DOI: 10.17951/b.2018.73.83-105

ANNALES
UNIVERSITATIS MARIAE CURIE-SKŁODOWSKA
LUBLIN – POLONIA

VOL. LXXIII SECTIO B 2018

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Reconstruction of palaeolandscaps of Ukraine during MIS 20-12 obtained by palaeontological methods

Rekonstrukcja paleokrajobrazów Ukrainy w ciągu MIS 20-12 uzyskana metodami paleontologicznymi

Abstrakt: Według nowego Schematu Stratygraficznego Plejstocenu Ukrainy klimatolity przyazowski, martonoszski, sulski, łubenski i tiligulski korelowane są z końcową częścią wczesnego i pierwszą połową środkowego plejstocenu według międzynarodowej skali stratygraficznej oraz z 20-12 MIS. Z kriochronami przyazowską, sulską i tiligulską wiązała się sedymentacja lessów i osadów lessopodobnych; podczas kriochrony tiligulskiej lądolód skandynawski (Krukenycki, Okski) objął północno-zachodnią Ukrainę. Podczas termochron martonoszskiej i łubenskiej formowały się gleby kopalne. Osady subakwalne (pierwsza połowa środkowego plejstocenu) tworzą aluwialne terasy V i VI, a także osady basenów morskich Czauda i Postczauda.

W celu rekonstrukcji warunków paleogeograficznych zostały wykorzystane własne wyniki badań palinologicznych, malakologicznych, mikroteriologicznych osadów kontynentalnych i morskich, dane z analizy paleopedologicznej z lat ostatnich oraz materiały publikowane (por. bibliografia). Uzyskane dane potwierdziły cykliczny charakter ewolucji krajobrazów i zmian klimatu na Ukrainie podczas glacjałów i interglacjałów w okresie między 800 a 430 tysięcy lat temu. Zasięgi stref roślinnych, wyróżnianych na terenie Ukrainy w tych jednostkach stratygraficznych, przedstawiają ryc. 3–7. Z przeprowadzonej analizy wynika, że powierzchnia i granice jednostek biostratygraficznych w poszczególnych jednostkach plejstocenu nie zawsze pokrywają się z powierzchnią podjednostek klimatostratygraficznych, zidentyfikowanych na podstawie rekonstrukcji paleogeograficznych. Cechą charakterystyczną jest duża rola doliny Dniepru, wykazana przez zróżnicowanie strefowych odmian roślinności w prawo- i lewobrzeżnej części jego basenu.

Słowa kluczowe: rekonstrukcje paleogeograficzne, pokrywa roślinna, mikroteriofauna, malakofauna, paleoklimat

Abstract: The palaeolandscaps reconstruction and changes in the boundaries of the physicogeographical countries and zones of Ukraine during the end of Early and the first half of Middle Pleistocene are examined. The section spans from MIS 20 to MIS 12, time interval 430–800 kyr and includefive stratigraphic units. This study is based on palynological, microtheriological, malacological analyzes and literature data. Our results support significant changes, which can be associated with the cold and warm stages, but this study demonstrates that the surface and boundaries of the Pleistocene biostratigraphic units do not always coincide with the surface of the climatostratigraphic subunits identified on the basis of palaeogeographic reconstructions.

Keywords: palaeogeographic reconstructions, vegetation cover, micromammal fauna, malacofauna, palaeoclimate

INTRODUCTION

Pleistocene deposits in Ukraine have been an object of special research since the second half of the 19th century. The basics of these deposits investigations were laid in works of outstanding researchers I. F. Levakovsky, V. D. Dokuchaev, P. A. Tutkovsky, N. A. Sokolov, A. I. Nabokikh, and V. D. Laskarev, who also proposed the first schemes of division of Pleistocene (Quaternary) deposits. The results were further detailed and transferred to a new level by research carried out by V. I. Krokos, A. P. Pavlov, L. A. Lepikash, V. G. Bondarchuk, P. K. Zamoriy and others, which gave start to geological and paleontological division of Pleistocene (Quaternary) deposits.

Contemporary views on the geological structure and history of development of Ukraine were formed thanks to the hard work of geologists A. D. Arkhangelsky, V. G. Bondarchuk, K. I. Makov, M. V. Muratov, N. P. Semenenko, V. B. Sologub, I. A. Garkalenko, A. V. Chekunov, L. G. Plakhotniy, N. F. Balukhovsky and many others.

Numerous publications by V. I. Gromov (1948), I. G. Pidoplichko and V. A. Topachevsky (1962), A. I. Shevchenko (1965), A. L. Chepalyga (1967), N. A. Lebedeva (1974), N. A. Kunitsa (1974), P. F. Gozhik *et al.* (1976), V. M. Matsui and O.D. Mos'kina (1985), and others were devoted to biostratigraphic issues of marine, alluvial, estuarine, and subaerial Pleistocene deposits.

First A. I. Moskvitin in 1952, and later, M. F. Veklich (1968, 1969), A. A Velichko *et al.* (1975), based on lithostratigraphic, geomorphologic, geochronologic, and paleomagnetic data, made a wide correlation of loess and dividing it soil horizons with loess-soil series and stratigraphic divisions of glacial formations of the European part of USSR. However, the authors' conclusions about the stratigraphic division of covering Pleistocene deposits, correlation of stratigraphic divisions, and linkage of palaeogeographic settings within the East European Plain do not correspond. Recently, issues of reconstruction of palaeogeographic

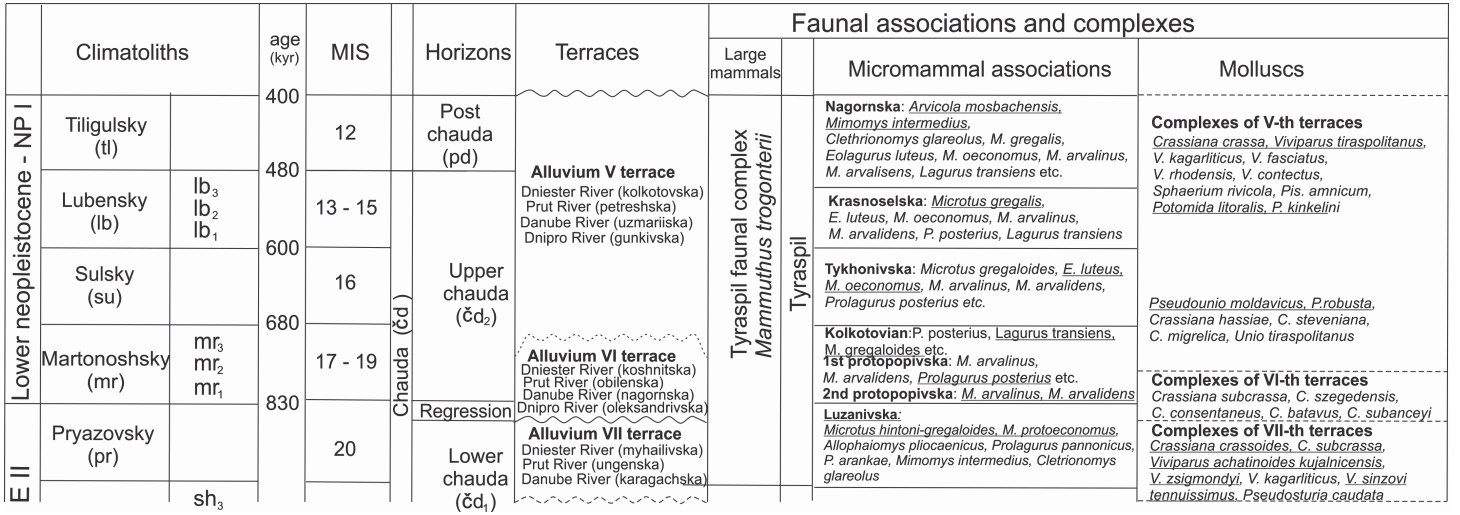

Fig. 1. Chrono- and biostratigraphic scheme

Ryc. 1. Schemat chrono- i biostratygraficzny

conditions of the Quaternary on the territory of Ukraine have been studied by Zh. M. Matviishyna, N. P. Gerasimenko, V. I. Perederiy and others (2004, 2010).

In the new stratigraphic scheme of Quaternary deposits of Ukraine pryazovsky cryochron (20 Marine Isotope Stage), Martonoshsky (17–19 MIS), Sulsky (16 MIS), Lubensky (13–15 MIS) and Tiligulsky (12 MIS) regional stratigraphic units (climatoliths[1]) correspond to the end of Early and the first half of Middle Pleistocene of the International stratigraphic scale. These climatostratigraphic units combine sedimentary rocks in the age range from 430 to 800 thousand years. They correspond to three significant cooling (glaciations) – Pryazovsky, Sulsky, Tiligulsky and two large warming (interglacials) – Martonoshsky and Lubensky (Fig. 1). Horizons of buried soils match warm phases in the loess formations of Ukraine. Several of them may be formed during one interglacial. Loess and loess-like loams horizons correspond to cold stages.

Subaqueous depositions of the first half of the Middle Pleistocene form alluvial strata V and VI of above the flood plain terraces, as well as sediments of Chaudinsky and post-Chaudinsky marine basins.

Tiligulsky cold stage (climatolith) is characterized by the existence of fields and tongues of Oka (Krukenichskiy) cover (valley) glacier in the North-Western Ukraine. Glacial moraine formations of this age are found in sections of over deepened portions of the valleys of some rivers in the western part of Ukraine, as well as the river valleys of the Middle Dnieper R. basin.

METHODS

Literary and original data from resent years on the palynological analysis of subaerial deposits, molluscs and micromammal fauna of continental sediments or liman-marine origin were used to restore palaeogeographic conditions at the end of the first half of the Early-Middle Pleistocene.

Palynological analysis of subaerial deposits

Palynological samples were taken at irregular intervals of 5–35 cm. The palynomorphs from each sample of 100 g dry weights were extracted using

[1] Climatolith – climatostratagraphic unit combining rocks formed during a single climatic semi-rhythm on an interregional scale: warming (interglacial) or cooling (glaciation). Have their own name associated with the geographic name of the stratum location. Climatoliths, as a rule, correspond to the regional horizons of the section of the Quaternary system. As the geochronological equivalent of climatolith, the terms „cryochron" and „thermochron" are used. For example: Martonoshsky, Sulsky, Lubensky (https://geodictionary.com.ua/).

methods for processing of Quaternary samples. This method for our samples uses hot hydrochloric acid (10%) to remove the carbonate minerals. EDTA is used to disaggregate the sediment, then sieving with nylon screens to remove the sand fraction. Palynomorphs were separated from mineral part by means of heavy liquid flotation method (specific weight = 2.2 g/cm^3 and 2.0 g/cm^3). This is followed by a 4 h heating to 60°C in 52% hydrofluoric acid to remove the silicates.

The processed palynology residues are located in glycerine+water solution and routinely counted at a magnification of 600, using a Zeiss light microscope. All slides are completely counted.

Micromammalian analysis

Bone remains of small mammals were collected from Quaternary deposits of different origin by washing or sieving with sieves with meshes of 1.0 mm.

Morphological structures of the masticatory surface of vole teeth were measured using an MBI-9 microscope with a measuring scale. The following measurement were taken: L – tooth length, M – tooth width, A – anteroconid length, P – anteroconid width, H – length of anteroconid's unpaired loop, w, c, b, k, d, e – level of differentiation of anteroconid structures (Fig. 2). The following coefficients were used in order to determine the degree of evolutionary advancement of taxa: A/L, b/w, c/w, k/e, d/e, and SDQ (coefficient of enamel's divergence calculated as ratio of the enamel's thickness on the lower wall of conids to its thickness on the upper walls).

Data about malacofauna of continental sediments or liman-marine origin were taken from literature

RESULTS AND DISCUSSION

Pryazovsky cryochron (Nidanian, 20 MIS)

At the beginning of Pryazovsky cryochron time at Donbas and Pridonetskiy plain the areas occupied by arboreal groups were reduced. Within their components the role of thermophilic elements decreased and the role of small-leaved arboreal plants (birch, alder) increased. The beech, fir, and wing nut completely disappeared from the vegetation.

Space occupied by herbaceous vegetation of depleted composition was expanded. These changes in vegetation were caused by an increase in climate dryness and some cooling. In the Lower Dnieper, steppe vegetation apparently

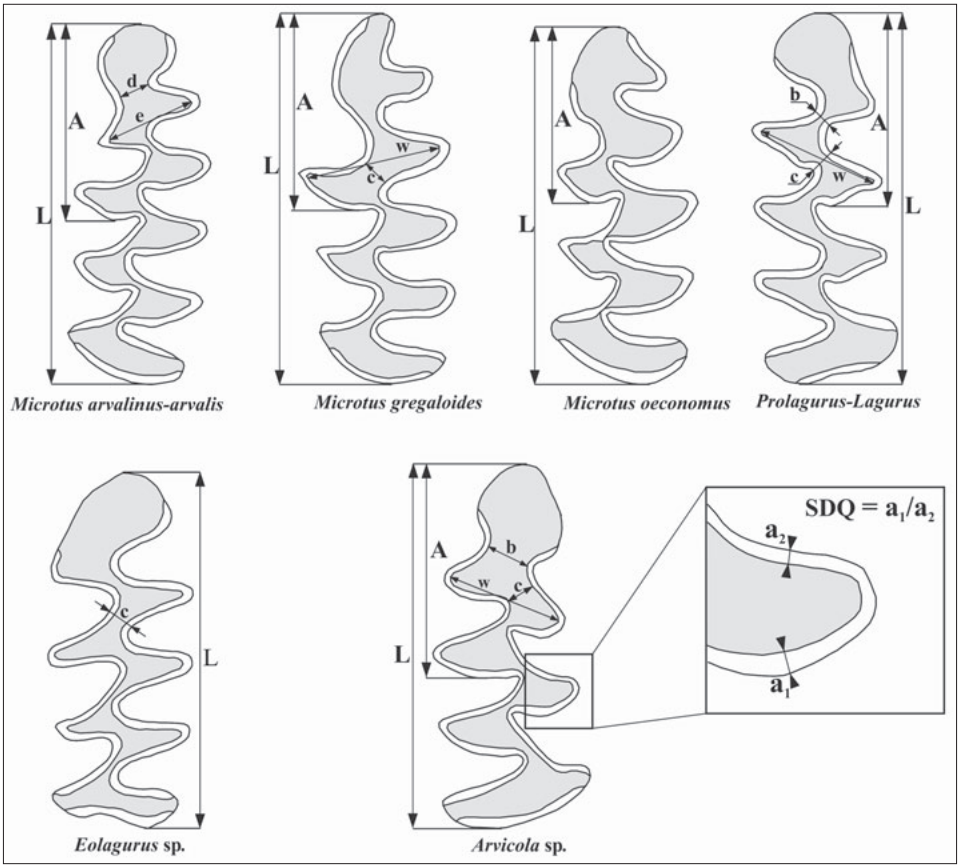

Fig. 2. Examples of measurement of the occlusal surface elements of the first lower buccal teeth of the Pleistocene Arvicolinae of Southeastern Europe

Ryc. 2. Przykłady pomiaru elementów powierzchni żującej pierwszych dolnych zębów Arvicolinae z plejstocenu w Europie południowo-wschodniej

dominated. Forest groups occupied a small area and weighty role belonged to the pine tree. The birch, alder, elm, and hazel presented among other arboreal plants.

According to N. P. Gerasimenko (Matviishina *et al.* 2010) landscapes were subpereglacial: forest-steppe in the north, steppe and dry steppe in the central-southern Ukraine, forest-meadow in the Carpathians. Stratigraphically below the Brunhes orthozones border (778,000 years) in biochronological scheme for small mammals Pryazovsky cryochron is fixed by the presence of *Microtus hintoni-gregaloides* and *Microtus protoeconomus*. This boundary is fixed in the subaerial sequence of alluvium with micromammals fauna in Karaj-Dubina cross-section (Krokhmal' and Rekovets 2010). On the left bank of the

Middle Dnieper (Manzheliya) meadow steppes were well represented. At that time in the lower reaches of the Dnieper (Karaj-Dubina) a steppe landscape with a predominance of small mammals – the representatives of open spaces was extended.

The presence of a large river artery resulted in a high number of intrazonal species. Forest and grassland species were rare and apparently found only along the banks of water bodies (Krokhmal 2008, 2009). The existenceof micromammals is related with this time segment. Their remains are presented in Skala Podolskaya location in the middle reaches of the Dniester. The conditions of open spaces also prevailed here, but the forest areas were not uncommon and located not only on the banks of rivers and slopes of beams, but also in elevated areas. These conditions are typical for the northern steppe transition to the forest (Fig. 3).

Perhaps Mikhailovskiy faunal complex of freshwater molluscs from alluvial VII of the Dniester terraces near Mikhaylovka partially corresponds to Pryazovsky cryochron. A boundary of the Brunhes-Matuyama epoch was found in the alluvium of the terrace above the layers with molluscs. Forms of Kosnitskiycomplex *Pseudosturia caudata* Bog., *Ps. brusinaiformis* Mod., *Ps. ovata robusta* Rudyuk., *Crassiana subcrassa* Gr. Ppv., *Unio pseudochasaricus* Tschep., that became extinct during the formation of Michael alluvium is still present here. *Crassiana crassoides* Tschep. gets flourishing. There are rare *Pseudanodonta, Unio tiraspolitanus* Tschep. and modern *Crassiana crassa* Phil. The extinction of the Pliocene fauna relics and development of ancient forms of modern fauna are fixed in the deposits of the terrace. Based on the taxonomic composition of molluscs, they existed in the turbulent hydrodynamic conditions which are associated with a riverbed insert. This usually occurs during the climatic coolings (Rudyuk 2002).

Martonoshsky thermochron (Malopolanian, 19–17 MIS)

In the Martonosh time, in the modern forest zone, forests where conifers (*Pinus sylvestris, Pinus* sect. *Strobus, Picea excelsa, P. omorica, Abies sp*., etc.) and boreal amentiferous (*Betula* sect. *alba*, several species of *Alnus*) were the main edificatory, were spread.

As an admixture broad-leaved trees: oak, lime, hornbeam, elm, hazel and Pliocene relics such as *Carya, Pterocarya, Juglans, Rhus, Cornus, Taxus, Nyssa,* and others constantly presented in them. Forests also dominated in a forest-steppe zone. Forest groups occupied not only the river valleys, ravines, they also reached watersheds. Woodlands consisted of broad-leaved plants and conifers. Among

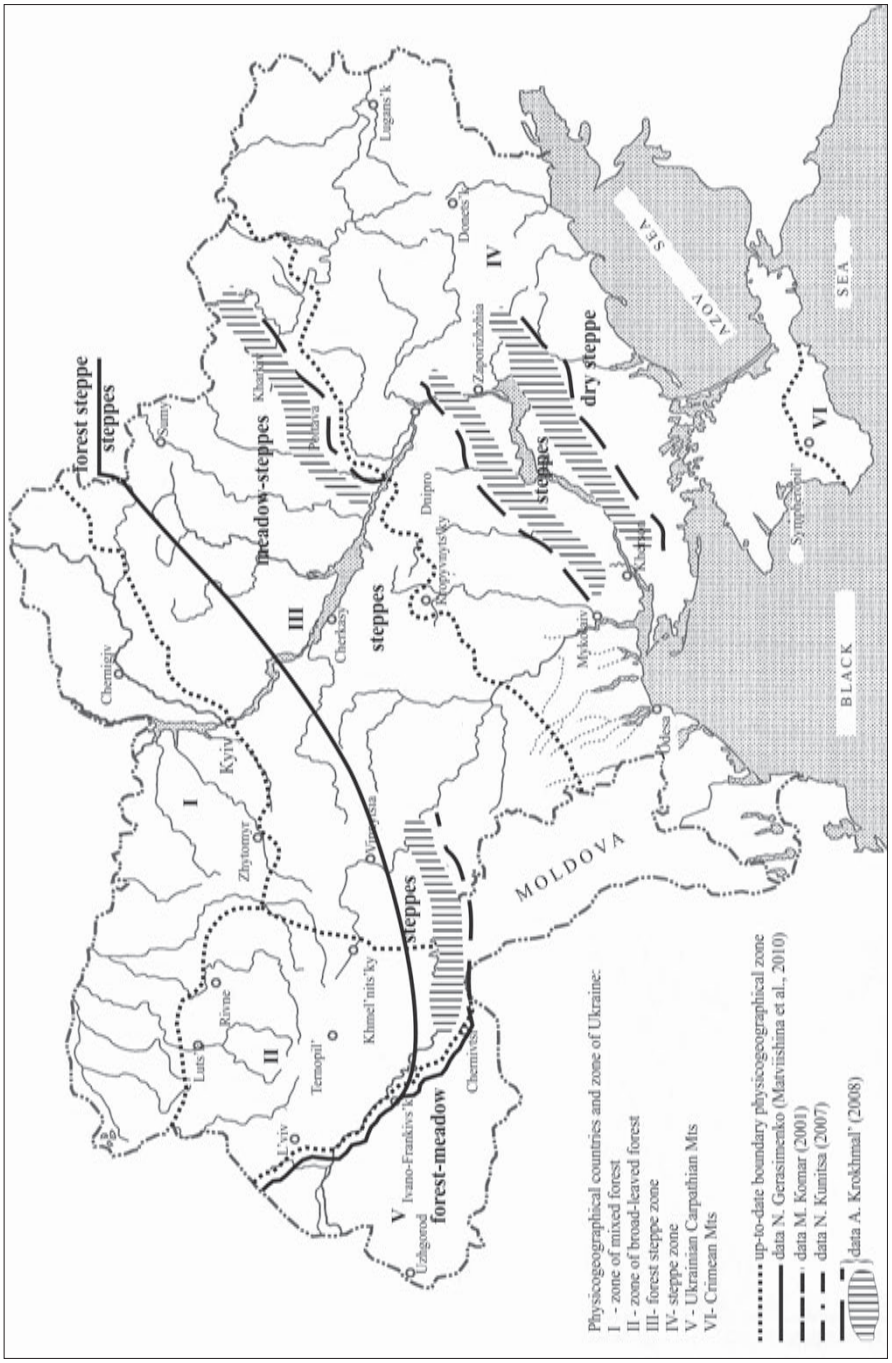

Fig. 3. Paleolandscapes of the Pryazovsky (Nidanian, 20 MIS) cryochrone of Ukrainian territory
Ryc. 3. Paleokrajobrazy przyazowskiej (Nidanian, 20 MIS) kriochrony na terytorium Ukrainy

them there were elements of Central and Balkan-Caucasian flora. Vegetation of open spaces was introduced by grass-forbs coenoses with Chenopodiaceae and Artemisia (Komar 1999, 2001).

In the steppe zone forest type vegetation was also spread. For the entire Early Pleistocene period the maximum variety of arboreal plants was characteristic for the forests of that time.

Preference in the forest communities composition of American-Euro-Asian representatives, as well as the presence of representatives of the American-Mediterranean-Asian groups is the evidence of warm, similar to the Mediterranean, quite humid climate.

N. P. Gerasimenko (Matviishina *et al.* 2010) presents similar data on the landscape of the sub-step mr_1 optimum of Martonoshsky time: mixed forests with Neogene exotics spread into the modern steppe; mesophilic forest-steppe (North and South) spread to the southern borders of modern middle steppe subzone; sub-Mediterranean landscapes of dry forests covered the area of southern steppe.

The beginning of Neopleistocene we associate with the emergence of *M. arvalinus* and this event correlate with a change of polarity on the boundary of paleomagnetic orthozones Matuyama and Brunhes (location Shamin, Litvin). At that time in the South Eastern Europe (Lower Don) the typical steppes stretched at the background of well developed hydro net of the ancient Don. Arboreal vegetation was probably very rare, and meadow areas were noted only in the floodplain. Perhaps thanatocoenosis of Khadzhimus 2, I location in lower Transnistria (Krokhmal' & Rekovets 2010) belongs to this palaeogeographic stage. Here the first occurrence of *M. arvalidens* was recorded. Steppe conditions at the time are a characteristic feature of the area. Species diversity of forest species (over 25%) at their low abundance (6.1%) indicates the rare areas of wood and shrubs vegetation with a wide range of habitats. Theriofauna of Kotovka 1, Protopopovka II, Kolkotova balka IV, Bolshevik 2, III locations characterizes the next phase of physiographic transformations of the studied area. In the early stages (Kotovka 1) a slight humidization of climate, compared with the previous period was noted, which was manifested in a decrease in the number of steppe elements in ecosystems, along with the disappearance of meadow and increase in the number and size of forest-steppe forms.

Taxonomic diversity of intrazonal species was reduced. Probably, boundary conditions between the steppe and forest-steppe landscapes were here, that is why the border of the steppe and forest-steppe zones shifted somewhat to the south compared to modern one.

Later (Protopopovka II) a significant change in the landscape situation occurred at the Black Sea – a typical steppe developed considerably.

It was resulted in a significant reduction in the size of steppe species populations. At the same time taxonomic diversity and abundance of representatives of forest-steppe, meadow, forest, near-water coenoses increased. Taking into consideration the geographic proximity and marked differences in the biocoenotic characteristics of two above mentioned locations, one can assume the presence of a certain time interval during the time of accumulation of these host fauna alluvial strata.

At the same time in the Lower Transnistria (Kolkotova balka IV) landscapes of northern forest (forest border) with well-developed forest vegetation and high density populations of forest-steppe, forest and intrazonal species of small mammals were developed.

The number and diversity of steppe elements were on the same level with forest-steppe ones (Krokhmal' 2008). Micromammals of Bolshevik 2, III location (appearance of *Prolagurus posterius*) characterize the final stage of the forest-steppe landscapes at the Black Sea and Lower Dniester. In comparison with the previous time the number of forest-steppe species increases with a simultaneous increase in the species diversity of the forest and intrazonal elements of coenosis. Reducing the number of intra-zonal species indicates a slight decrease in water content of the area. The taxonomic composition of the inhabitants of the steppe areas increases, although their number remains constant. Species diversity of thanatocoenosis (21 taxa) indicates the presence of a large number of user-friendly habitats and optimal conditions for biota existence.

The next stage is climate aridity fixed on fossil micromammals of subaqueous deposits of the south western Black Sea and northern Sea of Azov regions (Tikhonovka 2, Altestovo, Protopopovka I). In the Sea of Azov region (Tikhonovka 2) open steppe spaces with relatively poor water basin of river and oxbow types with occasional meadows along the banks were widely presented. According to the number and taxonomic composition of theriofauna remains the representatives of open (steppe and forest-steppe) spaces are dominated. Forest species are absent.

At this time at the Black Sea region (Protopopova I) steppe coenoses also dominated, but the number of species of open space was slightly lower than in the Sea of Azov region, and the number of steppe and forest species was the same. The representatives of meadow habitats disappeared. The indicator of a marked increase in water content and the development of arboreal vegetation on the banks of reservoirs are the growing role of intra-zonal and forest component in the composition of palaeobiocenoses. Probably a little later a shift of accent of open spaces species abundance from steppe groups to the forest-steppe is observed in this region (Altestovo), but the number of steppe and forest component is reduced slightly as a whole. At the same time taxonomic diversity of steppe

species reduced almost twice. The number of forest species increases and representatives of meadow micro mammal communities reappear again. There are no intrazonal (wetland) species what possibly indicate the weak development of the hydro system.

The next phase of changing of physical and geographical conditions in the South East European fauna was fixed at Kolkotova balka III and Bolshevik 2, II locations, and we associate the first appearance of *M. gregaloides* with them. Location of Kolkotova balka III is the main body of the so-called „Tiraspol gravel". Thanatocoenosis of this location indicates the development of forest-steppe conditions in the area with approximately equal number of forest-steppe and steppe species, with a predominance of the latter in the taxonomic terms. The number of forest species was quite high (about 20%), indicating the distribution of forest species of forest outlier type on the average watered territories, which were timed to meadow areas. Southward in the Black Sea region (Bolshevik 2, II) forest steppe, but probably of the south, arid type, bordered the steppe regions was also distributed there. This is reflected in the low abundance and taxonomic representation of forest forms, as well as reduction in waterfowl species number. Grassland habitats are very rare. Most likely, micromammals fauna of Shirokino 1, I, and Platovo II locations are associated with this time interval, that characterize palaeogeographic conditions the Northern Azov sea side. The typical xerophytic grass steppes without arboreal and meadow vegetation presented here. Water supply was very poor – there were probably parched small rivers and oxbow lakes. The few remains of small mammals of Nagornoye 3 location on the Lower Danube, probably do not fully reflect the landscape setting of the time. But we can assume that in this region meadow forb steppes in conjunction with a developed system of reservoirs were common.

A new stage of climate humidization is reflected in the Sea of Azov thanatocoenosis of Semibalka 1 and Tikhonovka 1 locations (Krokhmal' & Rekovets 2010). In the first the occurrence of *L. transiens* is recorded, and *E. luteus* in the second. On the east coast of the Sea of Azov (Semibalka 1) the steppe was developed. With an equal taxonomic representation of steppe and forest-steppe species the number of latter was twice as high. In the delta of the ancient Don wetland species and species inhabited the forest litter of riparian forests (*Sorex*) presented. In the basin of the Molochnaja river forest-steppe also dominated at that time. Both taxonomically (8 species vs. 7) and quantitatively (72% vs. 26%) forest and forest-steppe species dominated in paleocommunity compared with the steppe fauna. The latter settled probably only on plakors. It is interesting that on the background of such diversity wetland species are practically absent, what is the evidence of poorly developed hydro system.

Fauna of Kotovka 1, Protopopova II, Kolkotova balka IV, Bolshevik 2, III locations, is likely characterized the first warm (humid) stage of Martonoshsky thermochron – optimum of sub-step mr_1 according to N. P. Gerasimenko (Matviishina *et al.* 2010) (Fig. 4). Perhaps, Middle Pleistocene Koshnitsky fauna complex, highlighted by the finds of freshwater mussels of alluvial terraces of the Dniester VI (Rudyuk 2002) near Koshnitsa, and Pogreby, Soroky corresponds to the given time interval. The complex is characterized by the absence of heat-loving species. There *Crassiana subcrassa* Gr. Ppv., *C. szegedensis* Hal., *Unio tiraspolitanus* Tschep., rare species of the subgenus *Pseudosturia* (B. (Ps.) *postumus coshnica* ssp. nov.) continue to exist. *Unio rumanoides* Tschep. and modern forms of *U. pictorum* L., *U. tumidus* Phil., *Crassiana crassa* Phil., *C. consentaneus* Ziegl., *C. batavus* Nilss appear at that time. Without any doubts malacofauna of Kolkotova balka IV location refers to Martonoshsky climatoliths.

From the findings of terrestrial molluscs Martonoshsky time was characterized by the formation of the landscape of warm steppe in the south of Ukraine, and of a kind of forest-meadow steppe in the middle belt. Xerophytic grass-shrub steppe dominated on the plakors on the south, meadow steppes – in the middle region, and coniferous-deciduous forests – along river valleys (Kunitsa 2007).

Sulsky cryochron (Sanian 1, 16 MIS)

On the territory of Ukraine in Sulsky time a tendency to cooling and aridity was marked. This is evidenced by a decrease in the role of thermophilic elements and the increased importance of herbaceous vegetation. Treeless landscapes expanded. In Zytomir Polissia pine forests dominated. The composition of deciduous plants existed in Martonoshsky time significantly reduced. In the structure of the central part of Ukrainian shield arboreal and herbaceous groups occupied almost equal areas (forest-steppe). The main components of these forests were *Pinus* sect. *Eupitys*, *Betula* sp. and *Quercus robur* were met much less there. Representatives of the family Chenopodiaceae and Asteraceae dominated in grassland (Sirenko 2005). Steppe type of vegetation spread in Lower Dnieper. Wood grouping with pine, birch, alder, oak and hazel occupied a small area in the most humid places. In southern Ukraine grassy psamophytes and xerogalophytes were widespread. In the valleys and on the gully slopes floodplain and bajrak forests of depleted composition were formed (Komar 1999, 2001).

According to N. P. Gerasimenko (Matviishina *et al.* 2010) Sulsky stage differed by intense loess accumulation and was comprised by two cryophases divided by warming phase. Cold phases were characterized by periglacial and

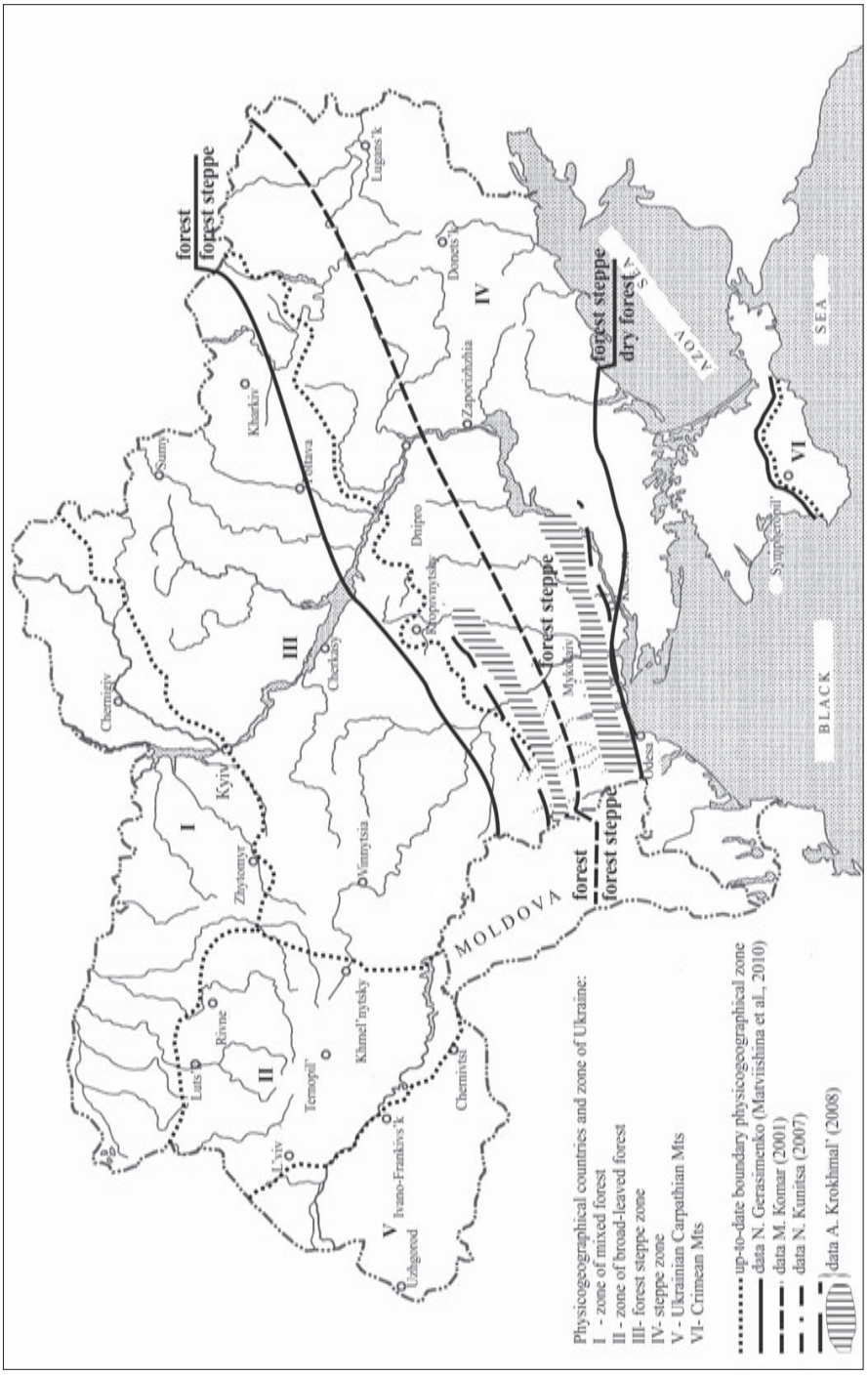

Fig. 4. Paleolandscapes of the optimum mr1 of Martonoshsky (Malopolanian, 19 MIS) thermochrone of Ukrainian territory
Ryc. 4. Paleokrajobrazy w czasie optimum interglacjału martonoskiego (Malopolanian, 19 MIS) na terytorium Ukrainy

sub periglacial steppes and warm one by the boreal forest-steppe in the north and in the center and steppes southward (Fig. 5).

In Sulsky time as judged by micromammals, forest-steppe habitats of biota in the south of Eastern Europe are replaced by steppe. This change is probably due to a general cooling of the climate in the northern Palearctic at that time. In the east of Northern Sea of Azov (location Platovo I) region there was a steppe landscape. Steppe species of small mammals comprised more than 50% of the total number of animals in paleotherio association. Probably along the banks of small rivers and water reservoirs a mosaic tree and shrub vegetation presented, where different species of forest and intrazonal biotopes inhabited. At that time, on the Lower Danube (Suvorovo II, the emergence of *M. oeconomus*) the typical steppe with small clumps of arboreal and meadow vegetation also dominated along the banks of rivers and lakes, although the area of grassland decreased significantly compared with the previous period (Nagornoye 3). Steppe species of small mammals, both in number and biomass dominated in ecosystems (Krokhmal' 2008). If we imagine an overall picture of the spread of the landscapes during the Sulsky cryochron, we will see the shifting boundaries of landscape zones to the north compared to the boundaries in Martonoshsky time.

According to the analysis of terrestrial mollusc in the middle zone of Ukraine, there were two palaeogeographic provinces; on the right bank of the Dnieper tundra-forest-steppes were developed, as well as tundra-meadow-steppes spread on the left bank. In the south of the country southward Dnepropetrovsk xerophytic cold steppe landscapes were located (Kunitsa 2007). Likely malacofauna of the Middle Kolkotovian faunistic complex refers to Sulsky climatolith and upper part of Martonoshsky climatolith; it was marked out by the finds of molluscs in the type locality near the city of Tiraspol in a gravel pit on the left side of Kolkotova balka. The complex is characterized by species *Pseudunio moldavica* Tsshep., *Ps. robusta* Tsshep., *Potomida kinkelini* Haas, *P. litoralis* Cuv. The representatives of the genus *Crassiana* (*C. steveniana* Kryn., *C. hassiae* Haas, *C. crassa* Phil., *C. bodamica* Rossm., *C. batava* Nilss., *C. mingrelica* Dr., *C. consentaneus* Ziegl.)and a few representatives of the genus *Unio – U. tiraspolitanus* Tsshep., modern *U. tumidus* Phil., *U. pictorum* L. were also presented. The analysis of the taxonomic composition and conditions of localities of studied mollusk fauna shows that two fauna of early *Pseudunio* and late *Potomida* weremixed in the complex. In sections V (Kolkotovian) of lower reaches of the Dniester, Danube terraces there are two sedimentation rates. Alluvial deposits of the lower rate are characterized by *Pseudunio moldavica* Tsshep., *Ps. robusta* Tsshep., as well as *Crassiana hassiae* Haas, *C. steveniana* Kryn., *C. mingrelica* Dr. The deposits of the upper rate contain numerous remains of *Potomida litoralis* Cuv., *P. kinkelini*

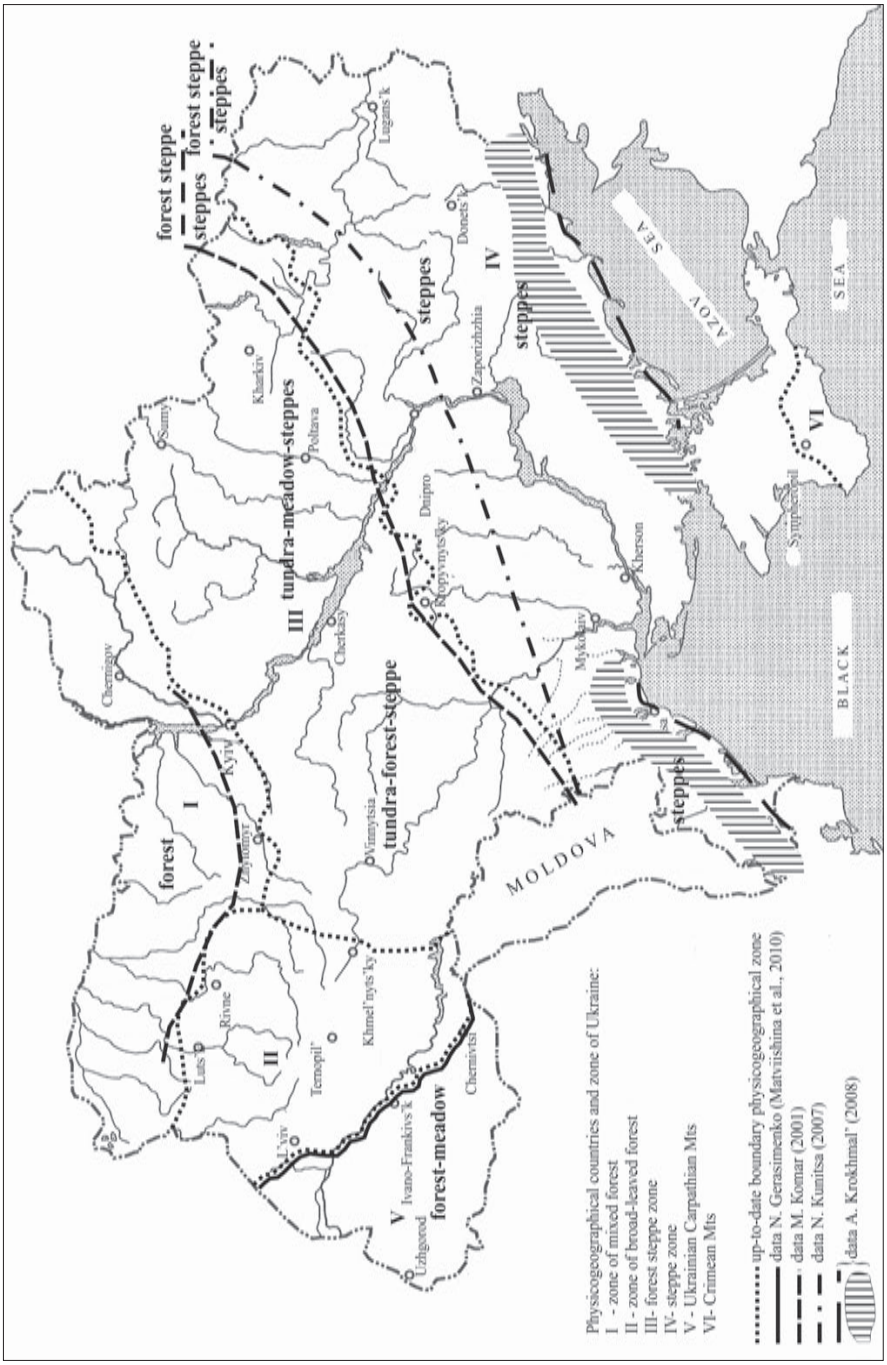

Fig. 5. Paleolandscapes of the Sulsky (Sanian1, 16 MIS) cryochrone of Ukrainian territory
Ryc. 5. Paleokrajobrazy sulskiej (Sanian1, 16 MIS) kriochrony na terytorium Ukrainy

Haas and *Crassiana crassa* Phil., *C. pseudocrassa* Cl. *Pseudunio* presence is the indicator of sufficiently high flow velocities and water clarity, which is explained by the formation of the lower rate of alluvium in the regressive stage at high speed turbulent flow during probably middle-martonoshsky cooling. Availability of *Potomida* indicates the formation of the Upper rate in warm climate at the end of Martonoshsky thermochron and during Sulsky cooling (Rudyuk 2002).

Lubensky thermochron (Ferdynandovian, 15–13 MIS)

Lubensky thermochron on the territory of Zhytomyr Polissya was marked by slight reduction in the territories occupied by arboreal vegetation and distribution of open spaces with grassy groups. Compared with Martonoshsky time taxonomic composition of forests become poorer; beech, hornbeam, elm, and almost all thermophilic species were absent there. Forest-steppe landscapes dominated in the central part of the Ukrainian shield. A decrease of thermophilic elements, low taxonomic diversity of broad-leaved trees, and the disappearance of beech is also characteristic for the forests of the area. Birch-pine and mixed forests with linden (*Tilia cordata)*, oak and hornbeam with an undergrowth of hazel and *Rhamnus* spread at that time (Sirenko 2005).

In the Lower Dnieper nature of vegetation was mostly forest-steppe. Forest group consisted of broad-leaved (mostly oak) and coniferous plants and occupied river valleys, over deepened areas, sometimes spread to the watersheds. Herbaceous vegetation was represented by grass-forb coenoses with goosefoot and worm wood. This time interval is in the south of Ukraine was characterized by slight strengthening of the role of forest formations with a significant participation of mixed deciduous forests (with oak domination). However, compared with Martonoshsky stage, steppe formation was slightly wider. Forb-meadow and steppe cenoses played a significant role in the vegetation.

According to N. P. Gerasimenko (Matviishina *et al.* 2010) Lubensky warm phase is represented by two sub-steps of soil formation (lb_1 and lb_3) and a stage forest formation (lb_2). At sub-step lb_1 subboreal moderate, warm-temperate and warm landscapes change each other from north to south. At sub-step lb_3 moderate landscapes give way to warm-temperate. The characteristic features of the early substages of soil formation (lb_{1b1} and lb_{3b1}) are increased hydration, accompanied by the displacement of deciduous forests zone into the modern forest-steppe and forest-steppe zone into the steppe one. At the later substages (lb_{1b2} and lb_{3b2}) aridity traits are expressed (Fig 6).

Palaeogeographic conditions associated with forest formation stage (lb_2), on the south-western Ukraine meet the conditions of arid climate of the southern

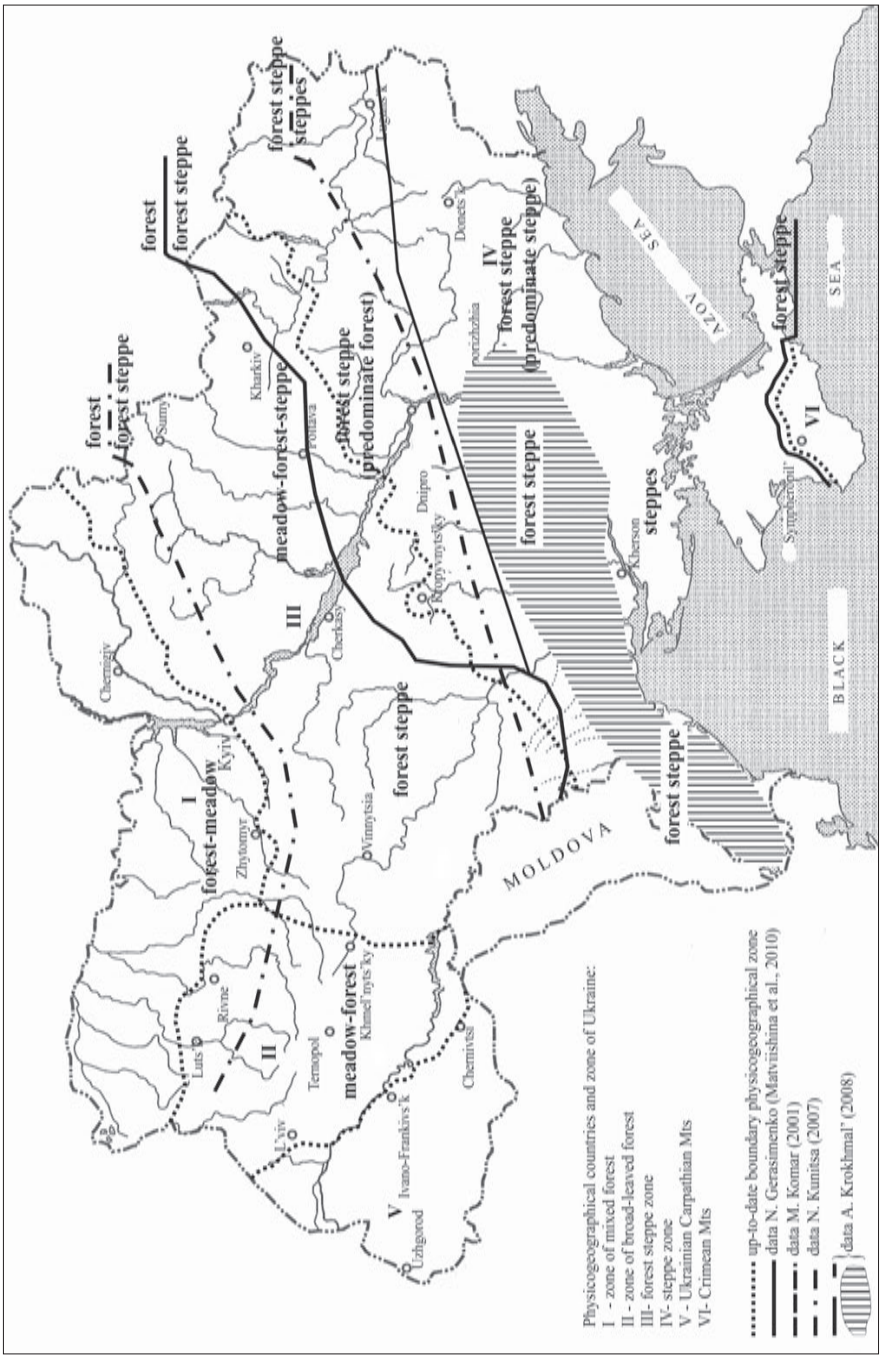

Fig. 6. Paleolandscapes of the substage lb3 of Lubensky (Ferdynandovian, 13 MIS) thermochrone of Ukrainian territory
Ryc. 6. Paleokrajobrazy w czasie substadium lb3 interglacjału łubenskiego (Ferdynandovian, 13 MIS) na terytorium Ukrainy

steppes, which are fixed by us on the species composition and size of the micro mammal cenotic groups. *M. gregalis* currently a representative of open spaces in the tundra zone appears for the first time. It seems to us, the vast steppes were distributed in the south-western Black Sea region (Krasnoselka 1), although tree and shrub vegetation populated with steppe and forest-meadow species of small mammals grew in ravines. On the Lower Danube (location Suvorovo I) climate aridity reached its peak at this time. Representatives of the steppe fauna dominated both in number of species and their quantity.

While on the banks of small reservoir and canals inhabited by representatives of the few species of meadow-forest and riparian coenoses. Fauna of close age was described from the lower section of buried soil of Kolkotova balka (location Kolkotova balka II). Habitats reconstructed on its basis meet steppe conditions. Only open spaces species were recorded in thanatocoenosis, although they contained both steppe and forest-steppe forms. Representatives of meadow, forest and riparian communities are absent, and perhaps this is due to the taphonomy of location.

Fauna correlated with late Cromer and soil formation stage lb3, are characterized by the appearance of the water vole – *A. mosbachensis*. conditions of the time were radically different from preceded ones. Climate humidity in the south of Eastern Europe increased significantly, leading to the extension of the areas of forest-steppe landscapes, and a shift of the southern borders of the forest and steppe zones far south. Changes in palaeogeographic conditions sequentially from west to east with the Lower Danube (Nagornoye 1, I, Bolshevik 2, II) to the Lower Dnieper (Lysaya gora 1) are considered below. On the Lower Danube (Nagornoye 1, I) a forest-steppe zone prevailed, and woodland occupied much bigger area than the steppe, due to the rapid spread of sub-trees and shrubs at this time. Steppe (3 species) and forest (6) forms more than 50% of the total number micromammals of thanatocoenosis, whereas steppe species (9) accounted for less than 10% of the total number. A marked reduction in the area of open (steppe) spaces led to the reduction in number the steppe species of rodents. Due to the presence of large water bodies the intrazonal species of small mammals became abundant.

During this period, in the south-western Black Sea region (location of the Bolshevik 2, II) forest-steppe was also distributed, but the share of each of the biocenotic groups was different. The number of steppe elements was approximately one-third of the total number of residues, as well as in forest-steppe and forest species. At that the species diversity did not differ from that of Nagornoye 1, I location. It should be noted a small watering of the territory, what led to a low number of waterfowl species. In the Lower Dnieper (Lysaya gora 1) steppe

landscape was also dominated. The quantitative distribution of residues of different cenotic groups was about the same as in the Bolshevik location 2, II, but the number of taxa was 2–4 times less. It should be noted that the remains of species of meadow habitats were not found in any thanatocoenosis (Fig 4).

According to the analysis of terrestrial molluscs (Kunitsa 2007) in Polissia and the wide valley of the northern part of the Middle Dnieper meadow-broadleaved forest landscapes of moderately warm climate were developed. For the middle zone of Ukraine between Kiev and Dnepropetrovsk forest-steppe and meadow-steppe landscapes were typical, but in Western Podolia meadow forest predominated. In the Northern Black Sea and the Sea of Azov to the south of Dnipropetrovsk steppe meso- and xerophytic landscapes were dominant.

Tiligulsky cryochron (Sanian 2, 12 MIS)

Tiligulsky time was characterized by strengthening of continental climate and an increase in its aridity. In the northwest glacial landscapes dominated. Periglacial steppe was in northern Ukraine, which by the share of cryophytes approximated to tundra- forest-steppe. In the modern forest-steppe zone vegetation of open space represented by sagebrush-grass-Chenopodiaceae coenoses with admixture of xerophytic grasses dominated. Depleted forests occupied low-lying areas of the terrain. In the steppe zone in elevated areas monodominant phytocenoses with xerophytic Chenopodiaceae predominated, and forest groups were mainly composed of conifers (Matviishina *et al.* 2010; Komar 1999).

Data on terrestrial molluscs suggest that Tiligulsky time the boundaries of the forest-steppe and steppe zones passed through the south of Kiev along the line of geographical points Winnitsa–Kaniv–Romny (Kunitsa 2007). But quite clearly three paleolandscape province can be selected. The first one is the Dniester–Bug tundra-steppe with a predominance of open tundra-steppe landscapes. Right-bank Dnieper was occupied by tundro-forest-steppe province. Here there were small islands of woodland in ravines, gullies and valleys. On the left bank of the Dnieper terraces meadow and meadow-steppe landscapes were common and watershed plains were occupied by tundra-steppe. Cool grass-shrub steppe stretched the southward Dnepropetrovsk (Fig 7). Cooling of Tiligul time on the fauna of rodents in the studied localities has not yet registered.

As noted above, sediments of Chaudinsky and post Chaudinsky marine basins correspond to continental deposits of the end of the first half of early-middle Pleistocene. For a long time it was thought that Chaudinsky brackish basin had limited distribution in the northern part of the Black Sea and did not penetrate into the waters of the modern Azov Sea, where „Azov land" was at that time. But

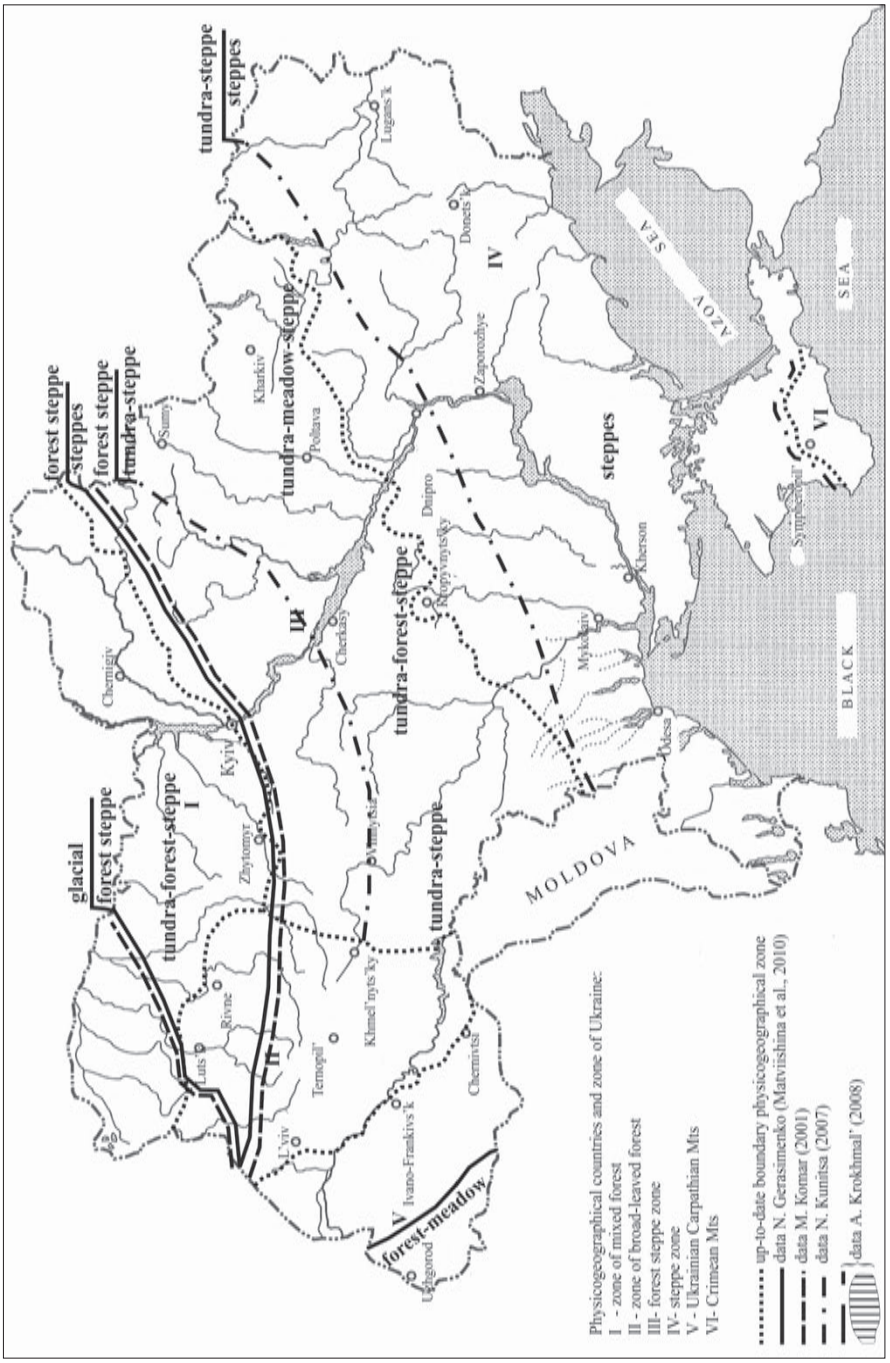

Fig. 7. Paleolandscapes of the Tiligulsky (Sanian 2, 12 MIS) cryochrone of Ukrainian territory
Ryc. 7. Paleokrajobrazy tiligulskiej (Sanian 2, 12 MIS) kriochrony na terytorium Ukrainy

representatives of Chaudinsky shellfish fauna were found in the Western Manych (Popov, 1955). This is proof that the Sea of Azov could not be the land, but was a saltwater basin (Shn'ukov *et al.* 2000). This is confirmed by the findings of the Chaudinsky-Bakinsky fauna on the northern and southern shores of the Sea of Azov (Kazantip cape, Chegeni, Manych gulf). In addition, chaudinsky deposits are widespread in Karkinitsky gulf in the north-western shelf of the Black Sea, in the lower reaches of the Danube (Konstantinova 1967).

At the end of the first half of the Middle Pleistocene after Chaudinsky transgressive phase post Chaudinsky regression occurred. Sea level, according to the incision of paleorivers and data on Kerch channel, fell to the level of 100 min relation to the current level (Fedorov 1993). In conclusion, it should be noted that the scope and boundaries of biostratigraphic units of Pleistocene not always coincide with those climatho-stratigraphic units allocated on the basis of palaeogeographic reconstructions.

CONCLUSIONS

1. Data on palynology, microtheriology and malacology have confirmed the cyclical nature of landscapes and climate change, associated with glaciations (cooling) and interglacial (warming) in the Pleistocene in Ukraine.

2. In biochronologic schemes for small mammals and molluscs:

– Pryazovsky cryochron sets below the Brunhes orthozones border (778,000 years) based on the appearance of *Microtus hintoni-gregaloides* and *Microtus protoeconomus*. Perhaps the Michael complex of freshwater molluscs from the VII-th Dniester terraces partially corresponds to the Pryazovsky cryochron. The boundary of the Brunhes-Matuyama epoch was found in the alluvium of this terrace above the layers with molluscs.

– it is possible to divide Martonosha thermochron into two stages. The first – is associated with the appearance of *Microtus arvalinus* and *Microtus arvalidens* species, the second – with the appearance of the *Prolagurus posterius*, followed by *Microtus gregaloides* and *Lagurus transiens*. At that time, the last representatives of *Prolagurus pannonicus* and *Mimomys pusillus* disappeared. Probably this period of time corresponds to the Kosznica complex of freshwater molluscs from the VI-th Dniester terraces (the complex is characterized by the lack of thermophilic species).

– Sulsky cryochron is associated with the first appearance of *Microtus oeconomus* and *Eolagurus luteus*. The analysis of the systematic composition and the location of molluscan fauna indicate that in the complex that characterizes

the upper part of Martonoshsky and Sulsky cryochrons, two fauna are mixed: early with *Pseudounio* and late with *Potomida*.

– the beginning of the Lubny stage was determined by the appearance of *Microtus gregalis*. In contrast, the appearance of *Arvicola mosbachensis* is an indicator of the end of thermochron (late Cromer).

3. The surface and boundaries of the Pleistocene biostratigraphic units do not always coincide with the surface of the climatostratigraphic subunits identified on the basis of palaeogeographic reconstructions.

4. The necessity and accuracy of the integrated use of common geological and palaeontological methods during reconstruction of palaeolandscaps is confirmed.

Authors' contribution: Aleksey Krokhmal' – 60%, Maryna Komar – 40%.

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