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PALEOGEOGRAPHIC RECONSTRUCTION OF THE CONTINENTAL WATER BODIES OF UKRAINE IN THE EARLY-MIDDLE PLEISTOCENE BASED ON OSTRACODS (ARTHROPODA, CRUSTACEA)

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Paleogeographic reconstruction of the continental water bodies of Ukraine in the Early-Middle Pleistocene based on ostracods (Arthropoda, Crustacea). Dykan, N. I. — A paleogeographic reconstruction of Quaternary continental water bodies in Ukraine based on ostracods requires the data necessary for correlating the stages of development of water bodies in Eastern and Western Europe to be generalised, and synchronised with the general climatic trend of the Quaternary. A variety of methods and analyses were employed, including actualistic, quantitative modification, taphonomic, statistical, population, ecological, zoogeographical and biostratigraphic approaches. The detailed reconstruction of river and lake paleo-biotopes (type of biotope, degree of trophicity, water depth of biotope, m; water temperature, °C) in the paleo-valleys of the Zbruch, Southern Bug, Psol and Dnipro rivers during the Early to Middle Pleistocene (Calabrian – Holsteinian) has been conducted. A comparative analysis of the development of continental water bodies in Ukraine, Lithuania, Belarus and Central Russia during the Middle Pleistocene (Holsteinian) was conducted based on the results of studying freshwater ostracods of Eastern Europe. Correlating fluctuations (increases/decreases) in the water levels of paleo-water bodies located at considerable distances from each other reveals a general trend in water level changes caused by Interglacial Holsteinian climatic oscillations. It also reveals asynchrony (the partial displacement of positive and negative peaks relative to each other) and different water level fluctuation amplitudes caused by geographical zoning of the territory. According to the ostracods, the Holsteinian interglacial period had three warm stages (temperate stages I, II and III) and two cold stages (cold stages I and II). In southern water bodies (Ukraine), three stages of warming (temperate stages I, II and III) are recorded by an increase in water temperature. The first and third stages of warming (temperate stages I and III) are also recorded by an increase in water level. The second period of warming (temperate stage II) occurred during the first prolonged cold stage (cold stage I), which is indicated by rising water levels in northern bodies of water and only by an increase in water temperature in southern water bodies. Based on ostracods the timing of the formation and dynamics of a paleo-landslide in the paleo-valley of the Zbruch River during the Early Pleistocene (Calabrian) have been reconstructed

Key words: freshwater ostracods, ecology, Eastern Europe, paleoclimate, Holsteinian

Introduction

Benthic ostracods are an important source of data for paleogeographic reconstructions of ancient (continental, marine) paleobasins. A wide range of ostracod tolerance combined with a narrow ecological adaptation (stenobiont) determine their widespread geographical distribution and existence in various water bodies. Ostracods occupy different positions in food chains and have a certain ecological specialization, and the species composition of assemblages of ostracods reflects the peculiarities of their habitat in biotopes (water bodies). Fossil ostracods are numerous, sufficiently well preserved for species identification, and predominantly autochthonous in Quaternary deposits. In addition, the structure of populations (adults, larvae, females, males) is preserved in fossil ostracods, which contains information about all, even minor, changes in the aquatic environment. The analysis of the conditions of existence of recent ostracods and their extrapolation to ancient environment are based on the principle of actualism, which implies the similarity of modern and past geological events. At the same time, it is essential to take into account the natural patterns of functioning of recent biota, the cause-and-effect series of ecological laws and rules of functioning of biosystems that determine the existence and spread of recent organisms (Reimers, 1991, 1994). 97% of Quaternary ostracods continue to exist in modern ecosystems of continental water bodies and the Black Sea (Dykan, 2005, 2006, 2012, 2016).

Quaternary freshwater ostracods in Ukraine have been studied fragmentarily (Matoshko et al., 2002, Dykan, 2006). The first data included a description of the species composition of ostracods from alluvial deposits of the rivers of Western Ukraine (rivers Danube, Prut, Dniester; Schneider & Konstantinova, 1966; Negadaev-Nikonov, 1974). Since the 1990s, studies of river terraces in Western Ukraine (rivers Zbruch, Prut, Southern Bug), Northern and Central Ukraine (rivers Dnipro, Norin, Desna, Sula, Ros, Vorskla), and Southern Ukraine (rivers Danube, Berda, Molochna) new data on the biostratigraphy of Lower Pleistocene-Holocene alluvial deposits, paleogeographic reconstructions of river and lake paleo-water bodies, and the ecology of recent freshwater ostracods have been obtained (Dykan, 1994 a, b, 1995, 1996, 2001 a, b, 2003, 2008, 2014, 2015) (Fig. 1). Paleogeographic reconstruction of Quaternary continental water bodies in Ukraine based on ostracods requires generalization of numerous data necessary for correlating the stages of development of water bodies in Eastern and Western Europe and synchronization with the general climatic trend of the Quaternary.

The aim of the study was to investigate the stages of development of freshwater ostracods in the continental (river and lake) water bodies of Ukraine during the Pleistocene, the correlation with the continental paleo-water bodies of Eastern Europe, and, at the final stage of analytical generalization, the reconstruction of the climatic cyclicality of the Interglacial Holsteinian in the Holarctic zone (48–60° N).

Material and Methods

The actual material was the author's collection of fossil and recent ostracods from natural outcrops of continental water bodies of Ukraine (rivers, lakes), collected during 1981–2022 (collection no. 2061 is housed at NMNH of NAS of Ukraine; collections no. 2567, 2589, 3000 is housed at the Department of Quaternary Geology, IGN of NAS of Ukraine, Kyiv).

A wide range of methods and analyses (actualistical, modified quantitative, taphonomical, statistical, population, ecological, zoogeographical, biostratigraphical) were used in paleogeographic reconstructions of Quaternary continental water bodies based on ostracods (Dykan, 2005, 2016, 2023, 2026).. Paleontological data for other fauna groups, results of paleopedological analysis, and paleomagnetic dating were also taken into account. This allowed us to obtain a wide range of data on fossil freshwater ostracods, make biostratigraphic conclusions about the geological age of alluvial deposits and paleogeographic conclusions regarding the conditions of ostracods existence in the Early-Middle Pleistocene. The biostratigraphic division of Quaternary alluvial deposits in Ukraine was carried out in accordance with SKU (2012); chronostratigraphic correlation with general subdivisions (Series, Subseries, Stages) and regional units (Ukrainian Loess Plain Stages, North West European Stages) and their substages are given according to GTS2020 (Gradstein et.al., 2020) and Global chronostratigraphical correlation table for the 2.7 million years (Cohen & Gibbard, 2019, 2022).

Results

Lower-Middle Pleistocene alluvial deposits of river terraces in Western and Central Ukraine (rivers Zbruch, Southern Bug, Psel, Dnipro) contain ostracods diverse in genus (15 genera) and species (32 species) composition (Tables 1–2 and fig. 6, 15 see in https://doi.org/10.5281/zenodo.21918941; Paleontological tables 3–6, here and further tables see in the Appendix).

Alluvial deposits of the Lower Pleistocene (Gelasian-Calabrian)

Geological section "Scala Podilska" (profiles A, B, C), the Zbruch River (Middle Dniester River basin), VII terrace of the Dniester River basin, the southwestern part of Podolian Plateau (270 m a. s. l.), the village of Burdyakivtsi (construction quarry), Chortkiv District, Ternopil Region, Western Ukraine, coordinates 48°50′ N, 26°10′ E (Boguckyja et al., 2009) (Fig. 1, here and further pictures see in the Appendix).

In the central part of the quarry, to the right of the landslide (profile A), the following are exposed (from bottom to top): Paleozoic bedrock (Silurian: limestones, visible thickness 10.1 m, layer 1); Neogene (Middle Miocene, Langhian/Badenian; marine deposits: lithotamnium limestones, sandstones, clays, sands; total thickness 20 m, layer 2), Quaternary (Lower Pleistocene, Tiglian/Beregovian-Eburonian/Berazanian, alluvial deposits: gravelly horizon, sands, loams, thickness 6.8 m, layers 3–6; Lower Pleistocene-Holocene, Waalian/Kryzhanivian-Eemian/Prylukian, subaerial deposits: loess, paleosols, thickness 11 m, layers 7, 9; redeposited deposits of Serravalian/Sarmatian, deluvial deposits: loams, thickness 5.8 m, layer 8) (Dykan, 2008; Boguckyja et al., 2009) (Fig. 2).

Alluvial deposits lie on the lithotamnium limestones of Langhian/Badenian, overlain by the subaerial deposits of Lower Pleistocene (Waalian/Kryzhanivian). Alluvium represented by channel facies (profile A) and floodplain facies (profiles B, C) of one alluvial cycle of the Zbruch River paleovalley (Fig. 3). The Lower Pleistocene age of the alluvium was determined according to paleomagnetic (TL age), paleontological and palynological data (mollusks, plant pollen) (Dykan, 2008; Boguckyja et al., 2009). Among ostracods, the species *Limnocythere tuberculata* Negadaev, 1957 (described from Lower Pleistocene, Gelazian; Balkan Peninsula; Krstić, 1985) and *Prionocypris zenkery* (Chyzer, 1858) (described from Lower Pleistocene, Calabrian, Moldova; Negadaev-Nikonov, 1974) have biostratigraphic significance. Other species (*Cypria candonaeformis* (Schweyer, 1949), *Ilyocypris gibba* (Ramdohr, 1808), *I. bradyi* Sars, 1890) are transient in Quaternary deposits. The basal horizon (redeposited gravel of silicon, sandstone, limestone; without paleontological remains; layer 3) lies at the bottom of alluvial deposits. The time of formation of the basal alluvium refers to "...the period of development of the primary river network of the Carpathian foreland..., to the first stage of local erosion and dissection... of Carpathian gravel deposits and basement rocks" and coincides with Gelasian (Tiglian/Beregovian; Boguckyja et al., 2009: 201–202). The accumulation time of channel and floodplain alluvium facies (layers 4–6) correlates with the Lower Calabrian (Eburonian/Berezanian).

Alluvial deposits contain numerous remains of freshwater ostracods of autochthonous burial (*Ilyocypris, Prionocypris, Limnocythere, Candona, Cypria*) (Fig. 4; Table 1). The accumulation of channel alluvium (Profile A) occurred under conditions of weakening deep erosion processes, a gradual increase in channel depth and water temperature (Fig. 5). A few ostracods existed in shallow (0.3–0.5 m) riverbed biotopes on sandy substrate, with a water temperature of +(18–20) °C (layer 4). These are reophile and cryophile *Il. bradyi* (single adults and larvae; typical habitats of recent representatives of the species are flowing water bodies, cold springs, a water depth up to 0.1–0.5 m, temperature pessimum more than +(18–19) °C; Bronshtein, 1947; Kovalenko. 1976; Meisch, 2000; Fuhrmann, 2012); cryophile *P. zenkery* (single adults; recent representatives exist at water depths of up to 0.3–0.5 m, water temperature not exceeding +20 °C; Kovalenko, 1976; Meisch, 2000; Fuhrmann, 2012); eurydaphic *L. tuberculata* (single adults). The species composition of ostracods changed with the subsequent increase in water depth to 3 m and an increase in water temperature to +(23–24) °C (layer 5). Thermophile, phytophile and deep-water stenobat *C. candonaeformis* appeared and became dominant (typical biotope is slow-flowing rivers, lakes, oxbows; depth 3.0–6.0 m, water temperature +(23–24) °C, dense aquatic vegetation; Kovalenko 1987). *Il. bradyi* had the high population density (adults, larvae), and the presence of the phytophile *P. zenkery* (single adults; typical biotopes are slow streams and cold springs with dense vegetation; Kovalenko, 1976; Meisch, 2000) indicates the presence of cold springs and the development of dense bottom vegetation.

Two temporary floodplain water basins were reconstructed in the Zbruch paleovalley (Calabrian, Eburonian/Berezanian) (layer 6). The ostracod association was represented by typical inhabitants of lakes and oxbows. The first floodplain water body (lake; Profile B) was deep (up to 4 m) and warm (+23–25 °C). Thermo-phytophile *C. candonaeformis* was dominated. The few thermophile *Il. gibba* appeared (this species exists in modern water bodies at water depth of up to 1.0–1.5 m and water temperatures of up to +25 °C; Kovalenko, 1976, 1988). The second floodplain water body was shallow (up to 1.5 m; profile C), with cold springs and dense aquatic vegetation. Two species, small numbers of cold-loving phytophiles *Il. bradyi* and *P. zenkery*, existed in the marshes around cold springs (Bronshtein, 1947; Kovalenko, 1976).

Reconstruction of the dynamics and timing of paleolandslide formation in the Zbruch paleovalley (Early Pleistocene, Calabrian).

Deposits of uncertain origin (layer 8, thickness 5.8 m; Figs 2, 3) lie in the lower part of the subaerial deposits, between the loess horizon (Menapian/Ilichivian) and the paleosoil horizon (Cromerian complex, Interglacial I-II/Martonoshian). They are represented by greenish-gray loam, homogeneous, with layers and lenses of detritus, numerous paleontological remains (ostracods, unidentified fish otoliths, bryozoans, hedgehog needles, foraminifera, Miocene (re-deposited) marine and brackishwater mollusks); "... these enigmatic greenish-grey loams" (Bogutsky et al., 2009: 179). The loam have fluvial-paludic genesis and "...the functioning of a shallow lake with weak currents, fed with spring water and small streams... lake periodically dried out, and paludal deposition occurred..." (Bogutsky et al., 2009: 179). The time of loam accumulation is comparable to Bivelian/Shyrokinian (Calabrian, Lower Pleistocene). At the same time, this hypothesis does not explain the presence of marine autochthonous/synchronous ostracods, as well as other marine organisms in the oryctocenosis, according to which the age of the layer 8 loam is determined as Lower Serravallian/Sarmatian (Middle Miocene). Autochthonous ostracods account for 26% of the total number of marine Sarmatian species (*Aurila sarmatica, Haplocytheridea dacica, Hemicytheria omphalodes*, *Loxoconcha kochi*). Synchronous ostracods account for 36% of the total number of Sarmatian species (*Loxoconcha ornata, Cytheridea hungarica, Aurila cicatricosa, Pterygocythereis jonesii, Cnestocythere truncata, Loxoconcha rhombovalis, Cushmanidea lithodomoides, Callistocythere* molesta) (Dykan, 2008) (Fig. 4).

According to the analysis of the geological structure of the Podolian Plateau, the presence of a thick layer of Sarmatian deposits (5.8 m, layer 8) between the subaerial horizons of Quaternary deposits (layers 7 and 9) is, in the author's opinion, the result of an ancient landslide process in the paleovalley of the Zbruch River.

The alluvium is cut into the thickness of the plateau (270 m a. s. l.), composed in the upper part of Sarmatian deposits with a thickness of about 30–40 m. The bottom of alluviam lies at the dates 230–235 m a. s. l. and 30–35 m above the water level of the Zbruch River. That is, the close transfer of fossil remains was possible either by direct erosion of Sarmatian deposits or by deluvial processes on the slopes of the paleovalley. Pedological and sedimentological analysis of subaerial deposits of layer 7 (partially preserved Menapian/Ilichivian loess horizon and clearly eroded Waalian/

Kryzhanivian illuvial humus soil) also indicates a significant local erosion during the accumulation of loess-soil deposits (Boguckyja et al., 2009). The active development of modern landslide processes in the studied area (groundwater discharge from numerous sources occurs through Silurian and Baden limestones) is additional confirmation of the possible landslide nature of the Sarmatian deposits of layer 8 (Fig. 2).

Conclusion. The accumulation of alluvial deposits in the paleovalley of the Zbruch River was replaced by the accumulation of subaerial deposits. A suffosion slip of part of the slope composed of Sarmatian deposits occurred during the accumulation of the loam-soil complex of layer 7 (Waalian/Menapian) along the displacement surface, which was formed by plastic Sarmatian clays. The loam-soil horizons of layer 7 (Waalian/Kryzhanivian, Menapian/Ilichivian) were partially eroded during the displacement of the landslide block, therefore the time of the paleolandslide is determined by the following stage, Bavelian/Shyrokinian. The accumulation of subaerial deposits (buried soil, Cromerian complex, Interglacial I-II/Martonoshian) on the surface of the landslide body continued after the landslide (Figs 2, 4).

Alluvial deposits of the Middle Pleistocene (Chibanian)

Geological section "Medschybisch" (Medschybisch 1 "Reindeer" profile, Medschybisch "A" profile; Lower Paleolithic archaeological site, Oldovan culture of ancient man, Stepanchuk et al., 2014), the Southern Bug River, IV floodplain terrace, Podolian Plateau, town of Medschybisch, Letychiv District, Khmelnytskyi Region, Western Ukraine, coordinates 49°35′40″ N, 27°42′23″ E (Figs 1, 6).

In the geological section "Medschybisch" the following are exposed (from bottom to top): Archean bedrock (granites), Neogene marine deposits (Serravallian/Lower Sarmatian; gravel-pebble horizon, sands; visible thickness 1.2 m), Quaternary deposits (Middle Pleistocene, alluvial deposits: sands, loams, loamy sands, thickness 2.05–4.4 м; Middle Pleistocene–Holocene, subaerial deposits: loess, paleosols, thickness 3.1–5.0 m) (Matviyishyna & Karmazynenko, 2014; Dykan, 2014). Alluvial deposits lie on the weathering crust of Archean granites (Medschybisch 1 "Reindeer" profile) and marine coastal sandy-gravel-pebble deposits of the Serravalian/Lower Sarmatian (Medschybisch "A" profile), are overlain by paleosols of the Eemian/Kaydakian horizon (Fig. 7).

The age of the alluvium (Middle Pleistocene, Chebanian) was determined according to paleontological (mollusks, fish, small and large theriofauna), paleopedological, palynological, and archaeological (Lower Paleolithic hominid artifacts) methods (Medschybisch 1 "Reindeer" profile); archaeological method (Lower Paleolithic hominid artifacts) (Medschybisch "A" profile) (Stepanchuk, 2014). Ostracods are represented by transitional species from the Neogene (Middle Miocene) to modern water bodies and have no biostratigraphic significance (Table 2).

Channel facies (Medschybisch 1 "Reindeer" profile) and floodplain facies (Medschybisch 1 "Olenyachiy" and Medschybisch "A" profiles) were studied for ostracods. Ostracods are numerous and diverse in genus (*Cypria, Cyclocypris, Cypridopsis, Cyprinotus, Candona, Typhlocypris, Ilyocypris*) and species (*Il. bradyi, C. candonaeformis*, *Cyclocypris ovum* (Jurine, 1820), *Cypridopsis vidua* (Müller, 1776), *Cyprinotus salinus* (Brady, 1862), *Candona candida* (O. Müller, 1776), *Typhlocypris rostrata* (Brady and Norman, 1889). All ostracod remains have an autochthonous type of burial (Fig. 8). Two types of floodplain water bodies have been reconstructed: a periodically drained, shallow water body (Medschybisch “A” profile) and a semi-flowing lake of the oxbow type (Medschybisch 1 “Reindeer” profile) (Fig. 9).

Medschybisch “A”profile. A continuous series of Cromerian/Martonoshian–Saalian/Dnieperian floodplain facies of the Middle Pleistocene has been studied in the Medschybisch “A” profile (Figs 7, 9, 10). The floodplain alluvium of the warm stage of the Interglacial I-II, Cromerian complex/Martonoshian (layer 20, thickness 0.55 m) is represented interlayers of sandy loam, loam, red-brown, black, strongly oxidized sands; at the base by sands dark gray, clayey with pebbles and limestone fragments; paleontological remains include ostracods and archaeological artifacts. Ostracods were represented only by single adult individuals of the rheophilic and cryophile *Il. bradyi* (recent representatives of the species are few in number at depths of more than 0.5 m and temperatures above +(18–19) °C. The reconstructed biotope had a water depth slightly more than, and a water temperature above +(18–19) °C, as evidenced by the low population density and absence of larvae in *Il. bradyi*.

The floodplain alluvium of the cold stage of the Glacial b, Cromerian complex/Sulian (layer 19, thickness 0.15 m) is represented by interlayers of gray and reddish-brown sands, with pebbles, boulders, and limestone fragments; paleontological remains are ostracods. The species *Il. bradyi* was the dominant species and has the high population density (only adults; optimal habitat water depth of recent representatives is the coastal zone up to 0.5 m, water temperature is around +11–12 **°C,** and aquatic vegetation). A small number (individual specimens) of eurythermic (close to thermophilic) *C. salinus* (Brady, 1862) (the recent representatives live at water depths of up to 0.30 m, the temperature range is +11–26 **°C;** Kovalenko 1976) and eurythermic, close to cold-loving *Il. gibba* (water depth from 0.3 m to 1.0–1.5 m, temperature range +4–26 °C; Deckker, 1979; Kovalenko, 1976) have colonized the biotope. The high population density of *Il. bradyi*, the appearance of the cold-loving *Il. gibba* and the shallow-water phytophile *C. salinus* indicate that the floodplain water body has become shallower (0.1–0.5 m) and colder (+11–12 °C), and bottom vegetation developed.

The floodplain alluvium of the warm stage of the Interglacial III–IV, Cromerian complex/Lubenian (layer 18, thickness 0.60 m) is represented interlayers of gray-brown and red-brown sands, with lenses of gray clayey sand, and sandy-pebble interlayers of eroded Sarmatian deposits; paleontological remains include ostracods and archaeological artifacts (bone fragments and remains of ancient campfires). Ostracods are represented by *Il. gibba* (average population density) and the few *C. salinus*. The disappearance of the shallow-water cryophile *Il. bradyi* and the increase in the population density of *Il. gibba* (it occurs as single individuals at +20–25 **°C)** indicate a slight increase in depth (up to 1.0 m) and an increase in water temperature to +20 °C.

The alluvium of the cold stage of the Elsterian/Tiligulian (layer 17, thickness 0.15 m) is represented by a coastal channel facies (gray and light gray sands). Ostracods are absent, indicating the significant cooling and temporary disappearance of the floodplain water body.

The floodplain alluvium of the warm stage of the Holsteinian/Zavadivian (layer 16 a, thickness 0.50 m) is represented interlayers of dark gray sandy loams and gray, red-brown sands; paleontological remains include ostracods and archaeological artifacts (remains of ancient campfires). Ostracods are represented only by single larvae of *Il. bradyi*, indicating a decrease in the water depth of the biotope to 0.5 m and a decrease in water temperature to +(18–19) °C.

The alluvium of the cold stage of the Warthe Drenthe, Saalian/Dnieperian (layer 14 a, thickness 0.2 m) is represented of light gray, fine-grained sands; paleontological remains are animal bones) does not contain ostracod remains, which indicates the significant cooling and disappearance of shallow water bodies.

Conclusion. The floodplain water body was cold (water temperature ranged from +11 to 25 °C), and cold springs were developed in the coastal zone. The water body was shallow (depth ranged from 0.1 to 1.0 m) and ceased to exist during cold periods (Elsterian/Tiligulian, Warthe Drenthe Saalian/Dnieperian) (Figs 9, 10). During warm periods (Lubenian/Cromeria, Zavadivian/Holsteinian), hominid settlements were located on the water body shore (Oldowan culture of the Holsteinian/Zavadivian era; Stepanchuk et al., 2014).

Medschybisch 1 "Reindeer" profile. Floodplain facies (Holsteinian/Zavadivian) and channel facies (Warthe Drenthe, Saalian/Dnieperian) of alluvium were studied in the Medschybisch 1 "Reindeer" profile (Fig. 11). Floodplain facies (layers 15–16, total thickness 1.5 m) lie on the eroded surface of alluvial deposits is represented by light brown, iron-rich loams, with pebbles and gravel (thickness 0.1 m). Floodplain facies contain numerous paleontological remains. There are ostracods, mollusks (*Viviparus, Theodoxus, Lithoglyphus, Unio*), vertebrate bones (deer, bear, southern elephant, beaver), archaeological artifacts (stone tools and bone fragments with signs of human processing) (Matviishyna & Karmazinenko, 2014; Gozhik et al., 2014; Stepanchuk et al., 2014). The genus and species composition of ostracods is close to the ostracod associations of the Medschybisch "A" profile. Ostracods are numerous and diverse in genus (*Cypria, Cyclocypris, Cypridopsis, Candona, Typhlocypris)* and species (*C. candonaeformis, C. ovum, C. vidua, C. candida, T. rostrata*). Ostracods have autochthonous and synchronous types of burial (Dykan, 2014) (Fig. 9).

Floodplain deposits of layer 16 (thickness 1.1 m) are represented by brown, iron-rich loams and sandy loams, with gravel and pebbles, with layers of numerous horizontally oriented valves and shells of *Unio* spp. (Fig. 12). Ostracods are represented by only one species, the limno-thermo-phytophile *C. candonaeformis* (recent representatives of species are typical inhabitants of lakes and oxbows, living at water depths of 3.0–6.0 m, at a water temperature of +23–24 °C). The reconstructed biotope had a water depth of 3–6 m, water temperature of +23–24 °C, and developed dense aquatic vegetation, as evidenced by the optimal development of *Cypria candonaeformis* (high density and composition of the population, where 82% were adults and 8% were larvae of various ontogenetic stages) (Fig. 9).

Floodplain deposits of layer 15 are represented by brown iron-rich loams (thickness 0.4 m, paleontological remains include ostracods, mollusks, freshwater fish, animal bones; archaeological artifacts; Matviishyna & Karmazinenko, 2014; Gozhik et al., 2014; Stepanchuk et al., 2014; Kovalchuk & Rekovets, 2014; Dykan, 2014).

The species composition of ostracods in the bottom layer 15 (layer 15 a) indicates a decrease in a water depth and water temperature in the floodplain water body.

The biotope was colonized by a few species of similar ecological specialization – limnobians and phytophiles, resistant to a wide range of temperatures *C. ovum, C.vidua, T. rostrata*. The thermophile *C. candonaeformis* dominated in terms of abundance, but its population structure changed (ratio of aduals/larvae, 52 to 48%, respectively), indicating a deterioration in the species' habitat conditions. The water depth range in which recent representatives of species *C. ovum* (shallow drying ponds, coastal areas up to 2.0 m), *C. vidua* (up to 3.0 m), *T. rostrata* (up to 1.0 m) exist indicates a decrease in the water depth of the biotope to 1–2 m. Eurythermic, close to thermophiles species *C. ovum* (temperature range of recent representatives +14–26 °C in ponds with spring water inflow, springs, lakes) and *T. rostrata* (up to +26 °C), as well as eurythermic, close to cold-loving *C. vidua* (water temperature +8–26 °C; found throughout the year, with lower numbers in winter than in summer) are an indicator of a slight decrease in water temperature to +20–23 °C.

At the end of the Holsteinian/Zavadivian stage (layer 15 b), the floodplain lake became shallow (about 1 m) and cold (up to +16–20 °C), and a new composition of ostracod communities formed. The stenothermic, cold-loving phytophile *C. candida* of medium population density (adults, larvae) appeared (the optimal conditions for the existence of recent representatives of the species are shallow standing water bodies and shallow water bodies with cold springs, water temperature +10–16 °C, egg laying occurs at +4–10 °C, upper temperature range +20 °C). The deep-water thermophile *C. candonaeformis* reduced population density by half. *T. rostrata* increased its population density by 2 times (recent representatives are numerous in shallow waters), *C. ovum* by 4.5 times. The relatively deep-water species *C. vidua* disappeared (Fig. 9).

The alluvium of the cold Warthe Drenthe, Saalian/Dnieperian stage is represented by the coastal zone facies of the riverbed (layers 13–14, thickness 2.05 m). There are light gray, fine-grained sands, sandy loams, clays; paleontological remains are represented ostracods, mollusks, animal bones and archaeological artifacts (remains of ancient hearths). The shallow biotope of the coastal zone of the riverbed (layer 14, thickness 0.7 m) is represented by gray sands with light gray interlayers and fine grain size. The dominance and threefold increase in the abundance of the stenothermic cold-loving species *C. candida*, as well as a threefold decrease in the abundance of the thermophile *C. candonaeformis*, are clear indicators of a further decrease in water temperature to +(10–16) °C and water depth of the biotope from 1.0 m to 0.5 m.

At the end of the Saalian/Dnieperian stage (layer 13, thickness 0.5–1.35 m; interlayers light gray, iron-rich sand, with layers of clay and sand), the depth of the biotope was less than 0.5 m, and the water temperature was less than +10 °C. Only one species, *T. rostrata*, existed in the biotope in small numbers (isolated individuals). Subsequently, this section of the reservoir ceased to exist, and the ostracods disappeared (Fig. 9).

Conclusion. At the beginning of its existence, the floodplain semi-flowing lake was deep (up to 3–6 m) and warm (+23–24 °C), with undisturbed bottom sediments after their accumulation (layers 15, 16). The autochthonous type of burial of fossil ostracods, as well as the taxonomic signs of fossil mollusk remains (subhorizontal and horizontal occurrence of shells and valves of *Unio* spp., good preservation and presence of unopened shells, and the absence of sorting of remains by size confirm the calm hydrodynamic regime in the lake (Fig. 12). Subsequently, there was a gradual decrease in the depth of the water body (up to 0.3 m) and a decrease in water temperature (to less than +10 °C). During the Glacial stage of Warthe Drenthe, Saalian/Dnieperian, the water body disappeared and the accumulation of subaerial deposits began (Kaydakian/Eemian) (Fig. 13).

Geological section "Hun'ky"**,** the Psel River (left tributary of the Dnipro River), IV floodplain terrace, Dnipro Lowland, north of the village of Hun'ky, Kremenchug District, Poltava Region, Central Ukraine, coordinates 49°14' N, 33°33 'E (Fig. 1).

In the river outcrop, the following are exposed (from the water level to top): Quaternary deposits (Middle Pleistocene, Holsteinian/Zavadivian, alluvial deposits: sands, loams, loamy sands, clays, lake marl, thickness 12–16.0 m; Middle Pleistocene, Warthe Drenthe, Saalian/Dnieperian, glacial deposits, moraine, thickness 3.2 m); Middle Pleistocene–Holocene, subaerial deposits: loess, palesoils, thickness 10 m) (Fig. 14).

The age of the alluvial channel facies (Elsrerian/Tiligilian, layer 1) was determined according to mollusks (Gozhik, 2006). The age of floodplain facies (Holsteinian/Zavadivian, layers 2–10) was determined by geological methods based on the occurrence of floodplain alluvium below the moraine of the Dnieperian horizon (Saalian/Dnieperian), as well as paleontological methods according to ostracods, mollusks, and small theriofauna (Dykan, 1994 a; Gozhik, 2006; Krokhmal & Rekovets, 2010). The index species Interglacial Holsteinian/Zavadivian is the freshwater species *L. tuberculata* (Holsteinian/Saalian is the upper boundary of the stratigraphic range of this species). The geographical barrier to the eastward expansion of *L. tuberculata* was the Ural Mountains, and the ecological factor leading to its extinction in continental waters of Europe was the onset of the Glacial Saalian/Dnieperovian (Middle Pleistocene) (Dykan, 2001 a, b, 2003, 2008) (Fig. 15).

The channel facies of alluvium (layer 1, thickness 6.0–7.0 m) are represented by white, yellow, fine-grained sands, obliquely-horizontally layered and does not contain ostracod remains. Floodplain alluvium facies (layers 2–10, thickness 6.0–9 m) contain ostracods of autochthonous burial type, diverse in genus (11 genera) and species (23 species) composition (Fig. 16).

In the bottom of floodplain deposits (layer 2, thickness 0.3 m; interlayers of blue-gray and ocher-colored, fine-grained sands), ostracods are represented by 12 species, mainly limnobionts and potamobionts. The dominant species were the deep-water thermophile *Cypria candonaeformis* (water depth of 3.0–6.0 m) and the eurythermic, close to the thermophiles *Cyclocypris laevis* (O. F. Müller, 1785) (inhabiting coastal and open areas up to 3–3.5 m; optimum temperature of +20–23 °C), as well as the cold-loving, deep-water species *Darwinula stevensoni* (Brady et Robertson, 1870) (high population density at a water temperature of +11–15 °C and a water depth of 6–10 m). Low population densities (single individuals) had eurythermic, cold-loving *P. zenkeri* (temperature range from +4 °C to no more than +22 °C), *Il.bradyi* (normal development up to +12 °C; unfavorable conditions are temperatures above +18–19 °C and water depths from 0.5 m to 4.0 m), *Il. gibba* (temperature range from +4 to 19.5 °C, simple individuals are found at temperatures above

+20 °C), *Candona* (*E.*) *balatonica* Daday, 1894 (temperature range from +10.5 °C to 17 °C, water depth of 0.2–50 m), *Candona* (*E.*) *protzi* Hartwig, 1898 (temperature range from +1°C to 15 °C, water depth up to 5.0 m). Other species were also few in number. There are eurythermic *Herpetocypris reptans* (Baird, 1835), (water depth of 0.2–5.0 m); eurythermic, close to thermophiles *Candona* (*C.*) *elongata* (Schweyer, 1949) (water depth of 1–4 m) and *Limnocythere inopinata* (Baird, 1843) (temperature range from +4 °C to 28 °C, water depth of 0.7–15 m), euryhedaphic *L. tuberculata*. Analysis of the ecology ostracods (cold-loving species accounted for 50% of the total composition of the association) and dynamics of ostracod population density allows us to reconstruct the floodplain water body as relatively deep (1.5–3.5 m) and cold (water temperature +15–20 °C), with cold springs at the bottom at the beginning of its existence. The edaphic factor was unfavorable for the development of cold-loving *Candona*, active mud-dwelling organisms, in the water body (populations of species were represented by single adults and numerous larvae) (Fig. 17).

Deposits of layer 3 (thickness 0.3 m) are represented by light gray loams, iron-rich in the roof, with fragments of small shells. The species diversity of ostracods has decreased by half. Deep-water species *C.* (*C.*) *elongata* and *C. candonaeformis* have disappeared, as well as some cold-loving species (*D. stevensoni*, *C.* (*E.*) *balatonica*, *C.* (*E.*) *protzi*, *P. zenkeri*). The number of heat-loving *C. laevis* has doubled (temperature optimum of species +20–23 °C); the eurythermal, close to thermophiles *L. inopinata* has increased seven times. The decrease in the number of cold-loving and deep-water species, as well as the increase in the number of heat-loving species, indicate an increase in water temperature up to +(20–23) °C and a decrease in the water depth up to 1 m. The phytophile *Candona* (*C*) *neglecta* Sars, 1887 and *Candona* (*C*) *angulata* G. Müller, 1900 appeared, while the cold-loving phytophile *Il. bradyi* increased its population density threefold (a typical inhabitant of cold springs and marshes with high population densities), indicating the presence of cold springs and the development of dense aquatic vegetation (Fig. 17).

The deposits of layer 4 (thickness 0.2 m) are represented by ochre-yellow sand with small shell fragments and dark gray sand in the roof. Significant changes in the species composition of ostracods occurred, with species diversity doubling (13 species) (Fig. 22). Phytophile *C. candonaeformis* appeared and became dominant. Shallow-water spesies, *Ilyocypris botniensis* Kovalenko, 1976 (depth of existence no more than 1–1.5 m) and phytophile *Typhlocypris compressa* (Kosh, 1837) (high population density at depths of less than 1 m) appeared, as well as recurrent cold-loving species *C.* (*E.*) *protzi* (adults are found at water temperatures no more than +14–15 °C) and *C.* (*E.*) *balatonica* (temperature range from +10.5 °C to 17 °C). The population density of *C. laevis* has declined to a few individuals (the species is small in number at a water temperature of +14.8 °C and a water depth of more than 1 m). The relatively deep-water *Typhlocypris pratinensis* (Hartwig, 1901) has disappeared (water depth of existence from 1 m to 3–5 m). Unfavorable factors for deep-water *Candona*, active mud dwellers, were sandy substrate and shallow biotope (the number of larvae in populations doubled). These changes in the species composition of ostracods, the appearance of shallow-water and cold-loving species, and the decline in the abundance of *C. laevis* indicate an increase in water level up to 1.5 m and a decrease in water temperature up to +(10–15) °C, dense aquatic vegetation (Fig. 17).

The deposits of layer 5 (thickness 0.8 m) are represented by dark gray, homogeneous, fine-grained, clayey sands with mollusk shells. There have been minor changes in the composition of the association of ostracods (12 species). Cold-loving eurybatic species *C.* (*C.*) *angulata* (temperature range of +10–17 °C, water depth range from 0.3 m to 30 m), stenobatic *Candona* (*C.*) *iliensis* Mandelstam, 1963 (depth 3 m), relatively eurybatic *T. compressa* (recent representatives found at a water depth of up to 8 m, optimal water depth up to 1 m; temperature range of +6–26 °C, adults found at temperature not lower than +18 °C), shallow-water *Il. botniensis* (water depth up to 1–1.5 m) disappeared from the biotope. Relatively deep-water species have appeared. There are the abundant *D. stevensoni* (optimal depth of 1.6–10 m), the few species of *C.* (*C.*) *elongata* (water depth of 1–4 m), *H. reptans* (water depth of 0.2–5 m), as well as the cold-loving inhabitant of springs and streams with dense vegetation *P. zenkeri* (temperature range from +4 °C to no more than +20–22 °C). Cold-loving, more shallow-water species *Il. bradyi* (small numbers at water temperature above +18–19 °C, water depth of 0.1–4 m) and *Il. gibba* (simple individuals occur at temperature above +20 °C) reduced population densities. Cold-loving species *C.* (*E.*) *protzi* and *C.* (*E.*) *balatonica* continued to exist in the biotype, suggesting a wider range of tolerance of these species to water temperature. The species *C. laevis* (water depth up to 3–3.5 m; optimum temperature of +20–23 °C) increased population density by 20 times and was dominant in the ostracod association. The accumulation of clayey homogeneous sands of the floodplain facies occurred under conditions of further water depth increase to 1.5–4 m and a slight increase in water temperature to +19–23 °C (due to the continued existence of cold-loving species). Cold-loving species *Candona* and phytophiles *P. zenkeri*, *H. reptans* lived around cold springs among dense aquatic vegetation (Fig. 17).

Deposits of layer 6 (thickness 0.4 m) are represented by gray loam, iron-rich at the bottom, with mollusk shells. The species diversity of ostracods decreased to 9 species (Fig. 22). The number of *Candona* species decreased, while the single cold-loving, relatively deep-water species *C.* (*E.*) *protzi* increased its population density sixfold (upper temperature threshold no more than +14–15 °C; water depth up to 5 m, lower water depth threshold not defined) and became the dominant species in the ostracod association. The cold-loving *Il. brady* had a population of medium density (there is range between the temperature optimum, +12 °C, and pessimum, +18 °C for recent representatives of the species). Eurythermic, close to the thermophiles *C. laevis* (simple individuals are found at a water temperature of +14.8 °C and a water depth of more than 1 m), as well as the thermophile and deep-water *C. candonaeformis* (water temperature of +23–24 °C, water depth of 3–5 m) have reduced their numbers to a few individuals. Cold-loving species *Cyclocypris globosa* (Sars, 1862) (temperature range of recent representatives of +4–18 °C) and *Eucypris* sp. (most species of the genus *Eucypris* are cold-loving) have appeared. These changes in the species composition and density of ostracod populations indicate a slight decrease in the water depth of the water body to 1–3 m and a sharp decrease in water temperature to +12–15 °C (Fig. 17).

The alluvial facies (layer 7, thickness 1.4 m) are represented by lake marl (gitya) dark gray to black, carbonaceous, with a large amount of organic matter, covered with light gray marl with numerous remains of mollusks and small mammals;

Gozhik, 2006; Krokhmal & Rekovets, 2010). Ostracods had low species diversity (7 species in the bottom of layer 7a, two species in the upper part of layer 7 b). The biocenosis was formed mainly from few, cold-loving and shallow-water species *Il. bradyi, Il. gibba, Typhlocypris insculpta* (G.Müller, 1900) (adults are found at +18–23 °C, water depth up to 0.4 m), *Cyprinotus vassoevichi* Schneider in Bodina, 1961 (recent representatives of the genus *Cyprinotus* inhabit the coastal zone of water bodies up to 0.5 m), the relatively eurybiont *T. compressa*, and the relatively deep-water *C.* (*C.*) *iliensis*. With the gradual shallowing of the water body and a decrease in water temperature, the number of *C.* (C.) *iliensis* larvae decreased, and the thermophiles and deep-water species of the genera *Limnocythere*, *Cypria* and *Candona* disappeared. In the lake marl roof (layer 7 b), ostracods were represented by only two species, namely the few *Denticulocythere dorsotuberculata* (Negadaev, 1957) and Il. *bradyi* with medium population densities (more numerous than in the ostracod association of layer 6). The reconstructed waater depth of the water body was up to 0.1 m, and the water temperature was +11–12 °C (Fig. 17).

The clay layer above (layer 8, thickness 0.1 m) does not contain any ostracod remains.

The deposits of layer 9 (thickness 0.4 m) are represented by gray sandy loam with a micro-layered subhorizontal texture at the bottom, with mollusk shells. The species diversity of ostracods increased to five species. Thermophilic, deep-water, few (single individuals) species *C. candonaeformis*, *L. inopinata*, as well as relatively eurythermic, shallow-water *Il. gibba* (single individuals at +20 °C and above, water depth up to 1.0–1.5 m) appeared. The reconstructed biotope was warm (the water temperature rose to +18–26 °C), and the water depth increased to 1.5 m (Fig. 17).

During the accumulation of layer 10 deposits (thickness 0.4 m; interlayering of light gray silt and gray, fine-grained, finely subhorizontal layered sand), rapid shallowing and a decrease in water temperature occurred, and ostracods disappeared from the biotopes.

Rapid shallowing and a decrease in water temperature occurred during the accumulation of deposits of layer 10 (interlayering of light gray siltstone and gray sand, fine-grained, with subhorizontal thin layering, 0.4 m thick), which led to the disappearance of ostracods. Later, the floodplain water body ceased to exist.

Conclusion. The floodplain water body that existed in the paleovalley of the Psel River during the Zavadivian/Holsteinian had an unstable hydrodynamic regime with periodic fluctuations in water depth and temperature (Figs 17, 18):

1. At the beginning of its existence, the water body was relatively deep (1.5–3.5 m) and cold (water temperature did not exceed +15–20 °C), with sparse vegetation or none at all, with outflows of cold spring waters (layer 2).

2. The subsequent shallowing of the water body (to 0.1–1 m) was accompanied by an increase in water temperature to +(20–23) °C, the dense aquatic vegetation developed, cold springs existed (layer 3).

3. The next stage was a gradual increase in water depth from 1–1.5 m (layer 4) to 4 m (layer 5), accompanied initially by a significant decrease in water temperature to +10–15 °C (layer 4), and then an increase in water temperature to +19–23 °C (layer 5).

4. At the next stage, the depth of the reservoir decreased from 1–3 m (layer 6) to 0.1 m (layer 7 b), and the water temperature decreased from +(12–15) °C (layer 6) to +11–12 °C, layer 7 b).

5. At the final stage of its existence, the water body became deeper (0.5–1.5 m) and warmer (water temperature rose to +18–26 °C, layer 9).

6. The subsequent rapid shallowing and decrease in water temperature led to the disappearance of ostracods (layer 10), and the disappearance of the floodplain water body. Subsequently, the floodplain ceased to exist.

Geological section "Melnyky", left bank of the Dnipro River, IV floodplain terrace, Dnipro Lowland, Melnyky village, Tscherkassy District, Tscherkassy Region, Central Ukraine, coordinates 49°18' N, 32°17' E (Fig. 1).

The river outcrops, the following are exposed (from the water level to top): Quaternary deposits (Middle Pleistocene, Holsteinian/Zavadivian: alluvial deposits, layers 1–2, total thickness 1,8 m: channel facies, layer 1, sands, thickness 1.4 m; floodplain-type soil, layer 2, thickness 0.4 m); lake deposits, layers 3–8, siltstone, total thickness 10.2 m; Middle Pleistocene, Warthe Drenthe, Saalian/Dnieperian, glacial deposits, layer 9, moraine, thickness 11.4 m; Holocene, subaerial deposits, layer 10, modern soil, thickness 0.3 m) (Fig. 19). Ostracods are fragmentarily distributed in the vertical section of alluvial and lake deposits, absent in alluvial deposits (layers 1–2) and lake deposits (layers 3, 8) and numerous and diverse (8 genera, 10 species) in lake deposits (layers 4–7), (Dykan, 1994 b) (Fig. 20).

The age of lake facies (Holsteinian/Zavadivian) was determined by geological methods based on the occurrence lake deposits (layers 3–8) of below the moraine of the Dnieperian horizon (Saalian/Dnieperian, layer 9). In the Melnyky and Hun'ky sections, common species account for 50%. Recent representatives of fossil ostracods in the Melnyky section account for 30% of the total number of species, in the Hun'ky section – 13%, which allows us to consider the time of accumulation of lake sediments in the Melnyky section to be younger than the alluvial deposits of Hun'ky section and assign them to the second half of the Holsteinian/Zavadivian (Tables 1, 2). The considerable thickness of lake deposits (10.2 m), homogeneity of lithological composition and textural features (siltstones are homogeneous, thinly layered) indicate the stability of sedimentation conditions in the paleo-water body and its considerable water depth. The "lake" type of ostracods, where 50% are limnobionts, typical inhabitants of lakes and other permanent standing water bodies (*Physocypria fadeevi* Dubowsky, 1927, *C.* (*E.*) *balatonica*, *H. reptans*, *C. laevis*, *T. compressa*), allows us to reconstruct the paleo-water body as a large drainless lake. Fossil ostracods and other flora and fauna remains are absent in the lower part of the lake deposits (layer 3, thickness 5.8 m), indicating extremely unfavorable conditions for the development of organic life in the lake at the beginning of its existence (low water temperature, great depth of the reservoir, absence of aquatic vegetation.

The first ostracods to colonize the water body (layer 4) were the cold-loving species *C.* (*E.*) *balatonica* (inhabiting large standing water bodies, water temperature of +10.5–17 °C, water depth of 0.2–5 m, optimal habitat being the coastal shallow zone less than 1 m). The presence of only a few larvae in the populations indicates that conditions are still unfavorable for the ontogenesis of *C.* (*E.*) *balatonica* (the water temperature was slightly above +10 °C, and the depth of the biotope was about 5 m) (Fig. 21).

In the overlying deposits (layer 5), the diversity of ostracods increased significantly (5 genera, 6 species). The water body was colonized by the dominant, thermophile and phytophile *T. compressa* (adults are found at water temperature not lower than +18°C and are numerous in shallow areas of standing water bodies up to 1 m deep); a few (single adult) species of *C. laevis* (single individuals at water depths more than 1 m and water temperature of +14.8 °C) and the phytophile *H. reptans* (water depth of 0.2–5 m). The conditions for *C.* (*E.*) *balatonica* remained unfavorable and numerous larvae prevailed in the populations. Changes in the species composition of ostracods and the presence of hytophiles indicate the appearance of aquatic vegetation, an increase in water temperature (up to +18–20 °C) and a decrease in depth to (at least) 1 m (Fig. 21).

The next stage of the paleolake's development (layer 6) was favorable and optimal for ostracods, which increased their genus and species diversity (8 genera, 10 species). Numerous phytophile *P. fadeevi* and few (single individuals) eury-edaphile *L. inopinata* (water depth of 0.7 –15 m) appeared. The species *T. compressa* and *C.* (*E.*) *balatonica* increased the population density (adults and larvae) threefold, *C. laevis* (numerous at a water temperature of +20–23 °C) doubled, *Paralimnocythere originalis* (Negadaev, 1965) increased fivefold, and *H. reptans* increased 13-fold. These changes among ostracods indicate an increase in water temperature to +(20–23) °C and a subsequent decrease in water depth to 0.7–15 m, as well as the development of dense bottom vegetation (Fig. 21).

In the overlying deposits (layer 7) the species *L. inopinata* and *P. fadeevi* disappeared. The population density of *T. compressa* and *C.* (*E.*) *balatonica* decreased by 6 times, the species *P. originalis* by 2.5 times, and the species *H. reptans* by 0.5 times. *C. laevis* remained the dominant species in the ostracod association. These changes in the association were caused by further shallowing of the lake up to 0.2 m and a decrease in water temperature up to +(15–17) °C. There are no ostracods in the overlying sediments of layer 8 (Fig. 21).

Conclusion. The trend of lake development in the Dnipro paleovalley during the second half of the Interglacial Holsteinian/Zavadivian was as follows (Figs 21, 22):

1. The paleo-water body was a large, drainless, deep lake. At the early stage of its existence, the lake was very cold (less than +10 °C) and deep (significantly more than 5 m), without aquatic vegetation, undeveloped or extremely poor in organic life (ostracods did not inhabit the lake either). The few cold-loving Candona were the first ostracods to colonize lake biotopes (the water depth of the reconstructed biotope was about 5 m), with a water temperature slightly above +10 °C; layer 4);

2. The depth of the water body continued to decrease and amounted up to (at least) 1 m, the water temperature rose up to +18–20 °C, and aquatic vegetation developed. The diversity of ostracods increased (layer 5);

3. The next stage was optimal for the development of ostracods. The water body was warm (the water temperature rose to +20–23 °C), shallow (the water depth decreased to 0.7–1 m), with dense aquatic vegetation. Various and numerous ostracods, limnobionts, and phytophiles gradually colonized the water body (layer 6);

4. Further shallowing up to 0.2 m and a sharp decrease in water temperature up to +15–17 °C became pessimistic factors for the existence of ostracods in shallow, cold water bodies with sparse aquatic vegetation and led to a reduction in population size and a decrease in ostracod species diversity (layer 7);

5. At the final stage of its existence, the paleo-lake became very cold and shallow, and the bottom vegetation disappeared, leading to the extinction of all ostracods. At the end of the Holsteinian/Zavadivian period, the water body disappeared.

Discussion

The Interglacial Holsteinian/Zavadivian was the most optimal period in the development of freshwater ostracods in Ukrainian water bodies during the Quaternary. A certain regularity in the change of ecological groups of fossil ostracods is recorded in the vertical sections of alluvial deposits of the Dniester, Southern Bug, Dnipro, and Psel rivers, which correlates with the periodicity of fluctuations of abiotic parameters (water depth, water temperature) in river paleo-water bodies in the Holsteinian/Zavadivian. Reconstruction of water depth based on quantitative and qualitative analysis of fossil ostracods in adjacent territories of Eastern Europe (Lithuania, geological section "Nyaravai"; Belarus, sections "Matveev Rov," "Kolodyazhny Rov"; Russia, "Likhvin" section) in Holsteinian/Zavadivian was carried out by S. Zubovich (1978; analysis of paleowater temperature was not performed). The correlation of the depth fluctuation curve of water bodies (water level rise/fall) located at considerable distances from each other records the general trend of water level changes caused by the Interglacial Holsteinian/Zavadivian climate oscillations. Asynchrony (displacement of positive and negative peaks relative to each other) and differences in the amplitude of water level fluctuations in paleo-water bodies of Eastern Europe are determined by the geographical zoning of the studied territory. According to the results of paleogeographic reconstruction of continental water bodies in Ukraine and Eastern Europe (N 48–60°) based on ostracods, the Interglacial Holsteinian/Zavadivian had three temperate stages (temperate I, II, III) and two cold stages (cold stage I, II). In southern water bodies (Ukraine), three stages of warming (temperate stages I, II, III) are recorded by an increase in water temperature, and the first and third stages of warming (temperate I, III) are also recorded by an increase in water level. The second warming (temperate stage II) occurs during the first prolonged cold stage (cold stage I) and is marked by a rise in water levels in northern water bodies and an increase in water temperature in southern water bodies (Fig. 23). The conclusion regarding climate oscillations in Holsteinian/Zavadivian (moderately warm, close to subtropical climate with short cool and warmer periods) was also made based on other paleontological data (theriofauna, Rekovets et al., 2014; freshwater fish, Kovalchuk & Rekovets, 2014; mollusks, Gozhik et al., 2014) and paleopedological data (Matviishina & Doroshkevich, 2014).

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Appendix

Fig. 1. Map-scheme of the study of alluvial deposits of rivers in Ukraine: 1 — Zbruch River, seventh floodplain terrace of the Dniester basin, Burdyakivtsi village, cross-section “Scala Podilska”, Ternopil Region, Lower Pleistocene, Gelasian (Tiglian/Beregovian) — Calabrian (Eburonian/Berezanian) (Dykan, 2008); 2 — Lower Danube, Lake Kahul, fifth floodplain terrace of the Danube River, Nagorne village, Odesa Region, Middle Pleistocene, Chibanian (Cromerian complex, Interglacial III-IV/Lubenian) (Dykan, 1995); 3 — Lower Danube, Lake Yalpukh, fourth floodplain terrace of the Danube River, Oserne village, Odesa Region, Middle Pleistocene, Chibanian (Holsteinian/Davnievksinian) (Dykan, 1995, 2001 a, 2003, 2006); 4 — Psel River, fourth floodplain terrace of the Dnipro River basin, Hun’ky village, cross-section “Hun’ky”, Poltava Region, Middle Pleistocene, Chibanian (Holsteinian/Zavadivian) (Dykan, 1994 a, 2001, 2006); 5 — Dnipro River, fourth floodplain terrace, Melnyky village, cross-section “Melnyky”, Cherkasy Region, Middle Pleistocene, Chibanian (Holsteinian/Zavadivian) (Dykan, 1994 b, 2001, 2006); 6 — Southern Bug River, fourth floodplain terrace, Medschybisch town, cross-section “Medschybisch”, Khmelnytskyi Region, Middle Pleistocene, Chibanian (Holsteinian/Zavadivian) (Dykan, 2014, 2015); 7 — Molochna River, fourth floodplain terrace, Molochna village, Zaporizhzhia Region, Middle Pleistocene, Chibanian (Holsteinian/Zavadivian) (Dykan, 1996, 2006); 8 — Berda River, fourth floodplain terrace, Ossypenko village, Zaporizhzhia Region, Middle Pleistocene, Chibanian (Holsteinian/Zavadivian) (Dykan, 1996, 2006); 9 — Dnipro River, third floodplain terrace, Vyschenky village, Kyiv Region, Late Pleistocene (Eemian/Kaydakian) (Dykan, 2006); 10 — Dnipro River, second floodplain terrace, Stare village, Kyiv Region, Late Pleistocene (Eemian/Prylukian) (Dykan, 2006); 11 — Dnipro River, second floodplain terrace, Trypillja town, Kyiv Region, Late Pleistocene (Eemian/Prylukian) (Dykan, 2006); 12 — Molochna River, second floodplain terrace, Kostjantynivka village, Zaporizhzhia Region, Late Pleistocene (Eemian/Prylukian) (Dykan, 2006); 13 — Noryn’ River, a left tributary of the Uzh River, the first floodplain terrace of the Prypjat River basin, Sorokopen village, Zhytomyr Region, Late Pleistocene (Weichselian/Prychernomorsk) (Dykan, 2006); 14 — Sula River, the first floodplain terrace of the Dnipro basin, Lubny city, Poltava Region, Late Pleistocene (Weichselian/Prychernomorsk) (Dykan, 2006); 15 — Ros River, the first floodplain terrace of the Dnipro River basin, Maslivka village, Kyiv Region, Late Pleistocene (Weichselian/Prychernomorsk) (Dykan, 2006); 16 — Desna River, a left tributary of the Dnipro, modern floodplain, Slabyn village, Zhytomyr Region. Holocene (Dykan, 2006); 17 — Dnipro River, Kaniv Reservoir, modern floodplain, Lyplyave village, Cherkasy Region, Holocene (Dykan, 2006); 18 — Vorskla River, left tributary of the Dnipro, modern floodplain, Krotenky (Semenivka) village, Poltava Region, Holocene (Dykan, 2006); 19 — Prut River, modern floodplain, Kolomyia, Ivano-Frankivsk Region, Holocene (Dykan, 2006)

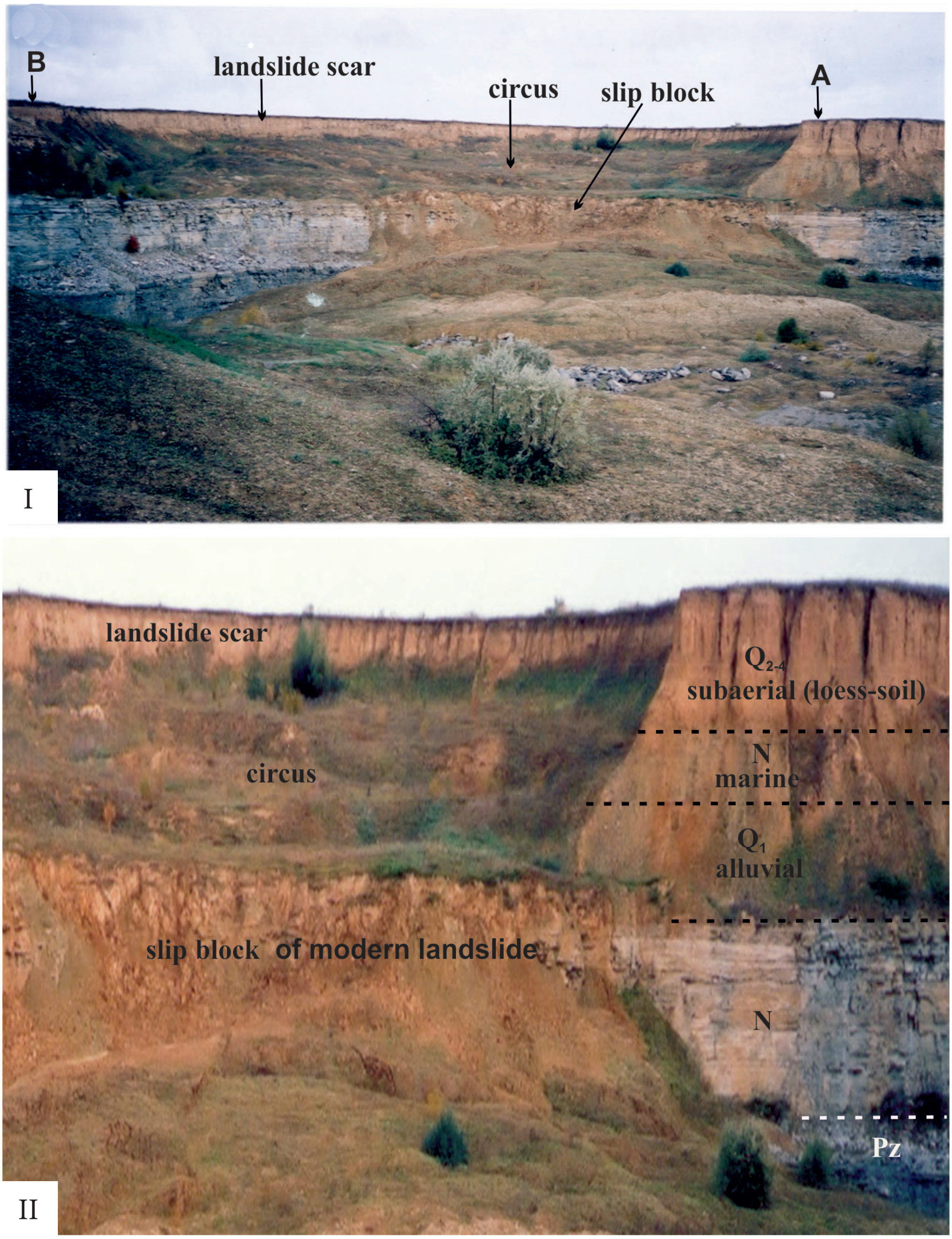

Fig. 2. Geological section “Scala Podilska” (Profiles A, B): I — modern landslide in the central part of the quarry; II — location of the main profile A (Zbruch River, Western Ukraine) (photo courtesy of A. Bogutskyi)

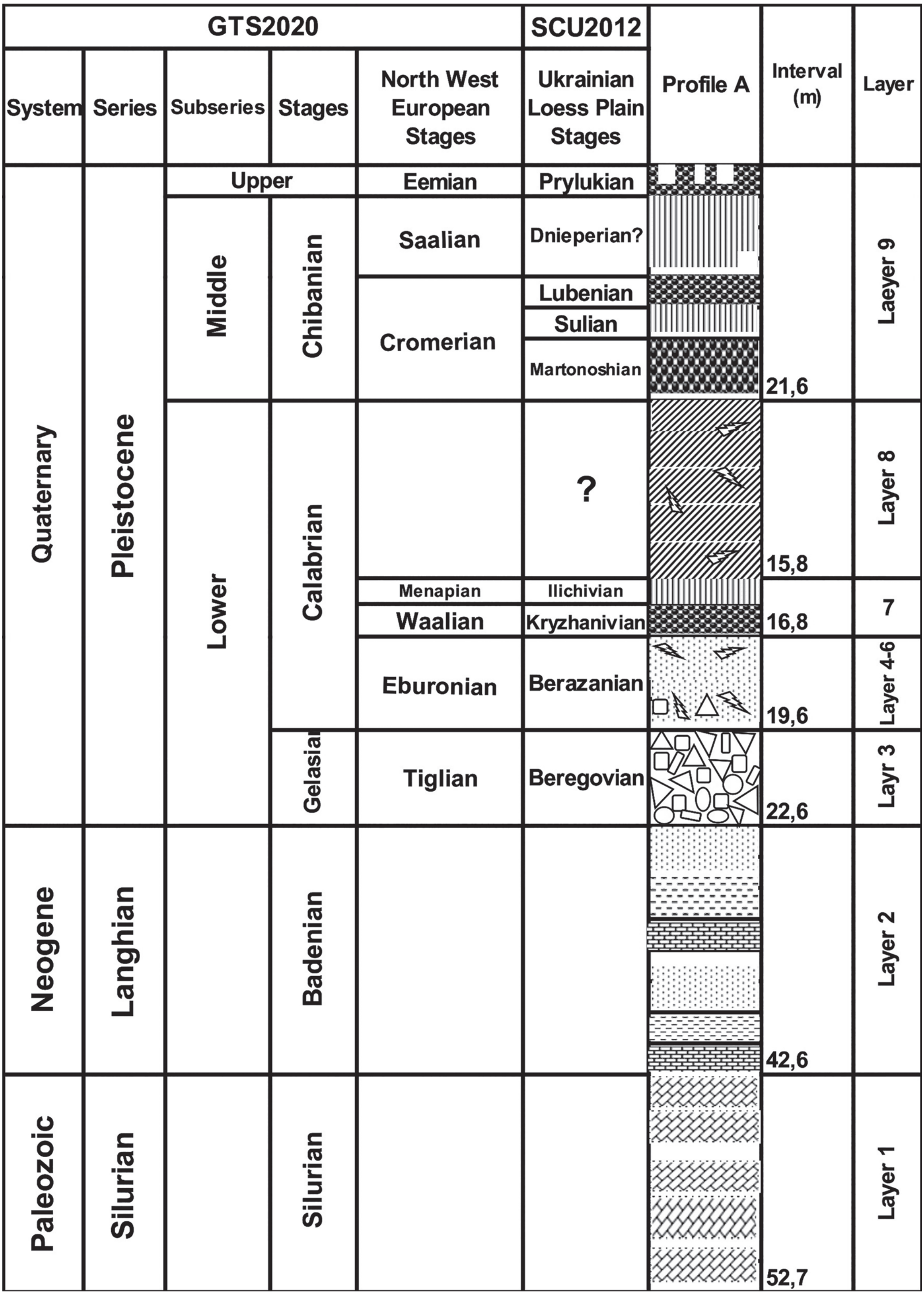

Fig. 3. Geological structure of the Paleozoic-Quaternary deposits of the "Scala Podilska" section (Profile A). Conventional notation: 1 — gravel deposits of basal alluvium; 2 — pebbles, gravel; 3 — modern soil; 4 — paleontological remains; 5 — paleosoil; 6 — loam, 7 — limestone, 8 — sandstones, 9 — sand, 10 — clay, 11 — loess; 12 — moraine; 13 — silt; 14 — loamy sand

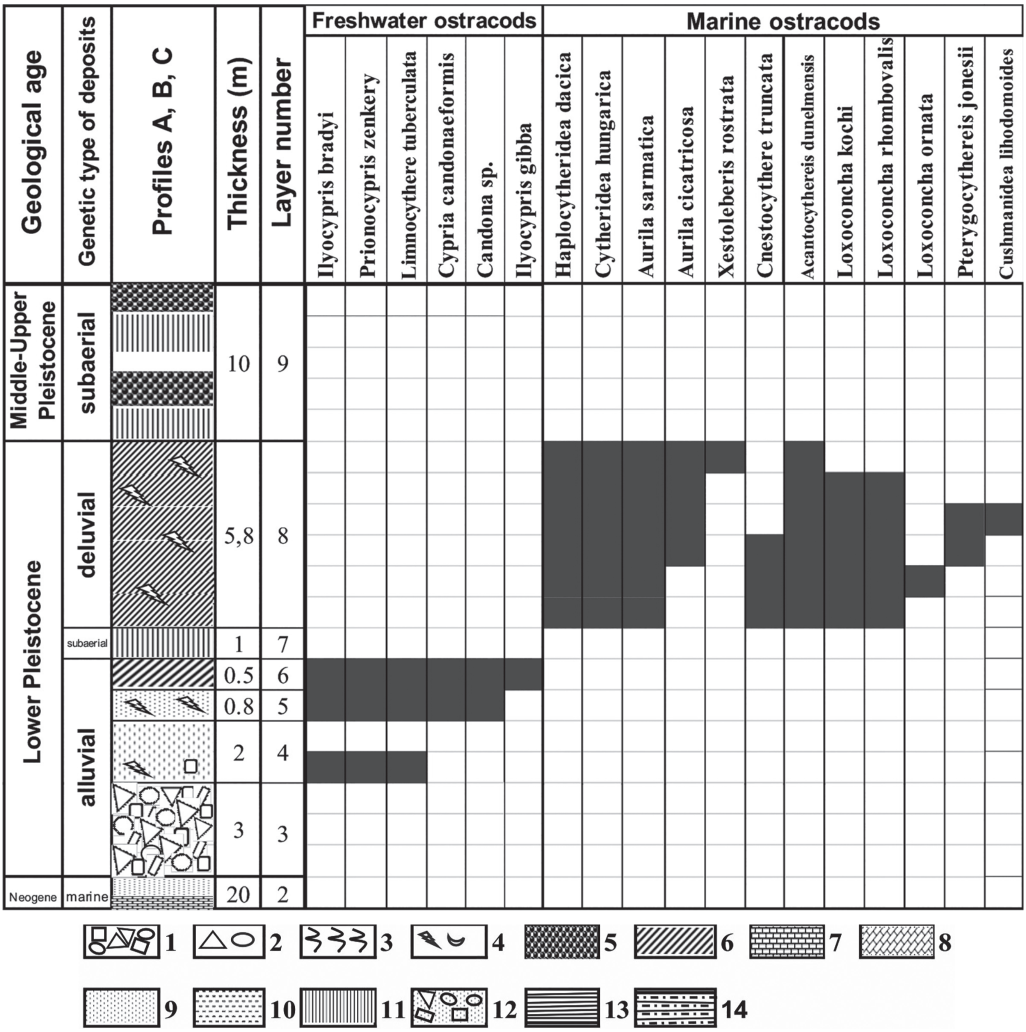

Fig. 4. Species composition of ostracods from alluvial deposits of the "Scala Podilska" section (Lower Pleistocene, Tiglian/Beregovian, Eburonian/Berezanian)

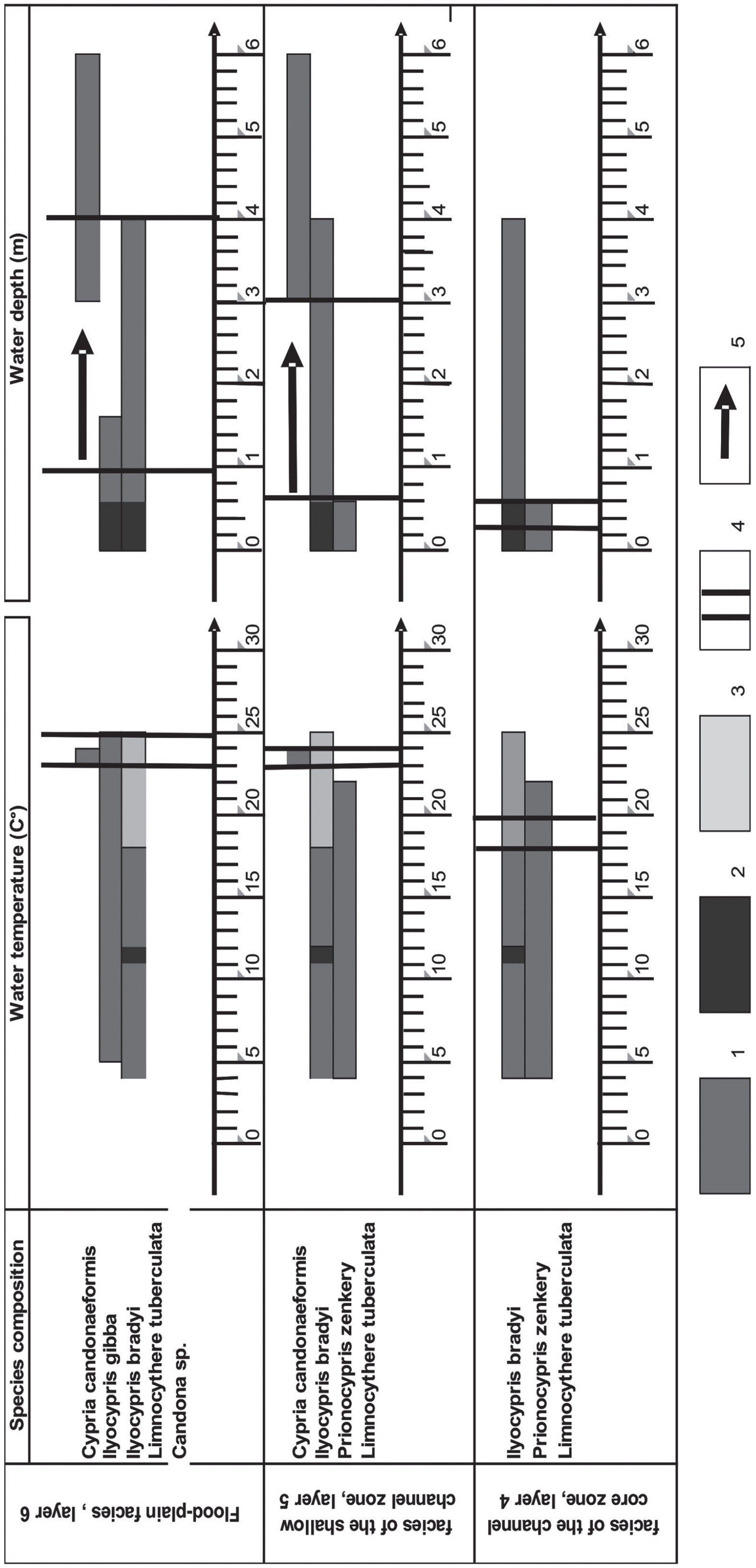

Fig. 5. Reconstruction of water depth and water temperature in paleobiotopes of the Zbruch River using the quantitative modification method ("Scala Podilska" section, Western Ukraine, Lower Pleistocene, Gelasian–Calabrian). Conventional notation: 1 — a species' tolerance range to an abiotic factor; 2 — optimal values of an abiotic factors for the existence of a species; 3 — negative values of an abiotic factors; 4 — reconstructed values of an abiotic factors; 5 — trend of an abiotic factor

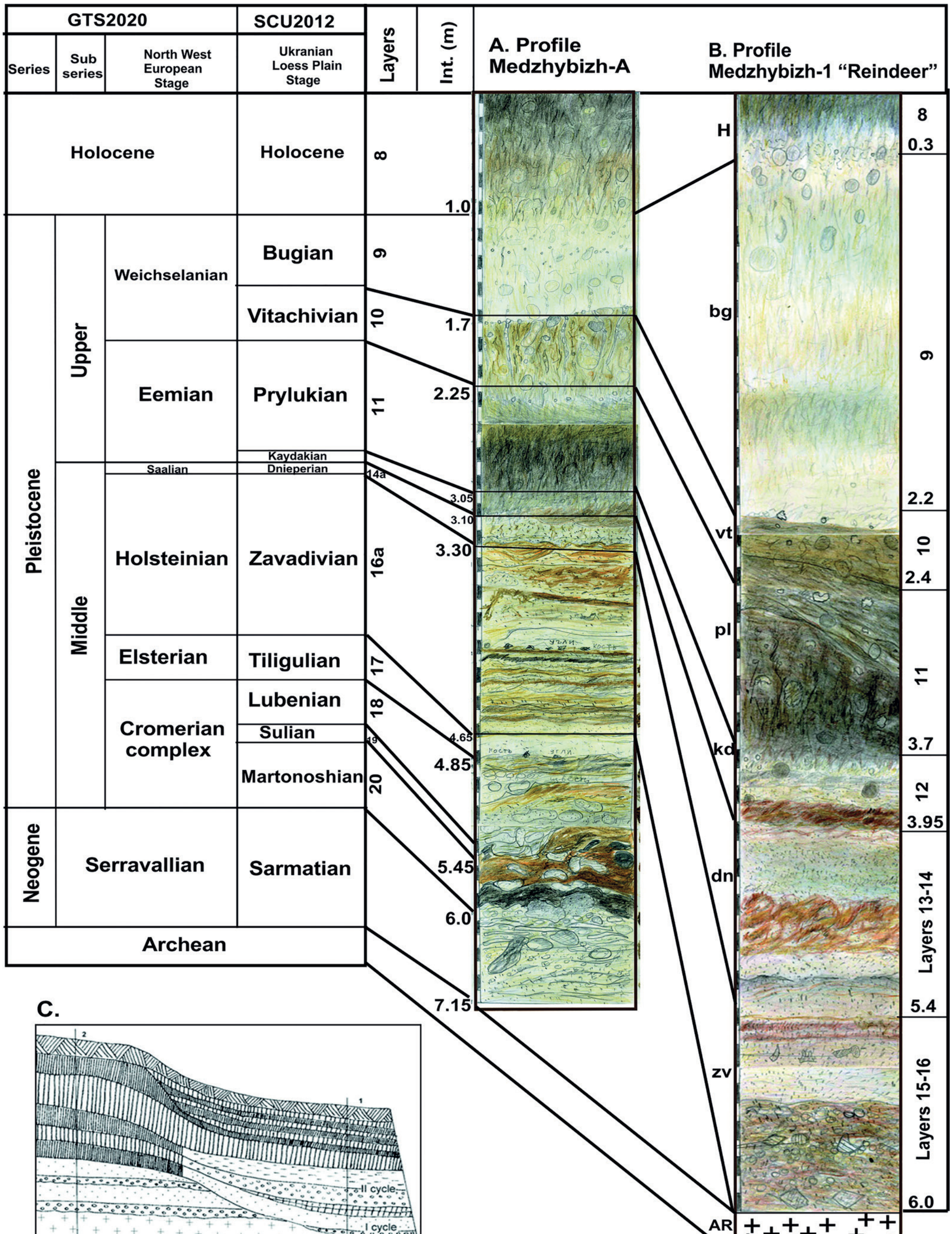

Fig. 7. Geological structure of the Archean–Quaternary deposits of the "Medschybisch" section (Stepanchuk et al., 2012; Matviishina & Karmazinenko, 2014): A — Medschybisch "A" profile, right bank of the Southern Bug River, 1 km north of the Medschybisch 1 "Reindeer" profile; B — Medschybisch 1 "Reindeer" profile, left bank of the Southern Bug River; C — stratigraphic profile of the "Medschybisch" section (Recovets et al., 2007). Conventional notation: 1 — gravel deposits of basal alluvium; 2 — pebbles, gravel; 3 — modern soil; 4 — paleontological remains; 5 — paleosoil; 6 — loam, 7 — limestone, 8 — sandstones, 9 — sand, 10 — clay, 11 — loess; 12 — moraine; 13 — silt; 14 — loamy sand

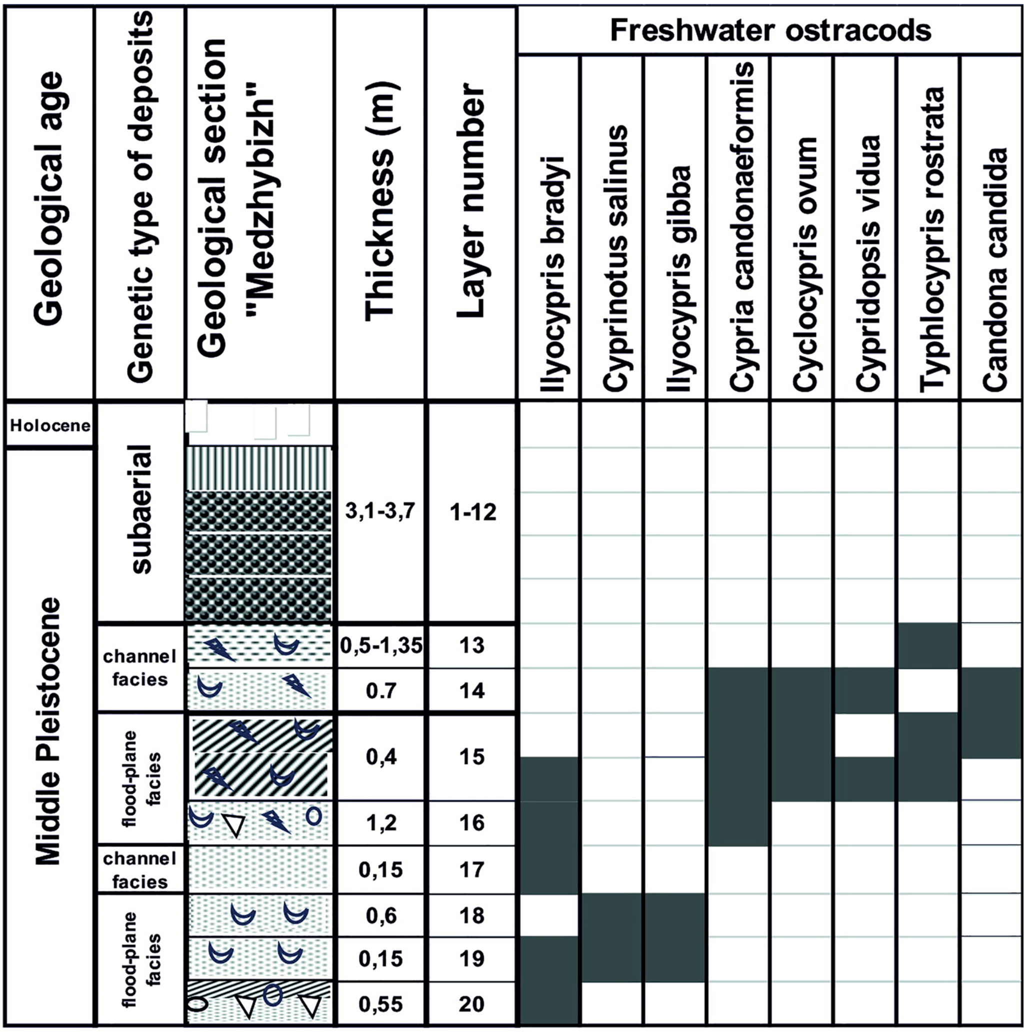

Fig. 8. Species composition of ostracods from alluvial deposits of the “Medschybisch” section (Middle Pleistocene, Cromerian/Martonoshian–Saalian/Dnieperian)

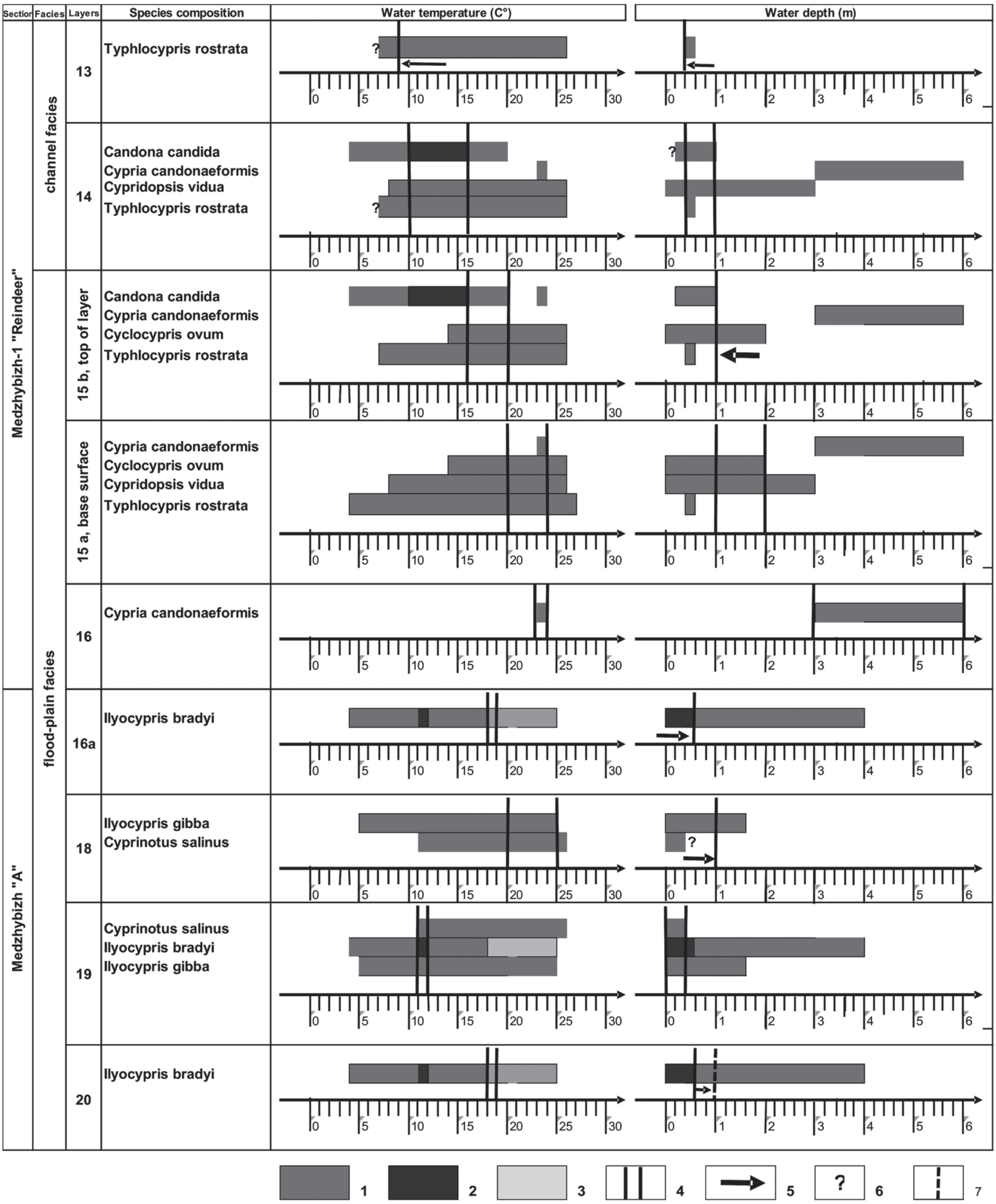

Fig. 9. Reconstruction of water depth and water temperature in paleobiotopes of the Southern Bug River according to the quantitative modification method ("Medschybisch" section, Western Ukraine, Middle Pleistocene, Cromerian/Martonoshian–Saalian/Dnieperian). Conventional notation: 1 — a species' tolerance range to an abiotic factor; 2 — optimal values of an abiotic factors for the existence of a species; 3 — negative values of an abiotic factors; 4 — reconstructed values of an abiotic factors; 5 — trend of an abiotic factor; 6 — undefined range of species tolerance to an abiotic factors; 7 — conditionally reconstructed value of an abiotic factor

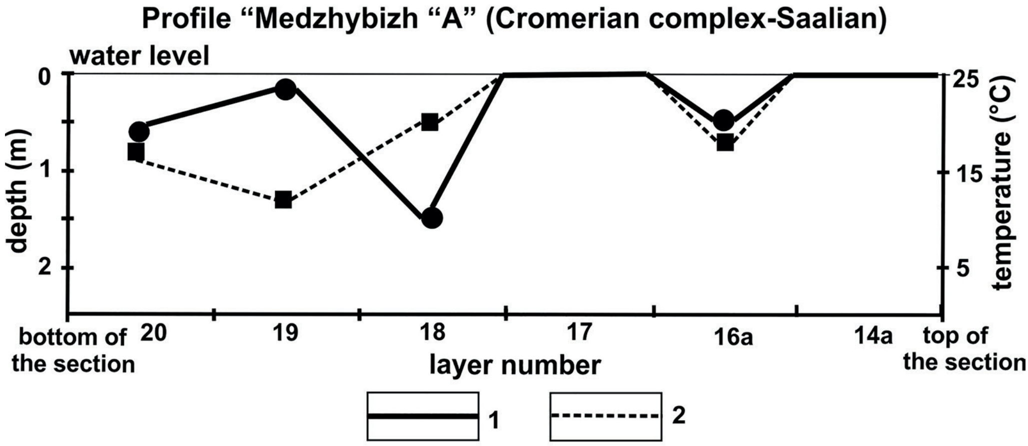

Fig. 10. Graph showing fluctuations in water depth and water temperature in the floodplain of the Southern Bug River ("Medschybisch A" profile, Middle Pleistocene, Interglacial I–II, Cromerian complex/Martonoshian–Saalian/Dnieperian). Conventional notation: 1 — water depth, m; 2 — water temperature, °C

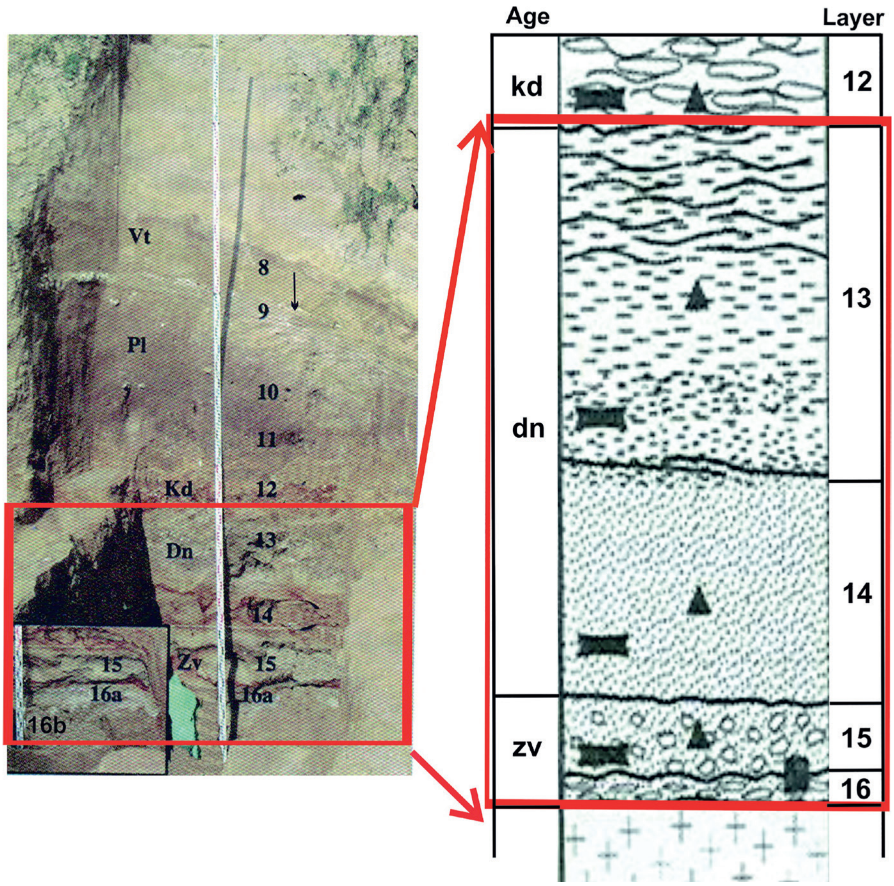

Fig. 11. Geological section of alluvial deposits of the Medschybisch-1 "Reindeer profile" (Stepanchuk et al., 2012; Matviishina & Karmazinenko, 2014; Dykan, 2014)

Fig. 12. Taphonomy of fossil mollusk shells *Unio* spp. of autochthonous burial (subhorizontal and horizontal orientation of shells and valves) at the bottom of a floodplain lake (Medschybisch-1 "Reindeer profile", Southern Bug River, Middle Pleistocene, Holsteinian/Zavadivian) (Gozhik et al., 2014)

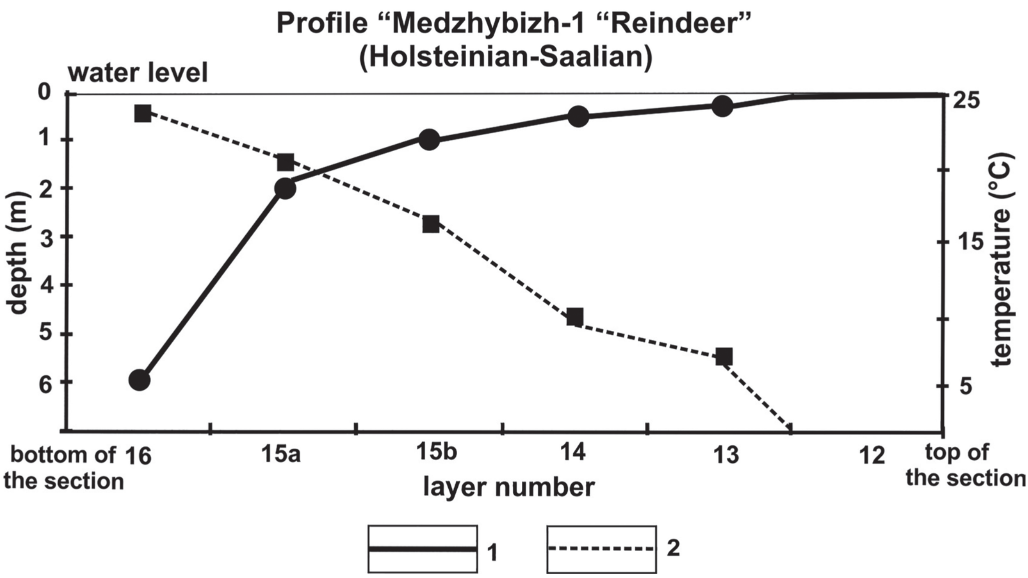

Fig. 13. Graph of the fluctuations in water depth and water temperature in the floodplain of the Southern Bug River (Medschybisch-1 "Reindeer profile", Middle Pleistocene, Holsteinian/Zavadivian–Saalian/Dnieperian)

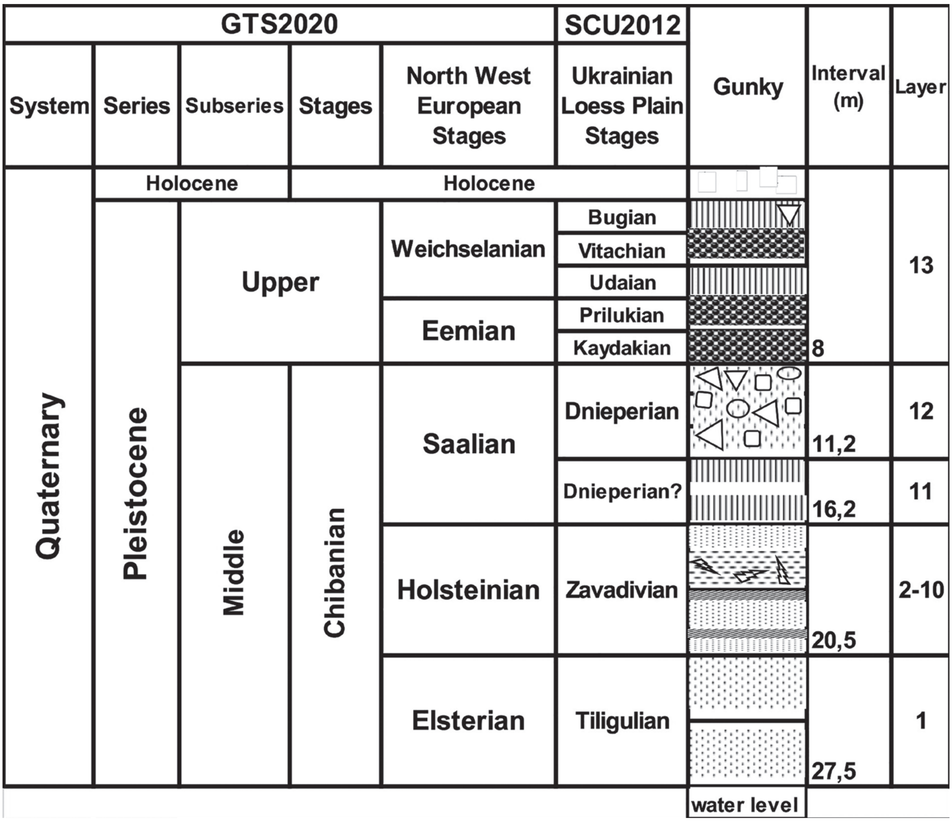

Fig. 14. Geological structure of Middle-Upper Pleistocene deposits of the "Hun'ky" section, right bank of the Psel River (left tributary of the Dnipro), Poltava Region, Central Ukraine (Dykan, 1994 a). Conventional notation: 1 — gravel; deposits of basal alluvium; 2 — pebbles, gravel; 3 — modern soil; 4 — paleontological remains; 5 — paleosoil; 6 — loam; 7 — limestone; 8 — sandstones; 9 — sand; 10 — clay; 11 — loess; 12 — moraine; 13 — silt; 14 — loamy sand

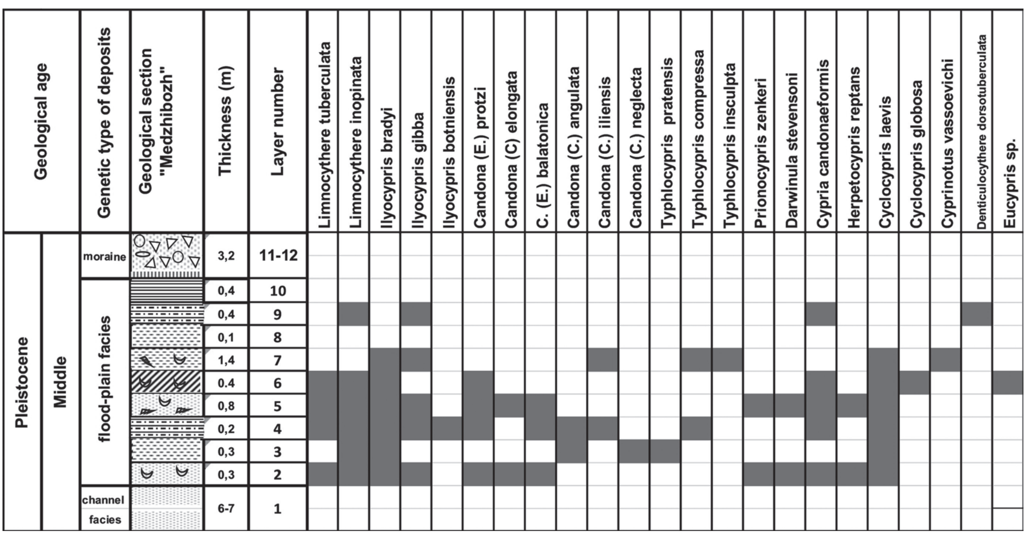

Fig. 16. Species composition of ostracods from alluvial deposits of the "Hun'ky" section (Middle Pleistocene, Chebanian, Holsteinian/Zavadivian)

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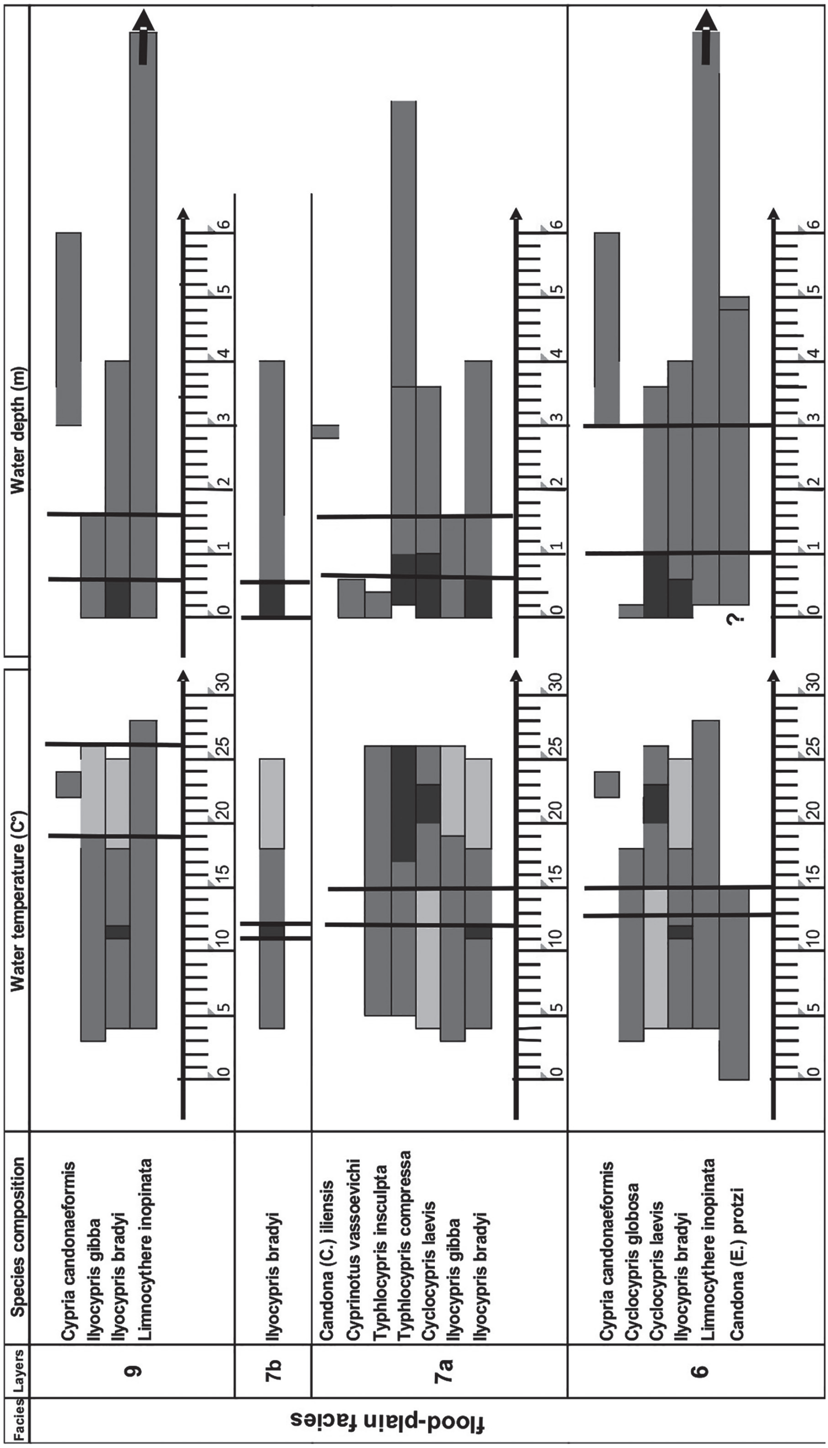

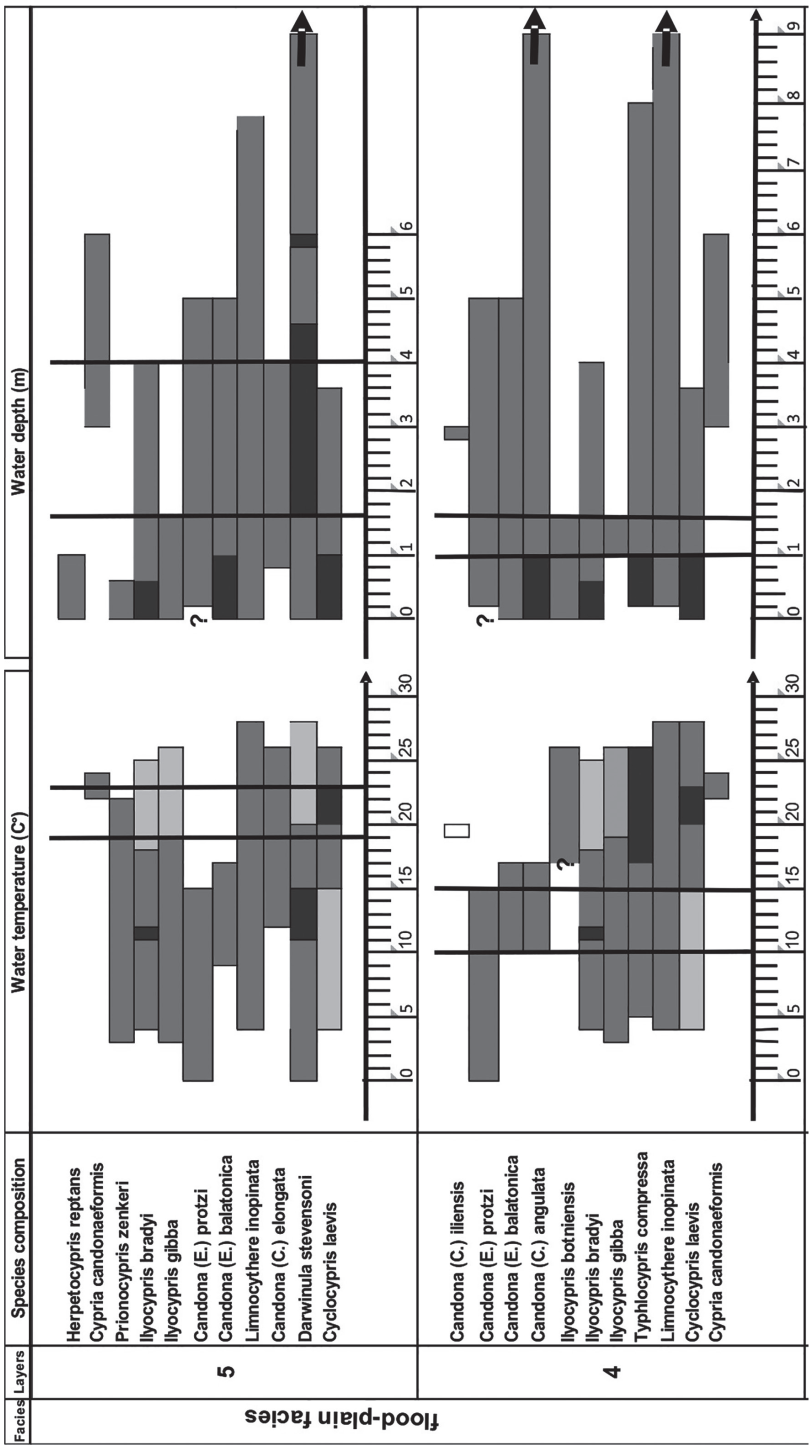

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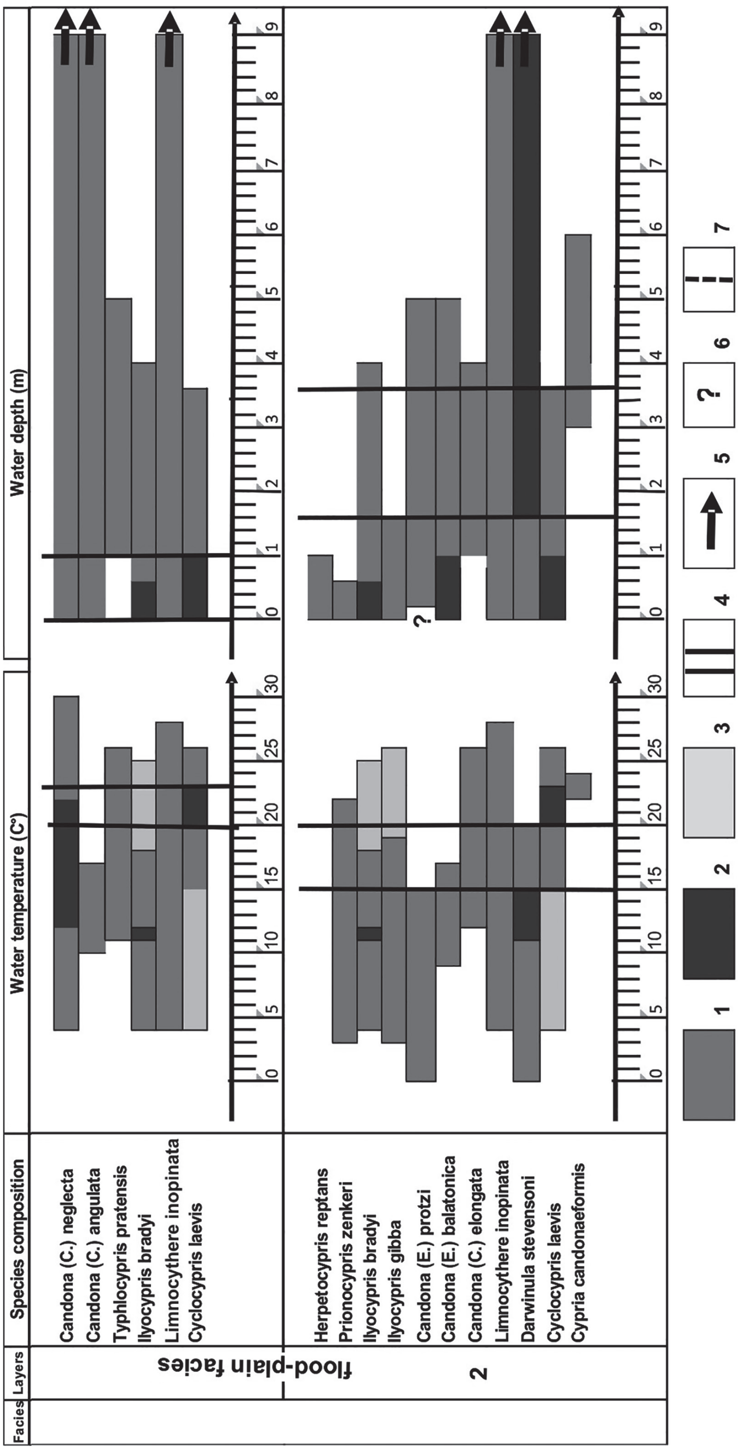


Fig. 17. Reconstruction of water depth and water temperature in paleobiotopes of the Psel River according to the quantitative modification method ("Hun'ky" section, Central Ukraine, Middle Pleistocene, Holsteinian/Zavadivian). Conventional notation: 1 — a species' tolerance range to an abiotic factor; 2 — optimal values of an abiotic factors for the existence of a species; 3 — negative values of an abiotic factors; 4 — reconstructed values of an abiotic factors; 5 — trend of an abiotic factor; 6 — undefined range of species tolerance to an abiotic factors; 7 — conditionally reconstructed value of an abiotic factor

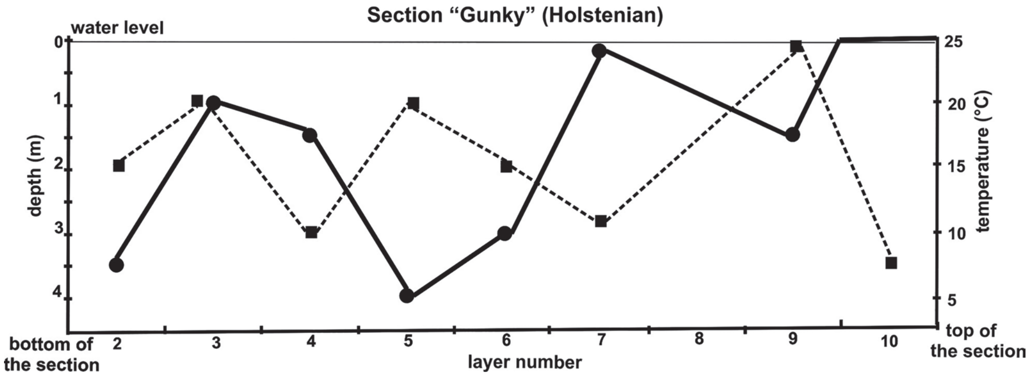


Fig. 18. Graph of fluctuations in water depth and water temperature in the floodplain of the Psel River ("Hun'ky" section, Central Ukraine, Middle Pleistocene, Holsteinian/Zavadivian). Conventional notation: 1 — water depth, m; 2 — water temperature, °C

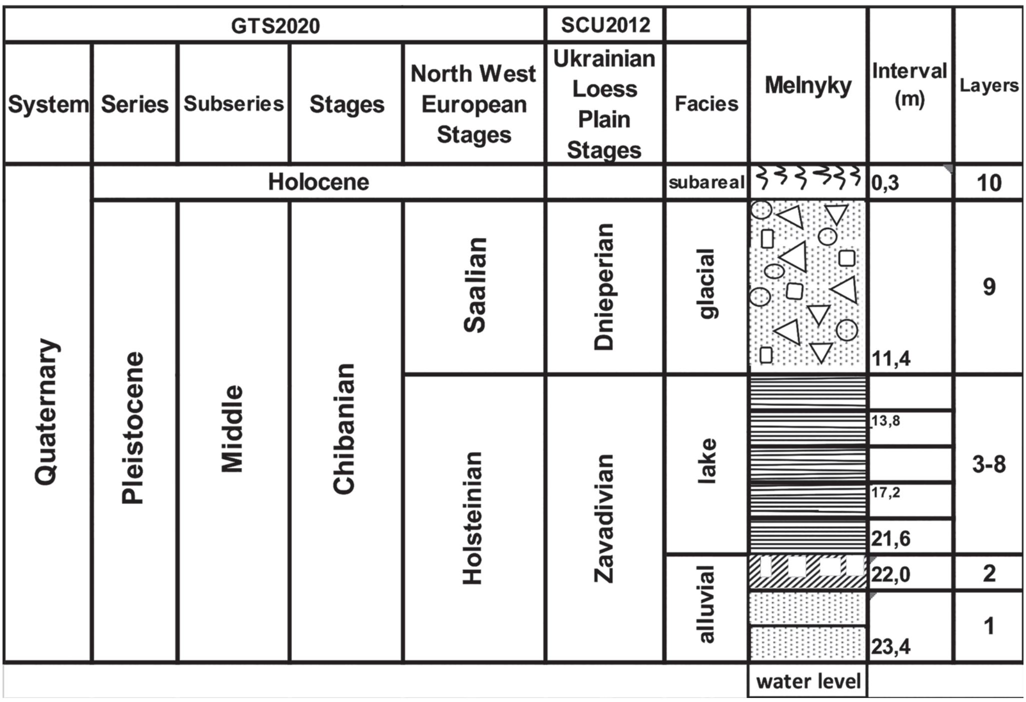


Fig. 19. Geological structure of Middle Pleistocene deposits of the "Melnyky" section, Dnipro River, Tscherkassy region, Central Ukraine (Dykan, 1994 b). Conventional notation: 1 — gravel deposits of basal alluvium; 2 — pebbles, gravel; 3 — modern soil; 4 — paleontological remains; 5 — paleosoil; 6 — loam, 7 — limestone, 8 — sandstones, 9 — sand, 10 — clay, 11 — loess; 12 — moraine; 13 — silt; 14 — loamy sand

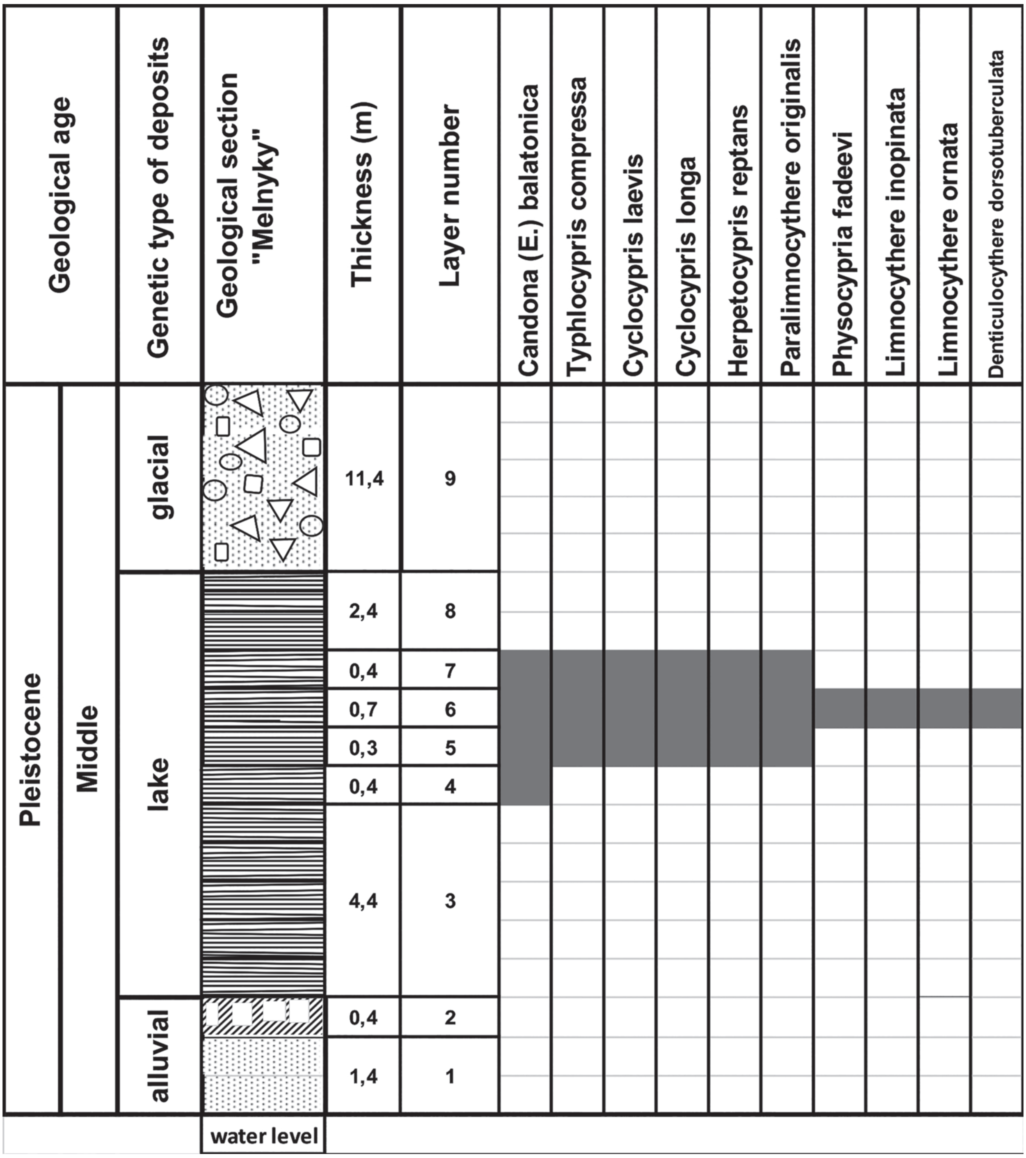


Fig. 20. Species composition of ostracods in alluvial and lacustrine deposits of the "Melnyky" section (Middle Pleistocene, Chebanian, Holsteinian/Zavadivian)

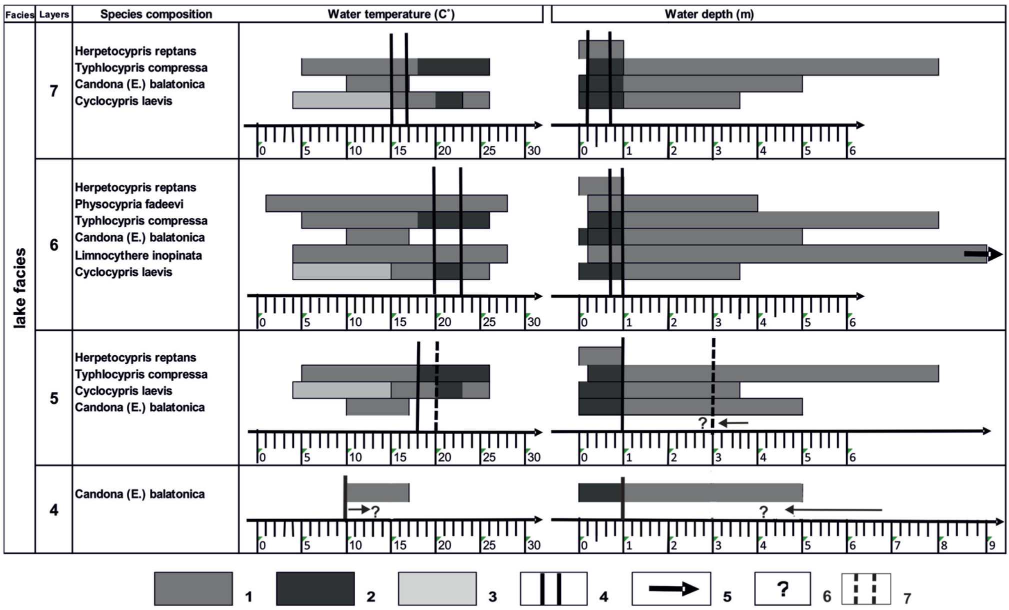


Fig. 21. Reconstruction of water depth and water temperature in paleobiotopes of the Dnipro River according to the quantitative modification method ("Melnyky" section, Central Ukraine, Middle Pleistocene, Holsteinian/Zavadivian). Conventional notation: 1 — a species' tolerance range to an abiotic factor; 2 — optimal values of an abiotic factors for the existence of a species; 3 — negative values of an abiotic factors; 4 — reconstructed values of an abiotic factors; 5 — trend of an abiotic factor; 6 — undefined range of species tolerance to an abiotic factors; 7 — conditionally reconstructed value of an abiotic factor

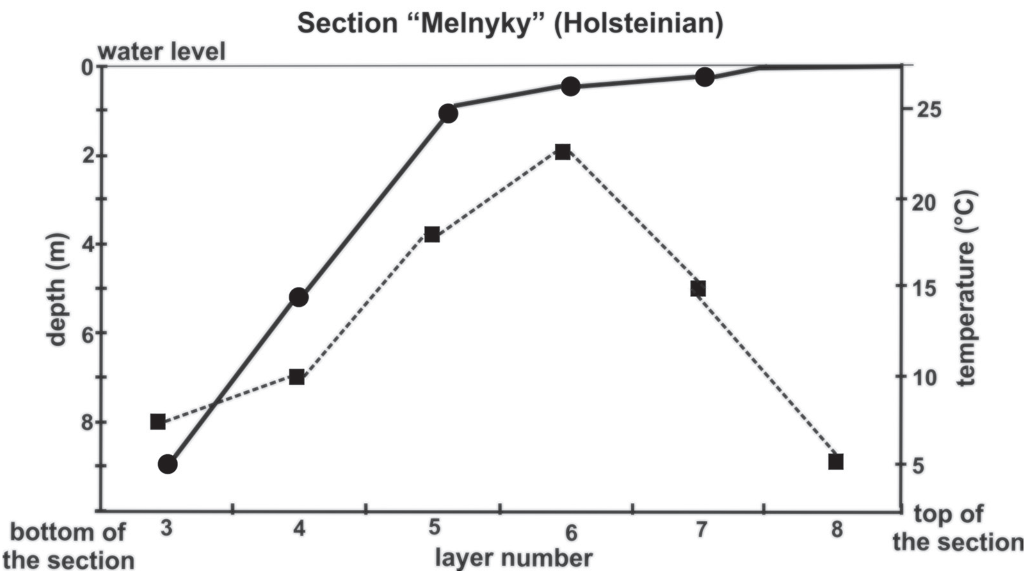


Fig. 22. Graph of fluctuations in water depth and water temperature in the floodplain of the Dnipro River ("Melnyky" section, Central Ukraine, Middle Pleistocene, Holsteinian/Zavadivian). Conventional notation: 1 — water depth, m; 2 — water temperature, °C

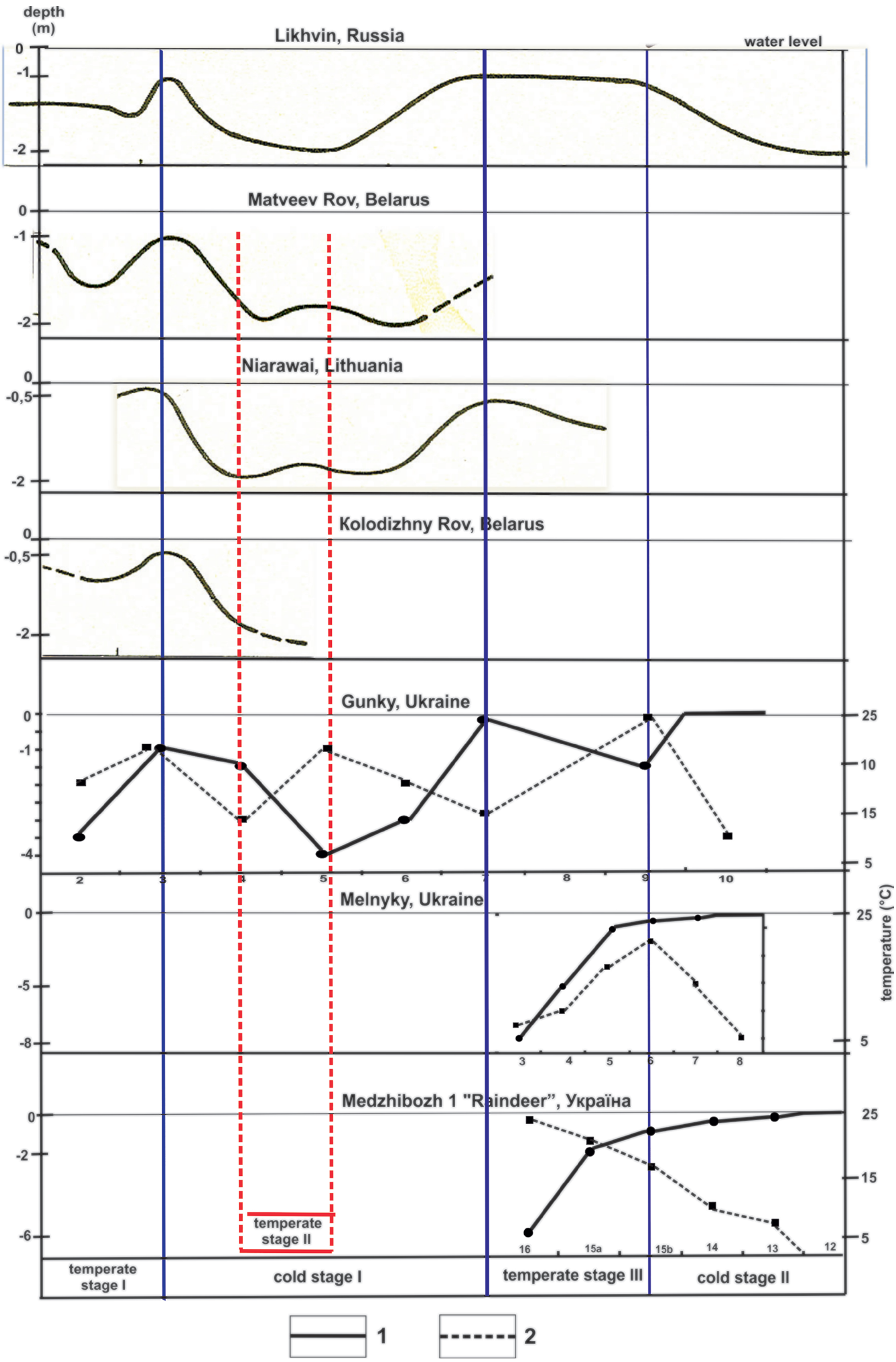
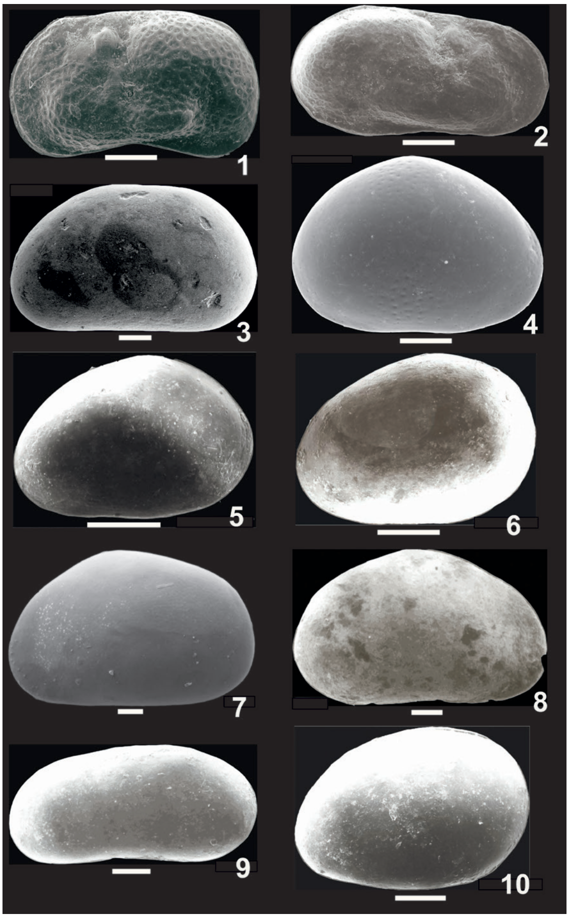
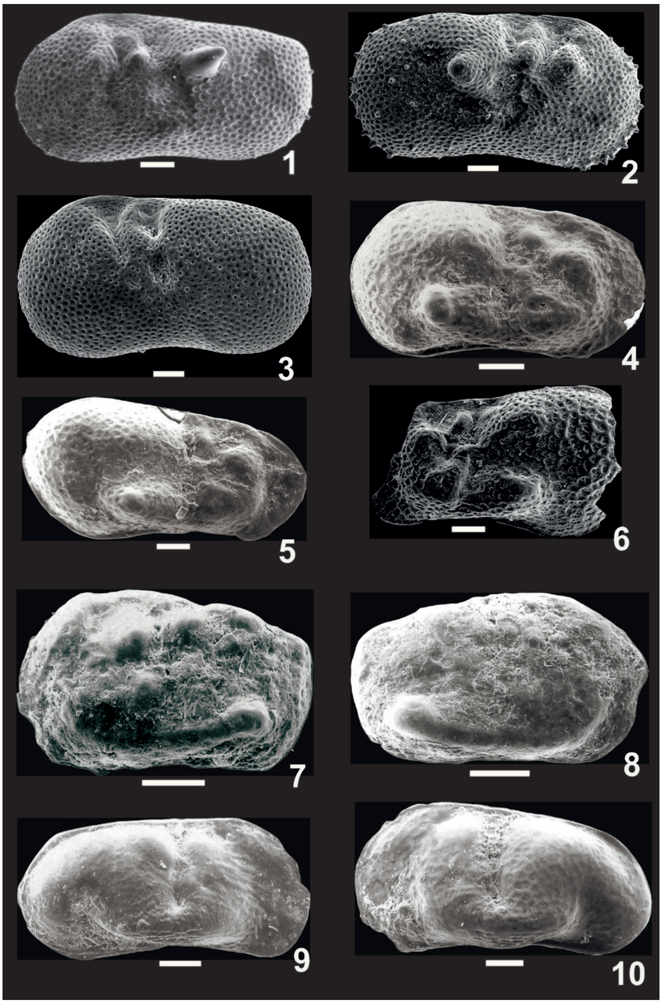


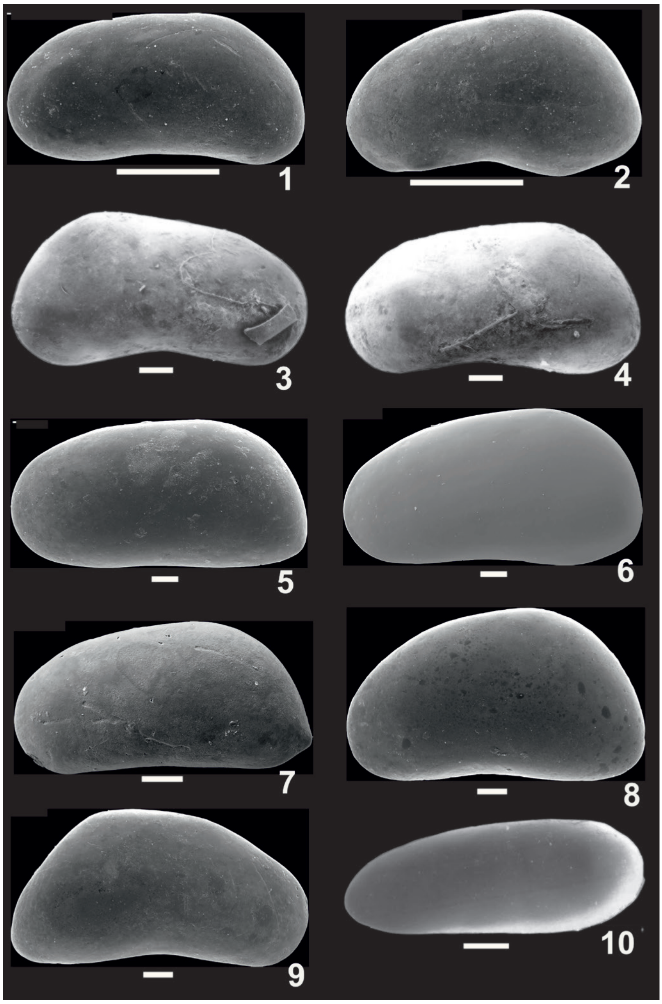
Fig. 23. Correlation of bottom depth and water temperature, reconstructed according to ostracods in continental water bodies of Ukraine (Dikan, 1994 a, b; 2014) and Belarus, Lithuania, and Russia (Zubovich, 1978) in the Interglacial Holsteinian/Zavadivian



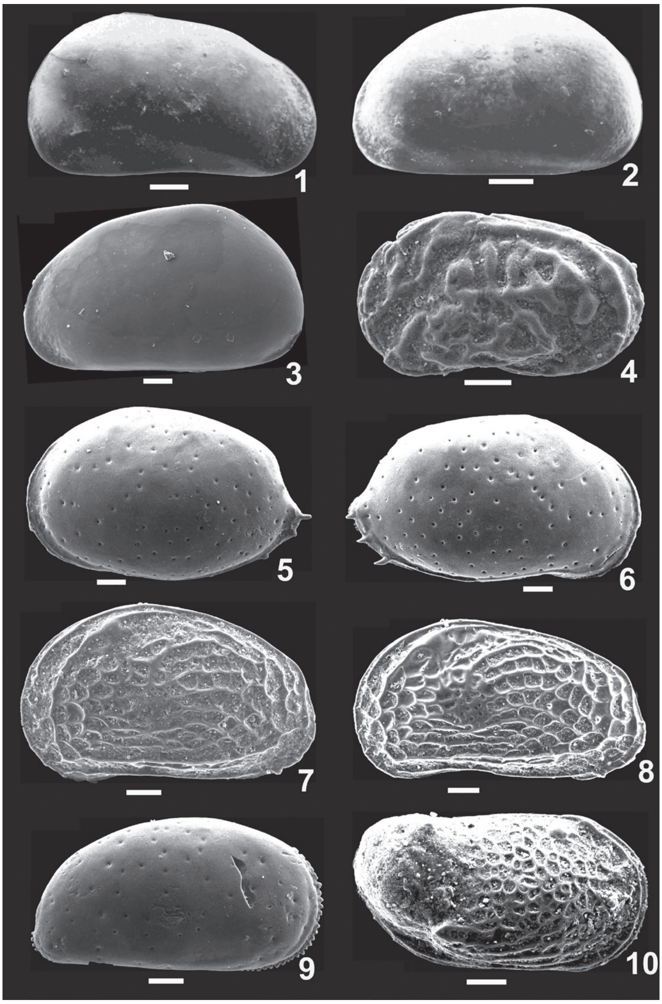
Paleontological table 3. Freshwater ostracods from alluvial deposits of river terraces of Ukraine: 1 — *Limnocythere inopinata* (Baird, 1843), adult, left valve, ♀, external, SEM, × 220, Central Ukraine, Psel River, "Hun'ky" section, floodplain facies, layer 5, Middle Pleistocene, Holsteinian/Zavadivian; 2 — *Limnocythere inopinata* (Baird, 1843), adult, right valve, ♂, external, SEM, × 220, ibid; 3 — *Cypria candonaeformis* (Schweyer, 1949), adult, left valve, external, SEM, × 160, Western Ukraine, Zbruch River, «Scala Podilska» section (profile "A"), facies of the shallow chanel zone, layer 5, Lower Pleistocene, Calalbrian, Eburonian/Berezanian; 4 — *Cyclocypris ovum* (Jurine, 1820), adult, right valve, external, SEM, × 150, Western Ukraine, Southern Bug River, "Medschybisch" section, profile «A», flood-plain facies, layer 15a, Middle Pleistocene, Holsteinian/Zavadivian; 5 — *Cyclocypris laevis* (O. Müller, 1785), adult, right valve, external, SEM, × 300, Central Ukraine, Desna River, "Slabin" section, facies of the shallow chanel zone, Holocene, modern deposits; 6 — *Cyclocypris globosa* (G. Sars, 1862), adult, left valve, external, SEM, × 220, Central Ukraine, Psel River, "Hun'ky" section, flood-plain facies, layer 5, Middle Pleistocene, Holsteinian/Zavadivian; 7 — *Cyprinotus salinus* (Brady, 1862), adult, left valve, external, SEM, × 110, Western Ukraine, Southern Bug River, "Medschybisch" section, profile "A", floodplain facies, layer 18, Middle Pleistocene, Holsteinian/Zavadivian; 8 — *Cyprinotus vassoevichi* Schneider in Bodina, 1961, adult, right valve, external, SEM, × 120, Central Ukraine, Psel River, "Hun'ky" section, floodplain facies, layer 7, Middle Pleistocene, Holsteinian/Zavadivian; 9 — *Herpetocypris reptans* (Baird, 1835), adult, left valve, external, SEM, × 160, Central Ukraine, Dnipro River, "Melnyky" section, lake facies, layer 5, Middle Pleistocene, Holsteinian/Zavadivian; 10 — *Physocypria fadeevi* Dubowsky, 1927, adult, left valve, external, SEM, × 220, Central Ukraine, Dnipro River, "Melnyky" section, lake facies, layer 6, Middle Pleistocene, Holsteinian/Zavadivian



Paleontological table 4. Freshwater ostracods from alluvial deposits of river terraces in Ukraine: 1 — *Ilyocypris gibba* (Ramdohr, 1808), adult, left valve, external, SEM, × 120, Western Ukraine, Zbruch River, «Scala Podilska» section (profile "B"), floodplain facies, layer 6, Lower Pleistocene, Calalbrian, Eburonian/Berezanian; 2 — *Ilyocypris gibba* (Ramdohr, 1808), juvenile, right valve, external, SEM, × 140, ibid; 3 — *Ilyocypris bradyi* Sars, 1890, adult, left valve, external, SEM, × 100, Western Ukraine, Southern Bug River, "Medschybisch" section, profile "A", flood-plain facies, layer 16a, Middle Pleistocene, Holsteinian/Zavadivian; 4 — *Limnocythere tuberculata* Negadaev, 1957, adult, right valve, ♂, external, SEM, × 160, Central Ukraine, Psel River, "Hun'ky" section, floodplain facies, layer 5, Middle Pleistocene, Holsteinian/Zavadivian; 5 — *Limnocythere tuberculata* Negadaev, 1957, adult, right valve, ♀, external, SEM, × 180, ibid; 6 — *Limnocythere tuberculata* Negadaev, 1957, adult, left valve, ♂ external, SEM, × 180, Western Ukraine, Zbruch River, "Skela Podilska" section, profile "A", facies of the chanel, layer 4, Lower Pleistocene, Calalbrian, Eburonian/Berezanian; 7 — *Denticulocythere dorsotuberculata* (Negadaev, 1957), adult, left valve, ♂, external, SEM, × 240, Central Ukraine, Psel River, "Hun'ky" section, flood-plain facies, layer 5, Middle Pleistocene, Holsteinian/Zavadivian; 8 — *Denticulocythere dorsotuberculata* (Negadaev, 1957), adult, right valve, ♀, external, SEM, × 220, ibid; 9 — *Paralimnocythere originalis* (Negadaev, 1965), adult, right valve, ♂, external, SEM, × 180, Central Ukraine, Dnipro River, "Melnyky" section, lake facies, layer 6, Middle Pleistocene, Holsteinian/Zavadivian; 10 — *Paralimnocythere originalis* (Negadaev, 1965), adult, left valve, ♀, external, SEM, × 160, ibid



Paleontological table 5. Freshwater ostracods from alluvial deposits of river terraces in Ukraine: 1 — *Candona neglecta* Sars, 1887, adult, left valve, ♀, external, SEM, × 50, Central Ukraine, Psel River, "Hun'ky" section, floodplain facies, layer 3, Middle Pleistocene, Holsteinian/Zavadivian; 2 — *Candona (C.) neglecta* Sars, 1887, adult, left valve, ♂, external, SEM, × 50, ibid; 3 — *Candona (C.) iliensis* Mandelstam, 1963, adult, right valve, ♀, external, SEM, × 110, Central Ukraine, Psel River, "Hun'ky" section, flood-plain facies, layer 4, Middle Pleistocene, Holsteinian/Zavadivian; 4 — *Candona(C.) iliensis* Mandelstam, 1963, adult, left valve, ♂, external, SEM, × 110, ibid; 5 — *Candona (C.) elongata* (Schweyer, 1949), adult, left valve, ♀, external, SEM, × 100, Central Ukraine, Psel River, "Hun'ky" section, flood-plain facies, layer 5, Middle Pleistocene, Holsteinian/Zavadivian; 6 — *Candona (C.) elongata* (Schweyer, 1949), adult, left valve, ♂, external, SEM, × 100, ibid; 7 — *Candona (C.) angulata* G. Müller, 1900, adult, left valve, ♀, external, SEM, × 80, Central Ukraine, Psel River, "Hun'ky" section, flood-plain facies, layer 4, Middle Pleistocene, Holsteinian/Zavadivian; 8 — *Candona (C.) candida* (O.Müller, 1776), adult, left valve, external, SEM, × 100, Western Ukraine, Southern Bug River, "Medschybisch"section. profile "A", floodplain facies, layer 15 b, Middle Pleistocene, Holsteinian/Zavadivian; 9 — *Candona (E.) balatonica* Daday, 1894, adult, right valve, external, SEM, × 100, Central Ukraine, Dnipro River, "Melnyky" section, lake facies, layer 5, Middle Pleistocene, Holsteinian/Zavadivian; 10 — *Darwinula stevensoni* (Brady and Robertson, 1870), adult, left valve, external, SEM, × 160, Central Ukraine, Psel River, "Hun'ky"" section, flood-plain facies, layer 5, Middle Pleistocene, Holsteinian/Zavadivian



Paleontological table 6. Freshwater ostracods from alluvial deposits of river terraces in Ukraine: 1 — *Typhlocypris compressa* (Kosh, 1837), adult, right valve, ♂, external, SEM, × 130, Central Ukraine, Dnipro River, "Melnyky" section, lake facies, layer 7, Middle Pleistocene, Holsteinian/ Zavadivian; 2 — *Typhlocypris compressa* (Kosh, 1837), adult, left valve, ♀, external, SEM, × 160, ibid. 3 — *Typhlocypris rostrata* (Brady and Norman, 1889), adult, left valve, external, SEM, × 120, Western Ukraine, Southern Bug River, "Medschybisch" section, profile «A», flood-plain facies, layer 15, Middle Pleistocene, Holsteinian/Zavadivian. Species-indicators of the Sarmatian: 4 — *Callistocythere molesta* Bonaduce, 1988, adult, left valve, external, SEM, × 100, Western Ukraine, Zbruch River, "Skala Podilska" section, profile "A", marine deposits, layer 8, Middle Miocene, Serravallian/Sarmatian; 5 — *Aurila sarmatica* (Zalányi, 1949), adult, left valve, ♀, external, SEM, × 100, ibid; 6 — *Aurila sarmatica* (Zalányi, 1949) adult, right valve, male, external, SEM, x 100, ibid; 7 — *Hemicytheria omphalodes* (Reuss, 1854), adult, left valve, ♀, external, SEM,100, ibid; 8 — *Hemicytheria omphalodes* (Reuss, 1854) adult, left valve, ♂, external, SEM, × 100, ibid; 9 — *Haplocytheridea dacica* (Hejas, 1894) adult, right valve, ♀ external, SEM, × 100, ibid.; 10 — *Loxo-concha ornata* Schneider, 1939, adult, right valve, external, SEM, × 100, ibid