.9 and L/L 114.2 ± 22.1/14.7 Ka (Лаухин и др., 2008). The lower optimum ends in the PC 4 characteristic of middle taiga of cedar forests with a fur-tree, birch (including its shrub forms) and single admixtures of oak and hazel pollen. The climate was probably softer than at present. Above the section (PC5) the coniferous forests are replaced by birch (birch pollen exceeding 74% of them shrub forms 9%). The PC6 reflects the development of cedar–fir taiga close in its structure to its modern middle sub-zone, but with a small admixture of fir and hazel (relict?). In the PC7, coniferous forests are replaced by a swampy open woodland; this is the end of peat formation.

Comparison of pollen diagrams of sections with the Gornaya Subbota (Гуртовая, Кривоногов, 1988) and Chembakchino (Лаухин и др., 2008) buried peat bogs demonstrates their large difference, though the exposures are separated from each other by merely 44 km and both are in the modern sub-zone of middle taiga. Such difference of palynospectra may indicate essential differences in the age of peat bogs of these exposures and in climatic optimums reflected in their pollen diagrams.

The U/Th date of Chembakchino, it is impossible to call the date of Shur 1 and the interval between cannot be considered brief and attributed to the short middle-Eemian cooling noted in the Baikal record of the last climatic cycle (Прокопенко и др., 2003). The confidence interval of the U/Th date of Chembakchino (at least TSD) allows to place it in the sub-stage 5d, 5c or in the event 5e1 of the ice-core SUMMIT curve (Dansgaard et al., 1993). Ascribing them to sub-stages 5d or 5c is excluded by the development at this time at the Chembakchino latitude of periglacial (5d) or north taiga (5c) vegetation (see below). Therefore, both optimums detected in the peat bog of Chembakchino are referred by us to the palaeoclimatic event 5e1 and the second palynocomplex (PC2) of the Chembakchino section to the end of the palaeoclimatic event 5e2, because it has no analogues in the palynospectra of Gornaya Subbota or in the intertill Golden Cape peat bog close to the macroflora of Gornaya Subbota (but removed from Chembakchino by 5° to the north); it has no connections with these palynospectra, either. The intensity of warming reflected in palynospectra of Chembakchino is somewhat higher than in palynospectra of Shur 1, but considering the location of Chembakchino by 6° to the south, the lower optimum noted in the Shur 1 palynospectra may be regarded as more intensive. It agrees also with the fact that in the ice-core of Greenland (SUMMIT) the upper peak, corresponding to 5e1, is slightly lower than the peak 5e5 (Dansgaard et al., 1993).

The first U/Th date of a peat bog of continental Siberia was obtained in the Bedoba exposure (58° 47' NL and 97° 30' EL) in the southern part of the middle sub-zone of taiga in Northern Priangarye (Fig. 1). At that time, the dating was made without separating TSD and L/L, and the date of 120 ± 13 Ka (Arslanov et al., 2004) was obtained. The repeated dating showed 126.6 ± 10.8/9.0 Ka on L/L and 148 ± 11.2/9.3 Ka on TSD. The reason of such a wide scatter between TSD and L/L (Fig. 2) is not yet clear, therefore, it is necessary to rely more on the data of palaeobotanics than on the U/Th dating. Comparison of the rich macroflora of Bedoba (Table) with the flora of Gornaya Subbota has shown (if to eliminate the lowest plants defined by L. A. Sozinova) revealed more than 50% of common genera. The differences are more significant at the level of species; this is explained by the distance between the exposures by latitude, which is almost 28°. The abundance in the flora of Bedoba of *Azolla interglacialis* Nikit megaspores is indicative. It is quite mature with massulas and without signs of re-deposition (Velichkevich et al., 2004). V. P. Nikitin (Никитин, 1970) found its massulas, usually depressed, underdeveloped, in the floras of Shurishkary and Gornaya Subbota, and considered them to be non-re-deposited. Later, some authors (Архипов и др., 1977; Гуртовая, Кривоногов, 1988, etc.) proposed re-deposition of this species in Kazantsevian depositions of Western Siberia. Its numerous finds in the flora of Bedoba confirm the opinion of V. P. Nikitin about the non-re-deposited occurrence of *Azolla interglacialis* Nikit. in Kazantsevian floras of Western Siberia.

In the Bedoba macroflora were determined such relatively thermophilic species as *Brazenia* sp., *Sambucus racemosa* L., *Potamogeton trichoides* Cham. et Schlecht., *Ceratophyllum demersum* L., *C. submersum* L. etc., not found in the flora of Gornaya Subbota. In the latter, *Nymphaea alba* L., *Aldrovanda versiculosa* L., *Andromeda polifolia* L. etc., not found in Bedoba were detected. As a whole, both macrofloras are representative for southern taiga with an admixture (on palynological data) of broad-leaved species. The optimum, based on palaeobotanic data, in the Bedoba section is somewhat lower than the U/Th date (Velichkevich et al., 2004). If the macroflora of Bedoba can be compared to floras of Gornaya Subbota and Golden Cape, their palynospectra practically are not comparable, and not only because Bedoba lies 28° to the east, but also, in contrast to Gornaya Subbota, Chembakchino, Golden Cape and Shurishkary lying in the lowland of the Ob' and the Irtish valleys running from the south, Bedoba lies on the Middle-Siberian plateau, on the small Irkineeva River which flows from the north. In these conditions, palynospectra can be compared only at a zonal level. And at this level, all palynospectra of oxbow-lake facies, the including Bedoba peat bog, belong to the sub-zone of southern taiga with an 2–5% admixture of broad-leaved species, basically hazel, followed by oak, elm and lime. On the common background of the southern taiga palynospectra it is possible to indicate 2 (3?) individual peaks of a warming, separated by coolings within the limits of southern taiga (Velichkevich et al., 2004). As a whole, palaeobotanic data in Bedoba exposure reflect the lower optimum (5e5) of Kazantsevian time and its second (partially?) half (5e4) on a transition to a stage described by the macroflora of the intertill Golden Cape peat bog.

The similarity of macroflora in Gornaya Subbota, Golden Cape and Bedoba (Table) removed from each other by large intervals (Fig. 1), but a considerable difference of the macroflora of Shurishkarian Sor even from the flora of Golden Cape situated only 1° to the south and practically on the same longitude, once again indicate that the macroflora of Shurishkarian Sor does not characterize one of the main optimums of the Kazantsevian Interglacial. As a whole, the macroflora of various places removed from one another by many hundreds (and even more than a thousand) km, was studied by different researchers in different years: by V. P. Nikitin in the 1960s, by S. K. Krivonogov in the 1980s, by F. Yu. Velichkevich early in the 21st century. The results, which are not only comparable, but also rather similar, indicate the objectivity of researches and a substantial similarity of fossil macrofloras.

As regards the palynological data, two optimums of the Kazantsevian Interglacial, corresponding to the palaeoclimatic events 5e5 and 5e1, and one pessimum (5e4) are rather distinct: also, though less legible, a pessimum in 5e2 may be noted (Fig. 2). The main optimum was an early event – it occurred in 5e5. It is somewhat youner, than the maximum bio-productivity in Baikal (Гольдберг и др., 2002). Preliminary differences of its manifestation are noted at about 59°, 60° and 66° NL and at about 70° and 97° EL. Less distinct is an earlier reflection of palaeoclimatic events in midland peat bogs as compared with their reflection in the ice-core of Greenland.

In east of the Western-Siberian plain, the Kazantsevian Horizon is studied by palaeobotanic data less full exhaustively. If in west, a displacement of the northern boundary of the southern sub-zone of taiga reaches more than 700 km to the north (up to the Kazantsevian Sea coast) and to the south from 60° NL the vegetative zones were shifted to the north by 300–400 km, in the east of the plain the displacement of the northern boundary of the southern taiga is not traced, but for a long time its advance had been known in Pryeniseiskaya Siberia of northern taiga in the Kazantsevian time in the north up to Lukovaya Protoka (Волкова и др., 1988), and recently palynospectra of northern taiga have been noted about 72° NL for Sopochnaya Karga (Стрелецкая и др., 2007) 500 km to the north from its modern northern boundary. It is possible that the displacement of vegetative zones to the north in the eastern regions of Western-Siberia plain was less distinct than in the western regions of this plain.

DISCUSSION OF MATERIALS OBTAINED FOR CONTINENTAL ANALOGUES OF MIS-5C AND MIC-5D SUB-STAGES

The beginning of the Zirianian (Early Valday, Early Weichelian) Glaciation with its most early interstadial was studied in the Kirias section.

The Kirias section (60° 57' NL and 75° 45' EL) is located in the middle taiga of Surgutian Pryobye and was considered a stratotype of the Kiriasian sub-horison of the Karganian Horizon on the basis of ^{14}C dates of the 1970s (Arkhipov, 1997; Волкова и др., 2003). Its description is published in a series of publications (Архипов и др., 1976, 1980; Левина, 1979; Лаухин и др., 2006; Laukhin et al., 2007). In this section, two levels of peat bogs (Архипов и др., 1980) have been noted. The modern ^{14}C dating has confirmed the Karganian age of the upper level (^{14}C dates 27.8–46.4 Ka were obtained) and has shown the pre-Karganian age of the lower peat bog, on its top the ^{14}C date being ≥60.7 Ka (Laukhin et al., 2007). In the middle part of this peat bog, a U/Th date has been obtained: TSD 104.4 ± 4.4/3.9 and L/L 105.5 ± 3.6/3.3 Ka. Thus, the peat bog can be referred to sub-stage 5c. Rich macroflora (thousands of speciments per sample) from this peat bog differs from Kazantsevian macroflora (MIS-5e) greatly and is characteristic of fir–larch forests (Table). The change of flora in the section demonstrates a transformation of the primary pool into an oligotrophic swamp. According to palynological data, the loam underlying the peat bog was formed in conditions of woodless periglacial vegetation (Левина, 1979), which before peat formation had been replaced by open woodland of forest-tundra. The lower half of the peat bog was formed in northern taiga which was higher replaced by swampy birch woodland (Laukhin et al., 2007). Thus, traces of sub-stages 5d, 5c and the beginning of 5b (Fig. 2) are distinct. Materials of the beginning of Zirianian Glaciation and especially of its early interstadial, referred by us to "Siberian Brørup", have been recently are published in more detail (Laukhin et al., 2007) and there is no necessity to repeat them here.

CONCLUSIONS

U/Th dates, with their large confidence intervals, do not show a high accuracy, but they have turned to be sufficient for:

– becoming a signal for revising the old ^{14}C dates;

– accepting the Kazantsevian age of peat bogs according to U/Th-dates when new ^{14}C dates confirm their pre-Karganian age;

– sequencing of palaeoclimatic events within the limits of the Kazantsevian Interglacial and comparing them to events reflected in the ice-core of Greenland. Increasing the quantity of U/Th dates, even at their present low accuracy, may reveal not only the main but also some individual climatic events in the Kazantsevian Interglacial of the north of Western Siberia. For example, the twin nature of the optimum in Chembakchino, corresponding to event 5e1 is even evident now. The data obtained over the last years allow a preliminary singling out in the Kazantsevian Interglacial in the north of Western Siberia optimums applicable to climatic events 5e5, 5e1 and one more possible optimum at the level of event 5e3 and a pessimum at the level of event 5e4. Also, though less distinct, a pessimum at the level of 5e2 has been determined. The main optimum was an early optimum – the palaeoclimatic event 5e5. Sub-stages 5d and 5c are rather clearly exhibited in Pryobye. The cold stages of sub-stage 5e are studied worse and mainly to the north of 65° NL in Pryobye. There, during event 5e4, the boundary of tundra and forest-tundra could shift to the south by 50–70 km. In the optimum of sub-stage 5c, the climate was much cooler than at present; in that time, at 60°–61° NL, the displacement of vegetative zones to the south could reach 450 km.

ACKNOWLEDGEMENTS

The authors thank Dr. G. N. Shilova and Prof. F. Yu. Velichkevich who studied palynospectra and macroflora from sections of Western and Middle Siberia. We also thank Prof. Kh. A. Arslanov, Prof. V. Yu. Kuznetsov and researcher F. E. Maksimov who obtained ^{14}C and U/Th dates for our samples from Western and Middle Siberia.

This work was supported by INTAS (grant 01-0675), RFBR (grant 06-05-64996) and the Integration Program SD RAS 16.4.

References

1. Arslanov Kh. A., Laukhin S. A., Maksimov F. E., Kuznetsov V. Yu., Velichkevich F. Y., Sanko A. F., Shilova G. N., Chernov S. B. 2004. The Bedoba Reference Section of the Kazantsevo Horizon in Central Siberia. *Doklady Earth Sciences*. ***397***(*5*). 604–607.
2. Arkhipov S. A. 1997. Record of Late Pleistocene geological events in West Siberia. *Russian Geology and Geophysics*. ***38***(*12*). 1891–1911.
3. Архипов С. А. 1971. Четвертичный период Западной Сибири. Новосибирск: Наука. 331 с.
4. Архипов С. А., Вдовин В. В., Мизеров Б. В., Николаев В. А. 1970. Западно-Сибирская равнина. История развития рельефа Сибири и Дальнего Востока. Москва: Наука. 279 с.
5. Архипов С. А., Фирсов Л. В., Панычев В. А., Орлова Л. А. 1973 Новые данные по стратиграфии и геохронологии террас Средней Оби. *Плейстоцен Сибири и смежных областей*. Москва: Наука. 21–33.
6. Архипов С. А., Довгаль Л. А., Левина Т. П., Липагина В. Я., Сухорукова С. С. 1976. Литологическая, палинологическая характеристика, диатомовая флора и остракоды из разреза третьей надпойменной террасы реки Оби (Сургутсоке Приобье). *Этюды по палеофитологии Сибири*. Москва: Наука. 83–101.
7. Архипов С. А., Вотах М. Р., Гольберт А. В., Гудина В. И., Довгаль Л. А., Юдкевич А. И. 1977. Последнее оледенение в Нижнем Приобье. Новосибирск: Наука. 214 с.
8. Архипов С. А., Астахов В. И., Волков И. А., Панычев В. А. 1980. Палеогеография Западно-Сибирской равнины в максимум последнего оледенения. Новосибирск: Наука.110 с.
9. Архипов С. А., Шелкопляс В. Н. 1982. Термолюминесцентный возраст западносибирских оледенений. *Проблемы стратиграфии и палеогеографии плейстоцена Сибири*. Новосибирск: Наука. 10–17.

10. Архипов С. А. 1987. Стратиграфия четвертичных отложений Тюменского нефтегазоносного региона. Унифицированная стратиграфическая основа. Новосибирск: ИГИГ СО АН СССР. 52 с.
11. Архипов С. А., Волкова В. С. 1994. Геологическая история, ландшафты и климаты плейстоцена Западной Сибири. Новосибирск: ИГИГ СО РАН. 106 с.
12. Архипов С. А., Зыкина В. С., Круковер А. А., Гнибиденко З. Н., Шелкопляс В. Н. 1997. Стратиграфия и палеомагнетизм ледниковых и лессово-почвенных отложений Западно-Сибирской равнины. *Геология и геофизика*. ***38***(*6*). 1027–1048.
13. Астахов В. И., Арсланов Х. А., Максимов Ф. Е., Кузнецов В. Ю., Разина В. В., Назаров Д. В. 2005. Возраст межледникового торфяника на нижней Оби. *Доклады АН*. ***401***(*1*). 95–99.
14. Астахов В. А., Мангеруд Я., Свенсен Й. И. 2007. Трансуральская корреляция верхнего плейстоцена Севера. *Региональная геология и металлогения*. ***30–31***. 190–206.
15. Velichkevich F., Sanko A., Laukhin S., Gaigalas A., Shilova G., Arslanov Kh., Kuznetsov V., Maksimov F. 2004. Palaeobotanical and palaeomalacological characteristics of Middle Siberia Kazantsevian Interglacial according to Bedoba section data. *Geologija*. ***46.*** 17–26.
16. Волков И. А., Волкова В. С., Гуртовая Е. Е. 1973. О возрасте верхней толщи западной части Обь-Иртышского междуречья. *Плейстоцен Сибири и смежных областей*. Москва: Наука. 40–45.
17. Волкова В. С. 1965. История развития растительности и основные этапы палеогеографии низовьев Иртыша в четвертичное время. *Основные проблемы изучения четвертичного периода*. М.: Наука. 342–354.
18. Волкова В. С. 1966. Четвертичные отложения низовий Иртыша и их биостратиграфическая характеристика. Новосибирск: Наука. 174 с.
19. Волкова В. С. 1977. Стратиграфия и история развития растительности Западной Сибири в позднем кайнозое. Москва: Наука. 237 с.
20. Волкова В. С., Букреева Г. Ф. 1970 Западная часть Обь-Иртышского междуречья (Тобольское Прииртышье). Спорово-пыльцевая характеристика основных разрезов позднеплиоценовых и четвертичных отложений. *История развития растительности внеледниковой зоны Западно-Сибирской низменности в позднеплиоценовое и четвертичное время*. Москва: Наука. 48–80.
21. Волкова В. С., Гуртовая Е. Е., Левчук Л. К. 1988. Палинология морских отложений казанцевского горизонта в низовьях Енисея. *Микрофитофоссилии и стратиграфия мезозоя и кайнозоя Сибири*. Новосибирск: Наука. 36–42.
22. Волкова В. С., Архипов С. А., Бабушкин А. Е., Кулькова И. А., Гуськов С. А., Кузьмина О. Б., Левчук Л. К., Михайлова И. В., Сухорукова С. С. 2003. Кайнозой Западной Сибири. Новосибирск: ГЕО. 247 с.
23. Волкова В. С., Хазина А. Е., Бабушкин А. Е. 2005. Стратиграфия плейстоцена Западной Сибири и палеоклиматическая шкала. *Квартер-2005*. Сыктывкар: Геопринт. 77–78.
24. Гольдберг Е. Л., Грачев М. А., Эджингтон Д., Новье Ж., Андрэ Л., Чебыкин Е. П., Шульпяков О. И. 2002. Уран-ториевая датировка двух последних межледниковий в осадках озера Байкал. *Основные закономерности глобальных и региональных изменений климата и природной среды в позднем кайнозое Сибири*. Новосибирск: ИаиЭСО РАН. 92–99.
25. Гуртовая Е. Е., Кривоногов С. К. 1988 Фитологическая характеристика континентальных отложений казанцевского горизонта. *Микрофитофоссилии и стратиграфия мезозоя и кайнозоя Сибири*. Новосибирск: Наука. 69–91.
26. Dansgaard W., Johnsen S. J., Clausen H. B., Dahl-Jensen D., Gunderstrup N. S., Hammer C. U., Hvidberg C. S., Steffensen J. P., Svendjornsdorttir A. E., Jouzen J., Bond G. 1993. Evidence for general instability of past climate from a 250-kyr ice core record. *Nature*. ***364*** (*6434*). 218–220.
27. Зубаков В. А. 1974. Приобская Сибирь. *Геохронология СССР*. ***III***. 187–209.
28. Зубаков В. А., Левковская Г. М. 1969. Стратиграфия новейших отложений низовий р. Оби. *Четвертичная геология и геоморфология Сибири*. Новосибирск: Наука, 62–83.
29. Каплянская Ф. А., Тарноградский В. Д. 1974. Средний и нижний плейстоцен низовий Иртыша. Ленинград: Недра. 159 с.
30. Лаухин С. А., Шилова Г. Н., Величкевич Ф. Ю. 2006. Палеоботаническая характеристика и палеоклиматы каргинского времени на Западно-Сибирской равнине. *Вестник археологии, антропологии и этнографии*. ***7***. 203–225.
31. Laukhin S. A., Arslanov Kh., A., Maksimov F. E., Kuznetsov V. Yu. 2007. The first Early Interstadial of Zirianian traces (Early Würm) Glaciation in Siberia: U/Th date and palaeobotanical data. *Geologija*. ***59***. 47–58.
32. Лаухин С. А., Арсланов Х. А., Максимов Ф. Е., Кузнецов В. Ю., Шилова Г. Н., Величкевич Ф. Ю., Чернов С. Б., Никоноров Я. А. 2008. Новое обнажение погребенного торфяника казанцевского возраста в низовьях Иртыша. *Доклады АН*. ***418***(*5*). 689–692.
33. Левина Т. П. 1979. Палинологическая характеристика отложений позднечетвертичной ледниковой эпохи в долине Средней Оби. *Стратиграфия и палинология мезозоя и кайнозоя Сибири*. Новосибирск: Наука. 74–98.
34. Лисс О. Л., Абрамова Л. И., Аветов Н. А., Березина Н. А., Инишева Л. И., Курнишкова Т. В., Слука З. А., Толпышева Т. Ю., Шведчикова Н. К. 2001. Болотные системы Западной Сибири и их природоохранное значение. Москва: МГУ. 584 с.
35. Maksimov F., Arslanov Kh., Kuznetsov V., Chernov S. 2006. 230^{Th}/U and 14C dating of Upper and Middle Pleistocene interglacial and interstadial organic deposits from the East European Plain and Siberia. In: *Pleistocene Environments in Eurasia: Chronology, Palaeoecology and Teleconnection*. Hannover: Geoscience Center. 45–48.
36. Никитин В. П. 1970. Четвертичные флоры Западной Сибири (семена и плоды). *История развития растительности внеледниковой зоны Западно-Сибирской низменности в позднеплиоценовое и четвертичное время*. Москва: Наука. 245–311.
37. Поспелова Г. А. 2002. О палеомагнитных экскурсах. *Физика Земли*. **5**. 30–41.
38. Прокопенко А. А., Карабанов Е. В., Кузьмин М. И., Вильямс Д. Ф., Хурсевич Г. К. 2003. Кратковременные климатические события 130–70 тыс. лет назад в осадочной записи озера Байкал. *Геология и геофизика*. ***44***(*7*). 623–637.

39. Стрелецкая И. Д., Гусев Е. А., Васильев А. А., Каневский М. З., Аникина Н. Ю., Деревянко Л. Г. 2007. Новые результаты комплексных исследований четвертичных отложений Западного Таймыра. *Криосфера Земли*. ***XI***(*3*).14–28.

40. Трофимов В. Т., Королев В. А., Вознесенский Е. А., Голодковская Г. А., Васильчук Ю. К., Зиангиров Р. С. 2005. Грунтоведение. Москва: МГУ. 1024 с.

41. Фотиев С.М. 2005. Современные представления об эволюции криогенной области Западной и Восточной Сибири в плейстоцене и голоцене. *Криосфера Земли*. ***IX***(*2*). 3–22.

Stanislav Laukhin, Algirdas Gaigalas

APIE SIBIRO VIDURINĖS DALIES PALEOKLIMATO STRUKTŪROS MIS-5 ANALOGUS (PALEOBOTANIKOS IR U/TH DATAVIMO DUOMENYS)

Santrauka

Vakarų ir Vidurio Sibiro pjūvių Šuriškary, Gornaja Subota, Zolotoj Mis, Čembakčino ir Bedoba radiokarboninės ir U/Th datos bei paleobotaninių tyrimų duomenys leido palyginti paleoklimato įvykius tuose pjūviuose su panašiais paleoklimato įvykiais, užfiksuotais Grenlandijos (SUMMIT) ledo kerno ėminiuose ir MIS-5. Platūs U/Th datų patikimumo intervalai neleido tiksliai datuoti išaiškintų paleoklimatinių įvykių, tačiau padėjo išryškinti jų nuoseklią seką ir amplitudes, analogiškas užfiksuotoms Grenlandijos ledo kerne ir MIS-5. Sibiro vidurinėje dalyje palaidotuose durpių kloduose, surastuose apie 60° šiaurės platumos ir šiauriau, pasisekė atpažinti klimato įvykių analogus 5e5, 5e1, 5e4, 5c, 5d ir pėdsakus 5e3, 5e2.

Kazancevo tarpledynmečio optimumas ir Grenlandijos (SUMMIT) ledo kerno kreivės pikas sutampa su MIS-5 (5e5). Pastebimas paleoklimato įvykių, išryškintų durpių kloduose, laikotarpių nesutapimas su analogiškais MIS-5 ir Grenlandijos ledo kerne: žemyne jie prasideda anksčiau negu vandenyne (MIS-5). Toks nesutapimas su MIS-5 gautas taip pat datuojant paleoklimato įvykius U/Th metodu Baikalo dugno nuosėdose. Dėl plačių U/th datų patikimumo intervalų durpių kloduose paleoklimato įvykių MIS-5 sutapimas su analogiškais žemyno vidurinėse dalyse dar nenustatytas.

Станислав Лаухин, Альгирдас Гайгалас

О ПАЛЕОКЛИМАТИЧЕСКОЙ СТРУКТУРЕ АНАЛОГОВ МИС-5 ВО ВНУТРИКОНТИНЕНТАЛЬНОЙ ЧАСТИ СИБИРИ (ПО ДАННЫМ ПАЛЕОБОТАНИКИ И U/Th ДАТИРОВАНИЯ)

Резюме

Одновременное использование ^{14}C-, U/Th датирования и палеоботанических исследований опорных разрезов внутриконтинентальной части Западной и Средней Сибири (Шурышкары, Горная Суббота, Золотой Мыс, Чембакчино и Бедоба) позволило провести корреляцию палеоклиматических событий, выявленных в этих разрезах, с аналогичными событиями, записанными в ледовом керне Гренландии (SUMMIT) и МИС-5. Широкие доверительные интервалы U/Th дат не позволяют точно датировать выявленные палеоклиматические события, но позволяют определить последовательность и амплитуды этих событий, сходные с записями в ледовом керне Гренландии и МИС-5. В погребенных торфяниках внутриконтинентальных разрезов, расположенных около 60°С. ш. и севернее, удается выделить аналоги климатических событий 5e5, 5e1, 5e4, 5c. 5d и наметить следы событий 5e3, 5e2. Главный оптимум казанцевского межледниковья, как и в кривой ледового керна Гренландии (SUMMIT), попадает в самое начало МИС-5 (5e5). Отмечается временное несовпадение палеоклиматических событий, выявленных в торфяниках, с аналогичными событиями МИС-5 и кривой ледового керна Гренландии: аналогичные события на континенте проявляются обычно раньше, чем в океане (МИС-5). Такое соотноше-ние с МИС-5 известно и для датированных по U/Th палеоклиматических событий в донных осадках Байкала. Однако из-за больших доверительных интервалов U/Th дат в торфяниках четкая закономерность в соотношении времени проявления палеоклиматических событий МИС-5 и аналогичных событий внутри континента не выявлена.