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Palaeoenvironment of MIS5 in the North of Western Siberia, reconstructed on the sub-fossil insect, crustacean and plant macrofossil data

E.V. Zinovyev[a,*], A.V. Borodin[a], A.A. Kotov[b], S.E. Korkin[c]

[a] Institute of Ecology of Plants and Animals Ural Branch of RAS, 8th March Str., 202, Ekaterinburg, 620144, Russia
[b] A.N. Severtsov Institute of Ecology and Evolution, Russian Academy of Sciences, Leninskiy Prt. 33, Moscow, 119071, Russia
[c] Nihznevartosk State University, Russia

A R T I C L E I N F O

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A B S T R A C T

Insect, tadpole shrimp and plant macrofodssil assemblages dated to different intervals of MIS5 are presented for three sites in the northern part of the West Siberian plain: Karymkarskyi sor, Belaya Gora and Kiryas. The beetle faunas suggest a relatively warm climate associated with boreal forest and marsh communities of the middle and southern taiga type; this interpretation is in agreement with the paleobotanical studies. Evidence of warm climate is provided by the occurrence of the carabid beetle *Trechus secalis*, found in Karymkarskyi sor and Belaya Gora sites. This fossil occurrence is referred substages to MIS5e and MIS5c on the basis of TL and U/Th dates, and coincides with the presence of bark beetle remains at the Kiryas locality. Both plant macrofossils from the Belaya Gora locality and tadpole shrimp remains from Kiryas site do not include species indicative of warmer-than-present climate, despite the presence of residues of woody plants. Our data were compared with paleobotanical data from a number of locatities in the central and northern parts of the West Siberian plain that have been dated to MIS5 on the basis of TL and Th/U dates. Most of these sites yielded paleobotanical data indicative of relative warm climate and forest vegetation. The exception is the Elizarovo point site, where the palynological data indicate periglacial environments. Insect, crustacean and plant macrofossil data are well correlated with the results of studies of fossil insect and paleobotanical data from other regions of Northern Eurasia and may confirm warm and humid climate during some periods of MIS5 (substages 5e and 5c) and distribution of forest landscapes and corresponding insect complexes.

1. Introduction

The Last Interglacial (Marine Isotope Stage 5) is the subject of close study by paleoecologists. There are a large number of publications on the paleogeography, paleoclimatology and paleoecology of MIS5 from the different regions of Northern Eurasia, in particular from Europe, and from west and northeastern Siberia (Gurtovaya and Krivonogov, 1988; Arkhipov and Volkova, 1994; Astakhov and Mangerud, 2005; Volkova et al., 2002, 2005; Arslanov et al., 2004; Velichkevich et al., 2004; Novenko, 2016; Markova and Puzachenko, 2018 etc.). MIS5 is thought to consist of three periods of warming alternating with two colder stages. Besides the Eemian warm period (MIS5e), the other two warm intervals are called the Brørup (MIS5c) and the Odderade (MIS5a), separated by periods of cooling known as the Herning, (MIS5d) and Redenstall (MIS5b) (Mangerud, 1989; Astakhov, 2009; Arkhipov and Volkova, 1994; Engels et al., 2010; Volkova et al., 1988; Volkova et al., 2005). According to the literature, the beginning of the Eemian («Kazantsevo» in the Siberian regional stratigraphic scheme) warming (MIS5e) in Siberia falls in the range of 138–140 thousand years ago (based on Th/U-dating of bottom sediments of Lake Baikal). The maximum bioproductivity occurred 131.5 to 128 thousand years ago (Goldberg et al., 2002). The middle of the Eemian (Kazantsevo) interval falls within 128–122 thousand years ago, and its end (transition from MIS5.4 to MIS5.5) i s correlated with the period of 113 - 100 thousand years ago (Goldberg et al., 2002). At the beginning of MIS5e. the climate was much colder than today, then there was a sharp warming, the peak of which fell in the middle of the MIS5e, which is considered the warmest period of the Late Pleistocene. It is characterized by a marine transgression associated with rising global sea level and widespread forests. At this time, broad-leaved tree species formed a continuous forest belt across Northern Eurasia (Volkova et al., 2002).

Currently, of the MIS5 paleogeography accumulated a wealth of material based mainly on paleobotanical and theriological data (Dutton and Lambeck, 2012; Bakker et al., 2013; Engels et al., 2010; Markova

* Corresponding author.
E-mail address: zin62@mail.ru (E.V. Zinovyev).

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and Puzachenko, 2018; Markova, 1985, 2000; Van Kolfschoten, 2000 etc.). In addition, the remains of insects from MIS5 assemblages have beene studied from various regions of the Northern Hemisphere, including North America (Elias, 2014), Europe (Coope, 1990, 2000, 2010; Behre et al., 2005; Ponel, 1995; Walkling and Coope, 1996 etc.) and North-Eastern Siberia (Kuzmina, 1989, 2015; Andreev et al., 2009 etc.). However, there has previously not been any research on the composition of insect fossil assemblages from Western Siberia. There was some discussion of regional insect faunas by S.V. Kiselev (1987), but these faunas are not firmly dated to MIS5. However, paleobotanical data from a number of sections associated with MIS5 on the basis of TL and Th/U dating, have previously been studied in Western Siberia.

In the course of our research, subfossil insect data were obtained from three locations attributed to the warm periods of MIS5 on the basis of absolute (TL, Th/U) dates. These dates allow the comparison of the fossil insect data from Western Siberia with MIS5 beetle complexes from other parts of Eurasia. In addition, the extraction and identification samples of insect and tadpole shrimp remains from the same fossil sites and horizons allows the development of more complete reconstructions of the fossil localities. These results will be compared with the available data on the MIS5 paleogeography of this territory and other regions of Northern Eurasia. This makes it possible to determine whether the insect data obtained for the locations of the MIS5 period corresponds to the paleoenvironmental reconstructions based on paleobotanical data here and elsewhere.

2. Materials and methods

2.1. Regional settings

The study area belongs to north-central part of the West-Siberian plate, and disposed in the Low and Middle reaches of Ob' River (Fig. 1). Karymkarskiy sor site is located in the low reaches of Ob', Belaya Gora site – on the left bank of the River Vakh, right tributary of Ob' and Kiryas site – on the Middle streams of Ob. The study area belongs to the northern sub-zone of the Middle Taiga and southern zone of North Taiga (Ilyina et al., 1985). This region is characterized by a strong wetland watershed, so zonal forest communities are often confined to the valleys and floodplains (Ilyina et al., 1985). These fluvial systems have developed widespread floodplain landscapes and corresponding conditions of sedimentation. Besides this, the phenomenon of "heat

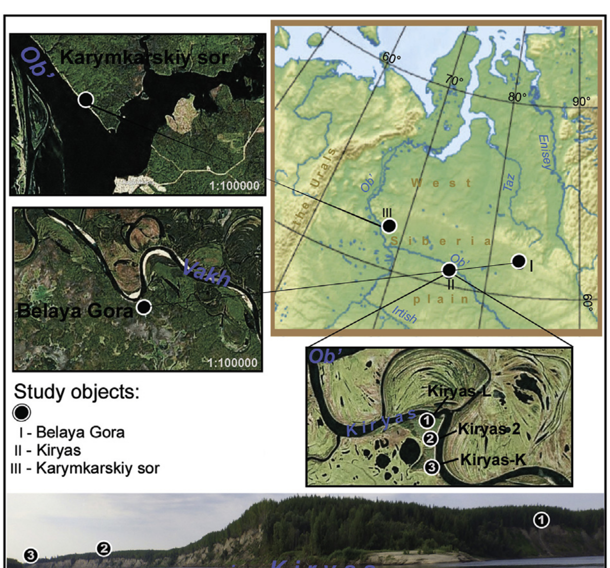

Fig. 1. Location of sites cited in the text: 1. – Karymkarskyi sor; 2. – Belaya gora; 3. – Kiryas.

flow" exists down the large rivers, such as the Ob and Irtysh. This allows the penetration of warm air masses northwards along the water courses, which in turn facilitates the northward expansion of thermophilous insect species along the flood plains (Zinovyev, 2006).

The present day climate of the studied area is cool continental and characterized by a mean low annual temperatures. Average annual temperatures are the following: −1.9 °C (Low streams of Ob', Karymkarskiy sor site), −2.7 °C (Middle streams of Ob', Kiryas site) and −3.5 °C (Vakh River, Belaya Gora site). Mean July temperatures (T_{max}): 18 °C (Low streams of Ob', Karymkarskiy sor site), 17.8 °C (Middle streams of Ob', Kiryas site) and 17 °C (Vakh River, Belaya Gora site); Mean January temperatures: −20.7 °C (Low streams of Ob', Karymkarskiy sor site), −21.7 °C (Middle streams of Ob', Kiryas site) and −22.7 °C (Vakh River, Belaya Gora site) (Climate-data.org: https://ru.climate-data.org/).

The region is characterized by a wide development of cover Late Cenozoic deposits, most of which were formed in the Quaternary period. In the middle reaches of the Ob' basin, the most complete Quaternary sedimentary sequences are found in the body of theterrace having a surface at an altitude of 120–140 m a.s.l. The relative height of the terrace is about 40 m (Sheinkman et al., 2016).

Modern beetle faunas of this area characterized by dominance on species, having boreal and multi-zone distribution (Zinovyev, 2002, 2007; Mordkovitch and Luybetchanskiy, 1999 etc.).

2.2. Materials and methods

This paper includes original data obtained in 2005, 2015 and 2017 by the authors. Samples from Karymkarskyi sor site were collected in 2005 by E.V. Zinovyev, samples from Belaya Gora and Kiryas sites were collected by A.V. Borodin and S.F. Korkin in 2015 and 2017. Sampling and subsequent laboratory processing were carried out according to standard methods adopted for this type of analysis Samples for insect and plant macrofossil analyses were sieved with the 0.25-milimeter soil sieves according to standard methods (Kiselev, 1987; Rasnytsyn, 2008). After subsequent drying, the plant detritus was viewed under a binocular glass during which the remains of insects and notostracan crustaceans, seeds and plant macrofossils were extracted. Identification of insect and plant fossils was based on comparisons with identified specimens in the beetle collection and herbarium of the museum of Institute of Ecology of Plants and Animals Ural Branch of RAS. The abundance of insect species was estimated using the minimum number of individuals of a species equal to the maximum number of identified fragments of one type (Gurina et al., 2018).

Environmental interpretations of insect assemblages based on the data of the modern distribution and ecology of species found in these layers. It includes such original data (Zinovyev, 2002, 2007; Koltunov et al., 2009, etc.), as information from literature sources (Silfverberg, 2004, Kryzhanovskii et al., 1995; etc.). We analysed ratio of environmental groups used by Kuzmina (2015), Sher and Kuzmina (2007) and Sher et al. (2005) and latitudinal groups used by Zinovyev (2006). However, we did not applied the Murual Climatic Range method implemented for the paleoenvironmental interpretations of insect assemblages from Quaternary sediments in Europe and North America (Atkinson et al., 1987; Elias, 1997, etc) because of uncertainties in climatic ranges of a number of species. When analyzing the Bugs CEP database (Buckland and Buckland, 2006), we found that the characteristics of the species do not cover our region, so we believe that the use of climatic characteristics of these species in our case is not correct.

Paleoclimatic reconstructions of insect data were providied by the following way. After determining fossil material and assessing the ratio of groups according to their current distribution and environmental characteristics, we determine the type of complex on the base of classification proposed by us earlier (Zinovyev, 2006). In case of similarity with the modern fauna of beetles known from the literature, the place of this complex in the system of modern natural zoning of the region is determined. For this purpose, data on the current state of the entomofaun of the study area (Kryzhanovskii et al., 1995; Zinovyev, 2002, 2007, etc.) are used. Then using the Climate-data.org website (https://ru.climate-data.org/) determined by the temperature conditions of the area, which is close to the environmental characteristics of the considered insect faunas.

Environmental interpretations of the tadpole shrimp (Notostraca: Triopsidae) remains (represented by mandibles only) was also based on the data of the modern distribution and ecology of species. Identification of their mandibles became to be possible recently, although there were only few previous attempts to identify their mandibles in Pleisocene deposits (Kirillova et al., 2016; Kotov et al., 2018). Some (5–10 from each sample) mandibles of the notostracans were attached to the aluminum stubs without any additional drying, coated with gold using an Edwards S-150A sputter coater and observed with MV 2300 (Camscan, Cambridge, UK) scanning electron microscope. Fortunately, there only two genera of the Notostraca in Palaearctic: *Triops* Schrank, 1803 and *Lepidurus* Leach, 1819, with eight species in both genera (Brendonck et al., 2008). According to AAK personal observations, mandibles of the latter have thinner transversal ridges on the gnathal end (Kirillova et al., 2016) and better developed clusters of small spines anterior and posterior to the mandibular ridges (terminology according to Richter, 2004), the same clusters are on the anteriormost hump-like tooth. The longest spines in the clusters are characteristic of *L. arcticus* (Pallas, 1793), which is also smaller as compared with other taxa.

Interpretation of paleobotanical data of the studied sites is based the literature data obtained earlier (Rusakov et al., 2019; Nikitin, 1970; Laukhin et al., 2007, etc.).

Datings for studied sites (14C, TL и 230Th/U dates) are given from literature sources. So, for Karymkarskyi sor site TL dating (130 ± 31 ka BP) is taken from Arkhipov and Volkova (1994). Radiocarbon datings for Belaya gora site is known from previous papers (Sheinkman, 2010; Sedov et al., 2016), besides that, it is known approximate 230Th/U data (~100 ky) (Rusakov et al., 2019). Kiryas site has a number of radiocarbon dates. Some of them vere published by Laukhin (Laukhin et al., 2007). Part of the samples for radiocarbon dating of Kiryas locality was sent by Korkin to the Laboratory of radiocarbon dating & electronic microscopy of Institute of geography RAS and Center for applied isotope research, Georgia state University (USA). Obtained dates were calibrated by radiocarbon calibration program CALIB REV7.1.0 (Reimer et al., 2013). 230Th/U dates of Kiryas site were given from several publications of Laukhin (2009; Laukhin et al., 2007).

2.3. Description of studied sites

2.3.1. Karymkarskyi sor (Fig. 1, 1)

This site is situated on right bank of the Ob near Karymkary settlement, in the lower reaches of Ob, KHMAO-Yugra, with coordinates of 62°03′21,1″N, 67°22′06,6″E. Geological description of the section is given in a number of publications (Nikitin, 1970, Arkhipov and Volkova, 1994; etc.). Sediments associated with MIS5 were layers of peat near the bottom of the 25-m-high coastal cliff. Seven samples were taken from this and underlying deposits. Five of them were taken from the MIS 5e peat lens, one from the underlying silts with plant detritus (depth 23.6–22.10 m) and one from the boundary layer between the underlying loam and the peat lens itself (Zinovyev, 2012). One TL date of 130 ± 31 ka BP was established for the peat layer (Arkhipov and Volkova, 1994).

2.3.2. Belaya Gora (Fig. 1, 2)

This site is situated on the right bank of the Vakh River in its middle reaches (Nizhnevartovsk district, KHMAO-Yugra), with coordinates 61°27′N, 82°28′E. A detailed description of the section is given in a number of publications (Zinovyev et al., 2016; Sedov et al., 2016; Rusakov et al., 2019). In the upper part of this section there is a thick, well developed paleosol. This layer has a calibrated radiocarbon age of 35,170 ± 350 yr BP (Beta- 410187) (Sedov et al., 2016). No insect remains or plant macrofossils were found in this sample (Zinovyev et al., 2016). The layers containing fossil material were found are at the bottom of the section. Four samples were taken from depths of 16.7–16.95 m (sample 1), 16.95–17.15 m (sample 2), 17.7–19.7 m (sample 3) and 19.7–20.45 m (sample 4) (Zinovyev et al., 2016). Organic materials from the lower layer of buried soil unit gave results outside the limits of the radiocarbon method: more than 40 kyr (COAH-7551, COAH-7552) and greater than 43.5 ka BP (Beta 410188) (Sedov et al., 2016). The sample, associated with the MIS5, was taken from a depth of 16.7–16, 95 m, it have the first estimate of ^{230}Th/U data (~100 ky) suggest that the peat layer was deposited during the first half MIS5 (Rusakov et al., 2019).

2.3.3. Kiryas (Fig. 1, 3)

The site is situated in the middle reaches of Ob River channel, in the Kiryas estuary (Nizhnevartovsk district, KHMAO-Yugra). The location corresponds to the Kiryas-1 section, described by Laukhin et al. (2007). The coordinates are 60°57′19,0″N. 75°45′42,3″E. Two clearings within Kiryas site have been made, one of these corresponds to the section given in the publications of Laukhin (Kiryas-L.) (Laukhin et al., 2007) (Fig. 3), the second made by S.E.Korkin (Kiryas-K) in 2017. Deposits associated with MIS5 are exposed in the central part of the Kiryas-L section, and represent 13 layers, according to description of Laukhin et al. (2008). Peaty layers from the upper part of the Kiryas-K section are correlated with MIS3. It based on the following radiocarbon dates: for the depth 6,0–6,1 m calibrated 14C data is 43871 ($IGAN_{AMS}$ 5328, UGAMS 27630) for the sample from the depth 8,20–8,40 m –calibrated 14C data is 46647 ($IGAN_{AMS}$5327, UGAMS 27629). The following consistent isochron-corrected U/Th ages were obtained for five samples of the Kiryas-K section from the depth interval of 30–60 cm below the top of the peat: 105.5 + 3.6/–3.3 and 104.4 + 4.4/–3.9 ka BP (L/L and

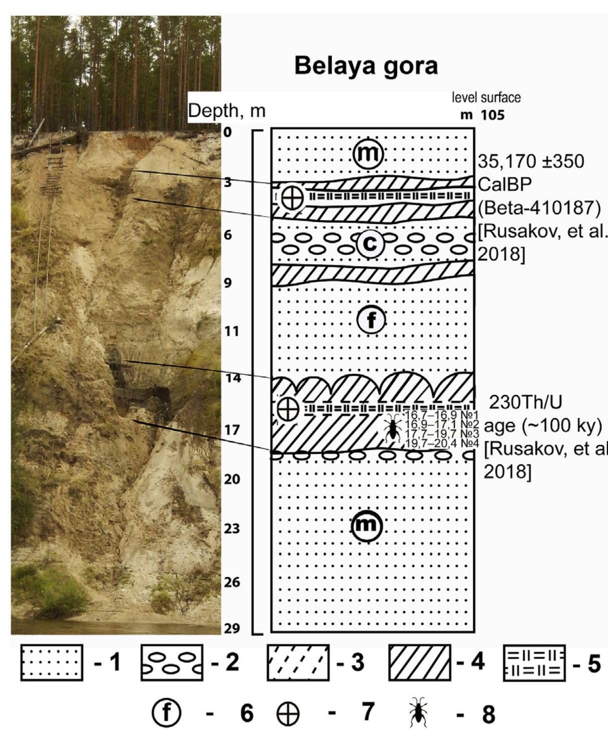

Fig. 2. Geological structure of Belaya Gora site (description made by S.E.Korkin). Legend: 1– sands; 2 – boulder-pebble material; 3 – cryogenic wedges; 4 – loams; 5 – peat layers; 6 –dimension of the sand fractions (particle size: f - fine sand, m - medium sand, c - coarse sand); 7 – samples for radiocarbon datings; 8 – samples of fossil insects and plant macrofossils.

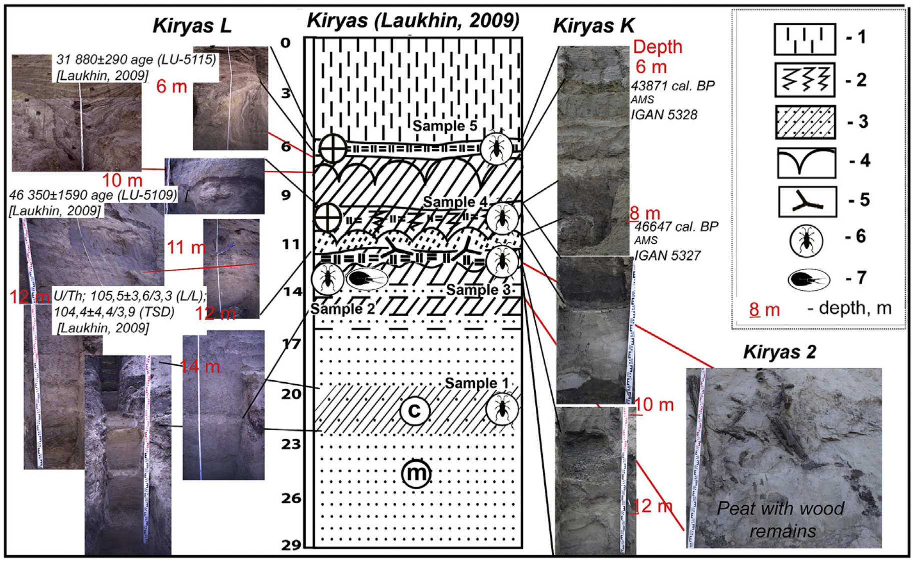

Fig. 3. Geological structure of Kiryas site (description made by S.E.Korkin). Legend: 1– loess-like loams; 2 – gley paleosols; 3 – diagonal lamination sands - inclined bedding of interlayers sand; 4 – silty clay loams; 5 – residues of woody plants; 6 – insect remains; 7 – remains of tadpole strimps.

TSD model, respectively) (Laukhin, 2009). The sediments, underlying peat and organic-rich silt of the period MIS5, consist of interbedded sands and organic rich clays, that are associated with the end of MIS3. Five samples were taken from this locality (Fig. 3). Sample 5 was collected from layer 13 of Kiryas-L section (stratified sands) underlying Late Pleistocene deposits. Sample 4 was collected from the layer of organic-rich fluvial sediment, representing layer 12 of the Kiryas-L section of underlying the lower peat deposit, sample 3 – from the lower peat deposit dated by ^{230}Th/U-method as 105 ± 3.6/3.3 thousands of years ago (L/L) and 104.4 ± 4.4/3.9 thousands of years ago. Sample 2 yielded from the corresponding layer of Kiryas-2 section characterized by presence of residues of woody plants. Ana, finally, Sample 1 was taken from upper peat layer of Kiryas-L section, corresponding to MIS3 (based on the radiocarbon date of 43,871 ka BP).

3. Results

3.1. Subfossil insect data

3.1.1. Karymkarskyi sor

Insect data from six samples were examined from this site Within the selected layers of this locality, the dynamics of beetle complexes is traced, which is compared with climate changes, correlated with the beginning of (Zinovyev, 2012).

A cryophilous insect fauna was described from a layer beneath a thick peat deposit (Sample 1). Most of these insects have subarctic distribution (*Pterostichus pinguedineus*, *Dicheirotrichus mannerheimi*, *Bembidion grapii* etc.), some species have modern multi-zonal distribution and assotiated with birch (*Betulapion simile*) and willows (*Lepyrus* sp.). This fauna is associated with subarctic tundra or forest tundra environments and may reflect cooler than present climate conditions (Zinovyev, 2012).

Fossil insect remains were found in Samples 2–6 of the peat deposit and udrlaying stratum. Insect faunas of peat deposit are similar and allow to reconstruct boreal environments. This assumption is based on the presence of boreal (*Pterostichus diligens, Hylastes* sp. etc) and cosmopolitan (*Dyschiriodes globosus, Bembidion guttula, Hydrobius fuscipes, Acidota crenata* etc.) beetle species, whereas arctic and subarctic species are not found there. At the same time, beetle remains identified as the thermophilous ground beetle *Trechus secalis* were found in three samples (Zinovyev, 2012). This species currently inhabits regions south of the study region. The northern most occurrences of this beetle are in the vicinity of Khanty-Mansijsk, Nizhnevartovsk and Surgut (Koltunov et al., 2009; Zinovyev, 2007). Occurrence of bark beetle *Hylastes* sp. in the sample 2 shows the presence of wood vegetation.

Insect assemblage from the upper stratum of this site (Sample 7) was very poor (Table 1). These insects not allow to make any paleoenvironmental reconstructions.

Fossil insects found in five samples of the peat deposit allows the reconstruction of swampy habitats with woody vegetation and relatively warm and humid climate, for which the average July temperatures (T_{max}) must be at least 17.7–18°C. Differences between fossil beetle faunas of underlaying layer and peat deposit (samples 2–7) may be considered as evidence of the MIS6-5 transition, because TL data 130 ± 31 ka BP (obtained for peat deposit) corresponds to the beginning of MIS5e.

3.1.2. Belaya Gora

Insect remains were found in four samples collected in organic-rich fluvial sediment of the lower part of this section (Fig. 2). Detailed descriptions of insect faunas, seeds and plant macrofossils were published earlier (Zinovyev et al., 2016; Rusakov et al., 2019).

One insect assemblage, Sample 2 (depth 16,95–17,15 m), was collected from peat layer having the preliminary 230Th/U data (~100 ky) correlated with the first half MIS5 (Rusakov et al., 2019). It contains mainly cosmopolitan (*Eubrychius velutus*, *Pterostichus nigrita*, etc.) and boreal (*Trechus rivularis, T. secalis, Pterostichus diligens, P. strenuus*) species of beetles. The discovery of the riffle beetle of the genus *Dryops* (Family Dryopidae) in sample 2 implies a fluvial origin for the formation of the studied layer.

Fragments of the thermophilous ground beetle *Trechus secalis* were found here. The occurrence of *T. secalis* might be indicative of warmer than modern climate because this species is distributed to the south of the location of Belaya Gora today.

The combined presence of this beetle and other boreal species (*Pterostichus diligens*, *Trechus rivularis* etc.) may reflect relatively warm climate conditions similar to that of the modern middle taiga forest zone (Zinovyev et al., 2016). It can be assumed that the presence of *T. secalis* may indicate relatively warm climate characterized by the following parameters: average annual temperatures −2.5-2.7 °C, T_{max} 17.7–18 °C, T_{min} −21 °C (it corresponds to the northern boundary of the modern distribution of this beetle). The lower part of this peat deposit yielded species associated with arctic tundra (sample # 4, depth 19,7–20,45 m) and subarctic tundra environments (sample # 3, depth

Table 1
List of Coleoptera from the Karymkarskiy sor site. The numbers opposite each taxon indicate the minimum number of individuals in the sample.

Taxon	Samples						
	1	2	3	4	5	6	7
Order Coleoptera							
Family Carabidae							
Dyschiriodes cf. *globosus* (Hbst.)	–	–	–	2	–	–	–
Trechus cf. *secalis* (Payk.)	–	3	1	–	–	1	–
Bembidion cf. *assimile* Gyll.	–	–	–	–	–	1	–
Bembidion cf. *guttula* (Fabr.)		1	–	–	–	–	–
Bembidion cf. *grapei* Gyll.	2	–	–	–	–	–	–
Bembidion sp.	1	–	–	–	–	–	–
Patrobus cf. *assimilis* Chd.	–	2	–	–	–	–	–
Pterostichus cf. *diligens* (Sturm)	–	–	1	–	–	–	–
P. cf. *pinguedineus* Esch.	6	–	–	–	–	–	–
Agonum cf. *fuliginosum* (Panz.)	–	–	–	1	–	–	–
Dicheirotrichus cf. *mannerheimi* (R.F.Sahlb.)	1	–	–	–	–	–	–
Carabidae indet.	1	1	2	1	1	2	–
Family Dytiscidae							
Agabus (*Gaurodytes*) sp.	–	1	–	–	1	1	–
Hydroporus sp.	–	–	–	–	–	1	–
Family Gyrinidae							
Gyrinus sp.	–	–	–	–	1	–	–
Family Hydrophilidae							
Hydrobius cf. *fuscipes* (L.)	–	–	1	–	–	–	–
Cercyon sp.	–	3	–	–	–	–	–
Hydrophilidae gen. sp.	2	1	2	–	–	–	1
Family Liodidae							
Agathidium sp.	3	–	–	–	–	–	–
Family Staphylinidae							
Acidota cf. *crenata* Mannh.	–	–	–	–	–	1	–
Olophrum sp.	–	1	1		2	–	–
Omaliinae indet.	–	1	4	2		1	2
Ocypus sp.	–	1	–	–	–	–	–
?*Ocypus* sp.	–	1	–	–	–	–	–
Quedinus sp.	–	–	–	–	–	1	–
Stenus sp.	–	1	1		–	1	–
Lathrobium sp.	–	–	1	1	–	–	–
Paederinae gen. sp.	–	–	–	–	–	1	–
Staphylinidae indet.	–	–	1	1	1	–	–
Family Nitidulidae							
Brachypterus sp.	–	–	1	–	–	–	–
Family Coccinellidae							
Coccinellidae gen. sp.	1	–	–	–	–	–	–
Family Clambidae							
Clambus sp.	–	3	1	–	–	–	–
Family Helmidae							
Dryops sp.	–	–	–	–	–	1	–
Family Helodidae							
Cyphon sp.	–	–	–	–	–	1	–
Helodidae	–	–	–	–	–	1	–
Family Erotylidae							
Erotylidae gen. sp.	–	–	–	–	1	–	–
Family Byrrhidae							
Morychus sp.	5	3	–	–	1	–	–
Family Curculionidae							
Limnobaris sp.	–	–	–	–	–	–	1
Lepyrus sp.	1	–	–	–	–	–	–
Tournotaris cf. *bimaculatus* (Fabr.)	–	–	–	1	–	–	–
?*Anthonomus* sp.	1	–	–	–	–	–	–
Phytobius sp.	–	1	–	–	–	–	–
Sitona sp.	1	–	–	–	–	–	–
Phyllobius sp.	–	–	–	–	–	2	–
Curculionidae indet	1		1	–	–	–	–
Family Brentidae							
Betulapion cf. *simile* (Kby.)	1	–	–	–	–	–	–
Family Scolytidae							
?*Hylastes* sp.	–	1	–	–	–	–	–
Coleoptera indet.	–	1	–	–	1	3	1
Order Hymenoptera							
Hymenoptera indet.	–	–	–	1	–	–	–
Order Diptera							
Diptera indet.	–	–	1	–	–	–	–
Total number of individuals	27	26	19	10	9	19	5

17,7–19,7 m). Fossil insect data from this locality allows the reconstruction of relatively warm climate during the time of accumulation of the upper part of peat deposit, comparable with the Brørup interval, MIS5c) whereas lower part of this organic deposit formed under cold climate conditions.

In sample 1 (a depth of 16.70–16.95 m) the joint findings of the beetles, having modern arctic (*Pterostichus sublaevis*), subartic (*Pterostichus* (*Cryobius*) spp), boreal (*Pterostichus oblongopunctatus*, *P. diligens*, *Trechus rivularis*, etc.) and multi-zone (*Dyschiriodes globosus*, *Agonum fuliginosum*, *Olophrum rotundicolle*, etc.) distribution could reflect the conditions of the northern taiga forests or open woodlands (Zinovyev et al., 2016; Rusakov et al., 2019). The occurences of subarctic species *Pterostichus* (*Cryobius*) spp. does not contradict the finds of boreal beetles, because these insects inhabit not only tundras but riparian forests within northen and middle taiga of West Siberia (Zinovyev, 2002, 2007). Only finds of *Pterostichus sublaevis* may be regarded as real evidence of cold climate conditions.

The species composition of insects from samples 3 (17.7–19.7 m) and 4 (19.7–20.45 m) is analogous to the insect faunas of modern typical (sample 4) and shrub (sample 3) tundras of Western Siberia. (Zinovyev et al., 2016; Rusakov et al., 2019).

So, fossil insect faunas found within in the middle part of Belaya Gora section reflects the following climatic changes. Insects of the low layers (19.7–20.45 m and 17.7–19.7 m) indicate cold climate. Insect assemblage of Sample 4 allows to reconstruct average annual temperatures not more than −10.5°C, average July temperatures were not exceed than 7.6°C., from Sample 3 – annual temperatures not more than −5,8 °C, average July temperatures not exceed than 15 °C.

3.1.3. Kiryas

Fossil insects were collected from the three sections, representing two peat thickness from this site, and from underlying deposits.

Diagonal lamination sand layer 13 of the Kiryas-L section (Sample 4), underlying Late Pleistocene deposits, contains a cryophilous beetle species (Table 2, Fig. 3) belongs mainly to subarctic species related to tundra ecological group. These beetles inhabit both open habitats (*Pterostichus* cf. *pinguedineus,* Fig. 4, 1, 2 and 10) and near aquatic biotopes (*Bembidion* cf. *grapii,* Fig. 4, 9). Xerophilous beetles, such as the pill beetle *Morychus* cf. *viridis* (Fig. 4, 11, 18), *Poecilus* (*Derus*) sp. and weevils of t h e Cleoninae group, were also found here. No wood-dwelling beetles were found in this sample. This insect fauna indicates a dry climate that was colder than present there is no evidence of woody vegetation.

Layer of organic-rich fluvial sediment from Sample 3, representing layer 12 of the Kiryas-L section, directly underlying the lower peat deposit, contains a rich beetle fauna with abundant remains of the aquatic beetles *Agabus* spp., *Hydroporus* spp., *Helophorus aquaticus* (Fig. 4, 10), *H. sibiricus* et al. The occurrence of the bark beetle *Pityogenes irkutensis* (Fig. 4, 19) indicate Fig. 4), *Pterostichus diligens*, and *Elaphrus uliginosus* (Fig. 4, 14) and the pill beetle *Simplocaria metallica*. However, the presence of subarctic species such as *Diacheila polita, D. arctica, Pterostichus* cf. *pinguedineus, Stereocerus haematopus* and the arctic species *Pterostichus costatus* (Fig. 4, 8), *Amara alpina*, and *Tachinus arcticus* reflect cold climate conditions and landscapes similar to modern forest-tundra or northern taiga.

Joint occurrences of arctic, subarctic and boreal beetle species in the same faunas not contradict the features of modern insect communities of the Northern taiga subzone of the studied area (Zinovyev, 2002, 2007; Mordkovitch and Luybetchanskiy, 1999). In particular, species of sugenus *Cryobius* of genus *Pterostichus*. inhabit riparian forests of Middle taiga subzone (Zinovyev, 2002). Moreover, *Pterostichus* (*Cryobius*) *brevicornis* found under the cortex of standing and toppled trees in the coniferous forests of the middle West Siberian plain (Zinovyev, 2006). Mordkovitch and Luybetchanskiy (1999) found *Amara alpina* in the vicinities of Noyabrsk (Northern taiga subzone of West Siberia). Only *Tachinus arcticus* and *Pterostichus costatus* does not found in modern

Table 2
List of Coleoptera from the Kiryas site.

Taxon	Kiryas-L			Kiryas-2, Sample 4	Kiryas-K, Sample 5
	Sample 1	Sample 2	Sample 3		
Order Coleoptera					
Family Dytiscidae					
Agabus (Gaurodytes) *affinis* (Payk.)			1		
A. cf. *affinis* (Payk.)					1
A. (*Gaurodytes*) sp.	1	13			8
Agabus sp.		1			2
Hydroporus sp.		16			10
Ilybius sp.		3			2
Colymbetes sp.		1			2
Family Gyrinidae					
Gyrinus sp.				3	
Family Carabidae					
Carabus sibiricus F.-W.					1
Carabus sp. 1					1
Carabus sp.					1
Nebria nivalis (Payk.)					1
Pelophila borealis (Payk.)		1			
Diacheila arctica Gyll.		2			
D. polita Fald.		2			5
Elaphrus riparius (L.)		2			
E. uliginosus F.		2			
Elaphrus sp.					1
Blethisa multipunctata (L.)		3			
B. catenaria Brown.					3
Dyschiriodes globosus Hbst.		1		1	2
Dyschiriodes sp.				1	
Bembidion cf. *grapii* Gyll.	1				3
B. cf. *macropterum* J.R.Sahlb.				1	
B. cf. *quadrimaculatum* (L.)				1	
B. (Plataphodes) sp.				1	
Bembidion sp.	1	1		1	
Patrobus septentrionis Dej.		1			
Poecilus (*Derus*) sp.					2
Pterostichus cf. *discrepans* A.Mor.		2			
P. (*Metallophilus*) sp.		1			
P. brevicornis (Kby)		2			10
P. cf. *argutoriformis* Popp.		1			4
P. cf. *pinguedineus* Esch.	3	8		2	40
P. (*Cryobius*) sp.					1
P. mirus (Tsch.)					1
P. sublaevis (J.Sahlb.)					3
P. costatus (Men.)	1	1			9
P. vermiculosus (Men.)					2
P. montanus (Motsch.)					1
P.(*Petrophilus*) sp.					1
P. diligens (Sturm.)		1			
Pterostichus sp.1					1
Pterostichus sp.		2			1
Stereocerus haematopus Dej.		1			2
Agonum ericeti quinquepunctatum Motsch.					1
A. (*Olisares*) sp.		1			
A. (*Europhilus*) sp.					1
Amara brunnea Gyll.				1	
A. quenseli (Schoenh.)		1			
A. alpina (Pk.)		3			12
A. *torrida* Pz		2			3
A. (*Curtonotus*) sp.					1
Amara sp.					1
Dicheirotrichus mannerheimi (R.F.Sahlb.)				1	
Harpalus sp.	1				
Chlaenius costulatus Motsch		2			
Cymindis vaporariorum (L.)	1				
Carabidae indet	1				
Family Hydrophilidae					
Helophorus aquaticus (L.)		1			
H. cf. *aquaticus* (L.)		26			
H. sibiricus Motsch.		2			
Helophorus sp.1		1			7
Helophorus sp.2		1			
Hydrobius fuscipes (L.)	1	2			1
Family Liodidae					
?*Colon* sp.					1
Family Staphylinidae					
Olophrum sp.	4	1		1	13
Omalinae indet.				1	
Stenus sp.		3			
Tachinus arcticus (Motsch.)					15
T. cf. *arcticus* (Motsch.)		7		1	
T. brevipennis J.Sahlb					2
Tachinus sp.	1				
Quedinus sp.				1	
Staphylinidae indet.	1			1	
Family Scarabaeidae					
Aphodius sp.					4
Family Byrrhidae					
Simplocaria semistriata (F.)					6
S. cf. *semistriata* (F.)					1
S. metallica (Sturm.)		9		1	2
Simplocaria sp.		1			
Morychus cf. *viridis* Kuzm. et Kor.	5			1	
Family Anobiidae					
Caenocara bovistae (Hoffm.)					1
Family Elateridae					
Hypnoidus sp.		1			
Family Coccinellidae					
Hippodamia arctica Schneider					2
Family Cerambycidae					
Cerambycidae indet				1	
Family Chrysomelidae					
Chaetocnema sp.				1	
Chrysolina spp.		2			5
Hydrothassa hannoverana (F.)		3			
Family Curculionidae					
Tournotaris bimaculatus (F.)	2	3		2	3
Notaris aethiops (F.)		2			1
Lepyrus nordenskjoeldi Faust.					3
L. cf. *nordenskjoeldi* Faust					1
Stephanocleonus eruditus Faust					2
Cleonini indet.	1				
Callirus sp.				1	
Hypera sp.		2			3
Pelenomus velaris (Gyll.)		1		1	
?*Isohnus arcticus* Kor.					1
Ceutorhynchinae		1			
Phyllobius sp.					1
Curculionidae indet.	2	1		1	1

(*continued on next page*)

Table 2 (*continued*)

Taxon	Kiryas-L			Kiryas-2, Sample 4	Kiryas-K, Sample 5
	Sample 1	Sample 2	Sample 3		
Family Apionidae					
Trichapion simile (Kby.)		1			
Hemitrichapion cf. *tschernovi* (T.-M.)	1				1
Apionidae gen. sp.					1
Family Scolytidae					
Pityogenes irkutensis Eggers		1			
Phoelotribus spinulosus Rey.				2	
Polygraphus sp.				1	
Order Hemiptera					
Family Corixidae					
Corixidae indet.				1	
Order Hymenoptera					
Hymenoptera indet.	1			1	
Insecta indet.	1			1	
Total number of individuals	30	150	1	33	218

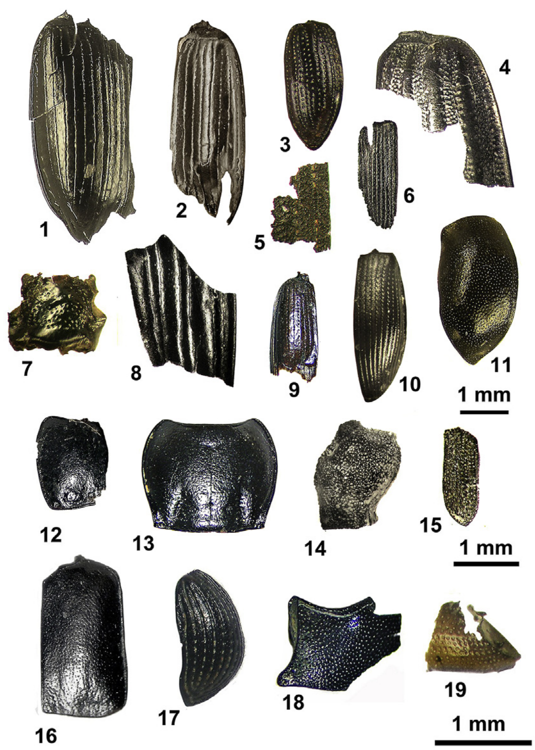

Fig. 4. Insect remains of Kiryas site: 1. *Pterostichus* cf. *pinguedineus* left elytron, Kiyas-L, Sample 2; 2. *Pterostichus* cf. *pinguedineus* right elytron Kiryas-L, Sample 2; 3. *Hydrothassa hannoverana*, left elytron, Kiryas-L, Sample 2; 4. *Chlaenius costulatus*, right elytron Kiryas-L, Sample 2; 5. ?*Pissodes* sp., piece of elytron, Kiryas-L, Sample 3; 6. *Dicheirotrichus mannerheimi*, left elytron Kiryas-L; 7. *Cymindis vaporariorum*, head, Kiryas-L, Sample 3; 8. *Pterostichus costatus*, piece of elytron Kiryas-L, Sample 3; 9. *Bembidion* cf. *grapii*, left elytron Kiryas-L, Sample 3; 10. *Helophorus aquaticus*, right. elytron Kiryas-L, Sample 2; 11. *Morychus* cf. *viridis*, left elytron Kiryas-L; 12. *Harpalus* sp., left half of pronotum, Kiryas-L, Sample 3; 13. *Pterostichus* cf. *pinguedineus*, pronotum, Kiryas-L, Sample 3; 14. *Elaphrus uliginosus*, right half of pronotum, Kiryas-L, Sample 2; 15. *Phoelotribus spinulosus*, right elytron Kiryas-L; 16. *Tachinus* sp. right elytron, Kiryas-L, Sample 3; 17. *Hemitrichapion* cf. *tschernovi*, left elytron, Kiryas-L, Sample 3; 18. *Morychus* cf. *viridis*, left half of pronotum, Kiryas-L, Sample 3; 19. *Pityogenes irkutensis*, top of left elytron, Kiryas-L, Sample 2. Scales 1 mm for 1–15 and 0.5 mm for 16–19.

boreal faunas. It is possible, that during rapid climate changes and expansion of woods some of these species could be preserved for some time in this area as part of other beetle complexes.

In the lower peat deposit dated by ^{230}Th/U-method as 105 ± 3.6/3.3 thousands of years ago (L/L) and 104.4 ± 4.4/3.9 thousands of years ago, only a single elytron of the water beetle *Agabus* sp. was found. However, a contempory layer of peaty clay from the Kiryas-3 section y i e l d e d some wood-associated beetles, such as the bark beetles *Phoelotribus spinulosus* (Fig. 4, 15), *Polygraphus* sp., and the weevil *Callirus* sp.) as well as inhabitants of forest litter, such as the ground beetle *Amara brunnea*. The presence of subarctic beetles, such as *Bembidion* cf. *macropterum*, *Pterostichus* cf. *pinguedineus,* and *Dicheirotrichus mannerheimi*, Fig. 4, 6) indicate cooler than present climatic conditions, because these beetles currently inhabit the northern part of the study region. The combination of subarctic and boreal species allows the reconstruction of landscapes similar to northern taiga forests during the Brørup interstadial of MIS5.

And finally, from the upper peat layer of Kiryas-K section, corresponding to MIS3 (based on the radiocarbon date of 43,871 ka BP), a representative sample contained a total of 402 fragments assigned to 218 individuals. This assemblage contains mainly arctic (*Tachinus arcticus* and *Amara alpina*, etc.) and subarctic species (*Pterostichus brevicornis, P.* cf. *pinguedineus* etc.), as well as some steppe beetles (*Poecilus (Derus)* sp., *Stephanocleonus eruditus.* In addition, near-aquatic and aquatic beetles found in this sample. Some of them (*Nebria nivalis, Bembidion grapii*) have subarctic distribution. Species of forest ecological group belongs to pill beetles of genus *Simplocaria* (*S. semistriata* and *S. metallica*), these insects inhabit intrazonal biotopes within taiga zone but cannot indicate the presence of woody vegetation. So, this insect fauna reflects the cold climate and open, tundra-like landscapes, corresponding to Middle Pleniglacial (MIS3).

MIS3 is defined as the cold period in the European part of Russia and Western Siberia. It confirmed by analysis of spore-and-pollen and plant macrofossil data, insect and mammalian faunas (Laukhin et al., 2007; Arkhipov and Volkova, 1994; Krivonogov, 1988; Legalov et al., 2016; Borodin and Kosintsev, 2001). According to Laukhin (Laukhin et al., 2008) this time is characterized dy wide distribution of open tundra-like landscapes reached the territories of middle reaches of Ob River.

Thus, subfossil insect data shows a sequence of paleoenvironmental conditions at the Kiryas site. Insect data from the Sample 1 of lower part of the Kiryas-2 section (corresponding to layer 13) indicates cold climate and the absence of trees. It allows to assume the formation of the layer in cold and arid climate conditions.

Insect material from overlying layer 12 in Kiryas-L section, shows the presence of trees (such as spruce and larch), however the climate was cooler than present. This insect fauna allows to reconstruct the environmental conditions, characterized by the following parameters: average annual temperatures −6 °C, T_{max} 14 °C, T_{min} −24 °C. It corresponds with modern climate of North Taiga subzone. It is possible, the buried peat (corresponding to layer 12), sampled from the Kiryas-2 section and dated by ^{230}Th/U- method as 105 ± 3,6/3,3 ka BP (L/L) и 104,4 ± 4,4/3,9 ka BP (TSD), formed in the same paleoenvironmental conditions. Finally, the upper peat horizon of Kiryas-K section, (Sample 4)corresponding to MIS3 (based on the radiocarbon date of 43,871 ka BP), formed in the severe climate conditions and open landscapes similar to modern tundra: average annual temperatures −9 °C, T_{max} 9,5 °C, T_{min} −25 °C.

3.2. Tadpole shrimp remains (Notostraca: Triopsidae)

Numerous notostracan mandibles were found in the sections Kirias-K and Kirias-L. All of them belong to a single species *Lepidurus arcticus* (Fig. 5) which is “circumpolar in areas of continuous permafrost in the Arctic and subarctic regions”, although some isolated populations are present in more southern regions like Kurile Islands, Primorsky Krai

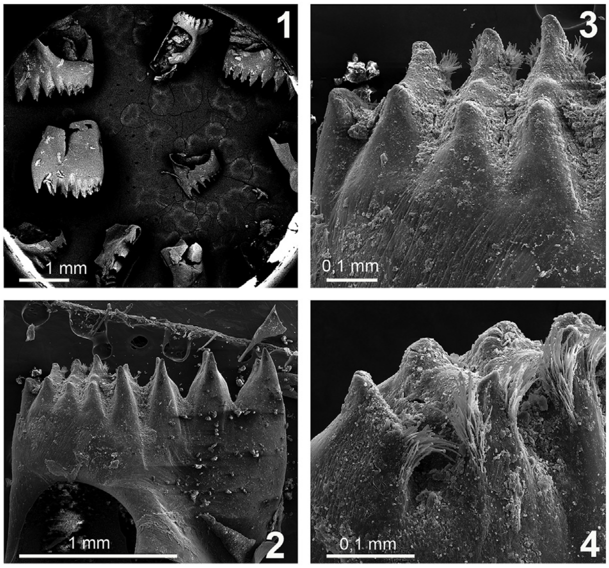

Fig. 5. Mandibles of *Lepidurus arcticus* (Notostraca) from Kiryas-2 section. 1, several mandibles attached to single stub; 2, mandible distal portion; 3, clusters of long spines on transversal teeth; 4, anterior hump-like tooth and two next teeth with cluster of these spines. Scales 1 mm for 1–2, 0.1 mm for 3–4.

(Rogers, 2001) and even Middle Portion of European Russia (Administration of Vladimir Area, 2018), therefore this taxon could be regarded as Arcto-boreal. In contrast to other notostracans mainly inhabiting small temporary ponds, this taxon occur in both ephemeral ponds and shallow water zone of large tundra lakes. It is clearly adapted to live in cold water and have a temperature optimum at 10 °C. This species should be considered as stenothermal, because it seems to be able to live only within a narrow temperature range (Lakka, 2013). These results correlated with fossil insect data, showing cool climate conditions. Ecolocical requirements of species *Lepidurus arcticus* not contradict to occurences of boreal and subarctic species at this site.

3.3. Paleobotanical data

In the present work we used the available literature data on spores, pollen and plant macrofossils.

3.3.1. Karymkarskyi sor

The pollen spectra from the layers underlying the peat deposit and dated to the end of MIS6 correspond to treeless landscape in periglacial conditions (Arkhipov and Votakh, 1989), as indicated by the dominance of pollen of non-woody plants, shrub birch and heather. The herbaceous pollen belongs to gramineae and grasses, besides *Ephedra* (Levina, 1979). The peat deposit with a TL date of 131 ± 31 ka BP (Arkhipov and Volkova, 1994) is characterized by pollen spectra dominated by tree taxa: spruce, pine and birch, and possibly larch. Pollen of aquatic plants was consistently present; spores of ferns were also found. This spectrum allows the reconstruction of spruce-pine-larch and birch woodlands. Finally, the spore-pollen spectrum from the peaty loam deposit overlying the peat deposit is characterized by the dominance of tree pollen, mainly birch and spruce; it corresponds to the presence of birch and spruce forests (Levina, 1979).

Seeds and other plant macrofossils from the peat deposit of the Karymkarskyi sor locality also represent relatively thermophilic species, such as *Isoetes echinospora* Dur., *Potamogeton obtusifolius* Mart. et Koch, *Najas marina* L., *Hydrocharis morsus-ranae* L., *Nymphaea candida* Presi, and *Fragaria viridis* Duch. etc. These occurrences allowan interpretation of a northward shift of modern vegetation zones under climatic conditions a little milder than modern (Martynov and Nikitin, 1964; Arkhipov and Volkova, 1994). This reconstruction matches those made on the basis of palynological and malacological analyses of sites in Western Siberia, known from literature. Previous research has indicated that MIS5e was characterized by the development of taiga forest vegetation, some broad-leaved species (linden, oak, elm) in the forests of the middle reaches of the Ob (Laukhin et al., 2007, etc.).

3.3.2. Plant macrofossil data from Belaya Gora section were published earlier (Zinovyev et al., 2016; Rusakov et al., 2019)

In the lower part of the peat deposit (sample 4, depth - 19,7–20,45 m, layer 15) the identified plant species allow the reconstruction of landscapes similar to typical modern tundra. Species associated with woody plants and aquatic habitats were not found. The plant macrofossil assemblage is characterized by grass communities with vegetation associated with high humidity habitats. The plant macrofossils from sample 3 include relatively cryophilic, swampy tundra species such as *Betula nana*, *Ranunculus hyperboreus* and the water species *Potamogeton sibiricus*. These plants are characteristic of the flora of Yakutia and the Taymyr Peninsula (Flora of Siberia, 1988; Pospelova and Pospelov, 2007). Among the grasses, the sedge *Carex*, buttercups *Ranunculus*, and bloodroot *Potentilla* prevail. The presence of aquatic taxa, such as *Batrachium, Potamogeton*, and *Myriophyllum verticillatum*, and taxa associated with disturbed soils, such as *Potentilla* and *Dianthus*, indicates erosion processes of the soil cover as a result of surface activity. Plant macrofossils found in sample 2 represent woody vegetation, including *Picea obovata, Larix sibirica, Betula* sect. *Albae*, and *Rubus idaeus*). Taxa associated with bankside thickets and woodland edges include *Naumburgia, Thalictrum* cf. *minus, Urtica dioica*, etc.) are abundant. Among grasses, the remains of swamp plants dominate, such as *Carex, Comarum palustre,* and *Calla palustris*. Singular remains of semi-aquatic and aquatic species were found, including *Sparganium, Hippuris vulgaris,* and *Potamogeton*. The composition of the paleoflora of sample 2 does not show any indicative species of warmer or colder climate in comparison with modern climate. The assemblage of plant macrofossils from sample 1, together with boreal plant species, contained the relatively cryophilic swamp-tundra species: *Ranunculus hyperboreus, Selaginella selaginoides* and *R.* cf. *pygmaeus*. Taxa of forest swamps (*Calla palustris* and *Typha*) are present, along with an individual specimen of the aquatic taxon *Batrachium* (Zinovyev et al., 2016; Rusakov et al., 2019).

3.3.3. Kiryas

Spore and pollen spectra were obtained for layer 12, showing the presence of forb-grass meadows, and damp swamps in depressions (Laukhin, 2009). On the north slopes, the tundra plants, dwarf birch, and heather were represented, while in the river valleys small areas of birch woodland with larch and spruce existed (Laukhin, 2009).

So, the paleobotanical data from the most of samples of Belaya gora and Karymkarskyi sor localities generally agree well with the fossil insect results obtained from the same layers. Some discrepancies are noted in Sample 2 of the Belaya Gora locality where the finding of a thermophilic carabid beetles (*Trechus secalis*) is not confirmed by the presence of heat-loving plant species, plant macrofossil floras are more consistent with those of layer 12 of the Kiryas locality desciberd in the literature (Laukhin, 2009).

4. Discussion

Based on abundant paleontological evidence, the climate of the Eemian Interglacial was warmer than that of the recent Holocene interglacial. Mean July temperatures in the Northern Hemisphere may have been 0.3–5.3 °C above that of the present day (Dutton and Lambeck, 2012; Bakker et al., 2013; Markova and Puzachenko, 2018). The end of this warming occurred in the middle of MIS5d, a short-term cooling associated with the end of this substage. T h e MIS5c period corresponds to warming, although not as significant, after which came another cold interval (MIS5b), which was replaced by short-term

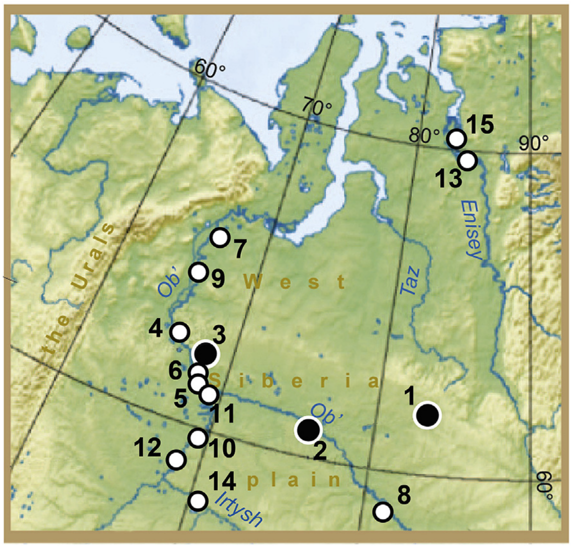

Fig. 6. Location of sites cited in the text: 1. – Belaya gora; 2. – Kiryas; 3. – Karymkarskyi sor; 4. – Kormuzhikhanskyi yar; 5. – Bogdashkiny gory; 6. – Elizarovo; 7. – Shuryshkary; 8. – Kolpashevo; 9. – Tugiyan-Yugan; 10. – Tchembakchino; 11. – Khanty- Mansiysk; 12. – Gornaya Subbota; 13. – Malaya Kheta; 14. – Yarsino; 15. – Mys Karginskyi.

warming (MIS5a) from 84 to 74 thousand years ago (Astakhov, 2009).

The data from this study were compared with the published data on the paleoenvironments of the MIS5 period in Western Siberia and other regions of Northern Eurasia, based on both spore-and pollen, plant macrofossil and insect data (Aalbersberg and Litt, 1998; Van Andel and Tzedakis, 1996; Frenzel, 1992; Behre, van der Plicht., 1992; Ponel, 1995, Coope, 2000, 2010; Nazarov, 1984; Andreev et al., 2004, etc.).

4.1. Comparison with paleontological data from other MIS5 localities in West Siberia

Spore-and-pollen data from other localities of West Siberia correlated with MIS5 shows the well expressed dynamics of paleoevironment during that time (Arkhipov et al., 1978; Arkhipov et al., 1987; Arkhipov and Volkova, 1994; Gurtovaya and Krivonogov, 1988; Arkhipov and Votakh, 1989; Kind, 1974; Astakhov et al., 2005 etc.).

So, palynolocical spectra of Elisarovo site (Fig. 6, 6) from the layer dated by 130 + 27 ka BP (depth 9,57–14,57 m) and referred to beginning of MIS 5e shows periglacial conditions and represent treeless vegetation with *Artemisia* and Chenopodiaceae (Arkhipov et al., 1978; Arkhipov et al., 1987).

Warm climate conditions and presence of conifer woodlands reconstructed for MIS5e on the base of palynological data of Kormuzhikhanskiy yar (Fig. 6, 4). The peat deposit of the site has TL date of 130 ± 31 and correlated with MIS5e (Arkhipov and Votakh, 1989). The same paleoenvironment reconstructed for Khanty-Mansiysk locality (Fig. 6, 11) from paleosol, dated by the TL-method to 130 ± 25 ka BP, This vegetation reflects the development of southern taiga forests and belongs to MIS5e. (Arkhipov and Volkova, 1994; Arkhipov et al., 1987). Spore-and-pollen spectra of Gornaya Subbota site, which has TL data 130 + 27 ka BP. (Fig. 6, 12), has the well expressed forest type of spectra is typical, where pollen of wood species reaches 73–80%; these data allow this layer to be associated with stage MIS5e (Gurtovaya and Krivonogov, 1988).

In addition warm climate conditions were reconstructed for Late Pleistocene layers, corresponded to MIS5e wer taken from the Mys Karginskyi locality (lower reaches of the Enissey River, Fig. 6, 15). Sand layers contained the remains of the freshwater clam *Arctica* (=*Cyprina*) *islandica* dated by the EPR method to 121.9 ka BP (Katzenberger and Grun, 1986). The occurrence of this species allows the reconstruction of warmer than present climate, because *A. islandica* inhabits the relatively warm areas of t h e Barents and White seas (Wanamaker et al., 2009; Butler et al., 2013).

Most of localities from Western Siberia were dated by MIS5c. So, in peat deposits of Kormuzhikhanskiy yar (Fig. 6, 4) with a TL date of 110 ± 27 ka BP the spore-and- pollen spectra similar to modern middle taiga forests were described (Arkhipov and Votakh, 1989). Palynological data have been obtained for layers of loam, dated by TL method at 110 ± 15 ka BP (depth 11 м) from Bogdashkiny gory locality (Fig. 6, 5). Spore-and-pollen spectra from this layer shows the dominance of pine-spruce-birch, then mixed coniferous and birch forests with pine, Siberian pine and fir with herbaceous cover (Arkhipov and Votakh, 1989).

The peat layer from the middle part of the Shuryshkary section (coordinates 65°55′N, 65° 30′E; Fig. 6, 7) has two 230Th/U-dates: 113 ± 14 ka BP (by leaching method) and 141 ± 11,7 ka BP (by the complete dissolution method) (Astakhov et al., 2005). Spore-and-pollen spectra are typical for the southern part of northern taiga forests with spruce and some fir (Laukhin et al., 2007). The peaty gyttja layers of Kolpashevo (Fig. 6, 8) section has been dated (Th/U) at 108 ± 18(12) ka BP (Arkhipov and Volkova, 1994). The pollen spectra reflects forest vegetation with a predominance of spruc; single occurrences of *Larix, Betula* sect. *Nanae, Alnus*, and thermophilous trees, such as *Quercus, Corylus, Ulmus* have been identified(Maksimov et al., 2017). In the lower part of Tugiyan-Yugan locality (Fig. 6, 9) the layer correlated with MIS5c on the base of TL date of 110 ± 14 ka BP. The pollen spectrum from this layer is characterized by the dominance of birch (Arkhipov and Volkova, 1994).

Peat deposit of Tchembakchino section (Fig. 6, 10) has ^{230}Th/U-dates have been obtained from including 114.2 ± 22.1/14.7 ka BP (based on L/L) and 110.1 ± 6.7/5.9 ka BP(based on TSD) (Laukhin, 2009). Pollen spectra reflect warmer climate corresponding to modern middle taiga, with the inclusion of a number of broad-leaved trees, such as *Quercus, Corylus*, and *Ulmus* (Laukhin, 2009). Spore-and-pollenl data from Malaya Kheta section (Fig. 6, 13) (TL date of 112 ± 6 ka BP (Astakhov et al., 2005) reflects vegetation cover indicating warmer than present climate and corresponds to taiga forests with a predominance of *Picea* and *Pinus sibirica* and an admixture of *Abies* (Kind, 1974; Astakhov et al., 2005).

Mammalian and insect data from Yarsino site (Fig. 6, 14) were obtained from the basal part of Yalbynya suite deposits, correlated with the beginning of MIS5, and overlying deposits of middle Pleistocene age (end of MIS6) (Smirnov et al., 1986). The fossil insect assemblage is rather poor and represents arctic and subarctic beetles (*Amara alpina, Pterostichus* cf. *pinguedineus*) and may indicate cold climate conditions.

Thus, the majority of paleontological data from these sites may be associated with the warm substages of MIS5 (5e and 5c), and show the distribution of forests in West Siberia during the last interglacial, reflecting relatively warm climate conditions. Moreover, warm climate conditions have also been reconstructed for regional fresh water and oceanic waters, associated with stage MIS5e on the basis of mollusk data.

4.2. Comparison with paleonological data from other regions of Northern Eurasia

The distribution of forests in Europe during MIS5e and 5c was a consequence of the relatively warm and humid climate that existed in these periods in the Northern Hemisphere (Frenzel, 1992; Dutton and Lambeck, 2012; Bakker et al., 2013; Markova and Puzachenko, 2018 etc.).

According to the published data, the warmest stage of the early Eemian (MIS5e) correlated with the period 130–125 ka BP with a gradual cooling to more similar-to- present conditions afterwards (van Andel and Tzedakis, 1996; Aalbersberg, Litt, 1998).

Subfossil insect data are correlated with the dynamics of natural communities during MIS5. Fossil insect faunas from the Eemian localities of England, Germany and France also indicate conditions of warmer-than-modern climate (Coope, 1990, 2000; 2010; Behre et al., 2005; Ponel, 1995). Thermophilous insect faunas have been described for Eemian (MIS5e)-age localities in Belarus (Nazarov, 1984, 1986) and lower reaches of the Volga and Ura Rivers (Bidashko, 1994; Bidashko and Proskurin, 1984).

Insect faunas of Karymkarskiy sor site suggests the warm climate conditions, although a small number of insect remains in the studied samples does not allow for more detailed reconstructions. We use only one indicator of warm climate, ground beetle *Trechus secalis*, in this site.

The subsequent warm episodes of MIS5 are associated with the Herning (5d) and Brørup (5c) interstadials. The return of a forest environment is demonstrated by the development of rich tree-dependent insect faunas, described from localities in (Ponel, 1995; Walkling and Coope, 1996). Insect assemblages from France and Germany reflect conditions of relatively warm climate. Moreover in the Gröbern locality, fossil beetle data allow the reconstruction of two peaks of summer temperatures – the first for the period MIS5d (Herning interstadial), the other for MIS5c (Brørup interstadial) (Walkling and Coope, 1996).

Warm climate conditions may be reconcstructed for the layer of Belaya gora site, which has known approximate 230Th/U data (~100 ky) (Rusakov et al., 2019). The occurrence of *Trechus secalis* may indicate average annual temperatures −2.5-2.7 °C, T_{max} 17.7–18 °C and T_{min} −21 °C.

In northeastern Siberia, sedimentary layers from MIS5 are not strongly pronounced. Paleobotanical and fossil insect data from two MIS5 sections (Kuobakh Beds on the Alazeya River and the Krest-Yuryakh Formation in the Laptev Strait) are indicative of forest–tundra environments, with a steppe–tundra admixture (Kuzmina, 2015). So, the environmental records from Eemian deposits of the Krest-Yuryakh Formation in the Laptev Strait (Bol'shoy Lyakhovsky Island site) show that shrub tundra and forest-tundra with numerous lakes dominated the area during the Eemian optimum (130–110 ka BP) (Kuzmina, 2015; Andreev et al., 2004). At the same time, insect assemblages from the Kuobakh Beds of the Alazeya section (Kuzmina, 2015, 1989) contain a significant number of forest beetle species, which may be an indicator of interglacial environments and the climate close to the modern one or even warmer (Kuzmina, 2015).

5. Conclusions

The results of our research indicate a wide-spread distribution of forest vegetation and associated thermophilous insect faunas from the Western and Eastern parts of Northern Eurasia during warm periods of MIS5. In particular, the wide development of forest vegetation of mainly middle- and north-taiga types is interpreted from fossils extracted from the sediments of the West-Siberian plain. These deposits come from MIS5, including the studied floras and faunas from Karymkarski sor, Belaya Gora and Kiryas sites. Environmental reconstructions of relatively warm climate made for these localities are based mainly on the basis of the presence of xylobiont species (mainly bark beetles associated with spruce and larch). The only beetle species indicative of slightly warmer than present climate is a ground beetle *Trechus secalis*, in which was found from the Karymkarskiy sor (MIS5e) and Belaya Gora localities (MIS5c). For both of these localities, the underlying beetle faunas contained only arctic and subarctic insect taxa. Similar changes in fossil beetle assemblages and their associated plant communities were described from the Kiryas locality, despite lack of *T. secalis* fragments in MIS5c layers.

Insect faunas of Kiryas site not suggests warmer-that-present climate and allows reconstructing cool climate conditions, similar to those of West Siberian modern north taiga. These conclusions correlated with occurences of cold-adapted tadpole shrimp (*Lepidurus arcticus*), which may be difined as subarctic species.

Likewise, the influence of MIS5 warmings on the species composition of insect assemblages has previously been established for several localities in the western part of the Eurasia (Western and Eastern Europe). In the central and eastern parts of Northern Eurasia (Western and North- Eastern Siberia), a significant increase in air temperature and the corresponding transformation of landscapes in the warm periods of MIS5 are also confirmed by insect data. However, these few fossil insect assemblages from West Siberia that are reliably dated to the warm periods of MIS5 are not sufficient to allow more detailed reconstructions of the nature of regional insect faunas from MIS 5 to be made In the West Siberian plain only three insect fossil assemblages may be reliably attributed to the warm stages of MIS5. However, the paleobotanical data from this period in Western Siberia allows a better-detailed characterization of the regional flora.

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References

Aalbersberg, G., Litt, T., 1998. Multiproxy climate reconstructions for the Eemian and early Weichselian. J. Quat. Sci. 13, 367–390.

Administration of Vladimir Area, 2018. List of Objects of Plant and Animal World Included in the Red Book of Vladimir Area. Supplement № 938 from 20.12.2018. http://docs.cntd.ru/document/450329136 (in Russian).

Andreev, A.A., Grosse, G., Schirrmeister, L., Kuzmina, S.A., Novenko, E.Y., Bobrov, A.A., Tarasov, P.E., Kuznetsova, T.V., Krbetschek, M., Meyer, H., Kunitsky, V.V., 2004. Late Saalian and Eemian palaeoenvironmental history of the Bol'shoy Lyakhovsky Island (Laptev sea region, arctic Siberia). Boreas 33, 319–348.

Andreev, A.A., Grosse, G., Schirrmeister, L., Kuznetsova, T.V., Kuzmina, S.A., Bobrov, A.A., Tarasov, P.E., Novenko, E.Y., Meyer, H., Derevyagin, A.Y., Kienast, F., Bryantseva, A., Kunitsky, V.V., 2009. Weichselian and Holocene palaeoenvironmental history of the Bol'shoy Lyakhovsky Island, new Siberian Archipelago, arctic Siberia. Boreas 38, 72–110.

Arkhipov, S.A., Panychev, V.A., Shelekhova, T.G., Shelkoplyas, V.N., 1978. Glacial Geology of the Belogorsk Upland, West-Siberian Plain. The Lower Ob Region. IGG SO AN SSSR, Novosibirsk, pp. 131 (In Russian).

Arkhipov, S.A., Panychev, V.A., Shelkoplyas, V.N., 1987. Geochronology of the Upper Pleistocene of Belogorskoye Priobye (West-Siberian Plain). Regional'naya Geokhronologya Sibiri I Dal'nego Vostoka. Nauka Publ, Novosibirsk, pp. 110–124 (In Russian).

Arkhipov, S.A., Volkova, V.S., 1994. Geological History, Landscapes and Climate of West Siberia during the Pleistocene. IGG SO RAN, Novosibirsk, pp. 106 (In Russian).

Arkhipov, S.A., Votakh, M.P., 1989. To the Problem of Separation of Early Zyryan Interstadials. Kaynozoy Sibiri I Severo-Vostoka SSSR. Nauka Publ, Novosibirsk, pp. 138–141 (In Russian).

Arslanov, K.Kh, Laukhin, S.A., Maksimov, F.E., Kuznetsov, V.Yu, Velichkevitch, F.Yu, San'ko, A.F., Shilova, G.N., Chernov, S.B., 2004. Bedoba – reference section of Kazantsevo horizon in central Siberia. Dokl. RAN 396 (6), 796–799 (in Russian).

Astakhov, V.I., 2009. Middle and Late Pleistocene of glacial zone of Western Siberia: problems of stratigraphy and paleogeography. Bulleten' Komissii po izutcheniyu chetvertichnogo perioda 69, 8–24 (in Russian).

Astakhov, V.I., Arslanov, KhA., Maksimov, F.E., Kuznetsov, V.Yu, Razina, V.V., 2005. The age of Interglacial peat in the Low reaches of Ob. Dokl. Earth Sci. 401 (2), 298–302 (In Russian).

Astakhov, V.I., Mangerud, J., 2005. The age of the Karginsky interglacial strata on the Lower Yenisei. Dokl. Earth Sci. 403 (5), 673–676.

Atkinson, T.C., Briffa, K.R., Coope, G.R., 1987. Seasonal temperatures in Britain during the past 22,000 years, reconstructed using beetle remains. Nature 325, 587–592.

Bakker, P., Stone, E.J., Charbit, S., Groger, M., Krebs-Kanzow, U., Ritz, S.P., Varma, V., Khon, V., Lunt, D.J., Mikolajewicz, U., et al., 2013. Last interglacial temperature evolution—a model inter-comparison. Clim. Past 9, 605–619.

Behre, K.-E., van der Plicht, J., 1992. Towards an absolute chronology for the last glacial period in Europe: radiocarbon dates from Oerel, northern Germany. Veg. Hist. Archaeobotany 1, 111–117.

Behre, K.E., Hölzer, A., Lemdahl, G., 2005. Botanical macro-remains and insects from the

Eemian and Weichselian site of Oerel (northwest Germany) and their evidence for the history of climate. Veg. Hist. Archaeobotany 14 (1), 31–53.
Bidashko, F.G., 1994. Reconstruction of Pleistocene Palaeoenvironment of Northern Prikaspiyskaya Lowland on Fossil Insect Data. Unpubl. PhD thesis. Moscow State University, Moscow (In Russian).
Bidashko, F.G., Proskurin, K.P., 1984. The environment of the lower reaches of the Ural River during the middle Pleistocene according to entomological and botanical data. Paleontol. J. 18, 80–86.
Borodin, A.V., Kosintsev, P.A., 2001. Pleistocene Mammals of the North of West Siberia Mamont I Ego Okruzhenie: 200 Let Izutcheniya. GEOS Publ, Moscow, pp. 244–252 (in Russian).
Brendonck, L., Rogers, D.C., Olesen, J., Weeks, S., Hoeh, W.R., 2008. Global diversity of large branchiopods (Crustacea: Branchiopoda) in freshwater. Hydrobiologia 595, 167–176.
Buckland, P.I., Buckland, P.C., 2006. Bugs Coleopteran ecology package (Versions: BugsCEP v7.63; Bugsdata v8.0; BugsMCR v2.02; BugStats v1.22) [Downloaded/ CDROM: DATE]. www.bugscep.com.
Butler, P.G., Wanamaker Jr., A.D., Scourse, J.D., Richardson, ChA., Reynolds, D.J., 2013. Variability of marine climate on the North Icelandic Shelf in a 1357-year proxy archive based on growth increments in the bivalve Arctica islandica. Palaeogeogr. Palaeoclimatol. Palaeoecol. V. 373, 141–151.
Climate-dataorg https://ru.climate-data.org/.
Coope, G.R., 1990. The invasion of northern Europe during the Pleistocene by Mediterranean species of Coleoptera. In: di Castri, F., Hansen, A.J., Debussche, M. (Eds.), Biological Invasions in Europe and the Mediterranean Basin, 203-215. Kluwer, Dordrecht.
Coope, G.R., 2000. The climatic significance of coleopteran assemblages from the Eemian deposits in southern England. Geologie en Mijnbouw - Netherlands J. Geosci. 79, 257–267.
Coope, G.R., 2010. Coleopteran faunas as indicators of interglacial climates in central and southern England. Quat. Sci. Rev. 29, 1507–1514.
Dutton, A., Lambeck, K., 2012. Ice volume and sea level during the last interglacial. Science 337, 216–219.
Elias, S.A., 1997. The Mutual Climatic Range method of paleoclimate reconstruction based on insect fossils: new applications and interhemispheric comparisons. Quat. Sci. Rev. 16, 1217–1225.
Elias, S., 2014. Environmental interpretation of fossil insect assemblages from MIS5 at Ziegler reservoir, Snowmass village, Colorado. Quat. Res. 82 (3), 592–603.
Engels, S., Helmens, K.F., Valiranta, M., Brooks, S.J., Birks, H.J.B., 2010. Early Weichselian (MIS ¨ 5d and 5c) temperatures and environmental changes in northern Fennoscandia as recorded by chironomids and macroremains at Sokli, northeast Finland. Boreas 39, 689–704.
Flora of Siberia, 1988. In: Malysheva, L.I., Peshkova, G.A. (Eds.), Lycopodiaceae-Hydrocharitaceae. Nauka, Siberian branch Publishing House, Novosibirsk, pp. 200 (In Russian).
Frenzel, B., 1992. Vegetation during the maximum cooling of the last glaciation. In: Frenzel, B., Pecsi, B., Velichko, A.A. (Eds.), Atlas of Palaeoclimates and Palaeoenvironments of the Northern Hemisphere. INQUA/Hungarian Academy of Sciences, Budapest, pp. 85–86.
Goldberg, E.L., Grachev, M.A., Edgington, D., Navier, J., Andre, L., Chebykin, E.P., Shulpyako, I.O., 2002. Uran-thorium Dating of the Last Two Interglacial Deposits in the Lake Baikal. Osnovnye Zakonomernosti Global'nykh I Regional'nykh Izmeneniy Klimata I Prirodnoy Sredy Pozdnego Kaynozoya Sibiri. Novosibirsk. Institute of archeology and ethnography SB of RAS Publ., Novosibirsk, pp. 92–99 (In Russian).
Gurina, A.A., Dudko, R.Yu, Zinovyev, E.V., Borodin, A.V., Tshernyshev, S.E., Legalov, A.A., 2018. Late Pleistocene Taphocoenosis of insects and small mammals from the upper reaches of the Ob River. Paleontol. J. 52 (13), 1610–1622.
Gurtovaya, E.E., Krivonogov, S.K., 1988. Palaeobotanical characteristic of continental deposits of the Kazantsevsky horizon. In: Shatskyy, S.B. (Ed.), Plant Microfossils and Stratigraphy of Mesozoic and Cenozoic of Siberia. Nauka, Novosibirsk, pp. 69–90 (in Russian).
Ilyina, I.S., Lapshina, E.I., Lavrenko, N.N., 1985. Vegetable Cover of the Siberian Plain. Nauka Publishing House, Novosibirsk, pp. 251 (in Russian).
Katzenberger, O., Grun, R., 1986. ESR Dating of circumarctic molluscs. Nucl. Tracks 10 (4–6), 885–890.
Kind, N.V., 1974. Geochronology of the Late Anthropogene According to Isotopic Data. M.: Nauka Publ, pp. 55 (in Russian).
Kirillova, I.V., Van der Plicht, J., Gubin, S.V., Zanina, O.G., Chernova, O.F., Lapteva, E.G., Trofimova, S.S., Zinovyev, E.V., Zharov, A.A., Fadeeva, E.O., Van Kolfschoten, T., Shidlovskiy, F.K., Kotov, A.A., 2016. Taphonomic phenomen of ancient mammal Fur from Glacial Beringia. Boreas 45, 455–469.
Kiselev, S.V., 1987. Paleoentomologicheskii Analiz (Field Sampling for Entomological Analysis). Kompleksnye Biostratigraphicheskie Issledovaniya. Moscow Univ. Press, pp. 21–26 (in Russian).
Koltunov, E.V., Zinovyev, E.V., Zalesov, S.V., Gilev, A.V., 2009. Flora I Fauna Prirodnogo Parka "Samarovskiy Chugas". Entomofauna (Flora and Fauna of Samarovskiy Chugas" Reserve Park. Entomofauna) Ekaterinburg. Ural State Forest Engineering University publ, pp. 178 (in Russian).
Kotov, A.A., Zharov, A.A., Chernova, O.F., Neretina, A.N., Gololobova, M.A., Trofimova, S.S., Zinovyev, E.V., Izymova, E.I., Zanina, O.G., Kirillova, I.V., Shidlovskiy, F.K., 2018. Crustacea (Branchiopoda) in the complex of organic remains from mammoth hair. Zoologicheskiy Zhurnal 97 (10), 1300–1314.
Krivonogov, S.K., 1988. Stratigrafiya I Paleogeografiya Nizhnego Priirtysh'ya V Epokhu Poslednego Oledeneniya (Stratigraphy and Paleogeography of Lower Irtysh in Era of the Latest Glaciations). Nauka Publ, Novosibirsk, pp. 1e232 (in Russian).
Kryzhanovskii, O.L., Belousov, I.A., Kabak, I.I., Kataev, B.M., Makarov, K.V., Shilenkov, V.G., 1995. A Checklist of the Ground-Beetles of Russia and Adjacent Lands (Insecta, Coleoptera, Carabidae). Pensoft Series Faunistica, vol. 3. Pensoft Publishers, Sofia-Moscow, pp. 1–271.
Kuzmina, S.A., 1989. Late Pleistocene insects from the Alazea river basin (Kolyma lowland)). Bulletin Moscow Society of Naturalists (MOIP) (ser. geol.) 64, 42–55 (In Russian).
Kuzmina, S.A., 2015. Quaternary insects and environment of northeastern Asia. Paleontol. J. 49 (7), 679–867.
Lakka, H.K., 2013. The Ecology of a Freshwater Crustacean: Lepidurus Arcticus (Brachiopoda; Notostraca) in a High Arctic Region. Mr. Sci. Thesis. University of Helsinki, pp. 151.
Laukhin, S.A., Maksimov, F.E., Arslanov, Kh A., Kuznetsov, V. Yu, Chernov, S.B., Shilova, G.N., Velichkevich, F. Yu, 2008. Geochronology and landscape–climatic environments of the early Zyryanian interstadial in West Siberia. Dokl. Earth Sci. 421 (5), 796–799.
Laukhin, S.A., 2009. The first U/Th dates of the continental sediments of the upper Pleistocene of Siberia and their significance for stratigraphy and geochronology. Vestnik arkheologii, antropologii i etnografii 9, 167–182 (in Russian).
Laukhin, S.A., Shilova, G.N., Velichkevich, F.Yu, 2007. Paleobotanical characteristics and paleoclimates of the Karginian time on the west Siberian plain. Vestnik arkheologii, antropologii i etnografii 7, 203–225 (in Russian).
Legalov, A.A., Dudko, R.Yu, Zinovyev, E.V., 2016. Sub-fossil weevils (Coleoptera, Curculionoidea) from the central part ofWest Siberia provide evidence of range expansion during the last glaciations. Quat. Int. 420, 233–241.
Levina, T.P., 1979. Palynological Characteristic of the Late Quaternary Glacial Epoch in the Valley of Middle Ob'. Stratigrafiya I Palinologiya Mezozoya I Kaynozoya Sibiri. Novosibirsk. pp. 74–98 (in Russian).
Maksimov, F.E., Savelieva, L.A., Laukhin, S.A., Kuznetsov, V.Yu, Arslanov, KhA., Petrov, A.Yu, Grigoriev, V.A., Levchenko, S.B., 2017. New data on age and conditions of buried organic-rich sediments Formation in the Central Ob River. Contemporary Problems of Ecology 10 (4), 370–379 2017.
Mangerud, J., 1989. Correlation ofthe Eemian and the Weichselian with deep sea oxygen isotope stratigraphy//. Quat. Int. 3/4, 1–4.
Markova, A.K., 1985. Small mammals of Mikulino interglacial (by the materials of the Russian plain). Dokl. Akad. Nauk 284, 718–721.
Markova, A.K., 2000. The Mikulino (=Eemian) mammal faunas of the Russian plain and Crimea. Geol. Mijnbouw/Neth. J. Geosci. 79, 293–301.
Markova, A., Puzachenko, A., 2018. Preliminary analysis of European small mammal faunas of the Eemian interglacial: species composition and species diversity at a regional scale. Quaternary 1, 9. https://doi.org/10.3390/quat1020009. 2018.
Martynov, B.A., Nikitin, V.P., 1964. The interglacial layers at the section Belogorsk «mainland» on the Ob River. In: Chetvertichnaya Geology i Geomorphologiya Zapadno- Sibirskoi Nizmennosti, vol. 25. Trudy IGG, Novosibirsk, pp. 73–82 (In Russian).
Mordkovitch, V.G., Luybetchanskiy, I.I., 1999. Zonal-catena order of ecological ordination in carabids (Coleoptera, Carabidae) from the west Siberian plain. Adv. Curr. Biol. 118, 205–215 (in Russian with English abstract).
Nazarov, V.I., 1984. Reconstruction of the Pleistocene Landscapes byPaleoentomological Data. Trudy of the Paleontological Institute. Nauka Publishing House, Moscow, pp. 96 (In Russian).
Nazarov, V.I., 1986. New Species of Entomofauna of Mikulino Interglaciation of Belarus. New and Little-Known Species of Fossil Animals and Plants from Belarus. Nauka i tekhnika, Minsk, pp. 167–171 (In Russian).
Nikitin, V.P., 1970. Quaternary floras of West Siberia (seeds and fruits). In: Istoria Razvitya Rastitel'nosti Vnelednikovoi Zony Zapadno-Sibirskoi Nizmennosti V pozdnepleistocenovoe i Chetvertichnoye Vremya. Nauka Publishing House, Moscow, pp. 245–312 (In Russian).
Novenko, E. Yu, 2016. The vegetation and climate in central and eastern Europe in the late Pleistocene and Holocene. Unpubl. PhD thesis.. pp. 50 (in Russian).
Ponel, Ph, 1995. Rissian, Eemian and Wiirmian Coleoptera assemblages from La Grande pile (Vosges, France). Palaeogeogr. Palaeoclimatol. Palaeoecol. 114, 1–41.
Pospelova, E.B., Pospelov, I.N., 2007. Vascular Flora of Taimyr Peninsula and Neighboring Territories. Part 1. The Annotated List of Flora and its General Analysis. KMK. Publ, Moscow, pp. 457 (In Russian).
Rasnytsyn, A.P., 2008. Specify of Fossil Insect Investigations. Introduction in Paleoentomology. KMK Publ, Moscow, pp. 80–100 (In Russian).
Reimer, P.J., Bard, E., Bayliss, A., Beck, J.W., Blackwell, P.G., Bronk Ramsey, C., Buck, C.E., Cheng, H., Edwards, R.L., Friedrich, M., Grootes, P.M., Guilderson, T.P., Haflidason, H., Hajdas, I., Hatt, Ch, Heaton, T.J., Hogg, A.G., Hughen, K.A., Kaiser, K.F., Kromer, B., Manning, S.W., Niu, M., Reimer, R.W., Richards, D.A., Scott, E.M., Southon, J.R., Turney, C.S.M., van der Plicht, J., 2013. IntCal13 and MARINE13 radiocarbon age calibration curves 0-50000 years calBP. Radiocarbon 55 (4), 1869–1887.
Richter, S., 2004. A comparison of the mandibular gnathal edges in branchiopod crustaceans: implications for the phylogenetic position of the Laevicaudata. Zoomorphology 123, 31–44.
Rogers, D.C., 2001. Revision of the Nearctic Lepidurus (Notostraca). J. Crustac Biol. 21, 991–1006.
Rusakov, A., Sedov, S., Sheinkman, V., Dobrynin, D., Zinovyev, E., Trofimova, S., Maksimov, F., Kuznetsov, V., Korkka, M., Levchenko, S., 2019. Late Pleistocene paleosols in the extra-glacial regions of Northwestern Eurasia: pedogenesis, post-pedogenic transformation, paleoenvironmental inferences. Quat. Int. 501, 174–192. https://doi.org/10.1016/j.quaint.2018.03.020.
Sedov, S., Rusakov, A., Sheinkman, V., Korkka, M., 2016. MIS3 paleosols in the centernorth of Eastern Europe and Western Siberia: reductomorphic pedogenesis conditioned by permafrost? Catena 146, 38–47. 2016. https://doi.org/10.1016/j.catena.

2016.03.022.
Sheinkman, V., 2010. Quaternary glaciation in North-Western Siberia e New evidence and interpretation. Quat. Int. 420, 15–23.
Sheinkman, V., Sedov, S., Shumilovskikh, S., Korkina, S., Korkin, S., Zinovyev, E., Golyeva, 2016. First results from the Late Pleistocene paleosols in northern Western Siberia: implications for pedogenesis and landscape evolution at the end of MIS3. Quat. Int. https://doi.org/10.1016/j.quaint.2015.12.095.
Sher, A., Kuzmina, S., 2007. Beetle records. Late Pleistocene of northern Asia. Encycl. Quat. Sci. 1, 246–267.
Sher, A.V., Kuzmina, S.A., Kuznetsova, T.V., Sulerzhitsky, T.D., 2005. New insights into the Weichselian environment and climate of the East Siberian Arctic, derived from fossil insects, plants and mammals. Quat. Sci. Rev. 24, 533–569.
Silfverberg, H., 2004. Enumeratio nova Coleopterorum Fennoscandiae, Daniae et Baltiae. Sahlbergia 9, 1–111.
Smirnov, N.G., Bol'shakov, V.N., Borodin, A.V., 1986. Pleistocenovye gryzuny Severa Zapadnoi Sibiri. In: The Pleistocene Rodents of the North of Western Siberia. Nauka Publishers, Moscow (in Russian).
van Andel, T.H., Tzedakis, P.C., 1996. Palaeolithic landscapes of Europe and environs, 150,000-25,000 years ago: an overview. Quat. Sci. Rev. 15 (5–6), 481–500.
Van Kolfschoten, T., 2000. The Eemian mammal fauna of central Europe. Geol. Mijnbouw/Neth. J. Geosci. 79, 269–281.
Velichkevich, F., Sanko, A., Laukhin, S., Gaigalas, A., Shilova, G., Arslanov, Kh, Kuznetsov, V., Maksimov, F., 2004. Paleobotanical and paleomalacological characteristics of middle Siberia Kazantsovian interglacial according to Bedoba section data. Geologija 46, 17–26.
Volkova, V.S., Arkhipov, S.A., Babushkin, A.E., Kul'kova, I.A., Gus'kov, S.A., Kuzmina, O.B., Levchuk, L.K., Mikhailova, I.V., Sukhorukova, S.S., 2002. Stratigraphy of Oil and Gas Basins of Siberia. Cenozoic of West Siberia. SO RAN Publ., «GEO» branch, Novosibirsk 246 pp. (In Russian].
Volkova, V.S., Gurtovaya, E.E., Levchuk, L.K., 1988. Palynology of Marine Sediments of the Kazantsevo Horizon in the Lower Reaches of the Yenisei. Mikrofitofossilii I Stratigrafya Mezozoya I Kaynozoya Sibiri. Nauka Publ, Novosibirsk, pp. 36–42 (in Russian).
Volkova, V.S., Khazina, A.E., Babushkin, A.E., 2005. Stratigraphy of Pleistocene of West Siberia and Paleoclimatic Scale. «Quarter-2005» — IV Vserossiyskoye Soveshshanie Po Izucheniyu Chetvertichnogo Perioda. Materialy Soveshshaniya (Syktyvkar, 23–26 Avgusta 2006 g.). Institut geologii Komi NC UrO RAN. Geoprint Publ, Syktyvkar, pp. 77–78 (In Russian).
Walkling, A.P., Coope, G.R., 1996. Climate reconstructions from the Eemian/early Weichselian transition in central Europe based on the coleoptera record from Gröbern. Ger. Boreas 25, 145–159.
Wanamaker Jr., A.D., Kreutz, K.J., Schöne, B.R., Maasch, K.A., Pershing, A.J., Borns, H.W., Introne, D.S., Feind, S., 2009. A late Holocene paleo-productivity record in the western Gulf of Maine, USA, inferred from growth histories of the long-lived ocean quahog (Arctica islandica). Int. J. Earth Sci. 98, 19–29.
Zinovyev, E.V., 2002. Species composition and habitat distribution of herpetobiont beetles from the "Sibirskie Uvaly" Nature Park. In: Ekologicheskye issledovaniya Vostochnoy Chasti Sibirskikh Uvalov, vol. 1. pp. 104–119 (in Russian with English abstract).
Zinovyev, E.V., 2006. Problems of ecological interpretation of Quaternary insect faunas from the central part of Northern Eurasia. Quat. Sci. Rev. 25, 1821–1840.
Zinovyev, E.V., 2007. Local faunas of ground beetles (Coleoptera: Trachypachidae Carabidae) of the Mid Ob and surrounding territories. Issue 10 In: Prirodniye Resyrsy i prirodopol'zovanye. Defis Publ, Surgut, pp. 134–148 (in Russian).
Zinovyev, E.V., 2012. Entomological characteristics of Kazantsev (Eemian) interglacial deposits of the late Pleistocene from Karymkarsky sor (low reaches of Ob') in West Siberia, Russia. Euroasian Entomol. J. 11 (5), 401–409 (In Russian).
Zinovyev, E.V., Borodin, A.V., Trofimova, S.S., Sheinkman, V.S., Rusakov, A.V., Sedov, S.N., Bobkov, R.A., 2016. Late Pleistocene insect complexes (West Siberia, Vakh river) and their paleoenvironmental characteristics. Euroasian Entomol. J. 15 (5), 483–498 (In Russian).