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Paleoclimatic and stratigraphic significance of *Belgrandia marginata* (Michaud) in Late Quaternary malacofauna of Belarus and Lithuania

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ABSTRACT

The fauna and flora of each Quaternary interglacial epoch of the middle latitudes possesses general and specific connections with climate. The presence of the Atlantic and West European mollusc *Belgrandia marginata* (Michaud) is distinctive in the freshwater malacofauna of the Eemian (Muravian, Merkinė) interglacial in Belarus, Lithuania, and Poland. This species is present in eight malacofaunas of the region, with exclusively Eemian age. Paleontologic researches show that the species occupied reservoirs in this territory only during an optimum Eemian interglacial, giving it stratigraphical value in the region. The 1000 km sublatitudinal extent of the species through the Central European plain and Russian plain to the Dnieper River reflects, most likely, the direction of circulation of Atlantic air masses deep into the continent. The Eemian extent of *B. marginata* in the upstream Dnieper basin is imposed on the range of the Ponto-Caspian mollusc *Dreissena polymorpha*, which also occupied the upstream Dnieper basin only in the Eemian Interglacial. Both species are characteristic representatives of the Eemian (Muravian) freshwater malacofauna of Belarus.

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1. Introduction

Quaternary research associated with INTAS-01-0675 has allowed active geological, geochronological and malacological study of the main sections in Belarus and Lithuania. One result of this work was the recognition of the palaeoclimate and stratigraphic significance of the Quaternary exotic mollusc *Belgrandia marginata* (Michaud).

Finds of rare shells and those unknown in a certain region, as well as other palaeontological remains, always excite the interest of specialists, as they expand the variety of species, enable more detailed palaeogeographic reconstructions and, in some cases, help to correlate buried beds. *B. marginata* is one such find. The present-day habitat of this western European mollusc does not reach the area of Lithuania, Belarus, and East Europe. However, during the Quaternary Eemian Interglacial, its habitat expanded eastwards. It was detected at first in the malacofauna of Poland (Niezabitowski, 1929; Skompski, 1983) and later in Belarus (Sanko, 2004). It is natural that similar findings among the molluscs in Lithuania are also possible (Sanko and Gaigalas, 2007).

The malacological characteristics of sediments of the Lithuanian and Belarus sections with this Interglacial exotic (Fig. 1) are presented here. Conditions of formation of sediments and mollusc fauna, including palaeoclimate, stratigraphy, and ecology, are discussed.

2. Characterisation of species

The shell (Fig. 2) is small (to 2.5 mm height, 1.1 mm width). Therefore it is difficult to determine specimen ages. The shell is conic with dim cross lines (striated). The first 1.5–2 whorls are not striated, with dimple texture seen at high enlargement. There are 4.5 whorls, convex and gradually increasing, more low than broad. Its aperture is round-oval, sometimes egg-shaped or slightly square at the top. At the outer side of the aperture there is a characteristic digitate roughness parallel to the aperture margin. Niezabitowski (1929) observed up to three such riblets on the shells taken from the Eemian deposits in Poland. Shells from the Szelong section at Poznan also had a shorter whorl, and the author proposed to consider it as a variety of *Belgrandia marginata polonica*.

The species discussed belongs to a group of West European Atlantic molluscs. Its habitat is in the rivers of France and Catalonia. During the Pleistocene interglacials, it widened its area into Central Europe. It was rather widely distributed in the Waalian, Cromerian and Holsteinian interglacials in northern Europe, including the

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Fig. 1. Location of sections discussed in the text.

Rhine basin (Meijer and Preece, 1996). During the optimum of the Eemian, the habitat of the species covered the area of Great Britain, Denmark, Germany, and Poland. The regions of Belarus and Lithuanian seem to be the easternmost and northernmost margins of the habitat. A total of 39 shells of this species were detected in the Muravian interglacial deposits, borehole TI-48 near the town of Belynovichi (Sanko, 2004). In Zhukevichi at Neiman and in Netiesos (Lithuania), only 1 shell was found, in Rumlovka near Grodno 3 shells, and in Petrovshchina (Minsk), 125 shells of this species was found.

3. Malacofauna at Netiesos (Lithuania)

The interglacial deposits in the Netiesos outcrop are considered a parastratotype of the Merkinė Formation in the Quaternary stratigraphic scheme of Lithuania. They are located on the right bank of the Nemunas River at Netiesos village, about 1 km downstream of the Netiesa Brook mouth, 3 km from Jonionys–Maksimons and 6 km westwards of the Merkinė settlement, after which the Merkinė (Eemian, Mikulino, Muravian) interglacial and the formation are named.

The interglacial deposits in the Netiesos section occur at the base of the glaciofluvial terrace of the ice marginal valley of the Nemunas River. The height of the terrace is at least 20 m. The deposits of the Netiesos palaeobasin supplement the stratotype

section significantly (Kondratene, 1996). The surface of the till has traces of weathering that occurred during the Merkinė interglacial. The section of the Merkinė interglacial is represented in Netiesos by lake and bog deposits. Generally, they form lenses in a buried valley, the base of which is inside the till of the Medininkai glaciation (Gaigalas et al., 2005a).

The lower part of this thickness is concave and composed of lake sand with pebble and interlayers of sandy sapropelitic sediment. Upwards, the interglacial thickness contains organogenic sapropelitic sediments (gyttja) covered by a peat bed. The thickness of the interglacial deposits ranges from 5 to 7 m. The lake–bog interglacial deposits are covered by sand–gravel deposits, locally with boulders corresponding to the early, middle and late phases of the Nemunas (Vistulian) glaciation (Gaigalas et al., 2005a,b). The total thickness of the cover is at least 12 m. To study molluscs, 12 samples were collected from the interglacial deposits.

The numerical age of the peat cover, as determined by uranium–thorium method was found to be 105.7 ± 10.0 ka and 108.8 ± 8.7 ka (Gaigalas et al., 2005a). These dates were confirmed by dating mollusca from the same layer by ESR (101.5 ± 11.5 ka) (Gaigalas and Molodkov, 2002). The age of the molluscs dated from the lower part of the interglacial section, as determined by ESR, was 112.1 ± 25.9 ka (Gaigalas and Molodkov, 2002). The age of the Merkinė Interglacial determined by a thermo-luminescence method ranged from 135.9 to 103.2 ka (Gaigalas et al., 2005b).

Malacological investigations of the deposits from the reference section of the Lithuanian Pleistocene have been carried out in the summer of 2006 with the participation of Monika Melešytė, Sigita Budėnaitė, and Rimantas Urbonavičius. Lake–bog deposits were described, and two malacological complexes – interglacial and periglacial – corresponding to the phase of the last Middle Pleistocene glaciation have been recognized. A full list containing 37 (8 terrestrial and 29 freshwater) mollusc taxa and their distribution are given in Sanko and Gaigalas (2007).

The interglacial complex of molluscs consists, almost solely, of freshwater species. Rare terrestrial taxa (Clausiliidae gen., Limacidae gen.) suggest that the slopes of the wetland basin were overgrown by a forest. A good confirmation of this is the occurrence of tree remains with abundant fruits of *Carpinus betulus*. The base of the terrestrial malacofauna in the interglacial is formed of such euryecological species as *Valvata piscinalis* and *Bithynia tentaculata*. *V. piscinalis* is a eurytopic species able to inhabit waters of glacial and interglacial basins and streams, whereas *B. tentaculata* is a thermophilic, mainly interglacial species. This is well confirmed by the distribution of the remains of both species in the section under discussion. The appearance of *B. tentaculata* shells and opercula in the deposits (samples 9 and 10) indicates the beginning of their accumulation in this interval of the interglacial thickness. The palynological and malacological diagrams (Fig. 3a and b) show the change of the climatic conditions from late glacial to interglacial in the zone where *Gyraulus laevis* is replaced by *B. tentaculata*. The freshwater fauna of the interglacial is less differentiated quantitatively. Under lacustrine conditions, the leading role was played by *B. tentaculata*. Only in the last stage of the lake and its transition into a bog, coinciding with the beginning of the climatic optimum of the Merkinė Interglacial, was the assemblage dominated by *Gyraulus albus*.

A single shell of *B. marginata* was detected in the deposits (sample 6) corresponding to the climatic optimum of the Merkinė Interglacial. This species appeared in the first half of the *G. albus* phase. The association of thermophilic molluscs of that time (local rise of *B. marginata*) included some species of Unioidea gen., as well as *B. tentaculata* and *G. albus*.

The periglacial complex of molluscs in the Netiesos section is represented by terrestrial species, such as *Columella columella*,

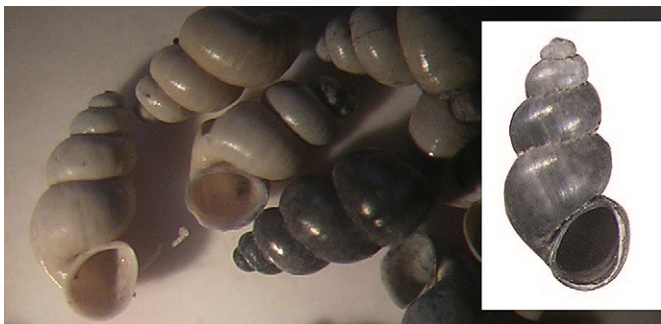


Fig. 2. *Belgrandia marginata* (Michaud) from section Petrovshchina in Minsk.

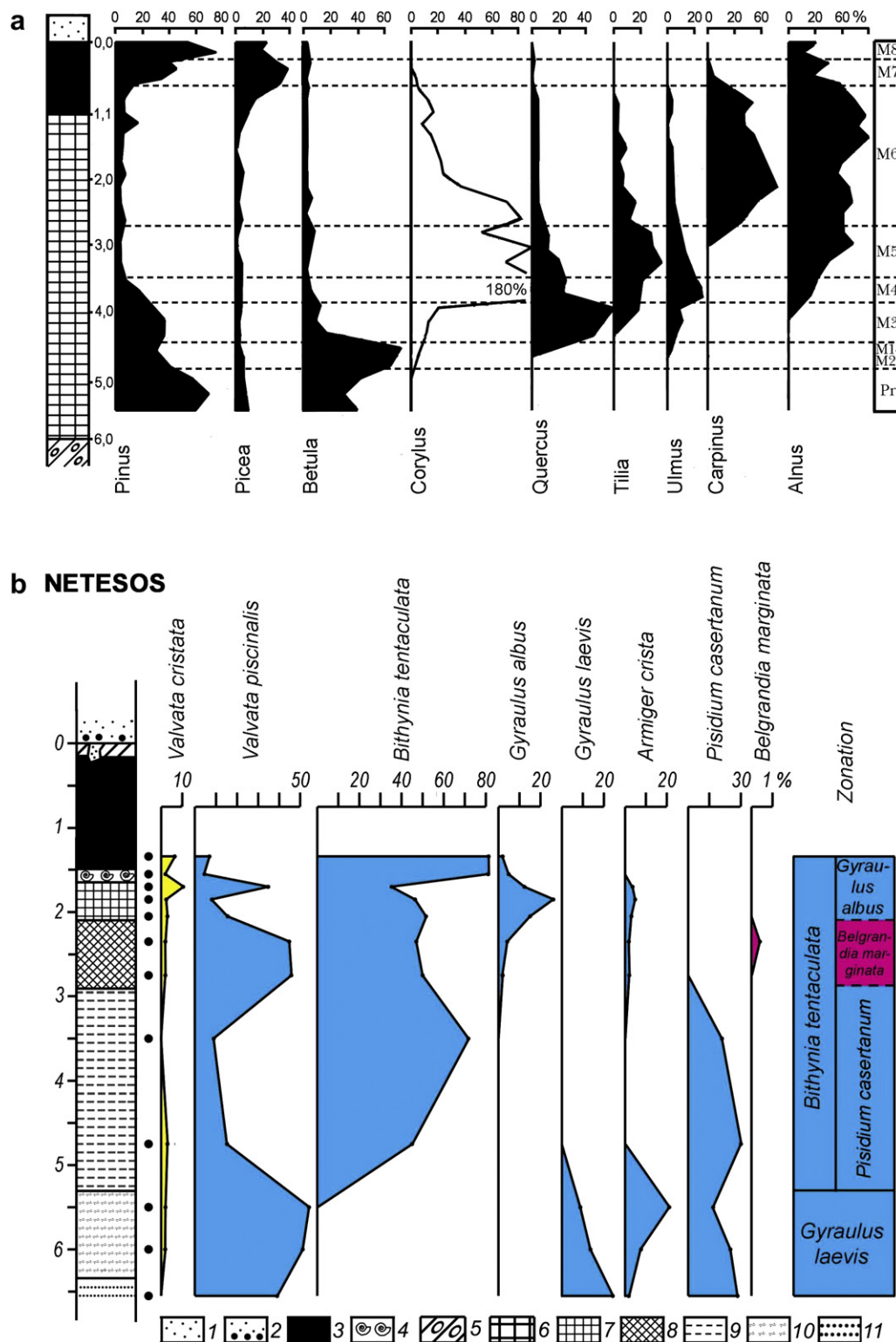


Fig. 3. Palynological (Kondratene, 1957), a, and malacological, b, diagrams of lake–bog deposits in the Netesos section: 1 – sand, 2 – sand with gravel and pebbles, 3 – peat, 4 – concentration of mollusc shells, 5 – peaty sapropelitic sediment, 6 – sandy dark grey sapropelitic sediment, 7 – silty light grey sapropelitic sediment, 8 – gyttja, 9 – sand with organics, 10 – sand with silt, 11 – decayed peat, 12 – till.

Vallonia tenuilabris, and *Vertigo genesii*. Such a combination characterises climatic conditions of a cool but not very cold stadial. All three species in the complex are absent in the present-day malacofauna of Lithuania.

4. Malacofauna at Rumlovka

The lacustrine deposits in Rumlovka near Grodno were discovered by Ludwik Sawicki. Based on preliminary palaeobotanic

analyses, Srodon (1950) assigned them to the last interglacial (Muravian, Eemian). Detailed pollen studies were conducted by Yelovicheva (2001). The floral remains were studied by Velichkevich (1982), malacofauna by Voznyachuk (1959) and Sanko (1999), and mammal remains by A.N. Motuzko. Preliminary results of these studies were presented during the "Field Symposium on Quaternary Geology and Geodynamics in Belarus" (Sanko et al., 2002). Recently, lacustrine deposits from Rumlowka were subject to diatom analysis (Marciniak et al., 2007).

The lacustrine deposits of the Muravian (Eemian) Interglacial in Rumlowka (Fig. 4) are represented by marls covered by a thin bed of clayey silts, whereas the overlying sands and sands with gravels represent (according to L.N. Voznyachuk) the highest terrace of the Niemen River from the Poozerian (Vistulian) glaciation. However,

OSL-dating of the sand with gravel, executed by M. Frechen in Hannover, has given a numerical age of 54–65 ka. Hence, the sediments belong to the Middle Poozerian (Mezhanian) megastage of last glaciations, and are not correlatable with the highest river terrace of the Niemen. This is the first numerical dating of the Mezhanian megastages sediments in Belarus. The marl deposits were sampled and measured in the Rumlowka-2 section. Pollen data from the lacustrine part of the succession indicate that the section represents only the younger part of the Muravian Interglacial (Fig. 5). Shells of molluscs are met in the marl mainly in its top part, and also in overlying sandy loams and sand approximately 24 m above normal water level in the Neiman River.

Preliminary malacofaunal data were presented in Sanko et al. (2002). As a result of additional study, the taxon list has increased,

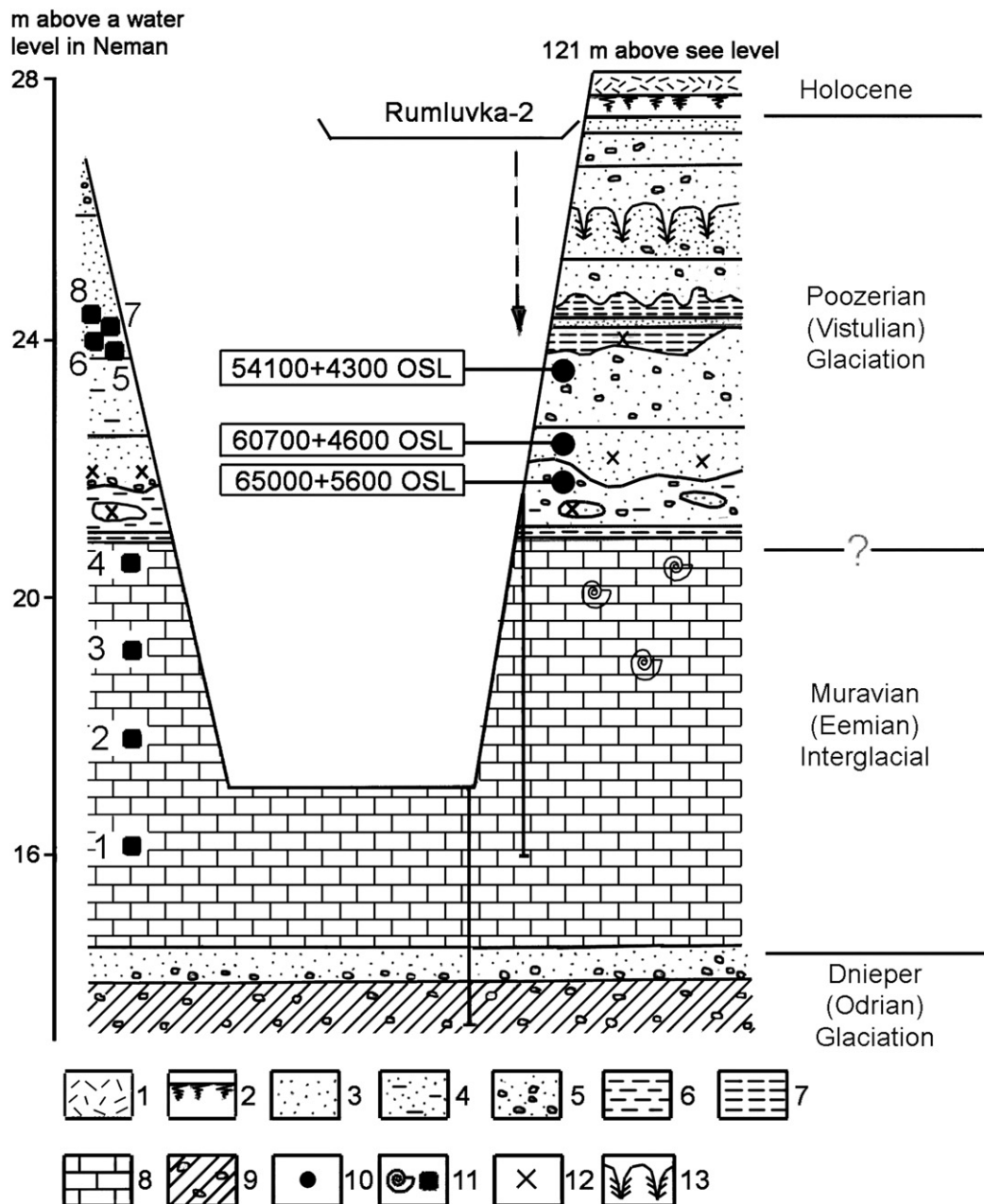


Fig. 4. Geological cross-section, Rumlowka: 1 – human-caused deposits, 2 – soil, 3 – sand, 4 – sandy silt, 5 – sand with gravel, 6 – silt, 7 – clayey silt, 8 – marl, 9 – till, 10 – OSL-date, 11 – shells of molluscs and malacological sample, 12 – remains of mammals, 13 – frost structure.

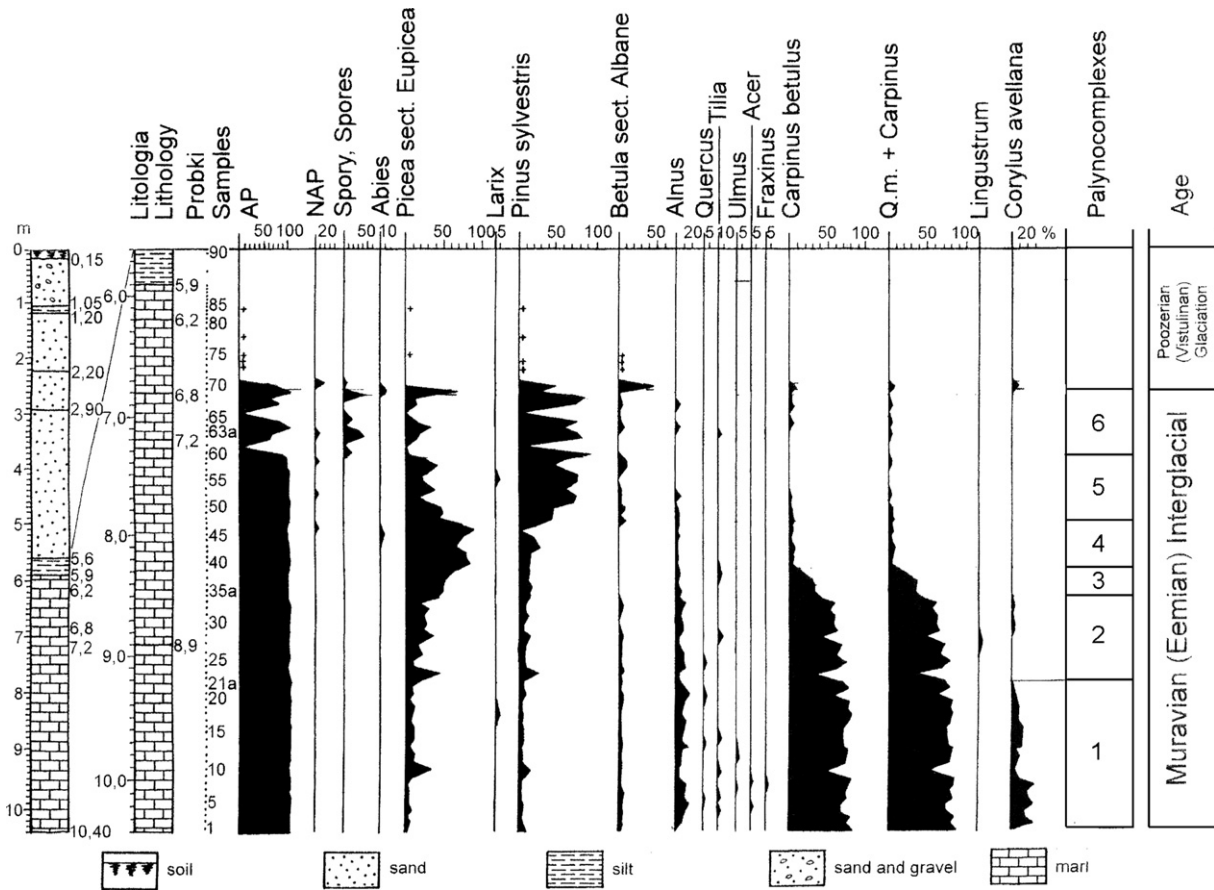


Fig. 5. Palynological diagram, Rumlovka-2.

including characteristic species of interglacial and glacial conditions (Table 1). The lesser preservation of molluscs in interglacial sediments in comparison with the glacial is caused by taphonomic conditions, mainly, the adverse geochemical environment. Nevertheless, shells of characteristic thermophilic and warm-water species are revealed in the interglacial marl. The interglacial complex includes Clausiliidae gen., *B. tentaculata*, *G. albus*, *B. marginata* and *Unio* sp. These species, as a rule, are not present in glacial fauna.

The Atlantic mollusc *B. marginata* is the most typical species of interglacial conditions. Three shells of this species are present in the uppermost interglacial marl (Fig. 6). *B. marginata* is present in the association with 14 (1 land and 13 freshwater) taxa. The ecological niches of West European species in the Rumlovka fauna are: woodland species (0.2%), hydrophiles (2.2%), lake molluscs (93.4%) and river molluscs (4.2%). *V. piscinalis*, *B. tentaculata*, *Pisidium casertanum ponderosa* and *Unio* sp. were the most frequent species. According to Skompski (1983), the species distribution was limited by a July isotherm of 18 °C.

The malacocomplex of Poozerian (Vistulian) glaciation contains indifferent and typical periglacial species. Periglacial *C. columella*, *Vertigo parcedentata*, *V. tenuilabris* represent approximately 10% of terrestrial fauna. Considering the OSL-dating, this fauna should be assigned to the oldest interstadial of the Middle Poozerian mega-interstadial, the Tursk (Moershoofd) interstadial.

The change of climatic conditions from interglacial to periglacial is appreciable not only in terrestrial, but also in freshwater malacofauna. The mainly interglacial *B. tentaculata* was replaced by *Bithynia leachi*, a lower-temperature species. A similar transformation is observed in genus *Gyraulus*, where the mainly warm-water mollusc *G. albus* was replaced by the mainly cool-water species *G. laevis*.

5. Malacofauna at Zhukevichi

Lacustrine deposits with snail shells, exposed on the right bank of the Gornitsa River (a left tributary of the Neiman), 300 m upstream from the mouth (Fig. 7), were found and studied by Polish geologists and palaeontologists (Halicki and Sawicki, 1935; Srodon, 1950; Urbanski, 1951). These researchers correlated lacustrine deposits with the Muravian Interglacial based on spore- and pollen and malacological data. The section has been studied by many Quaternary geologists and palaeontologists from Belarus and Russia. It has been recognized during this time, that not only Muravian, but also Dnieper (Upper Saalian) layers are presented in the lacustrine thickness. The Zhukevichi section is of great importance for the study of the Late-Dnieper and Muravian intervals in Belarus, because of its well-studied and representative palaeontological materials (palynoflora, seed flora, diatoms, mammal fauna, molluscs, ostracodes).

According to palynological data (Voznyachuk and Valchik, 1978), the lacustrine thickness may be divided into Muravian interglacial deposits and underlying Upper-Dnieper deposits. Two palynozones are determined in the latest interval. The lower one reflects periglacial cold-resistant and xerophyte vegetation with sparse tree communities consisting of birch and pine. The upper zone correlates with a time of distribution of fir and fir–pine–birch sparse forests within the area of study. The upper deposits (marls and sandy silts) of the Muravian Interglacial are divided into 6 local pollen zones, corresponding to the phases of development of interglacial birch, pine, oak, broad-leaf forests with hazel, as well as hornbeam–lime and hornbeam–fir forests (Fig. 8).

Table 1
Malacofauna at Rumlovka, specimens.

| Taxon | Muravian interglacial | | | | Poozerian glacial | | | |
|--|-----------------------|----|----|-----|-------------------|-----|------|------|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Clausiliidae den. | | | | 1 | | | | |
| <i>Columella columella</i> (Martens) | | | | | | | | 1 |
| <i>Vertigo parcedentata</i> (A. Braun) | | | | | 1 | | | 2 |
| <i>Pupilla muscorum</i> (Linnaeus) | | | | | 4 | 2 | 4 | 2 |
| <i>Vallonia tenuilabris</i> (A. Braun) | | | | | | 1 | | |
| <i>Vertigo alpestris</i> (Alder) | | | | | | 1 | 2 | |
| <i>Punctum pygmaeum</i> (Draparnaud) | | | 1 | | | | | |
| Limacidae gen. | | 3 | | | | | | 1 |
| <i>Succinea oblonga elongata</i> (Sandberger) | | | | | 1 | | | |
| <i>Succinea putris</i> (Linnaeus) | | | | | 2 | 8 | 11 | 36 |
| <i>Succinea elegans</i> (Risso) | | | | | | | 10 | 1 |
| <i>Valvata cristata</i> (Müller) | 4 | | | 2 | | | | |
| <i>Bithynia leachi</i> (Sheppard) | | | | | 2 | 2 | 4 | 10 |
| <i>Lymnaea ex gr. palustris</i> (Müller) | | | | | | 5 | 20 | 22 |
| <i>Lymnaea truncatula</i> (Müller) | | | | | | | | 5 |
| <i>Lymnaea peregra</i> (Müller) | | | 3 | | 7 | | | 3 |
| <i>Planorbis planorbis</i> (Linnaeus) | | | | | | 2 | 14 | 13 |
| <i>Anisus leucostomus</i> (Millet) | | | | | 1 | | 3 | 11 |
| <i>Gyraulus riparius</i> (Westerlund) | | | | 8 | | | | |
| <i>Pisidium obtusale lapponicum</i> (Sandberger) | | | | | | | 1 | 2 |
| <i>Valvata piscinalis</i> (Müller) | 31 | 8 | 7 | 245 | 579 | 424 | 930 | 2111 |
| <i>Valvata piscinalis antiqua</i> (Sowerby) | | | | 11 | 131 | 123 | 52 | 209 |
| <i>Bithynia tentaculata</i> (Linnaeus) – shells | 2 | | 5 | 5 | | | | |
| <i>Bithynia tentaculata</i> (Linnaeus) – operc. | | 4 | | 90 | | | | |
| <i>Lymnaea stagnalis</i> (Linnaeus) | | | | | 7 | 2 | 2 | 18 |
| <i>Planorbarius corneus</i> (Linnaeus) | | | | | | 1 | 3 | 5 |
| <i>Anisus vortex</i> (Linnaeus) | | | | | | 2 | 2 | 1 |
| <i>Bathymorphus contortus</i> (Linnaeus) | | | | | 3 | | 1 | |
| <i>Gyraulus albus</i> (Müller) | | | 3 | | | | | |
| <i>Gyraulus laevis</i> (Alder) | | | | | 5 | 6 | 4 | 31 |
| <i>Armiger crista</i> (Linnaeus) | | | | 2 | | | | 1 |
| <i>Sphaerium corneum</i> (Linnaeus) | | | | | 1 | 5 | 1 | 10 |
| <i>Pisidium henslowanum</i> (Sheppard) | | | | 1 | | 1 | 1 | 3 |
| <i>Pisidium milium</i> (Held) | | | | | | | | 1 |
| <i>Pisidium subtruncatum</i> (Malm) | | | | | | 7 | | 17 |
| <i>Pisidium pulchellum</i> (Jenyns) | | | | | | | | 1 |
| <i>Pisidium casertanum ponderosa</i> (Stelfox) | | 15 | | 46 | | | | |
| <i>Pisidium casertanum</i> (Poli) | | | | | | 2 | 40 | 10 |
| <i>Pisidium moitessierianum</i> (Paladilhe) | | | | 10 | | | | |
| <i>Pisidium</i> sp. | 2 | | 3 | 10 | | 5 | | 20 |
| <i>Belgrandia marginata</i> (Michaud) | | | | 3 | | | | |
| <i>Unio</i> sp. | 3 | | | 16 | | | | |
| <i>Pisidium amnicum</i> (Müller) | | | | | | 3 | 3 | 8 |
| <i>Pisidium nitidum</i> (Jenyns) | | | | | 4 | | | |
| Total | 42 | 30 | 22 | 450 | 748 | 602 | 1108 | 2555 |

According to palaeocarpological data (F. Ju. Velichkevich, unpublished), numerous remains of cold-resistant herbs are present in the lower layers of lacustrine thickness at Zhukevichi site. They are dominated by *Dryas octopetala*, *Polygonum viviparum*, and *Selaginella selaginoides*, evidence of open landscapes in the vicinity of the site, resembling the landscapes of modern tundra. This flora is known as the *Dryas* flora of the end of Dnieper Glaciation. This flora is rare not only for Belarus, but also for Europe. Upwards in the same layer, numerous remains of tree species start to occur, including *Picea obovata*, which is probably its last occurrence in the Pleistocene within Belarus. Further upwards in the section, the flora changes once again, and acquires features of typical interglacial Muravian (Eemian) flora, well studied at many other sites in Belarus and neighboring European countries.

Malacological studies, carried out in Dnieper (Saalian) periglacial and Muravian (Eemian) interglacial layers at Zhukevichi, revealed a predominance of lake molluscs (see Fig. 8), belonging to the freshwater *Piscinalis*-fauna. This fauna is evidence of the lacustrine genesis of deposits. The shells of river molluscs are found

only in one sample that indicates overflowing into the lake. Later, the lake developed as close system. In general, the Zhukevichi fauna consists of 71 taxa of terrestrial and freshwater molluscs from the Baltic sea drainage basin. An accumulation of shells of terrestrial species occurs in the bottom part. Most are representatives of cold-resistant species of tundra and tundra-steppe landscapes: *C. columella*, *Pupilla loessica*, *Pupilla densegyrata*, *V. tenuilabris*, and *V. genesii*. The shells of freshwater molluscs of mixed composition dominate upwards in the section. The shells of both tolerant and heat-loving species occur in the marl. There are rare finds of interglacial terrestrial and freshwater species: *Discus rudertatus* and *Planorbarius corneus* in this layer. An occurrence of the West European Atlantic freshwater mollusc *B. marginata* is noteworthy. The ecological niches of the species include: mesophiles (0.4%), hydrophiles (1.2%), lake molluscs (96.8%) and river molluscs (1.6%). *V. piscinalis*, *B. tentaculata*, *G. albus* and *Unio* sp. were the most frequent. The appearance of *B. marginata* in the Zhukevichi malacofauna occurred in an optimum of the Muravian interglacial, along with oak and oak-lime woods and a rich understorey with hazel (see Fig. 8).

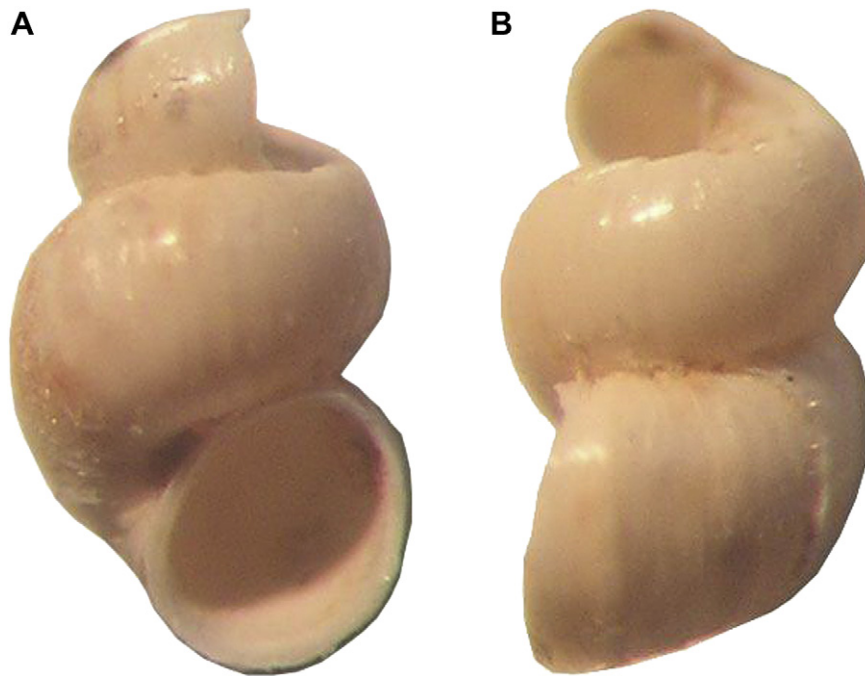


Fig. 6. *Belgrandia marginata* (Michaud) from Muravian (Eemian) interglacial sediments, Rumlovka. A: operculum view; B: side view.

Lacustrine deposits, similar to those outcropping at the Zhukevichi site, occur in the Upper Pleistocene section along the lower reach of the Gornitsa River. Most probably, the Zhukevichi and Kovaltsy sections contain sediments deposited in different parts of the same lake, which may be called the Gornitsa Lake. The length of this lake may have been more than 1 km: marls are exposed in the valley of a nameless stream 300 m eastward from the Zhukevichi outcrop, and they are also found in a borehole at Kovaltsy village. Palynological, palaeocarpological, malacological and teriofaunistic data argue for the Late Muravian age of deposits and lacustrine genesis. The lake had no connection with the river during this time. Local erosion processes, caused by active hydrodynamic conditions, took place during the Dnieper Late Glacial. These processes resulted in accumulation of sand, gravel, and shells of rheophile molluscs.

6. Malacofauna at Belynovichi

A total of 39 shells of *B. marginata* were found in sediments of borehole TL-48 (Belynovichi) in the Mogilev area. Malacofauna includes 18 taxa belonging to the Black Sea drainage basin. The sediments with shells of molluscs are deposited on a moraine and are overlain by periglacial sediments (sand, sandy loam). The section is beyond the maximum of the Last (Poozerian) glacier. Shells are more or less regularly distributed (Fig. 9). *B. marginata* does not exceed 2%. *B. marginata* together with *Dreissena polymorpha*, *Carychium tridentatum*, and *G. albus* form a complex of thermophilic species from the Black Sea drainage. The Ponto-Caspian mollusc *D. polymorpha* had an especially large concentration in the fossil malacofauna, almost never below 60%. This concentration of a warm-water mollusc indicates warm climate, corresponding to an Interglacial optimum. This mollusc has penetrated to Belarus only once in the Pleistocene, during the Muravian Interglacial (Sanko, 1999). Therefore, the age of fauna with *B. marginata* is estimated as Muravian. Humans caused a wide circulation of *D. polymorpha* to northern Europe in the Holocene and even caused penetration of this Ponto-Caspian species into North America.

The freshwater molluscs penetrated the drainage basin of the Upper Dnieper in an optimum of the Last Interglacial from the south (the Black Sea Coast), and from the west (the Atlantic Coast of Western Europe). This phenomenon indicates the warmer and

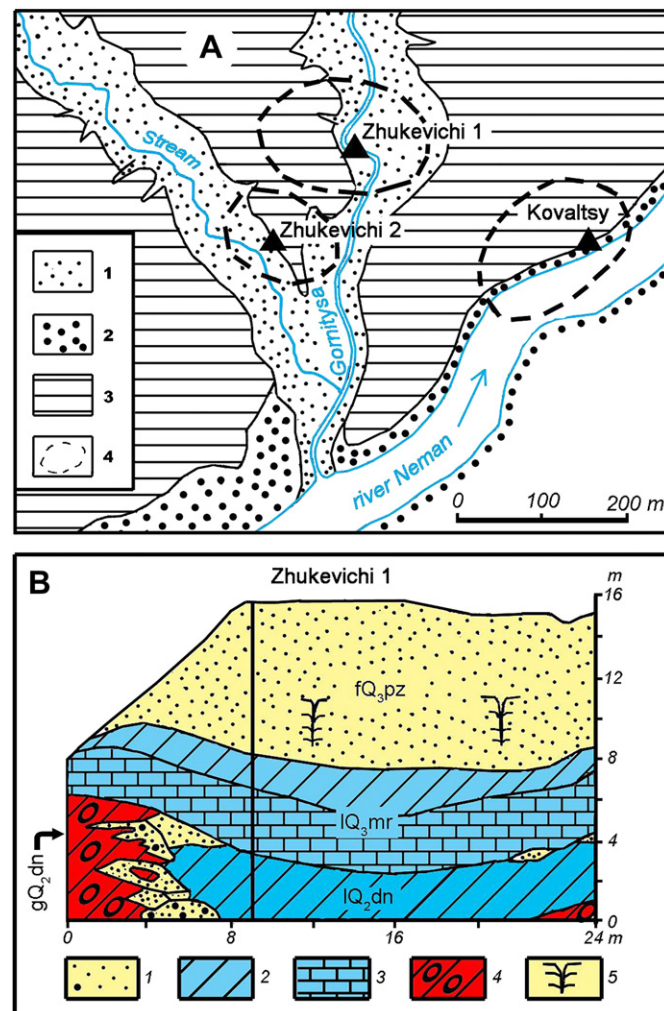


Fig. 7. A – Geomorphological sketch of the Neiman valley in the vicinity of Zhukevichi: 1 – tributary valley, 2 – Neiman valley, 3 – plateau, 4 – Eemian lakes. B – Geological section along the right bank of the river Gornitsa: 1 – sand, 2 – loam and loamy sand, 3 – marl, 4 – till, 5 – frost structure.

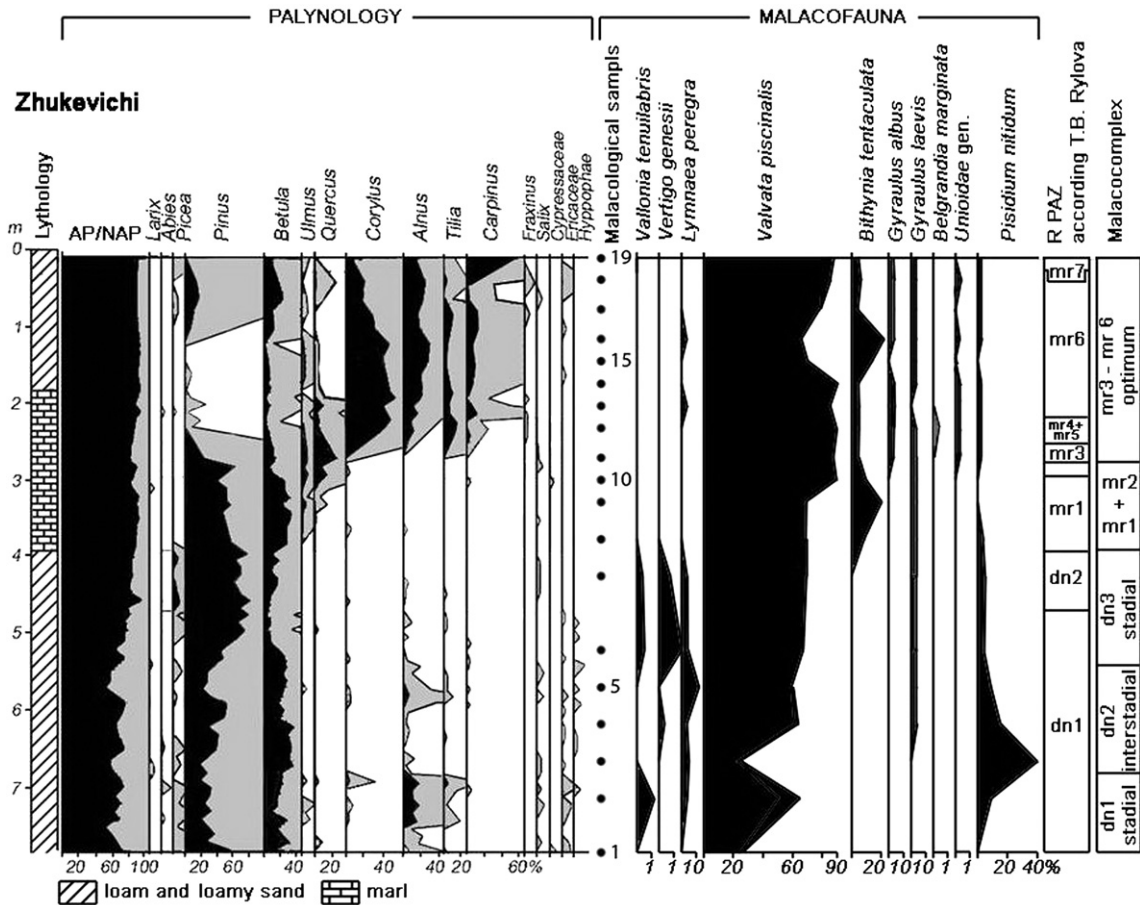


Fig. 8. Combined palynological and malacological diagram of Zhukevichi-1 deposits.

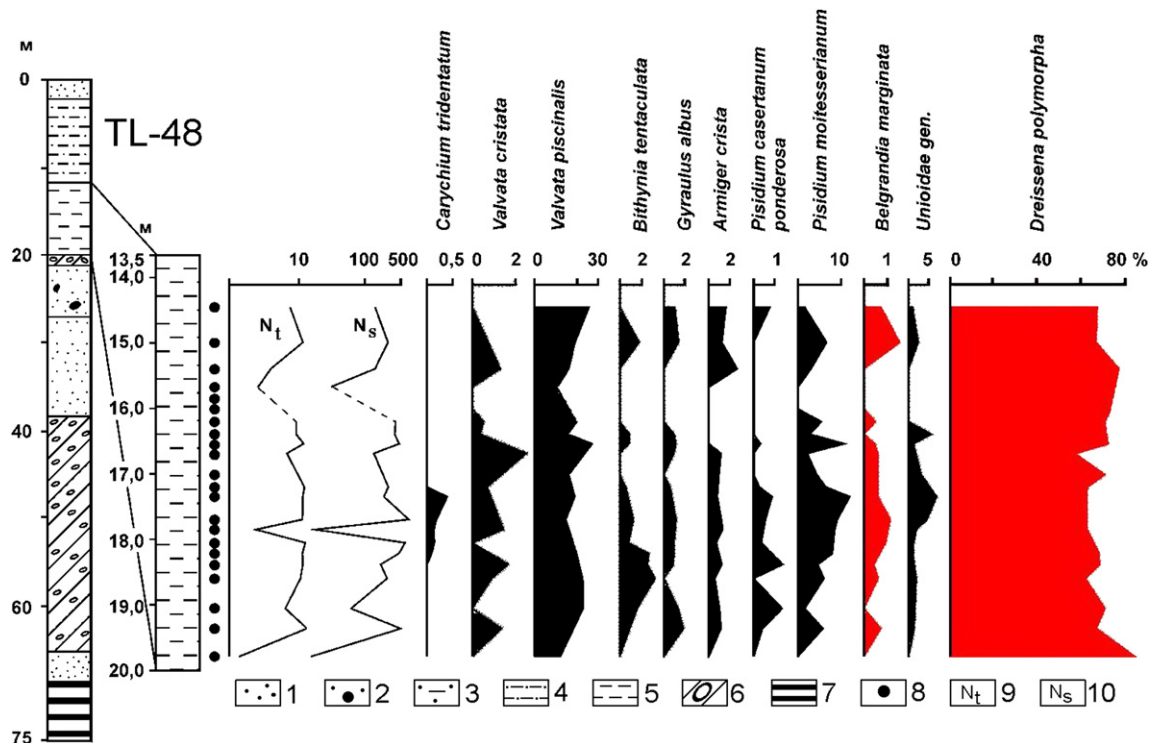


Fig. 9. Malacological diagram of the TL-48 borehole Interglacial sediments: 1 – sand, 2 – sand with gravel, 3 – sand with loam, 4 – laminated deposits, 5 – sandy loam, 6 – till, 7 – pre-Quaternary deposits, 8 – sample for malacological analysis, 9 – number of taxa, 10 – number of specimens.

Table 2
Malacofauna at Petrovshchina in Minsk, specimens.

| Taxon\sample | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|--|-----|------|-----|-----|-----|------|------|------|-----|-----|
| Limacidae gen. | 1 | 3 | | | | | | | | |
| <i>Vertigo</i> sp. | | | | | | 1 | | | | |
| <i>Valvata cristata</i> (Müller) | 25 | 21 | 13 | 1 | 13 | 15 | 14 | 102 | 137 | 55 |
| <i>Lymnaea</i> e gr. <i>peregra</i> (Linnaeus) | | 1 | | | | | | 1 | | |
| <i>Sygmentina nitida</i> (Müller) | 3 | | | | | | | 3 | 1 | |
| <i>Valvata piscinalis</i> (Müller) | 114 | 703 | 207 | 27 | 88 | 750 | 637 | 477 | 148 | 210 |
| <i>Bithynia tentaculata</i> (Linnaeus) – operculum | 3 | 21 | 9 | 1 | 5 | 32 | 38 | 65 | 22 | 13 |
| <i>Bithynia tentaculata</i> (Linnaeus) – shells | 3 | 50 | 42 | 4 | 7 | 46 | 54 | 101 | 97 | 100 |
| <i>Physa fontinalis</i> (Linnaeus) | | | | | 1 | | | | | |
| <i>Lymnaea stagnalis</i> (Linnaeus) | | 2 | 1 | | 2 | | 1 | | 2 | 2 |
| <i>Lymnaea auricularia</i> (Linnaeus) | | | | | | | | 2 | | 2 |
| <i>Anisus vortex</i> (Linnaeus) | | 1 | | | | | 2 | | | |
| <i>Gyraulus albus</i> (Müller) | 2 | 12 | 7 | 2 | | 15 | 17 | 11 | 8 | 9 |
| <i>Gyraulus laevis</i> (Alder) | 8 | 7 | 1 | | | | | | | |
| <i>Armiger crista</i> (Linnaeus) | 8 | 32 | 17 | 1 | 4 | 15 | 18 | 47 | 56 | 33 |
| <i>Acroloxus lacustris</i> (Linnaeus) | 1 | | | | 1 | 1 | | | | |
| <i>Pisidium henslowanum</i> (Sheppard) | | 2 | 1 | 1 | 2 | 12 | 6 | 19 | 8 | 1 |
| <i>Pisidium milium</i> (Held) | | | | | | | | 1 | | |
| <i>Pisidium subtruncatum</i> (Malm) | | 3 | 2 | | | | 10 | 1 | | |
| <i>Pisidium casertanum ponderosa</i> (Stelfox) | 19 | 18 | 15 | 3 | 4 | 25 | 37 | 15 | 13 | 9 |
| <i>Pisidium moitessierianum</i> (Paladilhe) | 15 | 115 | 63 | 1 | 7 | 90 | 88 | 61 | 5 | 20 |
| <i>Belgrandia marginata</i> (Michaud) | | 1 | 1 | 1 | 2 | 12 | 6 | 19 | 8 | 1 |
| Uniaecae gen. | | 5 | 2 | | | 5 | 10 | 1 | | |
| <i>Pisidium amnicum</i> (Müller) | | | | | | 1 | 1 | | | |
| <i>Pisidium nitidum</i> (Jenyns) | 10 | 5 | 4 | | | | 2 | 3 | 6 | 8 |
| <i>Dreissena polymorpha</i> (Pallas) | | 7 | 103 | 60 | 51 | 545 | 515 | 610 | 175 | 158 |
| Total | 212 | 1009 | 488 | 102 | 187 | 1565 | 1456 | 1539 | 686 | 621 |

damp climatic conditions of the Muravian Interglacial of Belarus in comparison with modern climate and even the Holocene optimum. Interpolating climatic conditions of northern France where the examined species lives to Middle Belarus suggests average temperatures for January of 1–5 °C and average July temperatures of 17–22 °C.

7. Malacofauna Petrovshchina in Minsk

Organic sediments with shells of *B. marginata* were found during building of a line of the Underground along Dzerzhinsky Prospect, at its crossing of a valley of an ephemeral stream near Petrovshchina, a southwestern suburb of Minsk. They lie in a lens over fluvioglacial sediment and a moraine, and are covered by cover loess and loess-like loams.

Shells of molluscs are present in sandy loams and gyttja. In total, 26 taxa are present, including 2 terrestrial and 24 freshwater ones (Table 2). The fauna basis is formed by lacustrine species, including

those capable of living in flowing and stagnant water. There are species of low energy flows, indicative of lacustrine currents. Current energy can be estimated by the *Bithynia-index*, related to the number of opercula of *B. tentaculata*, with increasing values indicating greater energy and consequent transport. The value of the *Bithynia-index* in the lower part of sediments is equal to 1, implying complete absence of current movement. In the overlying sandy loam, the index is 2.4, and in the gyttja from 1.4 to 7.7. This indicates substantial variability of flow in the lake, most likely a function of precipitation.

The age of fauna and sediments is defined by the presence of the two species *B. marginata* and *D. polymorpha* (Fig. 10), indicating a Muravian age (Sanko, 1999). Its wide and expanding distribution in the Holocene in Europe and North America, particularly during historical time, is caused by human migration. In essence, *D. polymorpha* is a synantropic water mollusc. It is not excluded, therefore, that this species was inadvertently transported by humans to Belarus across Pra-Dnieper in Muravian (Eemian) time.

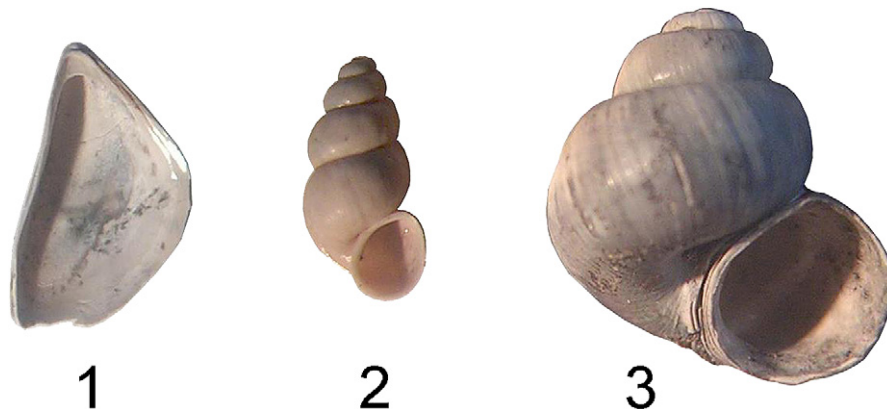


Fig. 10. Shells of *Dreissena polymorpha* (Pallas) (1), *Belgrandia marginata* (Michaud) (2) and *Valvata piscinalis* (Müller) (3) from sediments of Petrovshchina section, Minsk.

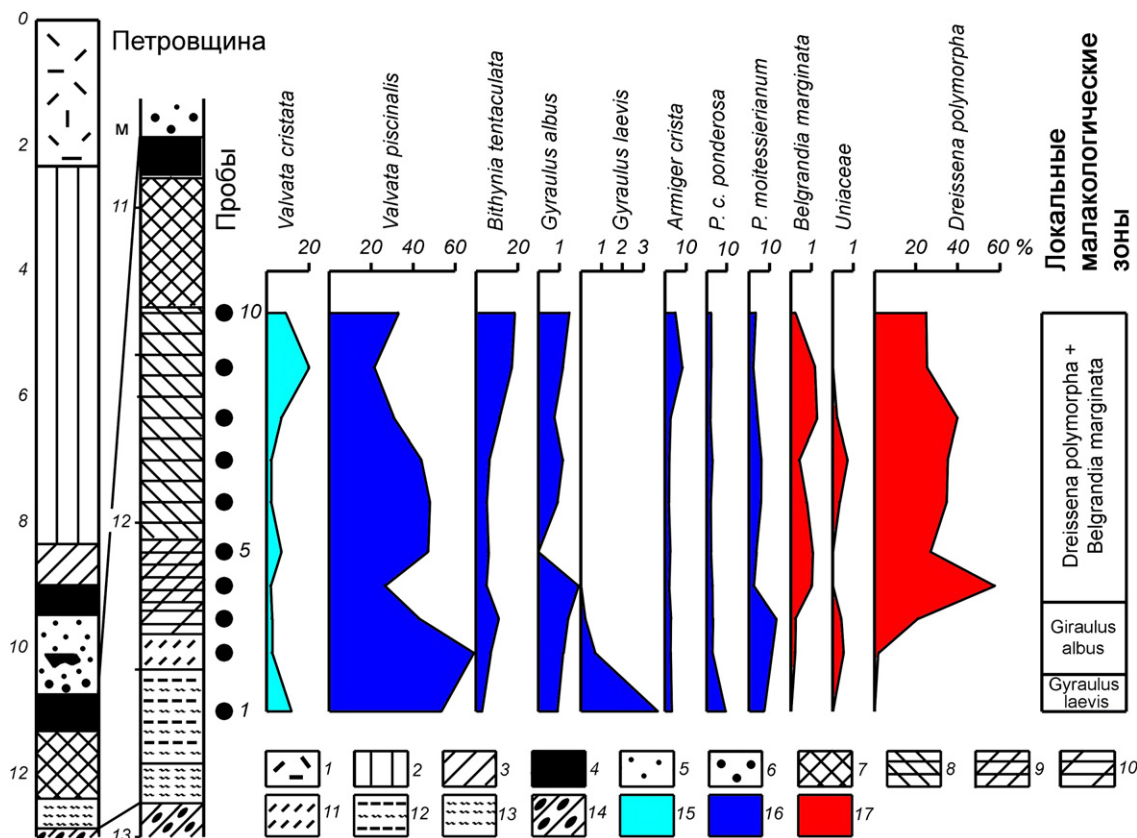


Fig. 11. Malacological diagram, Petrovshchina section: 1 – human-caused deposits, 2 – loess, 3 – loam and sandy loam, 4 – peaty gyttja, 5 – sand, 6 – sand with gravel, 7–11 – gyttja, 12 – silt, 13 – silty loam, 14 – till, 15 – hydrophiles, 16 – lacustrine molluscs, 17 – river molluscs.

The malacological diagram illustrates the distribution of basic elements of the fauna (Fig. 11). The local zone *G. laevis* is correlated to the Early Muravian Interglacial, and the local malacological zones *G. albus* and *D. polymorpha* + *B. marginata* correspond to an optimum Muravian (Eemian) interglacial. The freshwater fauna, which is a part of these zones, is the warmest-water assemblage to occupy Belarus during the Quaternary.

8. Conclusion

Two approaches – palaeoclimatic and stratigraphic – were applied to study the species of *B. marginata*. The palaeoclimatic significance of the species is due to its relationship with optimal climatic conditions of the last interglacial in Poland, Belarus, and Lithuania. According to Velichko (1973), the climatic optimum of the Mikulino (Eemian) interglacial on the Russian Plain corresponded to the most extreme climatic indices for the whole Quaternary. This conclusion recently has been confirmed. According to Skompski (1983), the spread of *B. marginata* northwards during the Polish Eemian was limited by the July isotherm of 18 °C. On the other hand, the penetration of the Atlantic mollusc far eastwards indicates the significant influence of the Atlantic marine climate during the Eemian interglacial. This influence, most probably, was stronger than that during the Holocene optimum or at present time. The stratigraphic or, to be more precise, climato-stratigraphic role of the species under discussion in the area of Poland, Belarus and Lithuania is, first of all, related to its double peculiarity as a migrant species and as an interglacial relict. *B. marginata* appeared here in the Quaternary malacofauna only once, during the warmest Eemian (Merkinė) Interglacial, and it was not observed in any other Quaternary malacofauna in the region, defining its climato-stratigraphic role. In Western Europe, where *B. marginata* is observed in malacofaunas of several interglaciations, its climato-stratigraphic significance is weaker.

The occurrence of *B. marginata* in malacofauna enables identification of the deposits corresponding to the climatic optimum of the last interglacial. In order to divide the deposits in the section according to the malacofaunal data, the whole complex of molluscs

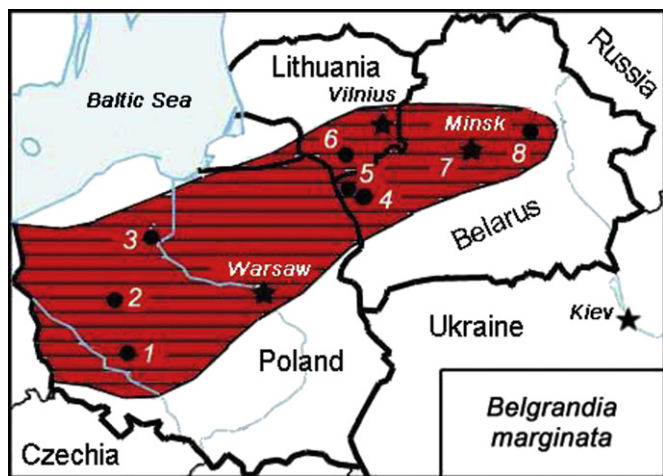


Fig. 12. Distribution of *Belgrandia marginata* (Michaud) in Poland, Belarus and Lithuanian Muravian (Eemian) interglacial: 1 – Żmigród, 2 – Szlag, 3 – Brachlewo, 4 – Zhukevichi, 5 – Rumlovka, 6 – Netiesos, 7 – Petrovshchina, 8 – Belynovichi.

should also be taken into account. The findings of fossil shells of *B. marginata* in Poland, Belarus, and Lithuania allowed stratigraphic correlation of deposits. Presently, the deposits from all seven sites are well correlated (Fig. 12). Further finds of *B. marginata* should be useful for stratigraphic identification of deposits.

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