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This volume of the journal – the main journal on the united branches of Earth Science in Ukraine – is devoted to the approaching XXth Congress of INQUA (Dublin, 2019) and, thus, it is a collection of papers by Ukrainian Quaternary researchers. The majority of them are members of the Ukrainian National Committee of INQUA, but several papers are contributed by young scientists. A similar specialized collection of papers on Ukrainian Quaternary was published in English by the Institute of Geological Sciences of Ukraine (as separate volumes) in 2011 and 2015, but, presently, in order to make the papers available on-line, the decision has been made to publish them in the journal "Geology, Geography and Geoecology" (represented in the Web-of-Science). Ukraine is a classic loess area in Europe. Climate change and its impact on continental ecosystems can best be investigated by studying continental deposits. Loess-palaeosol archives over large areas of Ukraine provide valuable data on time-space variability of Quaternary ecosystems. Hence, the main focus of the papers is on the stratigraphy of loess-palaeosol successions and palaeoenvironments derived from their studies. The volume consists of the papers on different aspects of the study of loess-palaeosol sequences: on indicative features (including micromorphology) of palaeosol units of differing ages, on palaeovegetational and palaeoclimatic reconstructions derived from loess-palaeosol sections, on cryogenic features in these sections, on determination of position of the Matyuama-Brunhes boundary within the Ukrainian loess-palaeosol sequences, on correlation of Ukrainian framework with Western Europe and, finally, on the problems which appeared through the acceptance of a 2.6 Ma lower boundary for the Quaternary in Ukraine. There are papers on Quaternary mapping, on palaeoenvironments of the Middle and Upper Palaeolithic, on the Late Glacial distribution of halophytic vegetational species in the plain area of Ukraine, on non-pollen palynomorphs in the salt lakes of Crimea, and on the biostratigraphy of the northern Black Sea deposits based on ostracods. The aim of this volume is to present at least a part of the data obtained by Ukrainian Quaternarists, as they are frequently published in Ukrainian language or in journals with a restricted distribution, and therefore almost inaccessible for researchers who are outside Ukraine.

UkrINQUA would like to take this opportunity to thank the Editor-in-Chief of the "Geology, Geography and Geoecology", Dr. V. Manyuk, who provides the opportunity to publish this collection of Quaternary papers in a special volume of the journal.

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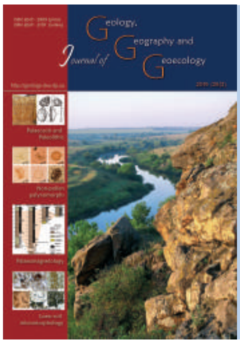

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The Upper Pleistocene stratigraphy of the Starunya site as a "bridge" between the stratigraphical frameworks of Western Europe and the plain area of Ukraine

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Abstract. The first discoveries of mummified carcasses of the woolly rhinoceros, mammoth, horse, roe deer and other animals were made at a depth of 12 m in the course of mining work at an ozokerite mine near the village of the Starunia. In 1929 an expedition of the Academy of Arts and Sciences from Krakow, when investigating the mine at a depth of 17 m, found the remains of 3 more woolly rhinoceroses. There were also numerous bones of small vertebrates (rodents), artichokes, numerous insects, beetles, parasitic worms, fleas, butterflies, spiders, snails, vascular plants, seeds and branches of dwarf birch, alder, and other representatives of tundra flora. In March 1977, after the earthquake in the Vrancha Mountains (Romania), the first and still the only mud volcano in the Carpathians, which added an entirely new " note " to the Starunia paleontological location , arose on the ozokerite deposit. In the 1970s-80s several dozen remains of ancient man from the late Paleolithic, Mesolithic and Neolithic periods were discovered. In 2004-2009, two Ukrainian-Polish expeditions were organized. The results of both expeditions were published in 2005 in the book «Polish and Ukrainian Geological Studies (2004-2005) at Starunia – the area of discoveries of Woolly Rhinoceros» and the scientific collection «Interdisciplinary Studies (2006-2009) at Starunia (Carpathian Region, Ukraine). The main achievements are set forth in 17 articles and relate to the geological environment, geomorphology, lithology, stratigraphy and paleography of the Holocene deposits, their palynological and paleobotanical characteristics, chronostratigraphy and environmental changes during the period of the late Pleistocene and Holocene, and also research by methods of electric probe, gravity and microgravity survey, geochemical analysis, microbiological characteristics and bitumen of Quaternary deposits. An important result was the discovery of the most productive area where the remains of giant mammals and even Pleistocene Cro-Magnon could still be found at depths. All the numerous interdisciplinary research of Polish and Ukrainian scientists confirms the uniqueness of Starunia on a global scale, requiring the preservation and further study of the paleontological finds and of the only mud volcano in the Carpathians. Such findings can only be made by organizing the Starunia International Ecological and Tourist Center «Geopark Ice Age».

Keywords: Upper Pleistocene, woolly rhinoceros, mammoth, tundra, natural-man-made geosystems, paleoclimate.

Схема стратиграфії верхнього плейстоцену Старуні як «місток» між аналогічними схемами Західної Європи та рівнинної України

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Анотація. Перші знахідки муміфікованих туш волосатого носорога, мамонта, коня, козулі та інших тварин здійснювалися на глибині 12 м при проходженні гірничіх виробок для видобутку озокериту біля села Сатруня. У 1929 році експедиція Академії мистецтв та наук із Кракова, під час проходження шахти на глибині 17 м, виявила залишки ще 3 волохатих носорогів. Були також численні кістки дрібних хребетних (гризунів), артишоки, численні комахи, жуки, паразитичні хробаки, блощиці, метелики, павуки, слимаки, судинні рослини, насіння та гілки карликової берези, вільхи та інших представників тундрової флори. У березні 1977 року, після землетрусу в горах Вранча (Румунія), на озокеритовому родовищі виник перший і до цих пір унікальний грязьовий вулкан в Карпатах, який надав старунському палеонтологічному місцезнаходженню нове «звучання». У 70-80-х роках ХХ століття було виявлено декілька десятків стоянок стародавньої людини пізнього палеоліту, мезоліту і неоліту.

У 2004-2009 роках було організовано дві українсько-польські експедиції. Результати обох експедицій були опубліковані у 2005 році в книзі «Польські та українські геологічні дослідження (2004-2005) у Старуні – області відкриття шерстистого носорога» та науковому збірнику «Міждисциплінарні дослідження (2006-2009) у «Старунії» (Карпати). Основні досягнення наведені в 17 статтях і стосуються геологічного середовища, геоморфології, літології, стратиграфії та палеографії голоценових відкладів, їх палінологічної та палеоботанічної характеристик, хроностратіграфії та зміни навколишнього середовища впродовж пізнього плейстоцену та голоцену, а також стосуються досліджень методами електричного зондуваня, граві- та магніторозвідки, геохімічних аналізів, мікробіологічних характеристик та бітумів четвертинних відкладів. Результатом цього було відкриття найбільш сприятливого району, де на глибині все ще можна виявити залишки гігантських ссавців і навіть кроманьонців плейстоцену. Усі численні міждисциплінарні дослідження польських і українських вчених підтверджують унікальність Старуні на глобальному рівні. що вимагає збереження і подальшого вивчення палеонтологічних знахідок і єдиного грязьового вулкана в Карпатах. Такі висновки можуть бути зроблені лише шляхом організації міжнародного еколого-туристичного центру «Геопарк Льодовиковий період».

Ключові слова: верхній плейстоцен, волохатий носоріг, мамонт, тундра, природно-антропогенні геосистеми, палеоклімати.

Relevance of the topic. The ecological state of the environment in the western region of Ukraine has considerably deteriorated over the last decade. It is caused by excessive recreational loading, pollution of water objects with domestic sewage, increasing emissions of vehicles into the air, uncontrolled felling of the forests, the impact of technogenically hazardous objects: Burshtinska TPP, Kalush salt mines, the Dombrovsky quarry and its tailings , objects of oil and gas extraction and petrochemical processing, unauthorized extraction of sand gravel-pebble deposits from river channels, active development of landslides, sulphurization, karst and erosion processes. The construction of a hydroelectric power station on the mountain rivers and the Dniester river, which involves the construction of a dam and a reservoir, water pipe lines along the channels of mountain rivers, can be a major new environmental threat. The catastrophic floods on the Dniester, Prut, Siret and Tisza rivers, which have become more frequent in recent years (2002, 2008, 2018), are associated with a special threat to natural geosystems, economy, transport infrastructure and population, which is associated with global warming and increasing technogenic load on geosystems. The western region of Ukraine is located in the zone of developed atmospheric storm activity and, accordingly, in the area of increased risk of occurrence of waterborne disasters occurring on various scales, including catastrophic, flooding and waterlogging of territories, destruction of engineering infrastructures and disruption of communications with devastating consequences.

Therefore, it is important to map natural and human structures based on maps of Quaternary deposits, geomorphology, landscapes, which are based on a detailed stratigraphic dismemberment of the Pleistocene and Holocene supporting sections. One of such sections is Starunia – the paleontological location of the late Pleistocene fauna of wooly rhinos and mammoths in Bogorodchansk district of Ivano-Frankivsk region, 18 km from the city of Ivano-Frankivsk.

From the history of research. The first finds at this site of the wooly rhinoceros, mammoth, horse, roe deer, and other animals of the Pleistocene's so-called mammoth fauna were made in October 1907 at a depth of 12 m during the excavation of a shaft for the extraction of ozokerite near the village of Starunia. Scientists from Krakow and Lviv duly appreciated these unique discoveries and published a number of articles and a monograph in 1914 (Bayger, 1914; Lomnicki, 1908).

In 1929, an expedition of the Academy of Arts and Sciences from Krakow while digging a special research shaft found three more carcasses of woolly rhinoceros embalmed in bitumen and salt at a depth of 17 m. There were also numerous rodent bones, mollusc shells, numerous insects, beetles, parasitic worms, fleas, butterflies, spiders, snails, vascular plants, dwarf birch seeds and branches, alder and other representatives of tundra flora (Kotarba, 2005). Comprehensive study of these finds and the corresponding publication were interrupted by the Second World War.

In the postwar years, ozokerite deposits in the villages of Starunia and Dzvinyach were explored, active exploration for oil was conducted, but its deposits in the dome of the Starunia fold proved not to be industrial.

In March 1977, after the earthquake in the Vrancha Mountains (Romania), on the ozokerite deposit of Starunia, the first mud volcano in the Carpathians arose, adding to the Starunia paleontological location a new «sound». Professors of the Ivano-Frankivsk Institute of Oil and Gas, N. Kh. Bilous and V. M. Klyarovsky, who studied the manifestations of mud volcanism in Starunia during 1977-1988 (Belous, Kliarovskyi, 1987), registered this 60 hectare site at as a natural geological monument of national value. At the same time, the study of Starunia drew the attention of geologists of the Department of General Geology of the Institute of Oil and Gas, O. Adamenko, O. R. Stelmakh, G. D. Stelmakhovich, N. M. Shevchuk, V. V. Kolencko (Adamenko, Kryzhanivskyi and Vekeryk, 2005; Adamenko, 2007; Adamenko et al, 2017; Adamenko O.M., Karpash O.M., Zorin D.O., Kotarba I.V., Mosiuk I.I., Kovbaniuk M.I., Adamenko O.M. 2007; Adamenko O.M., Kryzhanivskyi Ye.I., V.I. Vekeryk. 2005).

They were joined by paleontologists of the Natural History Museum of the National Academy of Sciences of Ukraine from Lviv, D. M. Drigant and others (Kotarba, 2005), as well as archaeologists of the Institute of Ukrainian Studies named after. I. Krepeyakevych of the National Academy of Sciences from Lviv, L.G.Matskevy and Ivano-Frankivsk Pedagogical Institute named after V. Stefanyk, B. A. Vasilenko and I. T. Kochkin (Adamenko, Kryzhanivskyi and Vekeryk, 2005; Lomnicki, 1908). In the vicinity of Starunia, several dozen remains of ancient man from the late Paleolithic, Mesolithic and Neolithic periods were discovered. It is worth mentioning that in 1914 Professor M. Lomnitsky (Bayger, 1914) wrote about a round hole in the skull of a rhinoceros, along with which a fragment of a wooden spear with a sharpened end was found. That shows that primitive hunters - Cro-Magnon lived alongside the woolly rhinoceros.

In 1988-1989 the Institute of Oil and Gas (O. M. Adamenko, O. R. Stelmakh, L. M. Mikhals'k, I. R. Mihailiuk) began research on Starunia financed by the Ministry of Education and Science of Ukraine. The detailed (1: 10,000) topographical (R.G. Pylypiuk) and radiometric (V.P. Stepaniuk) monitoring of the monument were also performed (Adamenko, Kryzhanivskyi and Vekeryk, 2005).

In 2004 two Polish-Ukraininan expeditions explored the area, their results were published in two monographs by M. Kotarba (Kotarba, 2005; Kotarba, 2009).

Materials and methods. In 2006-2009, it was possible to arrange drilling of 33 core wells with 100% core output for detailed study of sections II and I of the above-floodplain terraces and the re-enclosed valley of the River Lukavets Veliky buried beneath them. Geological and geomorphological, geophysical, geochemical studies with the use of modern technology continued. Several dozen radiocarbon dates from 44 to 11 thousand years have been received. Isotopic determination of carbon was performed to understand its origin from – taken from the depths of the oil deposit or from the decomposition of bioorganic plants and animals of the Pleistocene. Dozens of detailed spore-pollen charts, paleocarpological and malacofaunistic definitions have been obtained. The structure of deposits was detailed with the help of microgravity, electrostatic, microbiological methods. It is determined that the Pleistocene incision covers the period from the Eemian interglacial to the last phase of the Würm glaciation. The section of Holocene deposits is also studied in detail. But the most important result was the discovery of the most productive area, where the remains of Pleistocene mammals could still be found, and possibly their hunters - our ancestors Cro-Magnon, were found at depths from 4.5 to 8 m in paleoswamp sediments with a capacity of 2 m of bituminous black mud and salt

In 2016-2018 geologists and ecologists of the University of Oil and Gas, V.G. Omelchenko, T. Kalin, D.M. Vinnichuk, T.Yu. Fedorchak, V.P. Javorsky performed radiometric and snow-gauge measurements at Starunia, They evaluated the soil cover by selecting 133 samples and analyzing them for the content of heavy metals Cd, Pb, Cu, Zn and petroleum products, and determined the surface water quality of the Lukavets Veliky and Rinne streams.

Presenting the main material. The Starunia paleontological location is located within the limits of the historic nature monument of Starunia with an area of 60 hectares (Belous & Kliarovskyi, 1987) or on the Starunia geodynamic landfill (Adamenko et al., 2017). In geological-tectonic terms, this is the Boryslav-Pokutsky zone of the Precarpathian regional (advanced) deflection of the Carpathian oil and gas province (Kotarba, 2009).

The Quaternary part of the geological section is represented (from the top down) by the Miocene molasse of the Vorotischenskaya suite, often saline, criss crossed by ozokerite veins. Below is a flysch – a varied rhythmic alternation of sandstones, siltstones, argillites from the Upper Cretaceous to the lower Miocene (Stryi-Menilite suites). The Boryslav-Pokutsk (Inner) zone of the Precarpathian Bend is a complex of covers, chunks, and scales piled one upon another in a north-easterly direction. The zone from the southwest borders the Skybavy Carpathians, and in the north-east it borders Sambirskaya, and then further it borders the Bilche-Volytsky (External) bend zone. And further east-north-east extends the East European plain.

Oil and gas is associated with several horizons of the Menilite suite (Oligocene-lower Miocene) and middle Eocene. In the immediate vicinity to Starunia, there are several oil and gas condensate fields - Gvizdetsk, South-Gvizdetsk, Vysotsky, Monastyrchanske, Pnivske, Pasichniansk, Biitkov-Babchinsk. To the south-east of Starunia there is another deposit of ozokerite – Dzvinske, and further to the north – the Starunia deposit of natural salts.

The Quaternary part of the geological section has been studied only in recent years, after well drilling and core research (Fig. 1) (Kotarba, 2009; Sokolowski T. & Stachowicz-Rybka, 2009). The geological section (Fig. 2) was made by the author, according to the results of drilling, using space images and aerial photography from a drone.

The south-western part of the study area is the slope of the watershed, covered with Eolian-deluvial, so-called covered with loess-like loams and clay of pale-brown, yellow-grey and brown colour edp, Q^{2-3}. The zones contain numerous lenses of sand, gravel, rough debris of native rocks. There is a similar slope is to the east. Between the slopes is the valley of the Veliki Lukavets with II and I above- floodplain terraces, the alluvium of which is blocked by deluvial-proluvial-technogenic clay-salt deposits of mud-oil-salt streams $dptQ_4^3$ and man-made debris-clay deposits of mining waste dumps tQ_4^3 (Fig. 2).

Alluvium II aQ_3^{1-2} and I aQ_3^{3-4} of the terraces are represented by stream deposited pebbles, with gravel and sand at the bottom of the sections, and the greater part of the preposterior part are lake-marsh facies - dark-grey, often bituminous, peaty namulas lhQ_3^2 and lhQ_3^4. Under the terraces is the reburied, buried ancient valley alQ_3^1e. In the lower sections of the I terrace the remains of four rhinos and one mammoth were found.

The section of the quarter is finished with alluvial gravel and pebbles, loam and silt of high aQ_4^1, middle alQ_4^2 and lower aQ_4^3 of the floodplain terraces. The youngest Holocene formations include deposits of a mud volcano vQ_4^3 and oil emissions ptQ_4^3 from wells and «volcanoes».

The age of the Quaternary deposits is determined by radiocarbon dating of the mammals and molluscs, paleocarpological and palynological (spore-pollen) complexes and archaeological cultures.

Radiocarbon dating of the cores of the section of the 16th wells and 2d outcrop showed that the minimum age of the peat, peat mud, biogenic and clay mud fluctuates within the preboreal, that is, the late pleniglacial (28-13 thousand years ago). There are more ancient dates (34-48 thousand yerars ago.), which refer to the middle pleniglacial. The Holocene deposits are dated from 230-325 to 4,505-5,490 and 11,110-11,430 years ago. T.T. Kis, K. Rosanski, T. Gloslar, R. Stachowicz-Rybka (Kuc, T., Rozahski K., Goslar T., Stachowicz – Rybka R., 2009), who performed radiocarbon studies, believe that the age given by C14 is «deformed», because the samples are saturated with bitumen, oil and salt. It is recommended to continue to search for unchanged samples for radiocarbon dating.

Archaeological research. In 1976-1982, the Carpathian archaeological expedition of the Institute of Social Sciences (now the I. Krepiakevych Institute of Ukrainian Studies, NASU) (Matskevyj L.G., 2005) carried out comprehensive research in the vicinity of the village Starunia. As a result, near the paleontological location, 12 partially 2-3 spherical stands were discovered, in which at least 17 settlements of ancient man from the Paleolithic to the Middle Ages were traced. Thus, for millennia the territory was favourable for the settlement of our ancestors who hunted large animals.

This reveals great possibilities in Starunia for discovering the remains of people from the Cro-Magnon Era to later epochs. Such finds can be found both in settlements, and in deposits of ancient swamps. Stationary excavations have been carried out only at settlements of the Mesolithic and Neolithic periods in an area of 1649 m^2. More than 5 thousand artifacts and faunal remains (Starunia and culture of Vorotsiv-Starunia) have been found.

It is advisable to conduct excavations according to L.G. Matskevyj (Matskevyj, 2005), in the settlements of Starunia IV and XI, located nearer to the findings of woolly rhinoceros and mammoth.

Malacofauna, paleocarpological and palynological complexes have shown that in the late Pleistocene, Starunia is characterized by multiple alternation of periods of cooling with tundra flora and warming periods, which allowed us to offer a comparison (correlation) of the stratigraphic schemes of the upper Pleistocene of Starunia with similar schemes in Western Europe and lowland Ukraine (Table 1) .

On the basis of the obtained data, the author carried out paleoclimatic reconstruction, which should be characterized as from the post-Miocene age, the period of formation of the valley of the Dniester River and its tributaries , 1st order – the Bystrytsia River, 2nd – the Bystrytsy Solotvynsky and 3^{d} – the Veliki Lukovets , in which Starunia is located.

Consequently, at the end of the Miocene, the island of the Carpathian bend rose from the Thetis Ocean and its continental development began. In the Pliocene, the north-eastern macro-slope of the Carpathians was dismembered by many parallel river valleys, which carried from the mountains a coarse-deep alluvium, forming along the mountain range

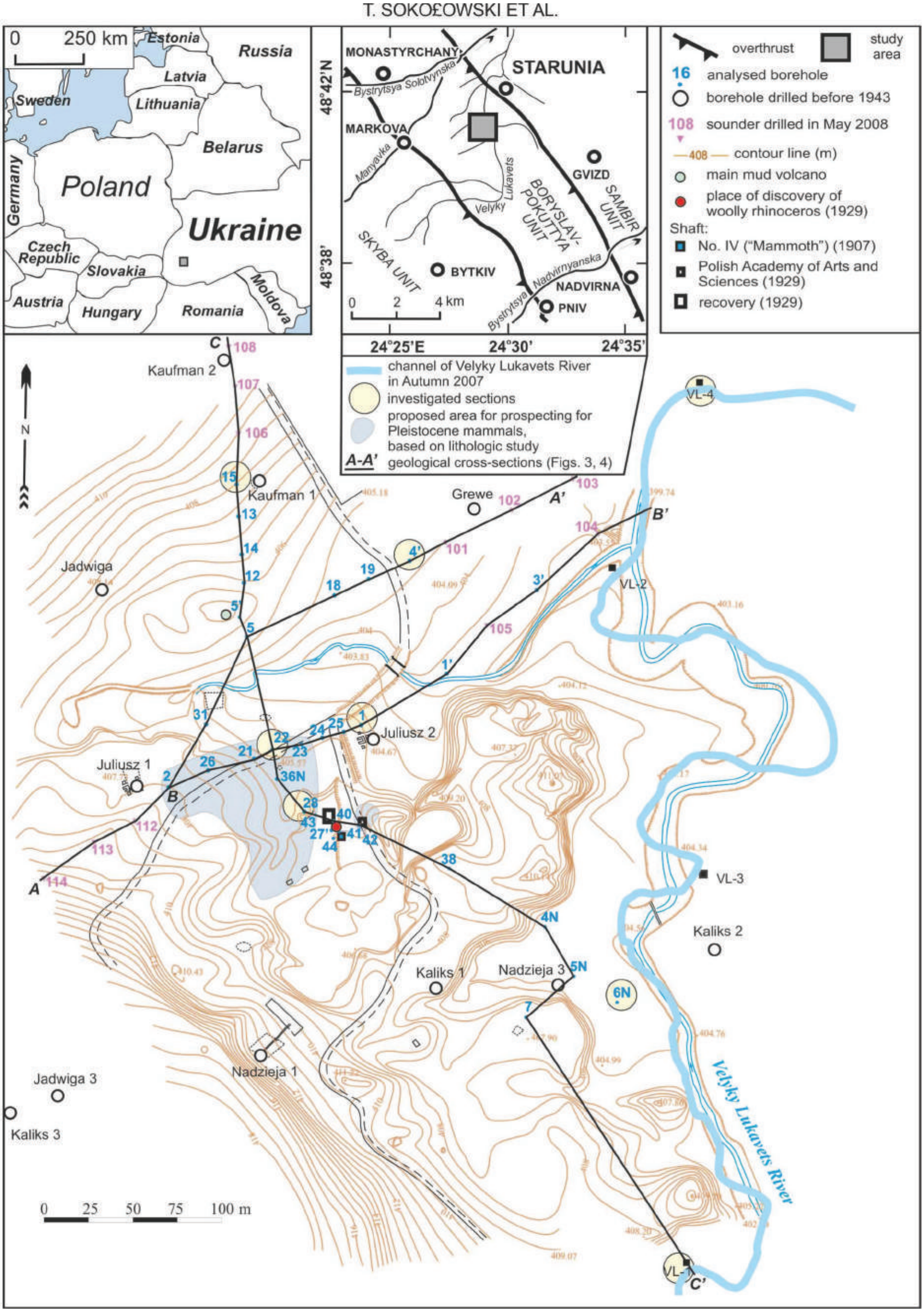
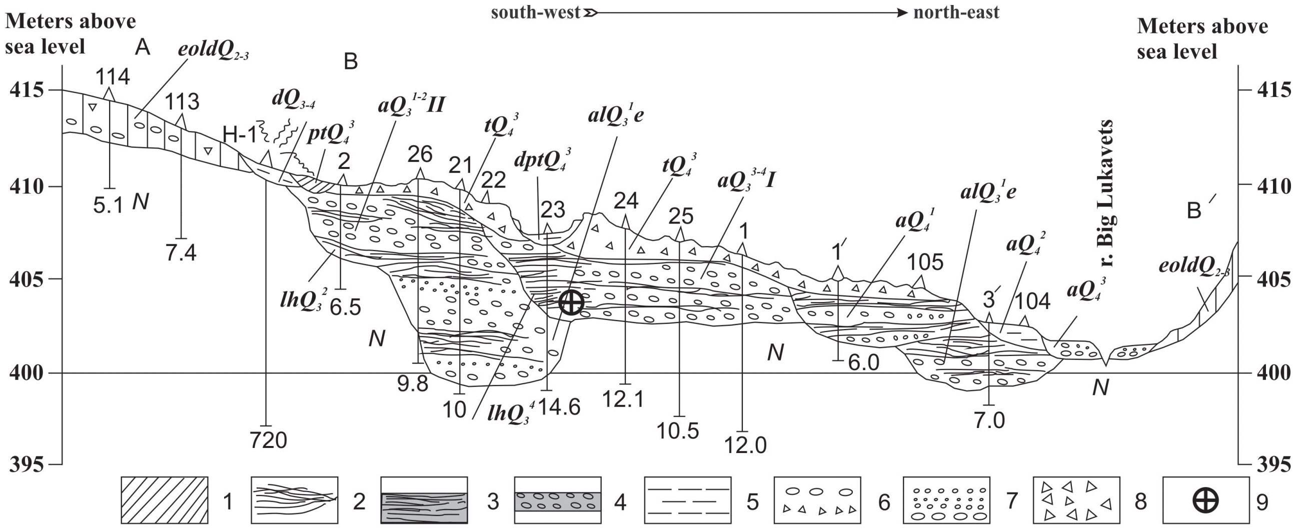


Fig. 1. Schematic map of the location of geological sections [15]



1 - salt and mud oil, 2 - biogenic mud, 3 - marsh nemulas, peat, 4 - mud with pebbles, 5 - loam, sandy loam, 6 - loess loam with sand and gravel lenses, 7 - sand, graphite, pebbles , 8 - runways of mining, 9 - fauna of rhinoceros and mammoth

Fig. 2. Cross section (profile) of the valley of Big Lukavets rive

numerous cones (inner delta) and the ancient valley of the Dniester, located in the district of the present-day village Loeva, about 30-40 km southwest of its present position near the town of Galich.

The rise of the Carpathians gradually pushed the Dniester east-north-east. Large- alluvium deposits formed two ancient Late Pliocene terraced plains - VII (Krasnaja) and VI (Loev). The climate was subtropical, like the current Mediterranean, as evidenced by the reddish-brown colour of the sand-clay cement globular alluvium and overlying clay. Their colour is due to the active migration of hydroxides of iron.

In the early Pleistocene the V (Galician) terrace of the Dniester was formed, in the middle - IV (Mariyampol), and in the beginning of the late - III (Yezupil) terraces. Then the history of the Dniester continues with the Veliki Lukovets. From the beginning, in the Eemian interglacial, the redevelopment of its valley was 10-15 m deeper than the modern channel (Fig. 2) under the influence of the warm and humid climate and neotectonic activity.

The landscapes were of tundra type, with dwarf birch (*Betula nana*), alder (*Alnus*), basket willow (*Salix viminalis*), etc. The climate was harsh, and corresponded to the Würm glaciations (59-13 thousand years ago). Its maximum occurred 18-16 thousand years ago, when the first above-floodplain terrace had already begun to form. Perhaps it was particularly at that time when herds of wooly rhinoceroses and mammoths grazed in the valley of Starunia and the Cro-Magnons who hunted them lived. During the late pleniglacial and the late Weichselian glaciation (Bølling-Allerød-early Dryas), the first terrace continued to form. The valley of Lukovets Velyky was rejuvenated, and new stream-bed facies appeared. Tundra conditions changed to forest-steppe conditions. Thus, it continued from 13.0 to 10.2 thousand years ago, that is the early Holocene. T. Sokolowski and R. Stachowicz-Rybka (Sokolowski T., Stachowicz-Rybka R., 2009) write that in the valley, instead of swamps, lakes appeared, which were often saline, related to thermo-karst processes. On the shore slopes of the Lukovets Velyky and the Rinne stream, shifts often occur due to the impact of solifluction.

At the border of the late Weichselian and Holocene, a division of the relief took place, but the Lukovets Velyky had lower energy compared to current epoch. Neotectonic movements and changes in climate led to formation of three levels of floodplain during the Holocene – high (Eo-Holocene), middle (Meso-Holocene) and low (Late Holocene).

Conclusions. In the future, it is planned to perform georadar sensing and other detailed geo-ecological and exploratory works at Starunia - this is a paleoclimatic benchmark survey for the development of the nature of ancient geosystems, a bridge between the stratigraphic schemes of the Quartet of Western Europe and the lowland territory of Ukraine; this is a globally unique paleontological location , famous for its well preserved mummified carcasses of woolly rhinos, this is the only active mud volcano in the Carpathians and, finally, it is an extremely interesting object of international tourism. The author has the hope that there will be investors who will help save for future generations the unique phenomenon of Starunia.

Table 1. Correlation of stratigraphic schemes of the Upper Pleistocene of Starunia with similar schemes of Western Europe and lowland Ukraine

Western Europe Behre., 1989 [7]		Poland Maruszak H., 1996 [14]	Starunja Adamenko O.M., 2017 [3], Sokolowski T., Stachowich-Rybka R., 2009 [15]						Galich, the Upper Dniester Boguckyi A., Lanczont M., 2002 [8]		The plain area of Ukraine Veklich M.F., 1982 [5], Gozhik P.F. and others, 2001 [16]
Holocene		Holocene	Holocene						Holocene		Holocene
Late Glacial Upper Pleniglacial	Pleniglacial	Loess younger upper LMg	WEICHSELIAN	LATE		10,2 Dryas Bölling-Allerød 13	aQ_3^{3-4} of the I terrace	Colluvium of slopes dQ_{3-4}	Loess		Prychornomorya loess
									Krasyliv palaeosol		
									Loess		
									Rivne palaeosol		Dofinivka palaeosol
									Solifluction level		Bug loess
Denekamp Hengelo Moershold Glinde Oerel	Middle	Interstadial palaeosol Yi/LMs		PLENIGLACIAL: EARLY MIDDLE LATE	LAKE-BASED FACTS OF ADVANCED ZONES II AND I TERAS lh, Q_3^{2-4}	28 Denekamp Huneborg Hengelo Hasselo Moershofd Latrop Glinge Oerel	Alluvium of the II terraces aQ_3^{1-2}	Eolian-colluvisl deposits on the eold interval Q_{2-3}	Dubno 1 palaeosol		2-3 Vytachiv palaeosols
		Less younger middle LMs							Loess		
		Interstadial palaeosol Yi/LMd							Dubno 2 palaeosol		
Lower Pleniglacial		Loess younger lower LMd		EARLY		59 Sehalkholz			Loess		Uday loess
Odderade Brörup Amersfoort	Early Glacial	Interstadial palaeosol LMn -------------------- Interstadial humus layer Yi/Yil				73 Odderade Rederstall Brörup Herning			Kolodiiv 1 palaeosol	Pedocomplex Horohiv	Pryluky pedocomplex
									Loess		
									Kolodiiv 2 palaeosol		
									Loess		
									Kolodiiv 3 palaeosol		
									Loess		
Last Interglacial		Interglacial forest palaeosol Yil	EEMIAN alQ_3^1e Alluvium of the redeveloped valley 129,000 years BP						Interglacial forest palaeosol (brown)		

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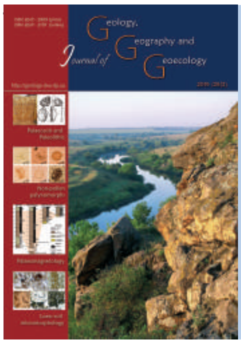

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Spatio-temporal differentiation of distribution patterns of *Salicornia perennans*, *Halimione verrucifera*, and *Suaeda* cf. *prostrata* (*Chenopodiaceae*) in the plain part of Ukraine during the Allerød–Holocene

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Abstract. The article provides paleofloristic evidence for the history of formation of modern halophytic vegetation in the plain part of Ukraine. Pollen grains of representatives of selected taxa of the family *Chenopodiaceae*, which belong to the ecological group of halophytes, are important components of palynological characteristics of the Pleistocene-Holocene deposits. Results of species-level identifications of halophyte fossil pollen provide a solid basis for the reconstruction of distribution patterns of plant communities on saline soils in space and time. Our analysis of paleofloristic data included both the original results of species-level identifications of pollen grains of *Chenopodiaceae* and the relevant literature data. The objective of the present research was to analyze and generalize the results of paleofloristic studies that provide evidence on the participation of three characteristic species (*Salicornia perennans*, *Halimione verrucifera*, and *Suaeda* cf. *prostrata*) in the palynofloras of the Allerød–Holocene deposits of the Right-Bank and Left-Bank parts of the Forest, Forest-Steppe, and Steppe physiographic and vegetation zones of Ukraine. The selected model species at present predominantly occur on wet solonchaks within the present-day Steppe Zone of Ukraine. Only occasionally they occur in the southern parts of the Left-Bank area of the Forest-Steppe Zone. It is worth noting that *S. perennans*, *H. verrucifera* and *S.* cf. *prostrata* can be also considered as indicators of changes of soil conditions in the past. To increase the reliability of specific-level identifications of fossil pollen of these model taxa, additional palynomorphological studies using both light microscopy and scanning electronic microscopy were performed. The generalized results of paleofloristic studies (fossil palynofloras in deposits of 12 sections) allowed tracing the spatiotemporal differentiation of distribution patterns of *S. perennans*, *H. verrucifera*, and *S.* cf. *prostrata* in the plain part of Ukraine during the Allerød–Holocene. We first reconstructed both a history of the dynamic ranges (areas of distribution/occurrence) of each of these three indicator species of halophytic vegetation and paleofloristic evidence of distribution of saline soils (in particular, wet salt meadows, salt marshes) in the plain part of Ukraine in space and time for the considered period. It is worth emphasizing that, as compared to the Right-Bank area, paleofloristic materials presently available demonstrate that the processes of soil salinization were more common in the territory of the Left Bank of the Forest and Forest-Steppe zones of Ukraine during the Late (Younger) Dryas. This trend is also quite clearly traced in the Holocene. *Salicornia perennans*, *H. verrucifera*, and *Suaeda* cf. *prostrata* most often participated in the formation of plant communities common in saline soils during the Early (PB, BO) and Middle (SB) Holocene in the Left-Bank area of the Forest-Steppe Zone. Due to the results of palynomorphological studies, additional qualitative and quantitative diagnostic characters have been identified and summarized; these characters can be used in the future for species-level identification of pollen grains of *S. perennans*, *H. verrucifera*, and *S.* cf. *prostrata* in the spore-pollen analysis of deposits of the Quaternary of Northern Eurasia.

Key words: paleofloristics, palynoflora, halophytes, Allerød–Holocene, pollen grains, morphology, spore-pollen analysis, Ukraine

Просторово-часова диференціація поширення of *Salicornia perennans*, *Halimione verrucifera* та *Suaeda* cf. *prostrata* (*Chenopodiaceae*) на рівнинній частині Україні впродовж алереду–голоцену

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Анотація. В статті розглядається питання палеофлористичного обґрунтування історії формування сучасної галофітної рослинності на рівнинній частині України. Пилкові зерна представників родини *Chenopodiaceae* Vent., які відносяться до екологічної групи галофітів, є однією з вагомих складових палінологічних характеристик відкладів плейстоцену–голоцену. Результати видової ідентифікації викопного пилку галофітів створюють надійну основу для реконструкції поширення рослинних угруповань на засолених ґрунтах в просторі та часі. До аналітичної обробки палеофлористичних матеріалів видового рівня були залучені як отримані нами результати видової ідентифікації пилкових зерен *Chenopodiaceae*, так і літературні дані. Метою статті були аналіз та узагальнення результатів палеофлористичних досліджень, які свідчать про участь трьох модельних видів (*Salicornia perennans*, *Halimione verrucifera* та *Suaeda* cf. *prostrata*) в палінофлорах відкладів алереду–голоцену Правобережної та Лівобережної частин Лісової, Лісостепової та Степової зон України. Зазначимо, що обрані нами модельні види, сьогодні поширені переважно на мокрих солончаках на території Степової зони. Зрідка вони трапляються на півдні Лівобережжя Лісостепової зони. Варто наголосити, що *S. perennans*, *H. verrucifera* та *S.* cf. *prostrata* можна також розглядати і як індикатори змін ґрунтових умов в минулому. Для підвищення ступеня обґрунтованості видових визначень викопного пилку цих модельних таксонів було проведено їхнє паліноморфологічне дослідження з використанням як світлової, так і електронної сканувальної мікроскопії. Отримані та узагальнені результати палеофлористичних досліджень (викопні палінофлори відкладів 12 розрізів) дозволили простежити просторово-часову диференціацію поширення *S. perennans*, *H. verrucifera* та *S.* cf. *prostrata* на рівнинній Україні впродовж алереду–голоцену. Нами вперше було реконструйовано як історію поширення кожного з цих індикаторних видів галофільної рослинності, так і наведено палеофлористичне обґрунтування поширення засолених ґрунтів (мокрі солончаки) на рівнинній Україні в просторі та часі. Важливо наголосити, що порівняно з Правобережжям наявні на цей час палеофлористичні матеріали свідчать про більше поширення процесів засолення ґрунтів на території Лівобережжя Лісової та Лісостепової зон України впродовж пізнього дріасу. Ця тенденція досить чітко простежується і в голоцені. S. perennans, H. verrucifera та S. cf. prostrata найчастіше брали участь у формуванні рослинних угруповань, поширених на засолених ґрунтах впродовж раннього (PB, BO) та в середньому (SB) голоцені на території Лівобережжя Лісостепової зони. За результатами паліноморфологічних досліджень були встановлені та узагальнені діагностичні ознаки якісного та кількісного рівнів, які перспективно використовувати для видової ідентифікації викопних пилкових зерен *S. perennans*, *H. verrucifera* та *S.* cf. *prostrata* в практиці спорово-пилкового аналізу відкладів квартеру Північної Євразії.

Ключові слова: палеофлористика, палінофлора, галофіти, аллеред–голоцен, пилкові зерна, морфологія, спорово-пилковий аналіз, Україна

Introduction. In Ukraine, the main stages of studies of modern halophilous vegetation and complicated issues of its classification were comprehensively considered in the pioneering work by G.I. Bilyk (1963). Subsequently, integrated studies of this azonal type of vegetation allowed obtaining new data, developing modern approaches for their interpretation, and producing an updated syntaxonomic scheme for communities of the halophyton in Ukraine (Dubyna, Dziuba, Neuhäuslova, Solomakha, Tyshchenko, Shelyag-Sosonko, 2007). Results of analyses of the taxonomic composition of the halophyte flora of Ukraine demonstrated that most of halophilous species occurring here belong to the family *Chenopodiaceae* Vent. These species play a significant role in the formation of the ecological group of halophytes that are common in the territory of modern Steppe and Forest-Steppe zones of Ukraine (Bilyk, 1963).

In modern palynology of the Pleistocene and Holocene deposits of Ukraine, many problems of paleobotanical and paleoecological reconstructions can be solved by increasing the number of more reliable species-level identification of components of fossil palynofloras (Bezusko, Mosyakin, Bezusko, 2011; Mosyakin, Bezusko, Tsymbalyuk, 2017; Andrieieva, 2011; Gerasimenko, Korzun, Ridush, 2014; Sirenko, 2017; Bezusko, Tsymbalyuk, Mosyakin, 2018). In this context, identifications of fossil pollen grains of representatives of *Chenopodiaceae* provide significant components for such reconstructions (Monoszon, 1985; Pashkevich, 1987; Grichuk, 1989; Bolikhovskaya, 1995; Komar, 2000; Yelovicheva, 2001; Velichko, Zelikson, 2001; Bezusko, Mosyakin, Tsymbalyuk, 2003, 2006; Bezusko, Mosyakin, Bezusko, 2011; Andieieva, 2010, 2011; Korniets, Komar, 2001). Such more accurate identifications are also important for solving many problems of the present-day indicative paleofloristics (Monoszon, 1973a). The successful development of paleofloristic studies was facilitated by the results of a thorough palynomorphological study of taxa of *Chenopodiaceae* conducted by M.H. Monoszon (1973b). At the present stage of palynological studies of the Pleistocene and Holocene deposits in Ukraine, we used for our species-level identification of pollen grains of *Chenopodiaceae* both a traditional identification key proposed by M.H. Monoszon (1973b) and new palynomorphological approaches that resulted from research by Z.M. Tsymbalyuk (Tsymbalyuk, 2005; Tsymbalyuk, Mosyakin, Bezusko, 2005) focused on pollen morphology of *Chenopodiaceae* of Ukraine using light and scanning electron microscopy.

It can be argued that a high degree of reliability of paleobotanical and paleoecological reconstructions is achieved with comprehensive application of paleopalynological and palynomorphological (actuopalynological) data, and that has been taken into account when formulating the purpose of the present article.

The objective of our present research was to analyze the lists of species of *Chenopodiaceae* in the palynofloras of the Allerød–Holocene sediments of the plain part of Ukraine and to determine the participation of the three model species: Salicornia perennans Willd., Halimione verrucifera (M. Bieb.) Aellen, and the species complex of *Suaeda* cf. *prostrata – S.* cf. *salsa* (L.) Pall.; these taxa belong to the ecological group of typical halophytes (occurring mainly in wet salt marshes, solonets and solonchak types). Another objective was to reconstruct their distribution in space and time and, using the example of these model taxa, to present the results of palynomorphological studies as revealing the patterns of formation of the present-day halophytic vegetation within the territory of Ukraine.

In the modern flora of Ukraine, Salicornia perennans Willd. (= S. prostrata Pall., nom. illeg.; S. herbacea auct. non L., S. europaea auct. non L., p.p.) occurs in the Steppe, southeastern Left Bank areas of the Forest–Steppe zones, and in steppe and maritime habitats of Crimea. The range of S. perennans covers areas of continental and coastal saline habitats (Opredelitel vysshikh rasteniy Ukrainy, 1987; Monoszon, 1973a). Salicornia perennans has a root system in the surface layers of wet to moist highly saline soils. The species is part of plant communities of wet saline soils and is an indicator of strongly mineralized chloride salinization of groundwater. The plant communities of S. perennans belong to the true solonchak succulent-herbaceous vegetation (Bilyk, 1963). Taxonomy and nomenclature of the species is accepted here following N.N. Tzvelev (1993, 1996a) and H. Freitag (2011). In earlier Ukrainian and East European publications [Iljin, 1936, 1952, and references therein] the names S. prostrata, S. herbacea (auct. non L., p.p.), and S. europaea (auct. non L., p.p.) were commonly used (mainly misapplied) to our species.

Halimione verrucifera (M. Bieb.) Aellen (= Atriplex verrucifera M. Bieb.) occurs along the shores of the Black Sea and the Sea of Azov on wet saline soils (solonets and solonchak). Occasionally isolated exclaves of the species occur on the Left Bank of the Forest-Steppe zone (Bilyk, 1963; Opredelitel vysshikh rasteniy Ukrainy, 1987). Communities of H. verrucifera belong to the true solonchak semi-shrub (subshrub) vegetation (Bilyk, 1963).

Two related species of *Suaeda* sect. *Brezia* (Moq.) Volkens (= sect. *Heterosperma* Iljin), *Suaeda prostrata* Pall. and S. salsa (L.) Pall., are distributed in Ukraine in the south of the Forest-Steppe Zone (occasionally), in the Steppe Zone, and in Crimea on wet solonchaks (Bilyk, 1963; Opredelitel vysshikh rasteniy Ukrainy, 1987). Nomenclature of these and some other taxa of *Suaeda* was rather confused (see Iljin 1936, 1952; Tzvelev, 1996b); here we accept the taxonomic and nomenclatural scheme proposed by H. Freitag and M. Lomonosova (2006). Since the pollen grains of these taxa are similar (probably somewhat larger in tetraploid S. salsa) and these two species were often not distinguished (or misidentified) in the past, we use here for fossil pollen the conventional identification "*Suaeda* cf. *prostrata*". The present-day communities with participation of S. prostrata and S. salsa belong mainly to the true solsonchak succulent-herbaceous vegetation (Bilyk, 1963).

Materials and methods. In order to achieve the objectives of our research, the two main blocks of studies were performed. The basic method during paleofloristic studies was spore-pollen analysis of the species composition of *Chenopodiaceae* in the palynofloras of the Allerød–Holocene deposits of sections in the plain part of Ukraine. Fossil pollen grains of the three model taxa of halophytic vegetation (*Salicornia perennans, Halimione verrucifera* and *Suaeda* cf. *prostrata*) were identified. We used both original species-level identifications of paleofloristic material, based on our identification approach for *Chenopodiaceae* (Bezusko, Mosyakin, Bezusko, 2011), and available data from literature (Andrieieva, 2010, 2011; Korniets, Komar, 2001). The main attention was paid to the presence/absence of pollen of the model taxa in the fossil palynofloras, which served as the base for further reconstruction of their distribution patterns in space and time.

The palynomorphological part of this study was aimed at increasing the level of reliability of species-level identifications of fossil pollen of *Salicornia perennans, Halimione verrucifera*, and *Suaeda* cf. *prostrata*. Pollen grains were sampled in the National Herbarium of Ukraine (KW, herbarium of the M.G. Kholodny Institute of Botany, National Academy of Sciences of Ukraine). For light microscopy (CM, Biolar) the material was treated according to the generally accepted acetolysis method (Erdtman, 1952). For studies of pollen under a scanning electron microscope (CEM, JSM-6060 LA), the material was fixed in 96% ethanol and sputter-coated with gold using the standard methods (Tsymbalyuk, Mosyakin, 2013). Morphology of pollen grains was described using the commonly used terminology (Kupriyanova, Aleshina, 1972; Punt, Hoen, Blackmore, Nilsson, Le Thomas, 2007), with minor adjustments.

Results and their analysis. Spatiotemporal distribution patterns of *Salicornia perennans, Halimione verrucifera*, and *Suaeda* cf. *prostrata* in the plain part of Ukraine were revealed according to the results of processing of the lists of species of *Chenopodiaceae* in the palynofloras of the Allerød–Holocene deposits of 12 sections: Doroshiv (Lviv Region), Ikva–I (Ternopil Region), Kukarins'ke (Chernihiv Region), Roman'kovo (Sumy Region), Komarivka (Kharkiv Region), Chugmak (Cherkasy Region), Orzhytsya and Perevod (Poltava Region), Kardashins'ke–II (Kherson Region), Kam'yana Mohyla and Chapayivka (Zaporizhzhya Region), and Razdol'ne (Donetsk Region).

Data on the presence/absence of pollen grains of the model taxa in Allerød–Holocene palynofloras provide new amended information on the composition and distribution of representatives of halophytic vegetation of Ukraine in space and time. It should be noted that the selected model species are now distributed mainly on wet saline soils within the territory of the present-day Steppe Zone of Ukraine. Occasionally they (or some of them) occur in the southern part of the Left bank of the Forest–Steppe Zone. It is worth noting that S. perennans, H. verrucifera and S. cf. prostrata can also be considered as indicators of changes in soil conditions in the past.

The obtained paleofloristic material provides the basis for reconstructions of the history of possible range changes of H. verrucifera, S. perennans, and S. cf. prostrata in the territory of the Forest, Forest–Steppe, and Steppe zones of Ukraine in the Allerød–Holocene (Table).

The results of our analysis of the species composition of *Chenopodiaceae* in fossil palynofloras of the last climatic rhythm of the Late Glacial indicate the participation of the three model species (*Halimione verrucifera, Salicornia perennans, Suaeda* cf. *prostrata*) in the halophytic vegetation of the studied area.

Palynofloras of deposits: SA – Subatlantic, SB – Subboreal, AT – Atlantic, BO – Boreal, PB – Preboreal times of the Holocene; DR–3 – Late (Younger) Dryas, AL – Allerød; «+» – presence of pollen grains in fossil palynofloras; «–» – absence of pollen grains in fossil palynofloras.

It has been demonstrated that S. perennans during the Allerød participated in the formation of halophytic vegetation in the territory of the Right Bank of the present-day Forest Zone area of Ukraine (sections Doroshiv and Ikva–I). During the same time interval both S. perennans and S. cf. prostrata were found in the Left-Bank area of the present-day Forest Zone (Kukarins’ke section).

During the Late (Younger) Dryas, S. perennans (sections Doroshiv and Ikva–I), H. verrucifera (sections Doroshiv and Ikva–I), and S. cf. prostrata (section Ikva–I) were components of halophytic vegetation on the Right Bank of the present-day Forest Zone. On the Left Bank of the Forest Zone, halophytic plant communities were formed with participation by S. perennans (sections Kukarins’ke and Roman’kovo), H. verrucifera (Roman’kovo section), and S. cf. prostrata (Kukarins’ke section). It should be noted, however, that there is no information available about the presence of fossil pollen grains of S. perennans, H. verrucifera and S. cf. prostrata in the Right Bank area of the Forest–Steppe Zone during the Allerød and Late Dryas. In the Late Dryas, S. perennans (Orzhytsya and Chugmak sections), H. verrucifera (Orzhytsya section), and S. cf. prostrata (Chugmak section) participated in the formation of halophytic plant communities on the Left Bank of the Forest–Steppe Zone.

The results of our analysis of the species composition of *Chenopodiaceae* in fossil palynofloras of the Holocene deposits on the plain part of Ukraine indicate the presence of S. perennans, H. verrucifera, and S. cf. prostrata in the territory of the plain part of Ukraine, including some continental habitats. However, there is no information yet available about occurrence of halophilic communities with participation of S. perennans in the territory of the Right Bank of the Forest Zone in the Holocene, but H. verrucifera participated in the formation of halophytic vegetation in the Right Bank area of the present-day Forest Zone in the Preboreal times (sections Doroshiv and Ikva–I), while S. cf. prostrata was registered there at the Boreal times of the Holocene (Ikva–I section). Plant communities with S. perennans occurred on the Left Bank of the modern Forest Zone in the Preboreal and Subboreal times (Roman’kovo section). However, it looks like H. verrucifera was present among components of halophilic vegetation in that area during the Preboreal, Boreal, and Subboreal times of the Holocene (Roman’kovo section). That probably indicates that this species had a much larger range at least in the Early Holocene, as compared to its present-day range.

It should be emphasized that there is no information available on the occurrence of halophytic communities with participation of S. perennans, H. verrucifera, and S. cf. prostrata in the territory of the Right-Bank part of the Forest–Steppe Zone in the Holocene. The results of our analysis of palynofloras of the Holocene deposits on the Left-Bank area of the Forest–Steppe Zone indicate some participation of S. perennans in plant communities on saline soils in the Preboreal (Orzhytsya section), Boreal

Table. Spatiotemporal patterns of distribution of the model species of halophytes in the plain part of Ukraine in the Allerød–Holocene

Taxon	Palynofloras of deposits of the Allerød–Holocene						
	SA	SB	AT	BO	PB	DR–3	AL
Forest Zone, Right Bank area							
Salicornia perennans (= *S. prostrata*)	–	–	–	–	–	+	+
Halimione verrucifera (=*Atriplex verrucifera*)	–	–	+	+	+	+	–
Suaeda cf. *prostrata*	–	–	–	+	+	+	–
Forest Zone, Left Bank area							
Salicornia perennans (= *S. prostrata*)	–	+	–	–	+	+	+
Halimione verrucifera (=*Atriplex verrucifera*)	–	+	–	+	+	+	–
Suaeda cf. *prostrata*	–	–	–	–	–	–	+
Forest-Steppe Zone, Right Bank area							
Salicornia perennans (= *S. prostrata*)	–	–	–	–	–	–	–
Halimione verrucifera (=*Atriplex verrucifera*)	–	–	–	–	–	–	–
Suaeda cf. *prostrata*	–	–	–	–	–	–	–
Forest-Steppe Zone, Left Bank area							
Salicornia perennans (= *S. prostrata*)	–	+	–	+	+	+	–
Halimione verrucifera (=*Atriplex verrucifera*)	–	+	–	+	+	+	–
Suaeda cf. *prostrata*	–	–	–	+	–	+	–
Steppe Zone, Right Bank area							
Salicornia perennans (= *S. prostrata*)	–	–	–	–	–	–	–
Halimione verrucifera (=*Atriplex verrucifera*)	–	–	–	–	–	–	–
Suaeda cf. *prostrata*	–	–	–	–	–	–	–
Steppe Zone, Left Bank area							
Salicornia perennans (= *S. prostrata*)	+	–	–	–	–	–	–
Halimione verrucifera (=*Atriplex verrucifera*)	–	–	–	–	–	–	–
Suaeda cf. *prostrata*	+	–	+	–	–	–	–

Palynofloras of deposits: SA – Subatlantic, SB – Subboreal, AT – Atlantic, BO – Boreal, PB – Preboreal times of the Holocene; DR–3 – Late (Younger) Dryas, AL – Allerød; "+" – presence of pollen grains in fossil palynofloras; "–" – absence of pollen grains in fossil palynofloras.

(sections Komarivka and Perevod), and Subboreal (sections Orzhytsya, Komarivka, and Perevod) times of the Holocene. Paleofloristic material confirms the Holocene distribution of *H. verrucifera* in the studied area in the Preboreal (Orzhytsya section) and Boreal and Subboreal (sections Orzhytsya and Perevod) times. *Suaeda* cf. *prostrata* was present in this area (section Chugmak) during the Boreal time of the Holocene.

The participation of Salicornia perennans and *Suaeda* cf. *prostrata* in the formation of halophytic vegetation of the Steppe Zone is confirmed only for its Left Bank part. We confirmed the occurrence of S. perennans during the Subatlantic times (section Kardashins'ke–II) and that of S. cf. prostrata in the Atlantic (sections Kam'yana Mohyla, Razdol'ne, and Chapayivka) and Subatlantic (Razdol'ne section) times of the Holocene.

Pollen grains of *S. perennans, H. verrucifera* and *S.* cf. *prostrata* are also representatives of halophytic *Chenopodiaceae* present in the subfossil spore-pollen spectra of the Steppe Zone of Ukraine. We can thus conclude that pollen grains of these three species form the dominant complex in the subfossil (or almost recent) spore-pollen spectra of the Artemisia–grass (Artemisia + Poaceae) steppes of the present-day Steppe Zone of Ukraine (areas with halophytic vegetation) (Bezusko, Mosyakin, Bezusko, 2011).

The obtained and generalized results of paleo-floristic studies allowed to trace the spatiotemporal differentiation of distribution patterns of *S. perennans, H. verrucifera* and *S.* cf. *prostrata* in the plain part of Ukraine during the Holocene. The reconstructed history of distribution of each of these indicator species of halophytic vegetation indicates the spread of saline soils (wet salt meadows) in the plain part of Ukraine in space and time. It is important to emphasize that paleofloristic materials available indicate more frequent salinity processes in the territory of the Left Bank of the Forest and Forest–Steppe zones of Ukraine during the Late Dryas, as compared to the Right Bank area. This trend is also quite clearly observed in the Holocene. *Salicornia perennans, Halimione verrucifera* and *Suaeda* cf. *prostrata* most often participated in the formation of plant communities in saline soils during the Early (Preboreal, Boreal) and Midlle (Subboreal) Holocene on the Left Bank of the Forest–Steppe zone. The history of distribution of *S. perennans, H. verrucifera* and *S.* cf. *prostrata* reconstructed here for the plain part of Ukraine during the Holocene is in agreement with palaeopalynological data on the presence of saline soils on the Left Bank of the Forest–Steppe Zone reported by other researchers (Artiushenko, 1970; Korniets, Komar, 2001; Bezusko, Mosyakin, Bezusko, 2011).

Species-level identifications of fossil pollen grains of *Chenopodiaceae* are largely based on palynomorphological studies of representative modern material (Tsymbalyuk, Mosyakin, Bezusko, 2005; Bezusko, Mosyakin, Tsymbalyuk, 2003, 2006; Bezusko, Bezusko, Mosyakin, Tsymbalyuk, 2007; Bezusko Mosyakin, Bezusko, 2011). In the following part of our research, the main focus is on the palynomorphological study of the three indicator species of halophytes.

***Halimione verrucifera* (M. Bieb.) Aellen** (Figure, 1–4).

LM. Pollen grains pantoporate, spheroidal, in outline circular, slightly undulate on edges. Diameter of pollen grains 18.6–22.6 µm. Number of pores 40–62, pore diameter 2.0–2.7 µm, pores with distinct or indistinct margins; border thin, mainly distinct, and rarely indistinct. Sculptural elements of the pore membrane centrally located or occupying most of the surface. Distance between adjacent pores 1.3–2.4 µm, between the centers of pores – 3.3–5.0 µm. Exine 2.4–2.7 µm thick. Columellae indistinct or distinct, long, arranged regularly. Endexine thin, regularly thickened. Exine texture indistinct, medium-punctate.

SEM. Sculpture spinulate. Spinules small, elongated, with acute apex, located with average density. Pore membrane with sparse spinules. Spinules 6–12, different in size, occasionally with merging bases, arranged unevenly.

Specimens investigated: 1. Crimea, Kerch Peninsula, Cape Kazantip, sands. 18.VIII 1976. O. Dubovik (KW). 2. Mariupol District, Berdyansk, solonets. 26.VIII 1929. M. Kotov (KW).

***Salicornia perennans* Willd.** (Figure, 5–8).

LM. Pollen grains pantoporate, spheroidal, rarely oval, in outline almost circular, slightly undulate or undulate on edges. Diameter of pollen grains 22.6–29.3 µm. Number of pores 36–62, pore diameter 2.4–4.0 µm, pores with distinct or indistinct margins; border thin, mainly distinct, and rarely indistinct. Sculptural elements of pore membrane centrally located or occupying most of the surface. Distance between adjacent pores 2.0–2.7 µm, between the centers of pores – 4.4–7.3 µm. Exine 1.6–2.7 µm thick. Columellae indistinct. Endexine thin, irregularly thickened. Exine texture indistinct, small-punctate (barely visible).

SEM. Sculpture spinulate. Spinules minute, rounded, with blunt apex, located sparsely and more or less evenly. Pore membrane with sparse spinules. Spinules 3–10, different in size, arranged unevenly.

Specimen investigated: On solonets places in the floodplain of the Donets, near Verhne [? illegible], Lisichansky District [now within Lysychansk town], Voroshilovgrad [now Luhansk] Region. 10.VIII 1939. F. Hryn' (KW).

***Suaeda prostrata* Pall.** (Figure, 9–12)

LM. Pollen grains pantoporate, spheroidal, in outline almost circular, slightly undulate on edges. Diameter of pollen grains 22.6–25.3 µm. Number of pores 54–64, pore diameter 1.3–2.0 µm; border thin, distinct. Sculptural elements of pore membrane centrally located. Distance between adjacent pores 2.0–2.4 µm, between the centers of pores – 3.3–4.0 µm. Exine 2.0–2.7 µm thick. Columellae indistinct. Endexine thin, regularly thickened. Exine texture distinct, small-punctate.

SEM. Sculpture spinulate. Spinules minute, rounded, with acute apex, located rarely and evenly. Pore membrane with sparse spinules. Spinules 5–7, different in size, arranged unevenly.

Specimen investigated: Kherson Region, Genichesk District, near Sivash st. [station?], solonchak. 31.VIII 1971. N. Loskot (KW).

For each of the three model species, descriptions and photomicrographs of pollen grains are presented. The additional morphological characters can be used in the practice of paleopalynological research, which may significantly increase the degree of reliability of species-level identifications of fossil pollen grains.

Conclusions. For the first time, three model taxa belonging to the ecological group of halophytes (*Salicornia perennans, Halimione verrucifera*, and

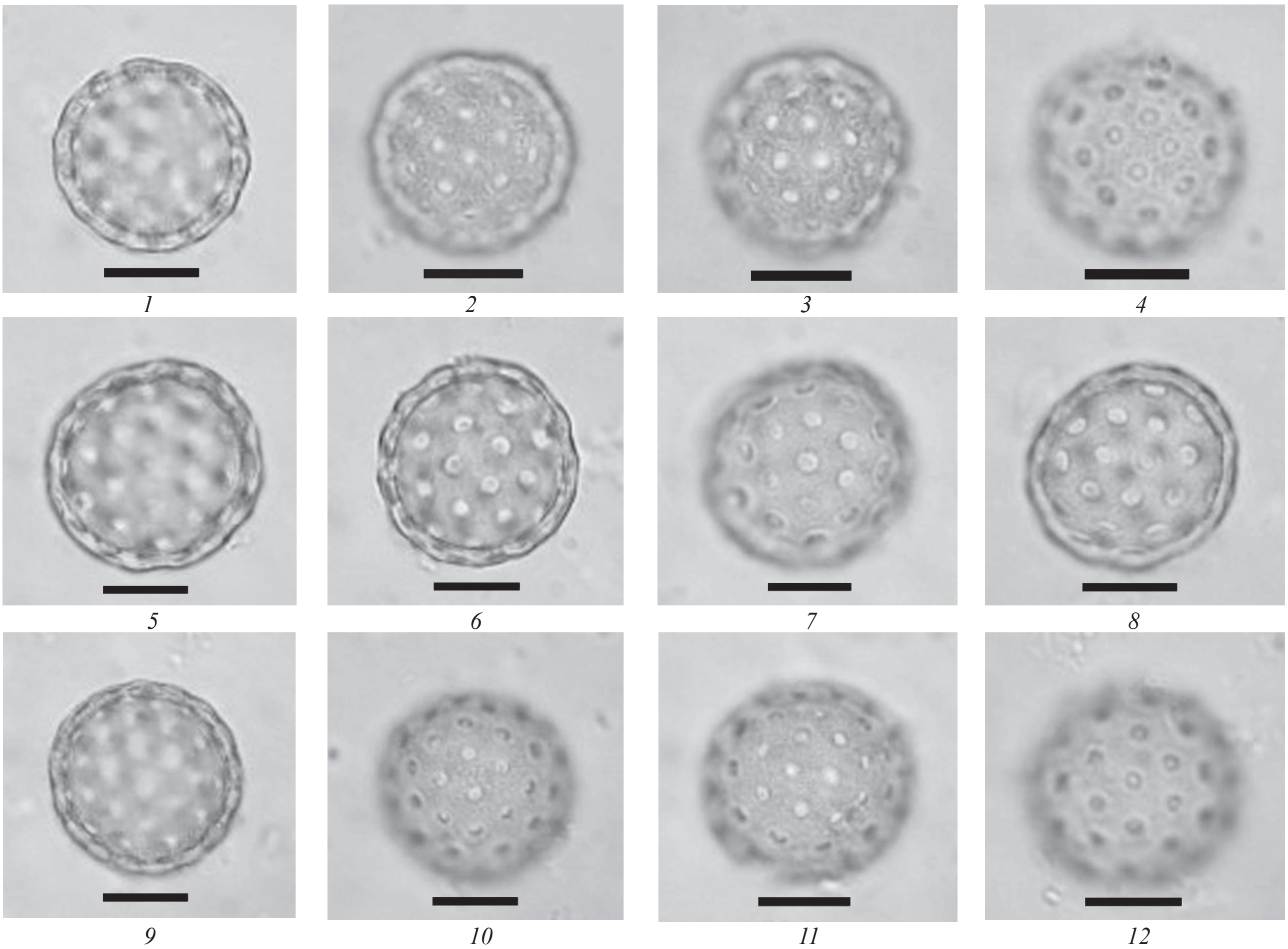

Figure. Pollen grains of the studied species (light microscopy): *1–4 – Halimione verrucifera; 5–8 – Salicornia perennans; 9–12 – Suaeda prostrata*. Scale bars: 1–12 – 10 μm

Suaeda cf. *prostrata*) have been identified in the fossil palynofloras of the Allerød–Holocene deposits in the plain part of Ukraine (Forest, Forest–Steppe, and Steppe zones). Based on case studies of these species, we reconstructed the spatiotemporal differentiation of their distribution in the composition of halophytic vegetation in the plain part of Ukraine during the Allerød–Holocene. Paleofloristic evidence of the presence of saline soils (mainly wet solonchaks) in the plain part of Ukraine during the Allerød–Holocene is provided. It has been demonstrated that the studied paleofloristic material shows somewhat wider distribution of soil salinity processes in the territory of the Left Bank of the present-day Forest and Forest–Steppe zones of Ukraine during the Late Dryas. The obtained and summarized results of paleofloristic studies indicate that the same trend is also quite clearly traced in the Holocene. *Salicornia perennans, Halimione verrucifera*, and *Suaeda* cf. *prostrata* most often participated in the formation of plant communities widespread in saline soils during the Early (Preboreal, Boreal) and Middle (Subboreal) Holocene on the Left Bank of the present-day Forest–Steppe Zone. The qualitative and quantitative diagnostic characters are promising for species identification of fossil pollen grains of *Salicornia perennans, Halimione verrucifera*, and *Suaeda* cf. *prostrata* for spore-pollen analysis of deposits of the Quaternary.

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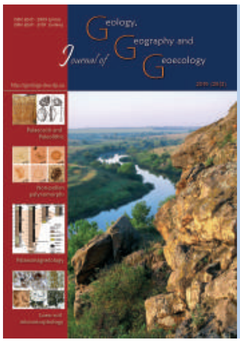

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Changes in pedogenic processes during Pryluky times (Late Pleistocene) in the central part of the Volyn Upland

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Abstract. In the central part of the Volyn Upland, the Pryluky palaeosol unit have been studied in nine loess-soil sites (Boremel 1 - 3, Novyi Tik, Smykiv, Shybyn, Kolodezhi, Kovban, Novostav). Several sections were excavated along a slope in each studied site in order to reveal the palaeocatena and to study the most complete palaosol successions. The last were found in palaeorelief depressions, which were acting as sediment traps. The genetic interpretation of palaeosols was carried out on the basis on field macromorphological and analytical (micromorphology, grain-size analysis, content of humus and $CaCO_3$) studies. In order to reconstruct the main features of palaeovegetation as an important factor of pedogenesis, pollen analysis of the palaeosols was carried out. It proved a good correspondence between a character of palaeovegetation and a palaeosol type. It has been shown that grain-size composition of the lower Prylyky soils strongly depends on that of parent rocks (Tyasmyn unit of hillwash sandy loam and Kaydaky unit of pedosediment).. The Chernozem-like polygenic soil is the most common within studied area. The lower part of soil has signs of podsolization (powder of SiO_2, light color, low content of clay). The upper Pryluky soils are distorted by erosional and cryogenic processes (mainly by solifluction textures) that hampers the interpretation of diagenetic and original pedogenic processes. The abundant bioturbations in the subsoil (the largest number among the Late Plestocene soils), high content of humus, complex microaggregates, but leach in the $CaCO_3$ have been established to Pryluky soil unit. The presence of relic pedogenic signs in the polygenetic soil, an assumption is made about the existence of several stages of its formation. The investigation of pedocomplexes confirm it. The study of well-developed pedocomplexes in sedimentation traps allows the allocation of those pedogenic phases during Pryluky times: pl_{1b1} – Podzolic, Cryptopodzolic, Albeluvisol, Albic Luvisol; pl_{1b2} – Luvic Chernozem, Chernic Chernozem and Cryptopodzolic,; pl_{1c} – Umbrisol and Cambic Luvisol; pl_{3a} – Luvic Cambisol; pl_{3b1} – Luvisol and Luvic Cambisol; pl_{3b2} – Mollic and Luvic Cambisol.

Keywords: pedocomplex, pedogenetic phases, micromorphological features, pedosediment, palaeosol catena.

Розвиток педогенних процесів впродовж прилуцького етапу у центральній частині Волинської височини

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Анотація. У центральній частині Волинської височини педокомплекс прилуцького кліматоліту (верхній плейстоцен) вивчено у 9 лесово-ґрунтових розрізах (Новий Тік, Боремель 1 - 3, Смиків, Шибин, Колодежі, Ковбань, Новостав). Поховані ґрунти досліджено макроморфологічним і мікроморфологічним методами, виконано їхній гранулометричний аналіз, визначено вміст карбонатів і гумусу. Це дозволило інтерпретувати генетичні ознаки палеоґрунтів та фар їхнього розвитку. З метою реконструкції природних умов формування давніх ґрунтів виконано палінологічний аналіз. Це дозволило виявити чітку кореляцію між типом рослинності і типом ґрунту. Показано, що супіщаний гранулометричний склад ґрунтів прилуцького педокомплексу у більшості розрізів обумовлений складом материнських порід (делювіальних супісків тясминського кліматоліту чи супіщаних педоседиментів кайдацького кліматоліту). Верхня частина прилуцького педокомплексу трансформована епігенетичними ерозійними і кріогенними процесами, зокрема соліфлюкцією. Встановлено, що на досліджуваній території прилуцький кліматоліт найчастіше представлений полігенетичними чорноземоподібними ґрунтами. У седиментаційних пастках простежено їхній перехід у ґрунтові світи потужністю понад 2 м. Дослідження ґрунтових світ дало змогу відтворити послідовність розвитку педогенезу впродовж прилуцького часу за такими фазами: pl_{1b1} – лісові ґрунти (дерново-підзолисті, дерново-криптопідзолисті, дернові опідзолені, буро-підзолисті); pl_{1b2} – лісостепові ґрунти (чорноземи опідзолені та вилугувані, дерново-криптопідзолисті); pl_{1c} – лісостепові ґрунти (дернові опідзолені та бурі лесивовані); pl_{3a} – лісостепові ґрунти (дерново-бурі ґрунти); pl_{3b1} – лісові ґрунти (бурі лесивовані і дерново-бурі опідзолені); pl_{3b2} – лісостепові ґрунти (дерново-бурі і дернові). За прошарками лесоподібного і делювіального матеріалу між грунтами та за наявністю кріогенних структур вдається виявити декілька стадій припинення або ж значного послаблення педогенних процесів.

Ключові слова: ґрунтова світа, стадія та фаза педогенезу, мікроморфологічна будова, педоседимент, ґрунтова катена.

Introduction. The Pryluky soil unit is one of the most reliable stratigraphic markers within the Upper Pleistocene in Ukraine (Veklitch, 1982; Sirenko, Turlo, 1986), including the Volyn Upland. The correlation of the upper boundary of the Pryluky unit with the transition between MIS 5 and MIS 4 is firmly established in Ukraine, but different views exist on the correlation of the lower soil of Pryluky unit with the global marine isotopic oxygen record. It has been correlated either with substage 5e (Veklitch et al., 1993; Gozhik et al., 2000; Lindner et al., 2002, 2006; Bogutskyi et al., 2012) or with the substage 5c (Rousseau et al., 2001; Gerasimenko, 2004; Matviishina et al, 2010; Haesaerts et al., 2016). In western Ukraine, the Pryluky unit corresponds, in the author's opinion, to the upper part of the Horokhiv pedocomplex of the regional stratigraphic framework of A. Bogutskyi (Bogutskyi, 1986). In recent years, the upper part of the Horokhiv pedocomplex has been considered as a separate Kolodiiv soil unit, which in the stratigraphically complete sections is represented by three soils (Lanczont, Bogutskyi, 2007; Bogutskyi et al., 2012). Two Kolodiiv soils have been studied in the Rivne and Dubno sections of the Volyn Upland (Bogutskyi, Voloshyn, 2008; Bogutskyi, Voloshyn, 2011), though in the majority of the sections of this area (Korshiv, Horokhiv, Novovolynsk, Boyanychi, Peremyslovychi, Zdolbuniv, and Torchyn) one chernozem-like soil is distinguished at this level (Tsatskin, 1980; Morozova, 1981; Bogutskyi, 1986). The description of palaeopedological and engineer-geological features of the Horokhiv soils has been presented in Bogutskyi, and Voloshyn (2008, 2010, 2011). Palaeopedological and micromorphological studies of the Horokhiv soils in their palaeocatenas were carried out by A. Tsatskin (1980) and T. Morozova (1982). Palynological characteristics of the Kolodiiv soil were presented by Artyushenko et al., (1982) and Bezusko et al., (2011).

Materials and methods. In the central part of the Volyn Upland, the Pryluky pedocomplex has been studied at nine loess-soil sites (Boremel 1 – 3, Smykiv, Novyi Tik, Shybyn, Novostav, Kolodezhi, and Kovban) (Fig. 1). In the majority of the sites, the Pryluky soil unit is represented by a polygenic chernozem-like soil with well-expressed mollic epipedon (0.3-0.7 m thick). The main aim of this research was to study the palaeosol catena, in order to reveal the lateral replacement of polygenic soils by well-developed pedocomplexes in the palaeorelief depressions (sediment traps). Thus, a series of excavated profiles have been studied at each site following the elements of modern and buried relief.

In the palaeodepressions, several soils of the Pryluky pedocomplex (up to five at the Novostav site) were revealed. In the field, diagnostic macromorphological features of paleosols, including their genetic profiles, were studied, as well as diagenetic and relic features of pedogenesis. The last produce 'noise' in the original palaeopedological information. Thus, the identification of relic, syngenetic or diagenetic elementary soil processes in the palaeosol is a most actual problem when interpreting their primary genetic types.

The genetic interpretation of soil types was also based on analytical studies: micromorphological, grain-size analysis, determination of humus content and $CaCO_3$. The grain-size analyses of Pryluky soils from the Boremel-1, Boremel-2, Novyi Tik, Novostav, and Kolodezhi sections has been carried out by the Kachynskyi'method; content of humus was determined by Turin's method (Fig. 2; 3). Palaeopedological interpretation of results has been done following Veklitch et al. (1979). Micromorphological analysis of the soils from Novyi Tik has been carried out using the methodology of Parfenova, Yarilova (1977), Matviishyna (1982), Gerasimova et al. (1992), Gagarina (2004), Karmazinenko (2010), and Doroshkevych (2018). In addition, pollen study of the Novyi Tik and Kolodezhi samples was done to reveal the correspondence between paleovegetation and palaeosoil formation. The use of the two methodologies is beneficial for identification of short-period phases in the development of pedogenic processes.

Results. On the basis of the described studies, those phases in the development of pedogenic processes during the Pryluky times have been identified. During phase $\mathbf{pl}_{1b1}$, several genetic types of forest soil were formed, controlled by differences in their parent rocks. Podzols formed on sands (Fig 4; 7b); Albeluvisols (Fig. 5c) and Cryptopodzols (Fig. 7c) developed on loess-like sandy loams; and Albic Luvisols (Fig. 5a) formed on the sandy material of

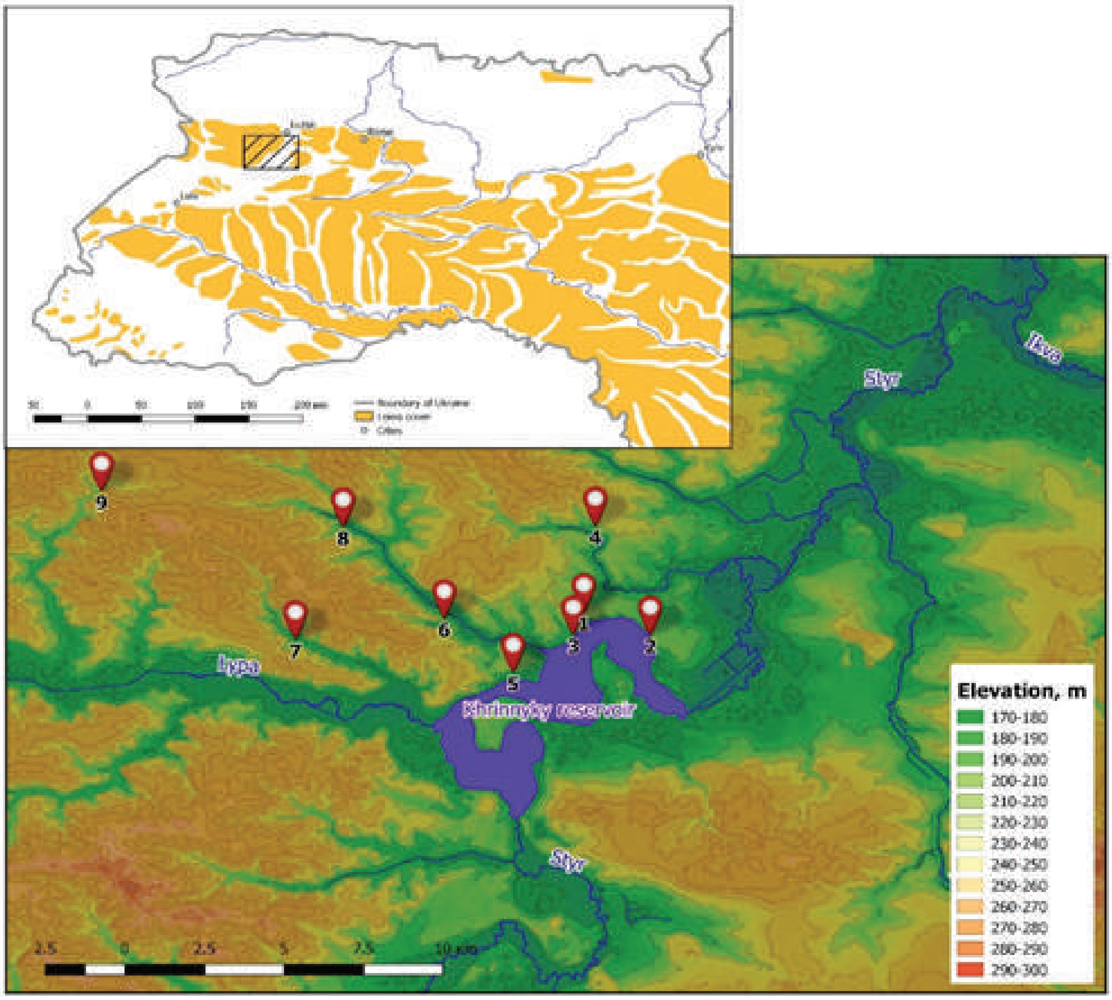

Fig. 1. Location of the sections studied: 1- Boremel-1; 2 – Boremel-2; 3 – Boremel-3; 4 – Novyi Tik; 5- Shybyn; 6 – Smykiv; 7 – Novostav; 8 – Kolodezhi; 9 – Kovban.

the Kaydaky unit. Frequently, the lower Pryluky soils overlying the Kaydaky unit form a polygenetic pedocomplex, consisting of forest soils.

Pryluky unit podzols occur on colluvial sands and sandy loam (at Novyi Tik and Kovban) or on Kaydaky sandy material in relief depressions (at Boremel). The profile of podzols (up to 0.5-0.7 m thick) consists of AEL, E, and BCf genetic horizons (Fig. 4; 7b). The AEL horizon, with a low content of humus (0.11%), form, in places, the lower podzoled part of the overlying soil $\mathbf{pl}_{1b2}$. The E horizon (up to 0.1-0.25 m thick) is composed by a whitish-grey sand or sandy loam (sand fraction up to 82% at Kovban), with an initial platy structure and pseudofibres. In thin sections of these soils, the material is depleted in plasma (Fig. 6a). Skelsepic iron-humus-clay plasmic fabrics are observed at the contacts of sand grains. Simple iron-humus-clay cutans are revealed in the voids. In places, iron-manganese micro-ortsteins occur. At Kovban, the E horizon overlies the Tyasmyn unit, composed by sands, and, thus, it is better expressed than in other sections. The BCf horizon overlays sands of the Tyasmyn unit or the Kaydaky pedocomplex. In the first case, it is represented by light-brown sandy loam, without soil structure, but with well-expressed pseudofibres. In thin sections, clear evidence of translocation processes are observed (a lot of iron and iron-clay coatings around rounded quartz grains, which are merged together. and forming 'bridges' (Fig. 6b).

Cryptopodzols (up to 0.3-0.5 in thickness) were revealed at Novyi Tik, Boremel-1, Smykiv, and Kolodezhi (Fig. 7c), where they are represented by sandy loams (sand content up to 65%), with a low incidence of humus (0.35% in the AEL horizon, 0.2% in the B horizon), and a downward increase in the clay fraction (from 12% up to 21%). The micromorphological fabrics of the B horizon have both depletion zones and zones of laminated iron-clay and humus-iron-clay cutans with the signs of their destruction. Traces of mobility of dust-plasma coating are observed in large pore spaces, which is reliable evidence of intense lessivage. There are a lot of iron-manganese pedofeatures in this horizon (micro-ortsteins, diffusion rings, stains and manganese coatings in the voids). Cutans and pedofeatures are

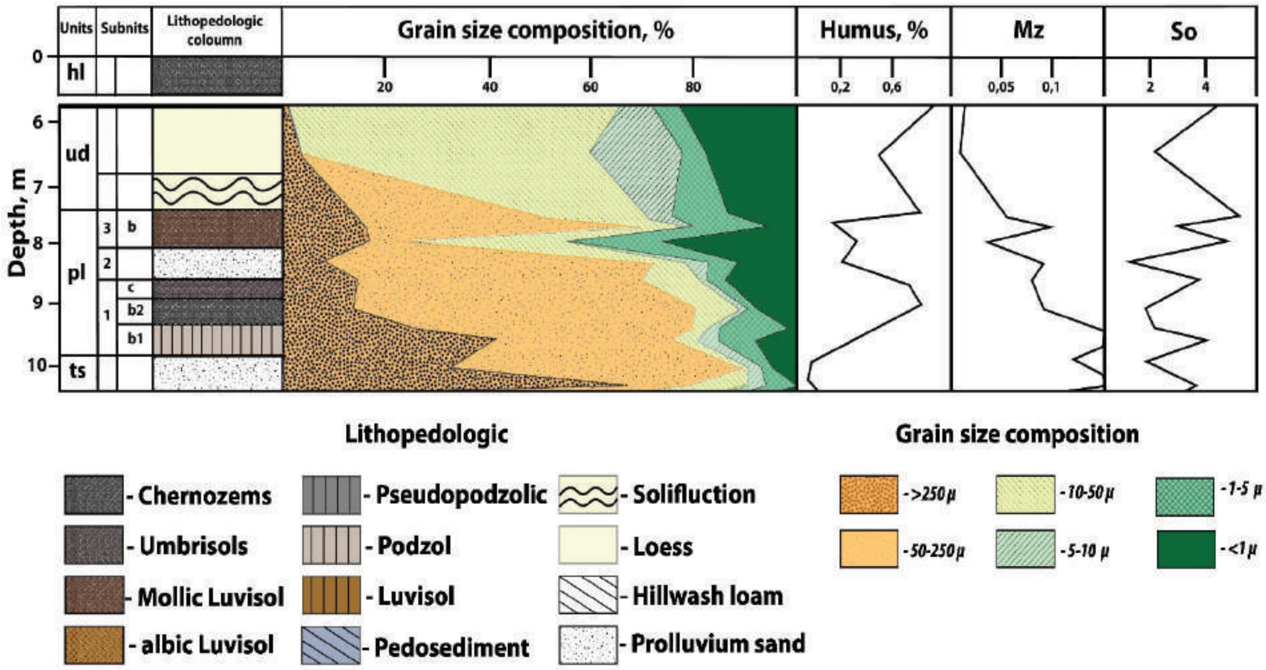

Fig. 2. Lithopedological features of the Pryluky unit in the Novyi Tik section.

characterized by mud-cracks, indicating alternating wet and dry periods.

An Albic Luvisol (up to 0.5-0.6 m in thickness) was revealed at Novostav (Fig. 5a), where it is a sandy loam (content of sand up to 52-70%), with a significant downward increase in clay (from 4% in the Eh horizon to 28% in the BELt horizon). The soil profile consists of AEL, Eh, and BELt horizons. The AEL horizon is greyish-brown, with single pseudofibres. The BEL horizon comprises cemented sands, with loose whitish sand lenses.

On the basis of the paleopedological data, it is

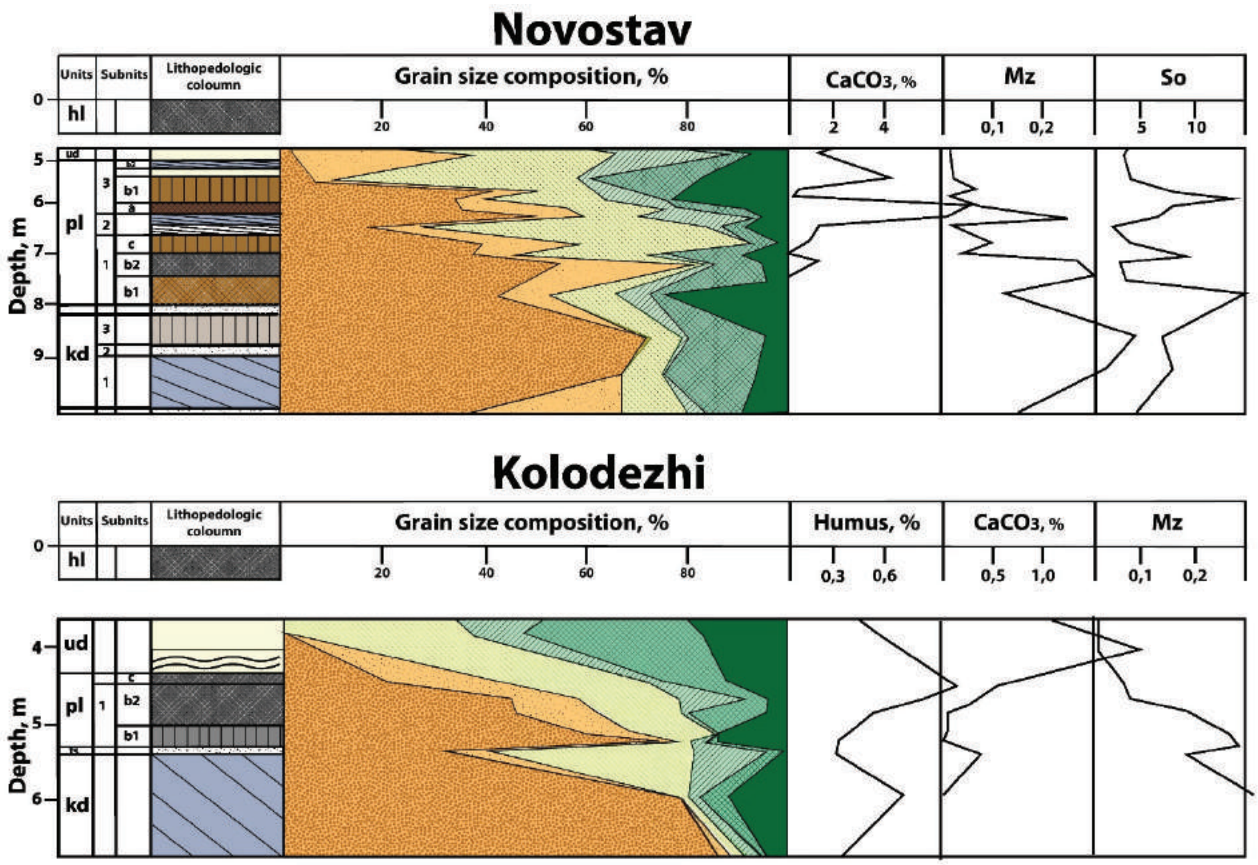

Fig. 3. Lithopedological features of the Pryluky unit in the Novostav and Kolodezhi sections (for legend see in Fig. 2).

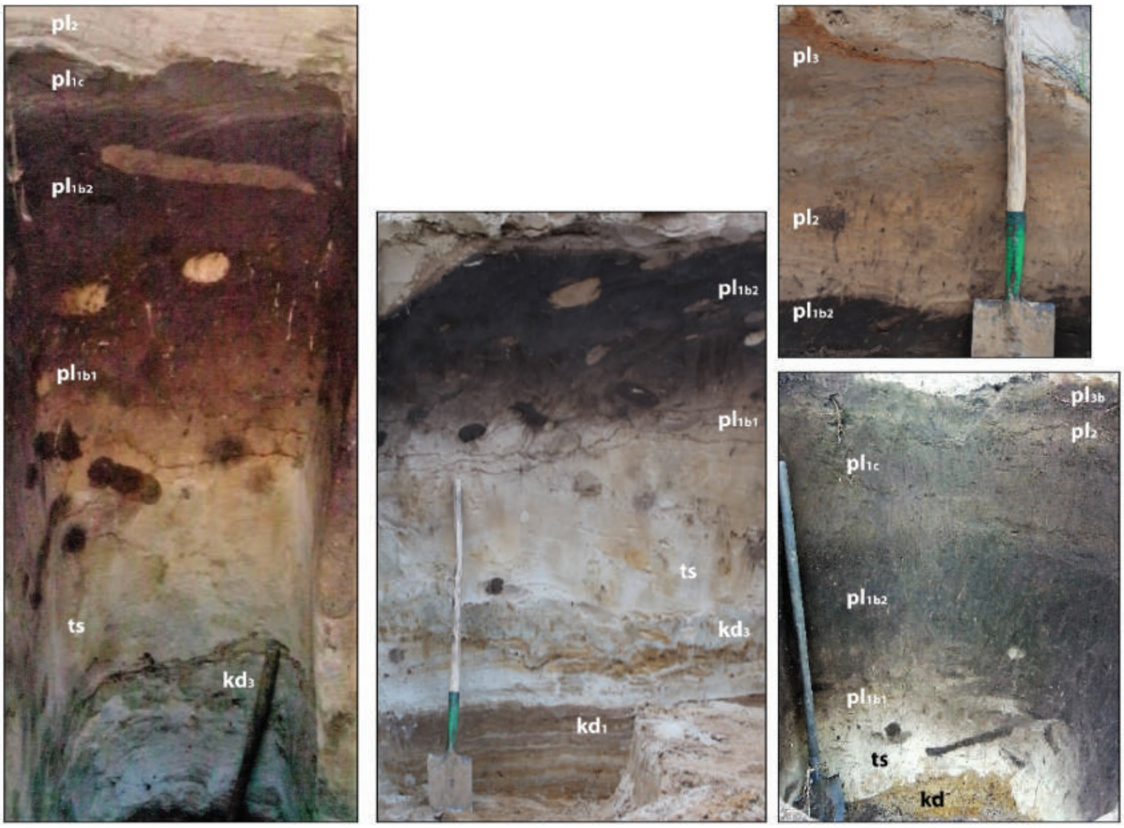

Fig. 4. The Pryluky pedocomplex in the Novyi Tik section.

suggested that the early optimum of Pryluky times (**pl**$_{1b1}$) had a humid climate, which lead to intense development of podzolisation in the soils. Processes of lessivage and leaching were mainly controlled by sandy material of the soil's parent rocks. The process of humus accumulation was rather weak: humus components were destroyed by aggressive organic acids which appeared as a result of podzolisation, or they were infiltrated as a result of lessivage. These soil properties indicate a wet temperate climate during the **pl**$_{1b1}$ phase. The pollen analysis of the soils of the early climatic optimum shows a rather high content of tree pollen (40.1%), with the predominance of the boreal taxa *Pinus sylvestris* and *Betula sp*. However, pollen of thermophiles (*Carpinus* and *Quercus*) is present in small percentages. Typical indicators of humid environments (pollen of *Salix, Alnus*, and *Humulus*), as well as a high percentages of spores (28.5%) have also been detected. The climate was wet and relatively warm (subboreal), apparently this was the climatic optimum of the Pryluky time. The forest soils and the similar forest palynospectra in the lower soils of the Pryluky unit have been described in other areas of Ukraine (Sirenko, Turlo, 1986; Bolikhovskaya, 1995; Gerasimenko, 2004, 2006; Lanczont, Boguckyj, 2007; Matviishyna et al., 2010 and others).

The formation of Chernozem-like soils and, thus, the intensification of humus accumulation, occurred during the next phase, **pl**$_{1b2}$. The pollen data obtained from the A and AB soil horizons an increase in pollen percentages of xerophytes, particularly Chenopodiaceae (up to 5%), Ephedra (up to 5-8%) and Poaceae (up to 20%) is the evidence of aridification the end of the **pl**$_{1b2}$ phase. Mesophytic (Poaceas – Herbetum mixtum) steppes spread then.

During the **pl**$_{1b2}$ phase, the soil cover was more homogeneous than before, as the dependence of soils on parent material was not as pronounced as during the early optimum. Although, such dependence was still present. Cryptopodzols were formed on a sandy loam substrate (at Kovban and Novyi Tik) (Fig. 4), Luvic Chernozem and Chernozem-like soils developed on the silt sandy-loam and silty-loam substrates, at Novyi Tik (Fig.4), Boremel (Fig. 7a), Smykiv (Fig. 5c), Kolodezhi (Fig. 7c) and Novostav (Fig. 5a), and chernic Chernozems on the silty loam substrates (at Novyi Tik and Korshiv). At Shybyn mollic Fluvisols developed on alluvial sands. The stratigraphic break on the overlying soil has led to the deformation of soils by solifluction processes, even on gentle slopes (2-3°), and the soils were disturbed by ground-wedges during Uday times.

Cryptopodzolic soils (up to 0.5-0.6 m in thickness) show noticeable signs of podzolisation in the upper part of their profiles, but there is no

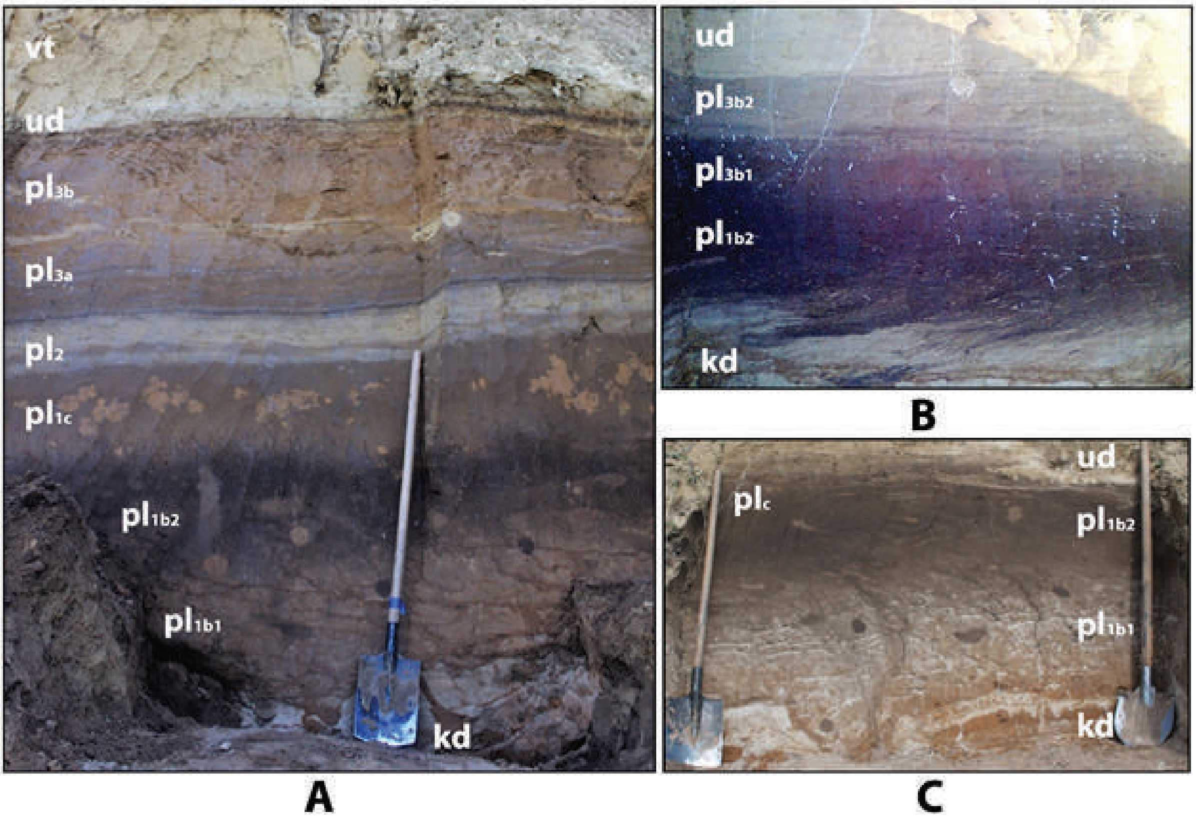

Fig. 5. The Pryluky pedocomplex in the Novostav (A), Smykiv (B) and Kovban (C) sections.

independent E horizon. Podzolisation and lessivage was mainly due to the sandy grain-size composition of the parent material. The soil is characterized by relatively low content of humus in the AEL horizon (0.46%), an increasing in the clay fraction downwards (from 17% to 27%), and the presence of a weak blocky structure in the AB horizon. Furthermore, numerous bioturbations are seen in the subsoil.

The micromorphological structure of the soil is a reflection of contemporaneous processes, such as podzolization and humus accumulation. In the AEL horizon, there are alternations of depleted plasma zones and layers enriched in clay. There is a prevalence of the humus mull that aggregated into rounded biogenic aggregates (Fig. 6c). The residues of organic matter also took place. Translocation processes in the AB horizon are identified by simple large iron-manganese fluid-like cutans (Fig. 6d), humus-clay hipocutans and quasicutans.

Luvic Chernozem and Chernozem-like soils were formed on silty sandy loam and silty loam substrates. Soils (up to 0.3-0.7 m in thickness) have a low degree of podzolisation: with weakly pronounced powdery of SiO_2, which is visible only in the upper part of profiles. The redistribution of silt content down the sequence is almost not observed. The content of humus in soils increasing to 1%. There are single secondary carbonates in the forms of pseudomorphs of roots. In places, carbonates emphasize the blocky post-cryogenic textures. In the subsoil, a large number of bioturbations are located.

There are no such bioturbations in any of the Late Pleistocene soils of the Volyn Upland. The A horizon has a spongy microstructure with complex microaggregates produced by network of channel-like and aggregates fill the voids (Fig. 6e). The silty-humus plasm is isotropic, but simple laminated iron-manganese cutans and clay coats in the AB horizon also formed. In the Ae horizon, there are zones depleted in plasm. Iron-manganese causes mottles and small stains, and less micro-ortsteins occur within profile. Inside fissures in quartz and feldspar grains iron oxides are located, which indicate processes of chemical weathering.

Chernic Chernozems (up to 0.4-0.6 m thick) were formed on silty loam parent materials and, within the studied area, they are the most similar to modern Chernozems. The soils almost lack signs of podzolisation, having a weak granular-crumb structure. Humus content is relatively high (up to 0.66%) with domination of humic acids over fulvic acids (HAs / FAs = 1.1-1.8) (Tsatskin, 1980). The soil fabric is strongly aggregated. There are dominant simple rounded ooid-like microaggregates (Fig. 6f). Such types of microaggregates, as well as bent fabrics, platy microstructure and networks of fissures (mud-

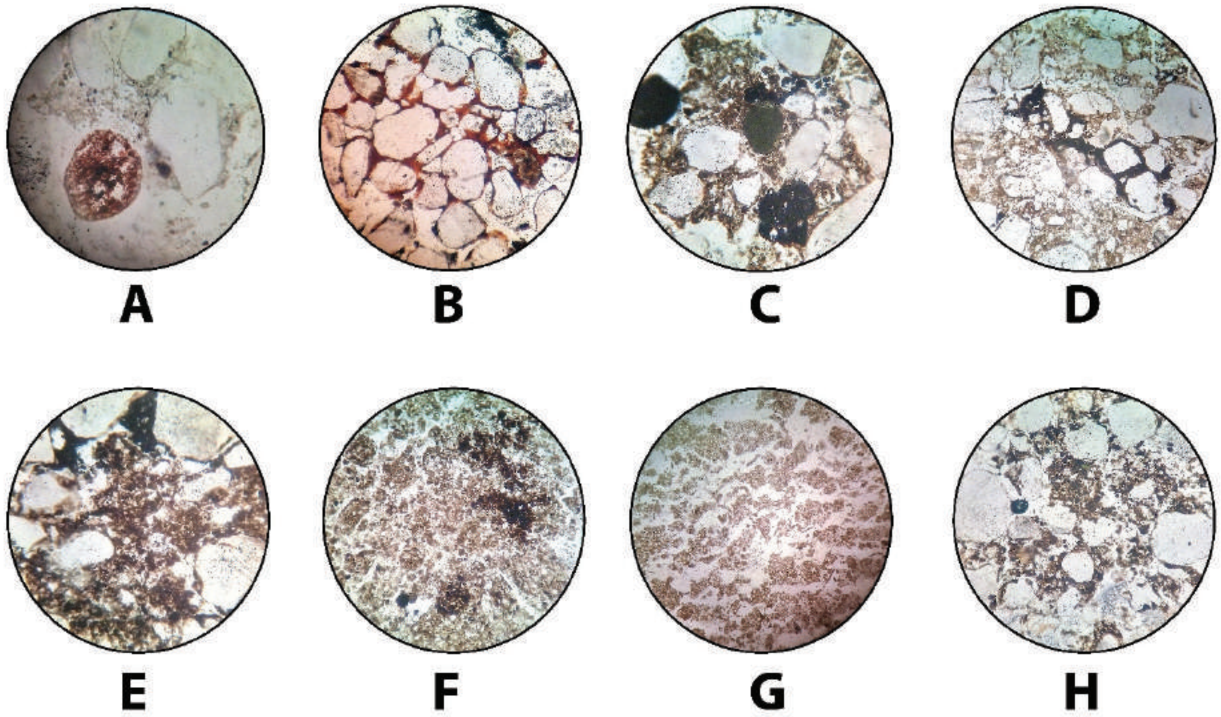

Fig 6. Micromorphological composition of the Pryluky soils in the Novyi Tik section: **A** – clean quartz grains (a result of podzolisation) and iron-manganese micro-ortstein in the E horizon of the **pl**$_{1b1}$ Podzol complex organic-mineral microaggregates between sand grains and manganese pedofeatures in the Ae horizon of the Cryptopodzolic soil **pl**$_{1b2}$ (PPLx70); **D** – iron-manganese cutans in channel-like pores in the BCh horizon of the Cryptopodzolic soil **pl**1b2 (PPLx40); **E** – complex biogenic microaggregates in the Ae horizon of the luvic Chernozem **pl**$_{1b2}$ (PPLx70); **F** – ooid-like mineral-organic microaggregates and diagenetic iron-manganese impregnations in the A horizon of the Chernic Chernozem **pl**$_{1b2}$ (PPLx40); **G** – bent fabric and platy microstructure in the A horizon of the luvic Chernozem **pl**$_{1b2}$ - the result of cryogenic processes (PPLx40); **H** – depletion in clay material in the A1 horizon of the Luvic Cambisol as a result of podzolisation processes (PPLx40).

cracks or cryogenic cracks) were caused by epigenetic cryogenesis (Fig. 6g). In the soil, there is much iron-manganese pedofeatures such as micro-ortsteins, coats, stains and nodules. Some pedofeatures have been disturbed by dehydration cracks.

In some sections (Boremel, Novyi Tik, and Novostov) it is possible to detect the initial soils of the final phase of **pl**$_{1c}$ (Fig. 4; 5a; 7a), which is separated from the soils of **pl**$_{1b2}$ by a loess streak, as well as small frost fissures and mud-cracks. At Novyi Tik and Boremel, Umbrisols (up to 0.2-0.4 m in thickness) occur, with a relatively high content of humus (0.41%), a weak powder of SiO_2 and with numerous worm infilled worm burrows and ochre spots of ferrugination. At Boremel, there is a small quantity are floury secondary carbonates in the upper part of the profile. The soil has a micromorphological structure with greyish-brown isotropic humus-clay aggregated plasm and a vosepic plasmic fabric with iron and manganese domains. The aggregates are divided by an intricate network of mud-cracks and rounded pores. Quartz grains have thin humus-clay coatings around them. Residues of the organic matter also occur. The depletion of plasm material within isolated zones is an indicator of weak processes of podzolization.

Following palynological data obtained from **pl**$_{1c}$ Umrisol in the Novyi Tik section, the mesophytic boreal steppe can be reconstructed. In the palynospectra, the incidence of pollen of xerophytic Ephedra (5%) and hydrophytic Cyperaceae (32.5%) is relatively high. Among tree species, there is a small amount of pollen of Alnus sp. and Pinus sylvestris.

In the Novostav section (Fig. 5a), there is a cambic Luvisol (up to 0.4 m thick), with a sandy loam composition (content of sand fraction is 52-55%), and a slight increase in the clay fraction down the profile (from 3% in the Ae horizon to 11% in the B horizon). The soil has a brown color, is leached (only secondary carbonates present), with a large number of worm holes and a weak powder of SiO_2. There are pale (light-brown) spots of a chimeric form of obscure origin, which in places reach 0.3 m in thickness and the same in width, forming separate isolated spots

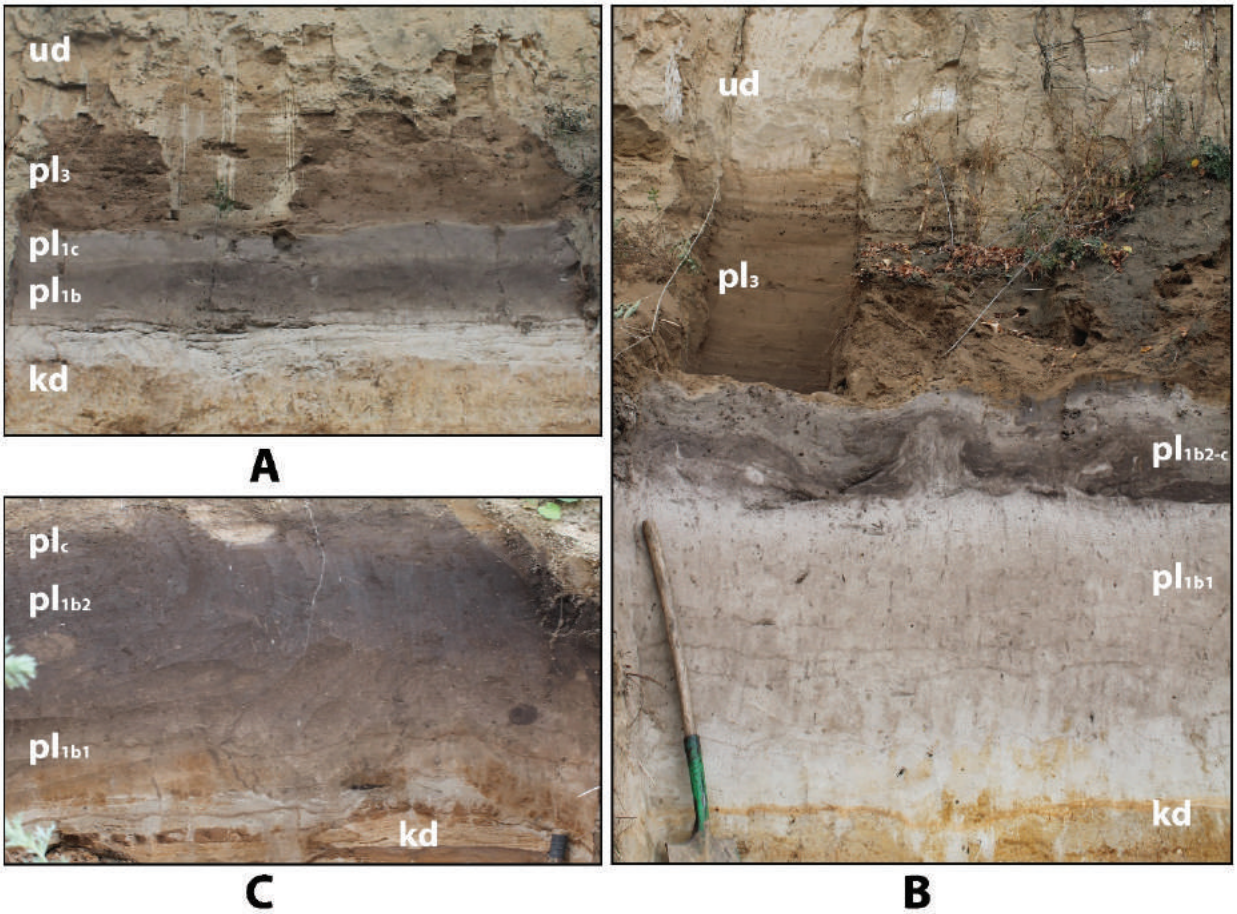

Fig. 7. Pryluky pedocomplex in the Boremel-2 (A, B) and Kolodezhi (C) sections.

or clusters (Fig. 5a). In some spots there are tiny injections of humus that creates ‘bridges’ inside the spots. The genesis of the spots is unclear so far. Perhaps they were the result of chemical destruction of pedofeatures, which were subsequently substituted by mineral material. Single small spots in the upper part of the Pryluky pedocomplex are also seen at Kovban, Novyi Tik and Smykiv. Similar features are known elsewhere in Ukraine (Gerasimenko, 2010).

The thin (up to 0.2 m thick) layer of non-soil material (loess, loess-like and hillwash loam) and a level with cryogenic features (solifluction, ground wedges and frost fissures) allow one to reconstruct a period of cold climate ($\mathbf{pl}_2$) within Pryluky times (Fig. 4; 5a; 5b).

The soils of $\mathbf{pl}_3$ have mostly been (partially or completely) denuded in the studied area (at Kovban, Kolodezhi, and Korshiv). It is difficult to trace a clear stratigraphic break, because soils and deposits were deformed by solifluction processes during Uday cold times. The presence of a denuded B horizon in the upper part of soil $\mathbf{pl}_1$, with increasing of clay content up the profile, as well as a residual blocky structure, allow one to interpret the former presence of soil $\mathbf{pl}_3$. At Boremel, Novyi Tik and Novostav, pedosediments of a Luvisol were revealed above the loess streak (Fig. 7a; 7b). In the area of the Volyn` Upland, Luvisols $\mathbf{pl}_3$ has been described in the Dubno section (Bogutskyi, Voloshyn, 2011), and correlated to the Kolodiiv-1 soil of the regional stratigraphic scheme (Lanczont, Bogutskyj, 2007).

At Boremel-3, the Luvisol $\mathbf{pl}_3$ (up to 0.7 m thick) occurs, with a dark A horizon and a brown unstructured Bmt horizon. At Novyi Tik (Fig. 4), an Upper Pryluky subunit consists of a lower luvic Cambisol ($\mathbf{pl}_{3b1}$) overlain by prolluvial sands. Above the last is pedosediment of a luvic Cambisol ($\mathbf{pl}_{3b2}$) occurs. The Luvic Cambisol ($\mathbf{pl}_{3b1}$) (up to 0.3 m thick) includes Ae and AB horizons. The soil, in microstructure, has brownish-grey, isotropic, well-aggregated clay-humus plasm with domains of the vosepic, mosepic and insepic plasmic fabrics. There are depleted in the plasm zones as a result of podsolization (Fig, 6h). In the AB horizon, simple, large iron-manganese cutans, as well as iron-manganese coatings and stains, appear.

Pedosediment of luvic Cambisol $\mathbf{pl}_{3b2}$ (up to 0.7 m thick) show signs of differentiation in the Ae, ABg_{ca}, and BCg horizons (Fig. 4). It is characterized by a relatively high humus content in the Ae horizon (0.43%) as well as a high content of clay in the ABg_{ca}

horizon, and secondary intensive gleying. There are a large number of secondary carbonate nodules. At the lower boundary of the soil, a resistant streak of ferrugination (up to 4 cm in thickness) occurs. It can be suggested that it fixes the position of the lower boundary of the active layer during in the Uday cryogenesis. Furthermore, the cryogenic metamorphism of the pedosediment was followed by development of a weak platy structure, a blocky post-cryogenic texture, solifluction and gelifluction.

A similar $\mathbf{pl}_3$ pedocomplex is revealed in the Smykiv section (Fig. 5b). A lower soil ($\mathbf{pl}_{3b1}$) is a loamy luvic Cambisol (up to 0.3 m thick) with abundant manganese pedofeatures. The upper soil ($\mathbf{pl}_{3b2}$) is a loamy mollic Cambisol (up to 0.3 m thick), with abundant secondary carbonates. It is differentiated into A and BC horizons. Down of the slope, the soil is strongly disturbed by solifluction.

At Novostav, a pedocomplex with three soils is revealed (Fig. 5a). However, soils of the beginning ($\mathbf{pl}_{3a}$) and the final ($\mathbf{pl}_{3b2}$) phases have the features of pedosediment of the mollic Cambisols. The pedosediment of the mollic Cambisol ($\mathbf{pl}_{3a}$) has a sandy-loam grain-size, with the sand fraction reaching 47.5%. In the subsoil, the Bca horizon has a content of $CaCO_3$, which reaches 7.3%. The Luvisol $\mathbf{pl}_{3b1}$ (up to 0.4 m thick) is a sandy clay loam, with increasing content of clay down the sequence (from 20% in the Ae horizon to 29% in the Bmt horizon). The soil is unstructured, partially gleyed, with abundant manganese pedofeatures and single secondary carbonate nodules (the content of $CaCO_3$ is 0.27-0.44%). In the direction of slope, the soil gradually turns/grades into pedosediment. A weak layer of loess-like loam (up to 0.2 m thick) lies above, under an incipient mollic Cambisol ($\mathbf{pl}_{3b2}$). The last has dark-grey color, a silty loam grain-size and secondary carbonates localized as soft white spots (content of $CaCO_3$ is 4.03%). The top of the soil is affected by mud-cracks and frost fissures.

From the correlation of the $\mathbf{pl}_3$ soil / pedocomplex in different excavations it may to inferred that it comprises three phases of pedogenesis. The soil of phase $\mathbf{pl}_{3a}$ is represented by a mollic Cambisol. During the $\mathbf{pl}_{3b1}$ phase, a Luvisol and a luvic Cambisol were formed. At Novyi Tik, a luvic Cambisol is characterized by relatively a large humus content and the presence of complicated microaggregates. Perhaps this is due to the imposition of the soil of the early optimum ($\mathbf{pl}_{3b1}$) on the underlying incipient soil ($\mathbf{pl}_{3a}$). During the late optimum ($\mathbf{pl}_{3b2}$) there was climatic aridification, which caused the formation of incipient luvic and mollic Cambisols.

The intense cryogenesis during the Uday times led to significant soil disturbance, the movement of soil material through solifluction, and significant cryogenic pedometamorphism. For instance, at Shybyn a mollic Gleysol $\mathbf{pl}_3$ is intensively disturbed by spot-medallions. Post-thixotropy textures, fairly signs of frost-sorting of the material (with the sand fraction located to the periphery of the polygons), gelifluction and cryoturbation are all detected in the soil. Obviously, the strong gleying of the soil and lack of genetic horizons are secondary phenomena, caused by cryogenic processes. Thus, the primary soil was radically transformed by cryogenesis to a Gleysol, and is now impossible to reconstruct. Only in places is there a thick A horizon that is barely noticeable.

Conclusions:

1. The Pryluky unit is frequenty represented by a polygenetic chernozem-like soil, but in favourable sedimentation conditions, it is transitional to a complicated pedocomplex (up to 2 m thick). On the basis of the investigation of the Pryluky pedocomplex in sedimentation traps, it is possible to identify up to 6 phases of soil formation: $\mathbf{pl}_{1b1}$, $\mathbf{pl}_{1b2}$, $\mathbf{pl}_{1c}$, $\mathbf{pl}_{3a}$, $\mathbf{pl}_{3b1}$, $\mathbf{pl}_{3b2}$

2. In most of the studied sections, the Prylyky pedocomplex has a sandy loam composition, due to the inheritance of parent lithologies. The main erosion breaks are situated at the lower boundary of the pedocomplex and on the top of the $\mathbf{pl}_{1b2}$ soil.

3. During the $\mathbf{pl}_{1b1}$ early optimum, forest soils were formed, with varying degrees of podzolization, depending on the variations in parent materials. On sands Podzols were formed, on loess-like sandy loam Albeluvisols and Cryptopodzolics were formed, and on the sandy loam soils of the Kaydaky unit albic Luvisols were formed.

4. During the $\mathbf{pl}_{1b2}$ late optimum, there was aridification, which led to the activation of humus accumulation under mesophytic steppe, indicated by high humus content (up to 1%), the dominance of dark mull humus and complex microaggregation. The spatial difference between soils is weak, but depending on the palaeorelief and grain-size composition of the parent material soils, there is variety: on the sandy loams Cryptododzol was formed; on the sandy loams and loams luvic Chernozem and Chernozem-like soils were formed; on the silty loams chernic Chernozem was formed; and on the alluvial sands mollic Fluvisol was formed.

5. During the $\mathbf{pl}_{1c}$ phase, Umbrisols and cambic Luvisols were formed. The former have relatively a high content of humus and complex microaggregation. The latter are characterized by increasing clay content

downwards in the profile. The origin of light-brown spots is not still clear of obscure origin.

6. Soils of the **pl**$_3$ subunit are often denuded, and strongly disturbed by solifluction and cryogenic pedometamorphism. In relief depressions, subunit **pl**$_3$ is represented by pedosediment of Luvisols. During **pl**$_3$ times a trend in the evolution of pedogenesis can be seen; **pl**$_{3a}$ – mollic Cambisol; **pl**$_{3b1}$ – Luvisol and luvic Cambisol; **pl**$_{3b2}$ – luvic and mollic Cambisols.

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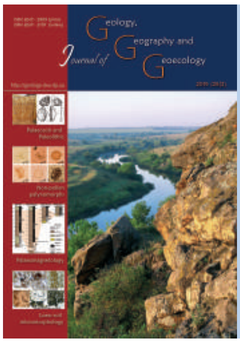

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On palaeomagnetic dating of fluvial deposits in the section of Neporotove gravel quarry on the Middle Dniester

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Abstract. The paper presents the results of palaeomagnetic studies of Quaternary non-cemented deposits from the section of Neporotove on the VIIIth terrace of the Dniester River valley with abnormal thickness (more than 20 m) of the channel alluvium near the village of Neporotove, located on the right bank of the Dniester River. Alluvial facies of river terraces' deposits are valuable palaeogeographic archives but not quite complete. They are affected by denudation and often do not contain fossils. The possible way for their dating is provided by a palaeomagnetic method performed on suitable for sampling underlying and overlying beds. The alluvial sequence consists of four units. Unit I is composed of inclined gravel-pebble layers with the sand filler with a visible thickness of about 8 m. Unit II has bedded over the denudated surface of Unit I; it consists of light-yellow laminated aleurit loam, 5-30 cm thick underlaid by 0.5-1.5 bed of fine sand. We consider Unit II to be lacustrine deposits accumulated in quiet water. Unit III is represented with inclined or sub-horizontally layered gravel-pebble-boulder deposits with up to 10 m of visible thickness. It includes boulders and blocks of sedimentary rocks up to 1.0 in diameter, considered as drop-stones. In the roof of the gravel-pebble Unit III, there is the white carbonate layer, probably, the illuvial horizon of the palaeosol (mr_1), which transited up into the brownish-red horizon A (Unit IV). Unit IV – dark-red sandy-gravel horizon, pedosediment, probably partly the reworked material washed into ice wages in the roof of Unit III. As a result of alternating field stepwise demagnetisation of natural remanence of sediments, we determined that loamy Unit II, which separates members of gravel stratum, and sandy Unit IV, which overlays packs of gravel alluvium, bear characteristic remanent magnetisation (RM) with normal geomagnetic polarity. Taking into consideration lithology and two-fold structure of terrace gravel alluvium as well as palaeomagnetic results, we assume the lacustrine deposits of Unit II was formed during Jaramillo palaeomagnetic subchron corresponding to the end of Shyrokyne Stage, and a pedosediment of Unit IV was formed during Martonosha Stage. The upper alluvial suite of a terrace (Unit III) was generally deposited during a cold stage, directly prior to the onset of lacustrine loam sedimentation, while the lower alluvial member (Unit I) dates from the preceding warm stage. Thus, we defined the geological age of the whole channel alluvium strata of the VIIIth Dniester terrace as Shyrokyne-Pryazovya Stage.

Keywords: Dniester River, Neporotove gravel quarry, river terrace, palaeomagnetic dating, channel alluvium, remanent magnetisation

Про палеомагнітне датування флювіальних відкладів у розрізі гравійного кар'єру Непоротове на Середньому Дністрі

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Анотація. У роботі представлені результати палеомагнітних досліджень четвертинних пухких відкладів з розрізу VIII-ї надзаплавної тераси долини Дністра з надпотужними (понад 20 м) шарами руслового алювію біля села Непоротове, що на правому березі Дністра. Алювіальні фації відкладів річкових терас є цінними палеогеографічними архівами, але часто не повними. Значна частина відкладів зникає внаслідок денудації, флювіальні шари переважно є палеонтологічно німими. Їхнє датування можливе за допомогою палеомагнітного методу, коли він застосовується на придатних для відбору зразків підстеляючих та перекриваючих відкладах. Розріз алювіальних відкладів у Непоротовому складається з чотирьох верств. Верства I являє собою косошарувату гравійно-галечникову товщу з піщаними прошарками та видимою потужністю близько 8 м. Верства II залягає на денудованій поверхні верстви I, вона складається з світло-жовтого горизонтально шаруватого суглинку товщиною 5-30 см, який підстелюється 0,5-1,5 м шаром дрібного шаруватого піску. Верства II складена озерними відкладами, накопиченими в спокійних водних умовах. Верства III представлена похилими або субгоризонтально-шаруватими гравійно-галечно-валунними відкладами з видимою товщиною до 10 м. Вона містить валуни і брили осадових порід діаметром до 1.0 м, які ми вважаємо дроп-стоунами. У покрівлі галечника верстви III знаходиться білий карбонатний прошарок – ймовірно, ілювіальний горизонт мартоноського викопного ґрунту (mr_1), який догори переходить у бурувато-червоний горизонт A (верства IV). Верства IV –темно-червоний піщано-гравійний горизонт, педоседимент. Складається з переробленого матеріалу, вмитого до морозобійних тріщин в покрівлі верстви III. У результаті магнітної чистки зразків пухких відкладів змінним полем встановлено, що і суглиниста верства II, яка розділяє пачки гравійної товщі, і піщана верства IV, яка перекривають пачки гравійного алювію, мають пряму характеристичну намагніченість. Враховуючи подвійну будову руслового алювію, а також палеомагнітні результати, було висунуто припущення про приналежність шару II озерних відкладів до субхрону прямої полярності Харамільо, який стратиграфічно відповідає верхньому широкинському підетапу, а педоседименту IV до мартоноського палеокліматичного етапу. Верхній терасовий алювій (верства III) накопичився під час холодної стадії, безпосередньо перед початком осідання озерного суглинку, тоді як нижній алювій (верства I) датується попереднім теплим етапом. Отже, геологічний вік всієї товщі руслового алювію VIII-ї тераси визначено як широкинсько-приазовський.

Ключові слова: річка Дністер, гравійний кар'єр Непоротове, річкова тераса, палеомагнітне датування, русловий алювій, залишкове намагнічення.

Introduction. Alluvial facies of river terraces' deposits are valuable palaeogeographic archives containing records about the history of the formation of these rivers' valleys and climate change during corresponding periods. The lithofacial composition, stratigraphy, structure of the alluvium reflects the interaction of many processes, such as short-term migrations of individual channels to long-term vertical tectonic movements (Matoshko et al., 2004; Mial, 2006). Meanwhile, like most other types of continental deposits, the alluvial archives are not quite complete, as they are affected by denudation. In particular, they often do not contain fossils, being palaeontologically mute. The palaeomagnetic method performed on suitable for sampling underlying and overlying beds provides a possible way for their dating.

We examined a terrace section near the village of Neporotove, where previously the abnormal thickness of the channel alluvium exceeding 20 m was described (Ridush, Popiuk, 2015). As described in the literature, the channel alluvium strata in the terrace sediments of the middle part of the Dniester valley usually does not exceed several meters, and only occasionally, together with the floodplain facies, reach up to 15-16 m (Veklych, 1982). Just in the lower reaches of the Dniester the so-called "Tiraspol gravel" is known – the river channel alluvium facia of Kolkotovo terrace, which is up to 15 m thick (Nikiforova et al., 1971). So, we faced the question of elucidating the age and the genesis of these strata, and their position within existing schemes of floodplain terraces.

This study reports the examination of characteristic magnetic remanence values in two layers of fine non-cemented sediments separating and overlaying coarse channel alluvium strata to estimate their magnetostratigraphic position relative to Brunhes-Matuyama geomagnetic polarity reversal. It leads to the dating of the VIIIth Dniester terrace.

Materials and methods. Many researchers studied the terraces of the middle reaches of the Dniester valley. The history of these studies is described in detail by O. Tomeniuk (2010). Her publication contains a comparison of the numbers and heights of terraces by different authors. So, within the middle part of the Dniester River valley Yu. Polyansky (1929) and S. Rudnytsky determined six terraces, R. Vyrzhykivskyi (1933) and I. Hofstein (Hofstein, 1979) – seven terraces, I. Ivanova (1969) – eight terraces, A. Yatsyshyn and A. Bogutsky (2008) - seven terraces, P. Gozhik and L. Lindner (2007) – thirteen terraces, M. Veklych (1982) – sixteen terraces. In this paper, we use the scheme of terraces by M. Veklych (1982), which, moreover, is used in State Geological Surveys in Ukraine.

Neporotove section. Previously the section was described by B. Ridush and Y. Popiuk (2015). The gravel outcrop uncovered by a quarry located on the northern outskirts of the Neporotove village (Sokyryany district, Chernivtsi region, Ukraine) (Fig. 1). Coordinates of the outcrop are N 48°36'32.47", E 27°17'11.22". Bedrocks represented with: Proterozoic shales with the inclusions of phosphorite nodules; Cretaceous deposits of varying lithological composition, among which is gaize with inclusions of flint nodules; Sarmatian detrital and tortoiseshell limestones.

Although the Quaternary gravel-pebble stratum is generally fairly homogeneous, it is nevertheless divided into two horizons by light-yellow, fine-grained laminated aleuritic loam (Unit II, Fig. 2, II),

The alluvial sequence consists of four units.

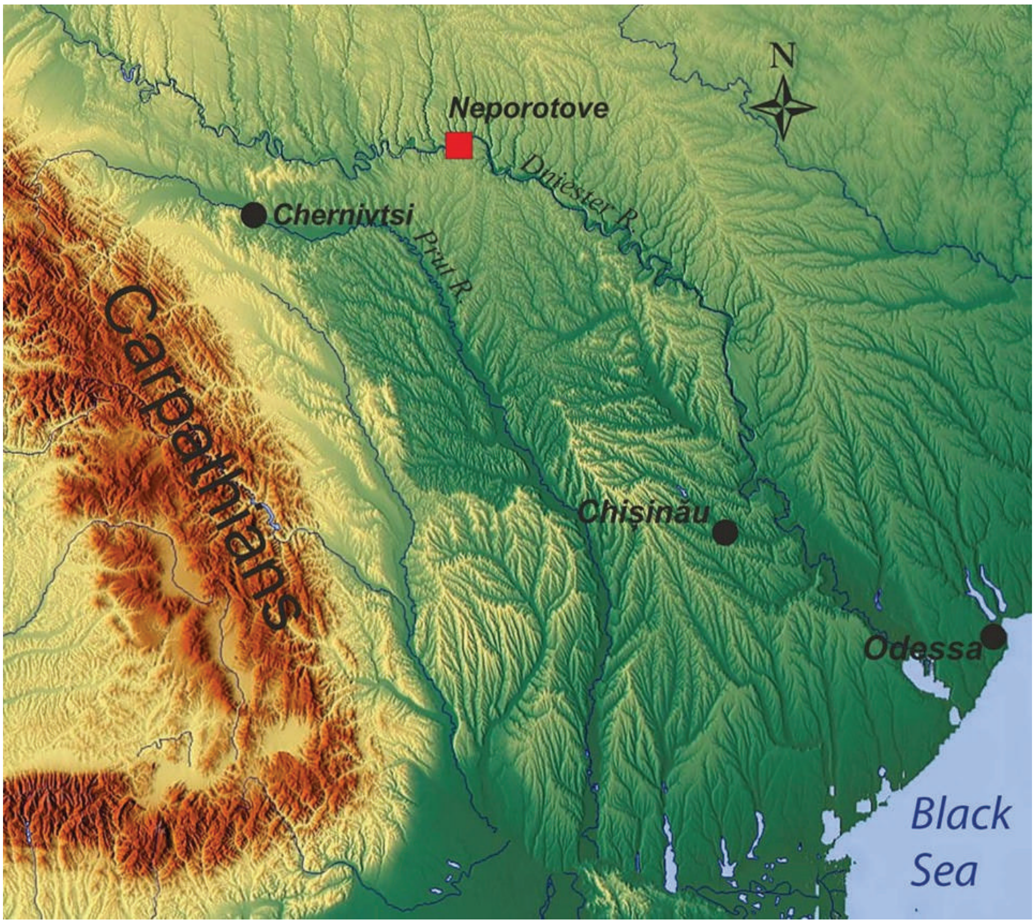

Fig. 1. Location of the Neporotove section of terrace deposits.

Unit I beds on the denudated surface of Ediacaran shale. It is composed of an inclined (the angle of approximately 30°) gravel-pebble layers with a sand filler (up to 20-30% of the volume), with a visible thickness of about 8 m. Gravel and pebble stones are generally well-rounded and sub-rounded. The layers usually are 10-20 cm thick, with larger and smaller sand content, between which there are no clear boundaries, alternate down the section.

Unit II has bedded over the denudated surface of Unit I. It consists of light-yellow laminated aleurit loam, 5-30 cm thick, which is here and there underlaid by lenses (up to 0.5-1.5 m thick) of fine-grained yellow and grey sand with gravel and pebble inclusions. We assume the lacustrine genesis of this stratum. It is evident that the loamy layer is quite dense and water-resistant, since directly over it in the covering gravel Unit III some suffosion channels with a diameter of 0.4-0.7 m have been traced.

Unit III – inclined (angle about 20°) or sub-horizontally layered gravel-pebble-boulder deposits, with or without sand filler (up to 10%), with up to 10 m of visible thickness. It lays with disconformity on the surface of Unit II, and, where Unit II is absent, on the surface of Unit I. There are overlapping layers of different granulometric composition: coarse pebbles, fine pebbles, gravel. Numerous inclusions (up to 10%) of weakly rolled and non-rolled boulders of Sarmatian and Cretaceous limestones and sandstones, sometimes Devonian sandstones or quartz, with a diameter of 0.8-1.0 m or more. There are pellets of Proterozoic dark grey, dark green, light green argillites in size from large pebbles to small boulders up to 0.5 m in diameter included in the strata. Among the pebble material, the weakly-rolled flint pebbles with traces of cryogenic weathering predominate (no less than 50%). Lithology of gravel and pebble material is also represented by Devonian red sandstones, Sarmatian limestones, light Cretaceous limestones and sandstones. Presence of argillite pellets indicates that the flood (or floods) was extreme and the water jet tore out the fragments of argillite rocks, rather than picking up the products of weathering of argillite, which would take place under a usual flood. The large boulders we consider as drop-stones, transported by river-ice. In the roof of Unit III, the ice wedges up to 1 m deep are often. In the roof of the gravel-pebble Unit III, there is the white carbonate layer, probably, the illuvial horizon of the palaeosol (mr_1), which transited up into the brownish-red horizon A (Unit IV).

Fig. 2. Gravel-pebble alluvium at the Neporotove outcrop. I – Unit I, the lower gravel-pebble bed of low-angle cross-bedding; II – Unit II, the loam layer, light yellow, laminated; III – Unit III, the upper gravel-pebble bed of low-angle cross-bedding, with domination of macro-fragmental material and drop-stones at the roof of the bed; IV – dark-red sandy-gravel, V – Unit V subaerial loess deposits of unknown age (Ridush, Popiuk, 2015). The scale stick on the photo is 2 m long.

Unit IV – dark-red sandy-gravel horizon, probably partly the reworked material of Unit III, coloured by the illuvium of red palaeosol, here and there washed into ice wages in the roof of Unit III. Thickness is around 0.4-0.6 m.

From 1.0 to 4.0 m of loess and loess loams of undefined age are deposited above (Unit V).

Sampling and measurements. Since the gravel-pebble deposits of Units 1 and 3 are not suitable for paleomagnetic examination, we focused on sampling Units 2 and 4 in order to achieve the objectives of the study. From the horizontally-layered loamy Unit II, we cut two samples from two stratigraphic levels, from which in the laboratory we drilled six 2.5 cm specimens for palaeomagnetic measurements using the standard procedure (Butler, 1992).

From the reddish sandy Unit IV at the top of the upper gravel-pebble layer we manually cut nine

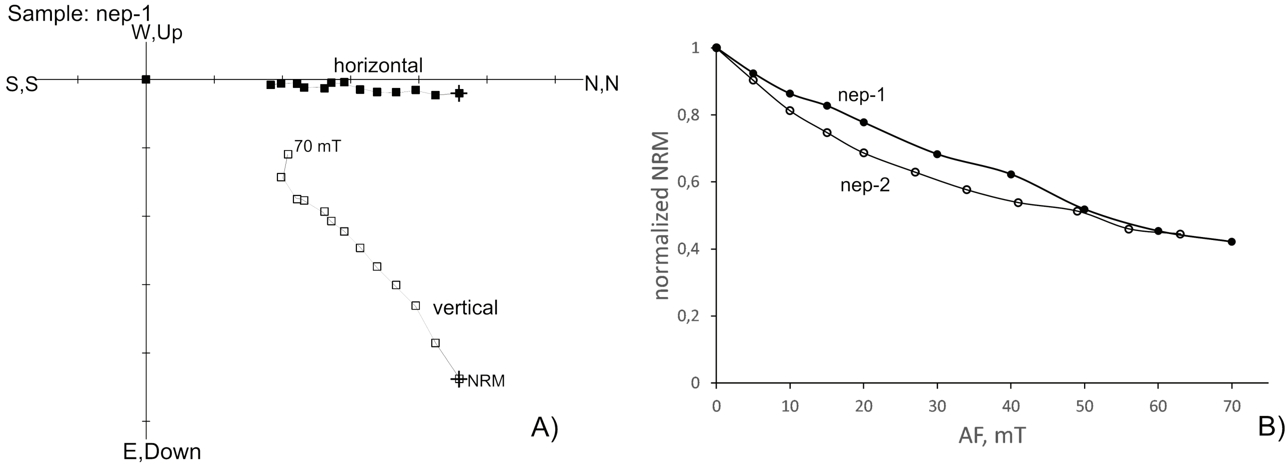

Fig. 3. Examples of AF-demagnetization of specimens from Unit II: (A) characteristic Zijderveld plot and NRM decay curves during AF demagnetization (B).

2.5 cm cylinder specimens. A magnetic compass was used to provide an unequivocal in situ geographic orientation of each manually cut sample.

The measurements were performed in the Ivar Giæver Geomagnetic Laboratory at the University of Oslo (Oslo, Norway) and the magnetic laboratory of ESI «Institute of Geology» of the Taras Shevchenko National University of Kyiv (Kyiv, Ukraine).

The magnetic susceptibility (k) of all samples was measured on Geofyzika KLY-2 Kappabridge.

The remanent magnetisation of specimens was measured using a three-axis WSGI Model 755 SRM (WSGI, USA) cryogenic rock magnetometer. The stable characteristic remanent magnetisation (ChRM) of samples was isolated by stepwise alternating field demagnetisation in a 2G demagnetizer (with steps of 2.5-10 mT until 70 mT for specimens from Unit II and 100 mT for specimens from Unit IV).

The Keonigsberger ratio (Q=NRM/Ji, Ji – induced magnetization) characterising relative magnetic hardness of the material (Evans and Heller, 2003) was calculated.

Results. Since the fluvial sediments represent the re-deposited in shallow water loamy and sandy material, their characteristic remanent magnetisation is rather depositional (DRM) with possible post-depositional (PDRM) contribution. DRM is formed due to the orientation of magnetic particles along the magnetic field during settling in the water and staying in the upper bottom layer until the sediment is compacted. In this case, the vectorial components of the magnetisation - inclination (I) and declination (D) may be biased due to the direction of the waterflow and because of the settling of the elongated magnetic grains when falling on the horizontal bottom. The latter leads to a shallowed I compared with the geomagnetic field inclination of the time and place of sediment's formation (Tauxe, 2018). The magnetisation of sediments could be formed after the formation of a layer (PDRM). Under certain conditions "rejuvenation" of magnetisation relative to the age of the formation of the loose stratum itself is evidenced by the absence of inclination shallowing (Kodama, 2012).

NRM of loam from Unit II makes 6.2...6.5*10^{-3} A/m, k makes 245...280*10^{-6} SI un. These values are typical for loess deposits from loess-palaeosol sequences of Ukraine. The NRM is relatively "hard"; the median destructive field (MDF) is 45-55 mT, the Keonigsberger ratio Q is 0.45 ... 0.50. The demagnetization path on the Zijederveld plots exibit almost straight line and is directed toward the origin. The magnetic declination D of the characteristic component (isolated under the AF-demagnetizing procedure in the range of 10-63 mT) is -12...3°; the inclination is shallowed relatively to the inclination of the recent geomagnetic field and makes 38...51°. Examples of Zijderveld plots and NRM demagnetisation curves are shown in Fig. 3.

Thus, we can conclude that the entire stratum bear ChRM with normal geomagnetic polarity, ChRM is probably depositional.

NRM and k of samples from Unit IV demonstrate low values. NRM makes 1,2...4,3*10^{-3} A/m, k makes 142...242*10^{-6} SI un. MDF makes 11-14 mT, the Q is 0.16...0.59 indicating presence of low-coercive magnetic mineral. As recognized from NRM decay curves, the remanence of samples probably consists of two components, relatively soft one is presumably viscous, it makes up to 65% of remanence. The demagnetization path on the Zijedrvild plots exibit almost straight line and is directed toward the origin, as both components of the NRM are directed equally.

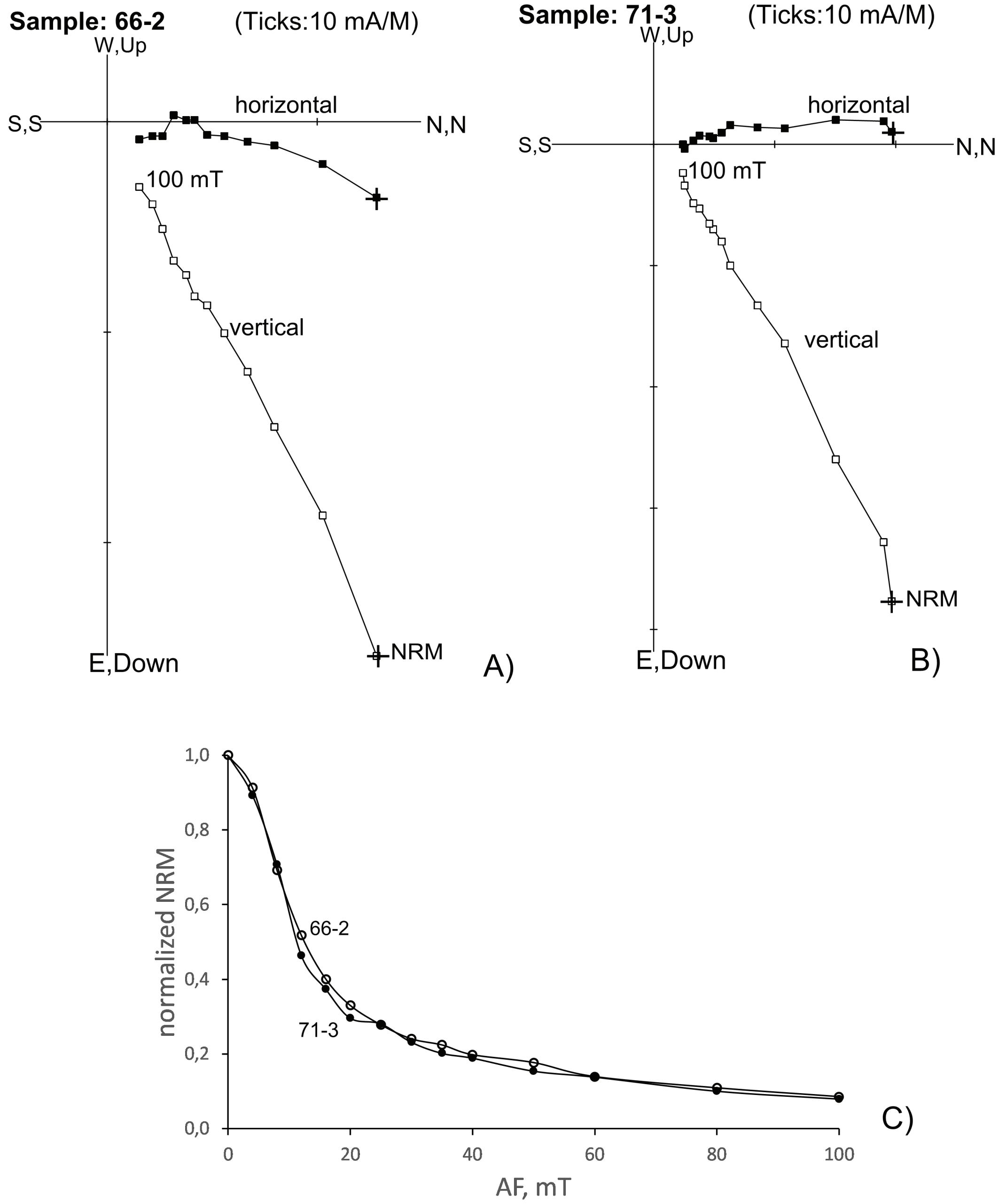

Fig. 4. Examples of AF-demagnetization of specimens from Unit IV: characteristic Zijderveld plots (A, B) and NRM decay curves during AF demagnetization (C).

The magnetic declination of the harder characteristic component (isolated under AF-demagnetizing procedure in the range of 20-100 mT) is -2...6°, the inclination corresponds to the inclination of the recent geomagnetic field and makes 65...71°. Examples of Zijderveld plots and NRM demagnetisation curves are shown in Fig. 4. We can conclude that the sediment acquired the magnetisation in the period of normal geomagnetic polarity, characteristic RM is probably post-depositional.

Discussion. When considering the possible age of the alluvium, it is crucial to determine which lithological horizon may bear the Matuyama-Bruhnes boundary (MBB) - the main Quaternary benchmark. It is important to consider modern ideas about the position of MBB, as this will significantly contribute to the correct interpretation of the palaeomagnetic results on the background of climate-stratigraphic evidence from the fluvial facies.

According to the magnetostratigraphic scale of Pleistocene of Ukraine (Tretyak and Vigilyanskaya, 1994), composed on the base of the regional stratigraphic scheme of the loess-palaeosol sequence of the Central Ukraine (Veklych, 1984) the MBB lays in the bottom of Shyrokyne unit. Early palaeomagnetic studies in the area of Lower Dniester put MBB into the loess mantle above the alluvium of the VIIIth terrace (Pevzner and Chepalyga, 1970; Pospelova

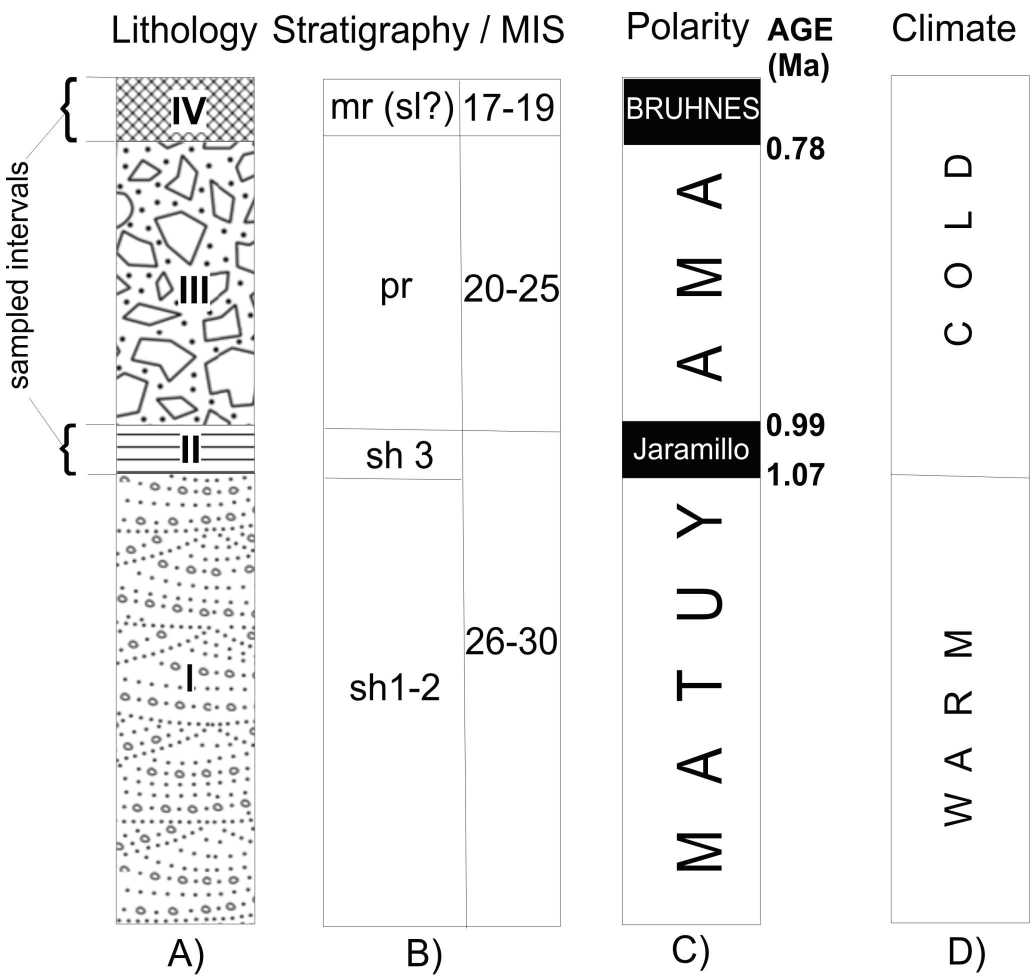

Fig. 5. Lithology (A): I – inclined gravel-pebble layers with a sand filler, thickness of about 8 m, II – light-yellow laminated aleurit loam, 5-30 cm thick, III – gravel-pebble-boulder deposits, up to 10 m of visible thickness, IV – dark-red sandy-gravel horizon, thickness around 0.4-0.6; stratigraphy with oxygen isotope stages (MIS) after (Gerasimenko, 2010) (B); magnetic polarity after (Cande, 1995) (C); and climate (D) of Dniester channel alluvium in Neporotove section.

and Gnibidenko, 1972; Trubikhin and Chepalyga, 1986). In the summarising publication (Lindner et al., 2006), which include data on the Upper, Middle, and Lower Dniester reaches, the MBB was lifted to the boundary of the Pryazovya and Martonosha units of Stratigraphic scheme of the Pleistocene of Ukraine (Veklych, 1984).

According to recent studies performed on precise magnetic equipment, the MBB was not distinguished in the section of Prymors'ke (Nawrocki et al., 1999), which is underlain with the soils of the Martonosha unit. The MBB was defined in the upper part of the Martonosha unit in the Dolynske section (Bakhmutov et al., 2005), in the lower part of the Shyrokyne palaeosol in the section of Viazivok (Glavatsky et al., 2016, Bakhmutov, Glavatsky, 2016). However, in the Viazivok section, the Martonosha unit was missed during sampling, and the authors themselves suspect that the palaeomagnetic record could be aged due to lock-in depth effect. In the section of Roksolany, the MBB was defined at the junction of buried soils of the Lubny and Martonosha units (Bakhmutov, and Glavatsky, 2014; Bakhmutov et al., 2017), relying on the temperature demagnetisation of RM. But authors also provide the data of AF-demagnetization of RM, according to which the MBB should be determined lower, in the Pryazovya unit. The AF-demagnetization method seems to be preferable for soils and loess since during the high-temperature heating experiment the formation of new minerals occur (Evans, 2003).

Thus, the most reasonable for today is the position of the MBB on the contact between the Pryazovya loess and the Martonosha palaeosol, as presented in the paper (Lindner et al., 2006).

Veklych and Dubniak (1975) considered that on the most of river terraces alluvium has a two-fold structure. The uppermost alluvial layer passes upwards into loess with a subaerial palaeosol developed in its upper part and further burial by a sequence of younger loesses and soils. The upper alluvial suite of a terrace was generally formed during a cold stage, directly prior to the onset of aeolian loess sedimentation, while the lower alluvial member dates from the preceding warm stage. Thus, the alluvium of a terrace corresponds to a certain loess-soil couplet on interfluve areas, i.e. to a particular climatic cycle. Matoshko with co-authors (Matoshko et al., 2004) consider this approach problematic because the evidence from the fluvial facies themselves is neglected in favour of simplistic climate-stratigraphy. Nevertheless, we still use this approach.

The palaeomagnetic record of sediments may provide chronostratigraphic information as sediments may acquire magnetic remanence upon deposition and shortly after deposition.

According to this, the normal polarity sandy Unit IV should be attributed to the Martonosha unit (mr). Without contradicting the geological data, it can be assumed that the normal polarity of Unit II may indicate its formation during the Jaramillo subchron inside the Matuyama Chron of reversed polarity, i.e. in the range of 0.99-1.07 million yrs. (Cande and Kent, 1995), which corresponds to the end of the Shyrokyne stage (sh3) (Lindner et al., 2006).

Such an interpretation makes it possible to limit the upper dating of the lower alluvium Unit I to 1.07 million years. So, the Unit I itself can be attributed to the Shyrokyne 1-2 subunits (MIS 24). Going further in our assumptions, let us point out that the erosion of loamy sediments of Unit II and the accumulation of the upper gravel pack of Unit III occurred in Pryazovya Stage (Fig.5).

Conclusion. The layers of non-cemented deposits that separate and overlay alluvium packs were formed during periods of normal geomagnetic polarity. We assume the Unit II of lacustrine deposits we attributed to Shyrokyne-3 unit, the normal polarity zone found here is correlated to the Jaramillo subchron. Unit IV belongs to the Martonosha unit; however, this pedosediment was formed during one of cold Martonosha substages by inwashing the material to frost-cracks in gravel Unit III.

We defined the geological age of the channel alluvium of the VIIIth terrace of the Dniester River as Shyrokyne-Pryazovya.

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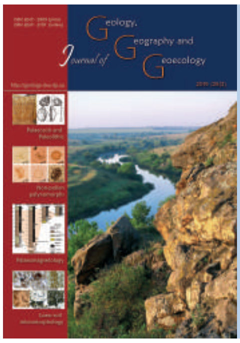

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Stratigraphy of the Pliocene deposits of the Black Sea (Ukraine) according to evidence from ostracods (Arthropoda, Crustacea)

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Abstract. This article presents a detailed analysis of the taxonomic composition of the Pliocene (Kimmerian, Kujalnikian) and Eopleistocene (Gurian) ostracods in the northern part of the Black Sea. It presents the patterns of the stratigraphic position of the fossil ostracods in the Miocene - Quaternary and their geographic distribution in Western and Eastern Europe (the Pannonian Basin, the Dacian Basin, the Euxinian basin of the Paratethys) and the Mediterranean region.We determined the characteristic species for the Kimmerian, Kujalnikian and Gurian in the northern part of the Black Sea. We established a change in the taxonomic composition of ostracods at the Pliocene (Kujalnikian)/Eopleistocene (Gurian) boundary, namely the disappearance of a large number of Pliocene species and the appearance of new species. Ten species disappeared in the Kujalnikian: Cyprideis pontica, Euxinocythere (M.) crebra, Amnicythere mironovi, Camptocypria lobata, Loxoconcha subcrassula, Loxoconcha verticalitercostata, Xestoleberis (X.) cellulocus, Xestoleberis (P.) communis, Candona (C.) expressa, Ilyocypris caspiensis; one species Amnicythere postbissinuata appeared in the Gurian. The brackish water species Cyprideis pontica is the Kujalnikian index species. The stratigraphic position of Cyprideis pontica in the Mediterranean Basin, Pannonian Basin, Dacian Basin, Euxinian Basin (Black Sea) in the Miocene-Quaternary is analyzed. The time of the disappearance of Cyprideis pontica in the Mediterranean, Pannonian and Dacian basins (Messinian, Pontian/Zanclean, Dacian, Kimmerian boundary) and in the Black Sea (Kujalnikian/Gurian boundary) is established. The diagnostic morphological features of the shell Cyprideis pontica (morphology of the surface pore canals) are established and described, which allows us to place this species in the Neogene deposits. Surface pore canals are different shape, sieve-typed, deepened in relation to the surface of the valve. Sieve-shaped lamella contains 110-270 internal pores. The internal pores have a staggered shape, the diameter of the osculum of the internal pore is 302-994 nm; diameter of the central pore is 977 nm-1.8 μm). The evolution of Cyprideis pontica, which was separated from the parent species Cyprideis torosa in the Late Miocene, was reconstructed. In the occupation of a new ecological niche with a reduced oxygen content in deeper water biotopes, in the process of adapting to the conditions of hypoxia and necessity of increasing the volume of water filtration, there was a restructuring of the morphology of the surface pore canals of the shell Cyprideis torosa. This involved an increase in the size of the sieve-shaped lamella, the number of internal pores in the sieve-shaped lamella and the size of the osculum of the inner pore. A new morphotype Cyprideis pontica was thus formed within the existing Parathetys-Mediterranean basins. It had a mosaic, ecologically isolated range that coincided geographically or overlapped with the range of the species Cyprideis torosa (sympatric evolutionary speciation). The range of Cyprideis pontica and the dynamics of its populations in the Euxinian Basin during the Sarmatian-Kujalnikian have been reconstructed.

Keywords: stratigraphic boundary, Pliocene, Quaternary, Ostracoda

Стратиграфія пліоценових відкладів Чорного моря (Україна) за остракодами (Arthropoda, Crustacea)

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Анотація. Дано детальний аналіз таксономічного складу пліоценових (кіммерійських, куяльницьких) і еоплейстоценових (гурійських) остракод у північній частині Чорного моря. Встановлено закономірності стратиграфічного положення викопних остракод у міоцені-квартері та географічного поширення в межах Західної і Східної Європи (Панонський, Дакійський, Євксинський басейни Паратетису) і Середземноморської області. Визначено характерні види для кіммерійського, куяльницького і гурійського регіоярусів для північної частини Чорного моря. Встановлено зміну таксономічного складу остракод на границі пліоцену (куяльницького регіоярусу)-еоплейстоцену (гурійського регіоярусу), а саме зникнення у куяльницький час значної частки пліоценових видів, появі у гурійський час нових видів. Видом-індексом куяльнику у Чорному морі є солонуватоводних вид Cyprideis pontica. Проаналізовано стратиграфічне положення Cyprideis pontica у Середземноморскому, Панонському, Дакійському, Евксінському (Чорноморському) басейнах у міоцені-квартері. Встановлено час зникнення Cyprideis pontica у Середземноморському, Панонському і Дакійському басейнах (границя мессіну, понту –занклію, дакію, кімерію), у Чорному морі (границя куяльника–гурия). Встановлено та описано діагностичну морфологічну ознаку черепашки Cyprideis pontica (морфологію поверхневих порових каналів), яка дозволяє чітко ідентифікувати цей вид у неогенових відкладах. Поверхневі порові канали різної форми, ситовидні, заглиблені по відношенню до поверхні стулки. Ситовидна пластинка містить 110-270 внутрішніх пор. Внутрішні пори мають стовбчасту форму, діаметр вустя внутрішньої пори 302-994 nm; діаметр центральної пори 977 nm-1,8 µm). Реконструйовано еволюцію Cyprideis pontica, яка відійшла від материнського виду Cyprideis torosa у пізньому міоцені. При занятті нової екологічної ніші із зниженим вмістом кисню у більш глибоководних біотопах, в процесі адаптації виду до умов гіпоксії та пов'язаною з цим необхідністю у збільшенні об'ємів фільтрації води відбулась перебудова морфології поверхневих порових каналів черепашки Cyprideis torosa (збільшення розміру ситовидної пластинки, кількості внутрішніх пор у пластинці та розміру вустя внутрішньої пори).В межах існуючих басейнів Паратетис-Середземноморської області сформувався новий морфотип Cyprideis pontica із мозаїчним. екологічно ізольований ареалом, що географічно співпадав чи перекривався з ареалом виду Cyprideis torosa (симпатричне еволюційне формоутворення). Реконструйовано ареали Cyprideis pontica та динаміку його популяцій в Евксинському басейні протягом сармату-куяльнику.

Ключові слова: стратиграфічна границя, пліоцен, квартер, остракоди

Introduction. In the Geologic Time Scale (2012) the biostratigraphic divisions of the Pliocene deposits and the Quaternary base (2.588 Ma, between the Gelasian and Piacenzian (Riccardi, 2009) was substantiated by chronostratigraphy, event stratigraphy, magnetostratigraphy, radiometric dating ($^{40}Ar/^{39}Ar$ dating, ^{14}C and $^{230}Th/^{234}U$ dating, U/Pb dating, $^{87}Sr/^{86}Sr$), climate change and Milankovich cycles (sedimentation cycles), and oxygen and carbon isotopes $\delta^{18}O$, $\delta^{13}C$ curves. Palaeontological characteristic of the Gelasian and Piacenzian derive from different faunal groups (mammals, planktonic foraminifera, calcareous nannofossils, diatoms, radiolarians, dinoflagellates). However, formally, the Neogene-Quaternary boundary is uniquely substantiated on the appearance at the beginning of the Gelasian of dinoflagellate cysts of *Spiniferites pachyderma* and *Invertocysta tabulata* (middle part of D21, northwestern Europe) and the radiolarian *Pterocanium prismatium* (RN12b, northwestern Europe), as well as the disappearance at the end of the Piacenzian of the radiolarian *Anthocyrtidium jenghisi* (zone RN12a; northwestern Europe) and the planktonic foraminiferan *Dentoglobigerina altispira* (zone PL 5, Pacific Ocean). The Pliocene-Quaternary boundary (2,588 Ma) in the Paratethys region is compared with the boundary of the megacycle Ge1 without paleontological substantiation. It is located in the upper part of the Pannonian and within the Kimmerian (Fig. 29. Neogene-Quaternary Regional Subdivisions: Hilgen, Lourens, Van Dam, 2012).

In the Quaternary stratigraphic scheme for Ukraine, the Pliocene/Quaternary boundary is placed at the level between the Kujalnikian (Gelasian) and the Gurian (Calabrian) at 1.81 Ma (Stratigraphic Code of Ukraine, 2012). This is based on the appearance in the Gurian of the molluscs *Dreissena distanta*, *D. polymorpha*, *Didacna digressa*, *D. giriana*, *Modiolus phaseolinus*, nannoplankton *Pseudoemiliania*, *Gephyrocapsa oceanica*, *Emilia hyxleyi*, as well as the disappearance of the Kujalnikian form *Dreissena theodori*. The planktonic Foraminifera *Ammonia beccarii*, *Ammonia tepida*, *Fissurina porecta*, *Cananifera parcarae*, nanoplankton *Discoaster brouweri* and *D. pentaradiatus* (Tabl. 17.) are represented in the stratigraphic scheme of Cenozoic deposits of the Ukrainian sector of the Black Sea: Stratigraphic Code of Ukraine, 2012). The National Stratigraphic Committee of Ukraine adopted the decision on the recognition of the ICS Pliocene/Quaternary boundary at the level of 2.588 Ma (Resolution of the NSCU dated April 18, 2018: Geological Journal, 2018). Accordingly, the Pliocene/Quaternary boundary is now placed at a lower level in the Kujalnikian horizon, which needs additional palaeontological fauna-floristic substantiation.

The purpose of this article is to detail the microfaunistic characteristics (using ostracods) of the Pliocene (Kimmerian, Kujalnikian) and Eopleistocene (Gurian) marine sediments, and to substantiate the Pliocene/Quaternary boundary in the northern part of the Black Sea.

Neogene ostracods of the Paratethys and Mediterranean regions and the Quaternary ostracods of western and eastern Europe, the Black Sea, Caspian Sea and Mediterranean Sea have been well studied in their systematic, ecological, zoogeographical and palaeogeographical aspects. They are used for detailed relative-age determination and correlation of marine deposits, but fossil ostracods as a biostratigraphic tool have not been used in the international stratigraphic scales of the Neogene-Quaternary (Geologic Time Scale, 2004, 2012) and Ukrainian stratigraphic schemes of the Neogene-Quaternary (Stratigraphic

Code of Ukraine, 2012). This biostratigraphic analysis using ostracods was the first of its kind.

Fossil ostracods are a uniquely informative group of fossil microorganisms. In sediments, ostracods are often the only (and usually numerous) representatives of the fossil fauna. They had a predominantly autochthonous type of burial, often beautifully preserved or at least with a sufficient degree of conservation of the shell to allow species identification. Local and regional biostratigraphic divisions in the Neogene-Quaternary deposits of the Black Sea are distinguished using ostracods (Dykan, 2011; Dykan, 2012; Dykan 2016 a, b, c, d, f). Therefore, the application of fossil ostracods to stratigraphic correlation schemes, as a biostratigraphically important group of fossil microorganisms, is scientifically sound and expedient.

Material and methods of research. The Neogene-Quaternary and recent ostracods of the Black Sea were collected over a period of forty years (1978-2017) from outcrops on the northern coast of the Black Sea (from the Danube to the Taman Peninsula), well cores (Odessa region, Kerch Peninsula, Taman Peninsula, the estuaries of the northwest coast of the Black Sea) and stations (the shelf and continental slope of the northern part of the Black Sea, SRV NASU) (Fig. 1).

The biostratigraphic conclusions were based on the systematic study of fossil ostracods (the identification of species, the principles and criteria for the determination of taxonomic features, the estimation of the taxonomic weight of the morphological features, the determination of diagnostic features of the different taxonomic ranks, taxonomic diagnoses, unified method of the description of shell morphology) (Dykan, 2006). Electronic-microscopy, taphonomic, statistical, population, geochemical and facial methods, and zoogeographical analyses have been used in the study of fossil ostracods. The determination of the geological ages of the marine deposits was based on biostratigraphic and ecological criteria derived from ostracods. The biostratigraphy is based on the presence of index species; groups of fossil ostracods, which have the upper and lower boundaries, well established first and last appearances of characteristic species; in the presence of periods of optimum of ostracod species (genera); on the ratio of zoogeographical species (Mediterranean, Caspian) and species of different ecological specialization (marine, brackish water, freshwater). Literary sources on the stratigraphic position and geographical distribution of fossil ostracods in the Holarctic belt were also taken into account.

Results and their analysis. In the northern part of the Black Sea, Pliocene deposits are represented by Kimmerian and Kujalnikian horizons. The Kimmerian deposits are distributed on the western shelf from the mouth of the Tiligul estuary, on the Crimean continental slope from isobaths 287 m to 1750 m, to the southern slope of the Kerch-Taman shelf to the isobaths 150-200 m. They are presented by a layer of sandy clayey silts on the north-western shelf; oolitic iron ores with clay layers in the Crimean continental slope; iron-bearing sandstone on the eastern part of the northwestern shelf and the Kerch shelf. The thickness of the Kimmerian deposits decreases from east to west and is 40-50 m (Semenenko, 1987; Shuraev, 2015). The lectostratotype of the Kimmerian is the section near the village Arshintsevo (Kamish-Burun)

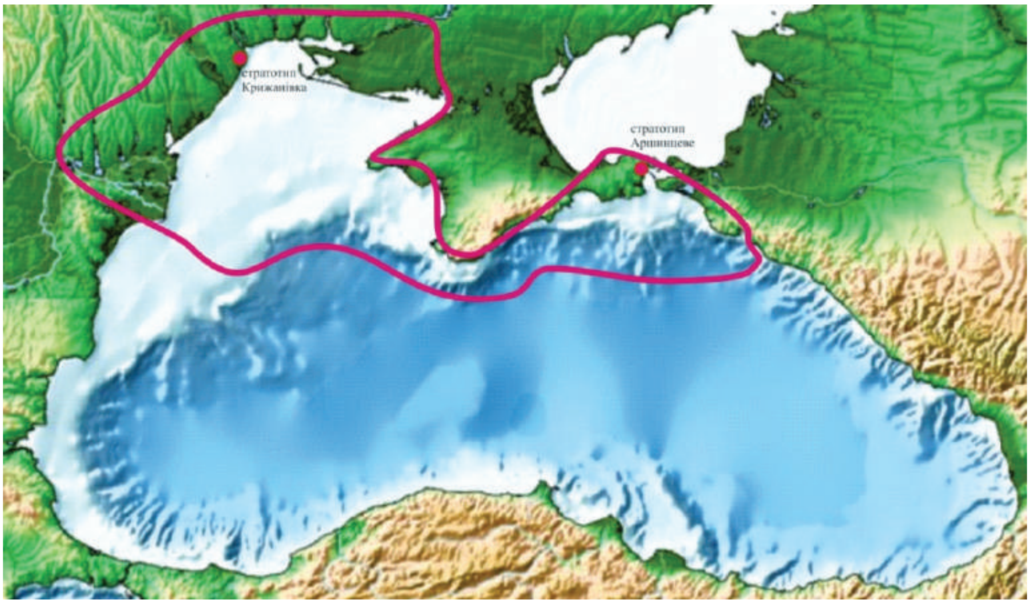

Fig. 1. Map of the research area in the northern part of the Black Sea

(Stratigraficheskij slovar SSSR. Paleogen. Neogen. Chetvertichnaya sistema, 1982).

The Kimmerian ostracods comprise 19 genera and 38 species. They include some inherited Pontian ostracod genera (*Cyprideis*, *Tyrrhenocythere, Euxinocythere (Maeotocythere)*, *Amnicythere, Loxoconchissa* (*Loxocaspia*), *Xestoleberis (Pontoleberis)*, *Advenocypris*, *Bacunella, Camptocypria, Caspiocypris, Pontoniella*) as well as some species. The peculiarity of the Pontian relic species in the Kimmerian deposits is that it is poor in crustaceans, which is also manifested in small shells. Typical species of the beginning of the Kimmerian are *Tyrrhenocythere amnicola donetziensis* Dub., *Loxoconchissa* (*Loxocaspia*) *eichwaldi* (Liv.), *Loxoconchissa* (*Loxocaspia*) *immodulata* (Step.), *Loxoconchissa* (*Loxoconchissa*) *bairdyi* (G.W. Müll.), *Loxoconcha lepida* Step., *Pseudocytherura pontica* Dub., *Camptocypria gracilis* (Liv.), *Caspiocypris merculiensis* Vek., *Candona (Candona) angulata* G.W. Müll., *Cypria candonaeformis* (Schw.), *Ilyocypris caspiensis* (Neg.) (Table. 1). In the northwestern part of the Kimmerian Basin, ostracods formed stable associations of the species *Bacunella dorsoarcuata, Camptocypria acronasuta, Camptocypria lobata, Cyprideis torosa, Tyrrhenocythere azerbaidjanica* (Liv.), and *Cryptocyprideis bogatschovi*. The Kimmerian species *Camptocypria lobata* and *Bacunella dorsoarcuata* had large shells in comparison with the Pontian individuals. This is a clear marker for separating the Pontian and Kimmerian deposits in the northern part of the Black Sea (Dykan, 2016 a).

The Kujalnikian deposits occur in wells on the shelf and in the deep-water zone of the continental slope; their areal distribution coincides with the Kimmerian deposits (Semenenko, 1987). They are presented by sand, silts, sandstones and clay with a total thickness of 40-50 m. The lectostratotype of the Kujalnikian is the section near the village Kryzhanivka (Odesa region, Ukraine) (Stratigraficheskij slovar SSSR. Paleogen. Neogen. Chetvertichnaya sistema, 1982).

Kujalnikian ostracods comprise 19 genera and 42 species. A characteristic feature of the Kujalnikian ostracods is the transitional Kimmerian-Kujalnikian type fauna, where 62% are Kimmerian relics: *Pseudocytherura pontica*, *Cyprideis torosa* (*Jones*), *Cyprideis pontica* Krstič, *Tyrrhenocythere amnicola donetziensis* Dub., *Tyrrhenocythere azerbaidjanica* (Liv.&Agal.), *Euxinocythere* (*Maeotocythere*) *crebra* (Schn.), *Amnicythere palimpsesta* (Liv.), *Amnicythere multituberculata* (Liv.), *Amnicythere mironovi* (Schn.), *Loxoconchissa* (*Loxocaspia*) *eichwaldi* (Liv.), *Loxoconchissa* (*Loxocaspia*) *immodulata* (Step.), *Loxoconcha lepida* (Step.), *L. subcrassula* Suz., *Xestoleberis* (*Pontoleberis*) *laevis* (Karm.), *Camptocypria acronasuta* (Liv.), *Camptocypria gracilis* (Liv.), *Caspiocypris labiata* (Zal.), *Bacunella dorsoarcuata* (Zal.), *Pontoniella acuminata* (Zal.), *Cryptocyprideis bogatschovi* (Liv.), *Advenocypris centropunctata* (Suz.), *Candona* (*Candona*) *expressa*, *Candona* (*Candona*) *angulata* (G.W. Müll.), *Candona* (*Candona*) *elongata* (Schw.), *Cypria candonaeformis* (Schw.), *Cypria arma* (Schn.). Caspian immigrants accounted for 28% of the total number of species: *Caspiocypris lobata* (Zal.), *Caspiocypris merculiensis* Vek., *Cyprideis ruggierii* Dec., *Amnicythere spectabilis* (Mark.), *Loxoconcha bulgarica* Car., *Loxoconcha verticalitercostata* Dyk., *Candona* (*Candona*) *neglecta* Sars, *Candona* (*Eucandona*) *balatonica* Dad., *Cyprinotus salinus* (Br.), *Ilyocypris bradyi* Sars, *Il. gibba* (Ramd.), *Il. caspiensis* (Neg.). Mediterranean immigrants account for 10% of the total number of species: *Aurila notata* (Reuss), *Xestoleberis* (*Pontoleberis*) *communis* G.W. Müll., *Xestoleberis* (*Xestoleberis*) *cellulosus* Vek., *X.* (*Xestoleberis*) *chanakovi* Liv.&Agal. (Fig. 2).

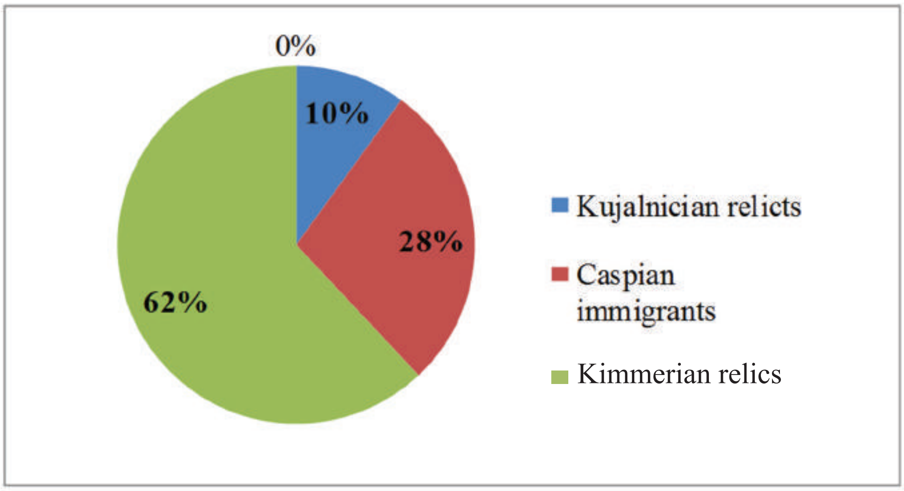

Fig. 2. The ratio of zoogeographic groups of ostracods in Kujalnikian deposits

Table 1. Stratigraphic position of ostracodes in Neogene-Quaternary deposits of the northern part of the Black Sea

Species composition of ostracods	Pliocene		Eopleistocene		Neopleistocene					Holocene				
	km	kj	gu	ch	de	eu	kg	pk	ne	bg	vz	kl	fn	gz
Cyprideis torosa**	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Cyprideis pontica**	+	+												
Cyprideis ruggierii**		+			+									
Cyprideis acervumis**	+													
Cyprideis compleporiferus**														
Cyprideis subtorosus**														
Cryptocyprideis bogatschovi*	+	+	+	+	+	+	+		+				+	
Cytheridea sakarauli***														
Paracyprideis naphtatscholana***					+									
Tyrrhenocythere amnicola donetziensis**	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Tyrrhenocythere azerbaidjanica**	+	+	+	+	+	+	+							
Tyrrhenocythere trabzonensis**	+													
Tyrrhenocythere sollertissimorete**	+													
Tyrrhenocythere pontica**	+			+										
Tyrrhenocythere complexolacunisae**														
Hemicytheria dubokensis**							?+							
Aurila dubowskyi***							+					+		+
Aurila notata***		+			+									
Urocythereis margaritifera***							+					+	+	+
Euxinocythere (E.) relicta**					?				+	+	+			+
Euxinocythere (E.) magma**														
Euxinocythere (E.) multipunctata***					+		+			+	+	+	+	+
Euxinocythere (E.) bosqueti**					?+									
Euxinocythere (M.) bacuana**				+	+	+	+		+	+	+	+		+
Euxinocythere (M.) lopatici**				+	+	+		+	+	+	+	+	+	+
Euxinocythere (M.) crebra**	+	+												
Euxinocythere (M.) praebaquana**														
Amnicythere quinquetuberculata**				+	+	+	+		+	+	+	+		+
Amnicythere resupina**				+					+	+	+	+		+
Amnicythere plana**														
Amnicythere postbissinuata**			+	+	+				+	+	+	+		+
Amnicythere longa**					+	+	+	+	+	+	+	+	+	+
Amnicythere palimpsesta**	+	+	+	+	+		+	+	+	+	+	+		+
Amnicythere multituberculata**	+	+					?+		?+					
Amnicythere polymorpha**														
Amnicythere spectabilis**		+		+	+				+	+	+			+
Amnicythere striatocostata**				+	+				+	+	+			+
Amnicythere cymbula**					+				+	+	+	+		+
Amnicythere mironovi**	+	+							?+					?+
Amnicythere volgensis**				+	+				+					+
Amnicythere pirsagatica**				+	+									
Amnicythere gracilloides**				+				+	+	+	+	+		+

Note: * - freshwater species; ** - brackishwater species; *** - marine species

Continuation of Table 1. Stratigraphic position of ostracods in Neogene-Quaternary deposits of the northern part of the Black Sea

Species composition of ostracods	Pliocene		Eopleistocene		Neopleistocene					Holocene				
	km	kj	gu	ch	de	eu	kg	pk	ne	bg	vz	kl	fn	gz
Amnicythere histriana***							+		+	+	+	+		+
Calistocythere flavidofusca***					+	+	+					+		+
Calistocythere diffusa***					+		+					+		+
Calistocythere cristata***							+							+
Mediocytherideis apatoica**														
Loxoconchissa (L.) petasus**	+													
Loxoconchissa (L.) eichwaldi**	+	+		+	+	+	+		+	+	+			+
Loxoconchissa (L.) babazananica**			+		+									
Loxoconchissa (L.) immodulata**	+	+			+	+	+		+	+	+	+		+
Loxoconchissa (L.) praeimmodulata**														
Loxoconchissa (L.) endocarpus**					+		+							
Loxoconchissa (L.) bairdyi**	+		+	+	+	+	+		+					
Loxoconcha subcrassula**		+												
Loxoconcha ljuljevi***														
Loxoconcha lepida**	+	+		+	+	+	+	+	+	+	+	+		+
Loxoconcha bulgarica***		+			+	+			+	+	+	+		+
Loxoconcha gibboides***					+		+		+	+	+	+		+
Loxoconcha rhomboidea***							+			+	+	+		+
Loxoconcha verticalitercostata	+	+												
Loxoconcha granulata***							+			+	+	+		+
Loxoconcha rennata***							+	+			+	+		+
Loxoconcha globosa***							+	+				+		+
Loxoconcha elliptica***							+			+	+	+		+
Loxoconcha aestuarii***							+			+	+	+		+
Loxoconcha pontica***							+		+	+	+	+		+
Palmoconcha agilis***							+			+	+	+	+	+
Paracytheridea paulii***							+					+		+
Paradoxostoma variabile***												+		+
Paradoxostoma guttatum***							+					+		+
Paradoxostoma naviculum***														+
Paradoxostoma simile***							+					+		+
Pseudocytherura pontica***	+	+					+					+		+
Cushmanidea tschernjawskiii***							+	+		+	+	+		+
Cushmanidea bacescoi***							+			+	+	+	+	+
Carinocythereis carinata***							+			+	+	+		+
Carinocythereis rubra***							+			+	+	+		+
Costa edwardsii runcinata***							+							+
Xestoleberis (P.) laevis**	+	+		+										
Xestoleberis (P.) communis***		+												
Xestoleberis (X.) decipiens***														+
Xestoleberis (X.) acutipensis***							+					+		+
Xestoleberis (X.) aurantia***					+	+	+	+	+	+	+	+	+	+
Xestoleberis (X.) cornelii***							+		+	+	+	+		+
Xestoleberis (X.) cellulosus***		+												
Xestoleberis (X.) elongata***														
Xestoleberis (X.) chanakovi***		+		+										

End of Table 1. Stratigraphic position of ostracods in Neogene-Quaternary deposits of the northern part of the Black Sea

Species composition of ostracods	Pliocene		Eopleistocene		Neopleistocene					Holocene				
	km	kj	gu	ch	de	eu	kg	pk	ne	bg	vz	kl	fn	gz
Semicytherura sulcata***							—					—		—
Semicytherura euxinica***							—					—		—
Cytherois cepa***							—							—
Camptocypria acronasuta**	—	—	—	—	—				—					
Camptocypria gracilis**	—	—	—		—	—	—			—	—		—	—
Camptocypria lobata**	—	—												
Caspiocypris labiata**	—	—		—										
Caspiocypris merculiensis**	—	—							—					
Bacunella dorsoarcuata**	—	—	—	—	—									
Pontoniella acuminata**	—	—	—	—						—	—?			
Advenocypris centropunctata*	—	—	—	—										
Limnocythere inopinata*					—		—	—	—	—	—	—	—	—
Metacypris cordata*						—	—							
Darwinula stevensoni*			—		—				—	—	—	—	—	—
Candona (C.) expressa*	—	—												
Candona (C.) candida*					—				—					
Candona (C.) angulata*	—	—		—	—				—	—	—	—	—	—
Candona (C.) iliensis*									—					
Candona (C.) neglecta*		—			—	—	—		—	—	—	—	—	—
Candona (C.) elongata*	—	—		—	—		—		—	—	—	—	—	—
Candona (C.) rawsoni*									—	—	—	—		
Candona (C.) angulata*	—	—			—				—	—	—	—	—	—
Candona (E.) balatonica*		—		—					—	—	—			—
Candona (E.) caucasica*														—
Typhlocypris rostrata*						—				—	—			—
Typhlocypris compressa*														—
Cyclocypris ovum*		—?		—	—	—			—					
Cyclocypris laevis*									—					
Cypria candonaeformis	—	—	—	—	—	—	—		—	—	—	—	—	—
Cypria arma*	—	—												
Cypria lacustris*												—	—	—
Cyprinotus salinus*	—	—							—				—	—
Ilyocypris bradyi*		—	—	—	—		—		—	—	—	—	—	—
Ilyocypris gibba*		—	—	—			—		—					
Ilyocypris caspiensis*	—	—?												
Eucythere ex.gr.declivis*														—
Eucypris clavata*									—					
Zonocypris membranae*	—								—					
Herpetocypris reptans*									—					
Heterocypris incongruens*									—					
Bairdia raripila ***												—		
Bythocythere schornikovi ***														—
Cytheropteron rotendatum***											—			
Cytheridea acuminata***										—				
Heterocytherideis reticulata***							—			—	—	—		—

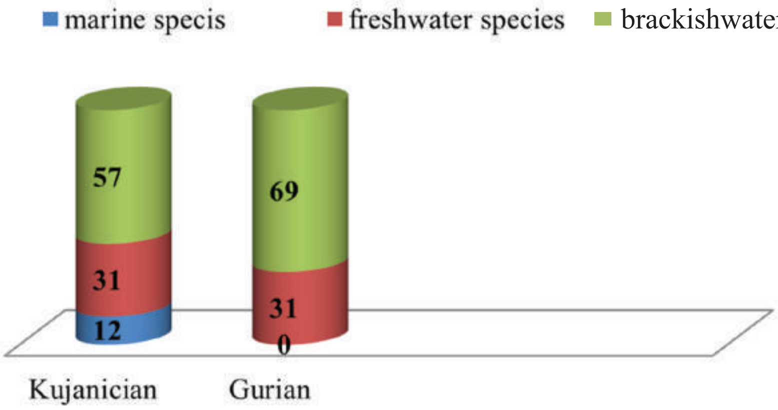

Fig. 3. Percentage ratio of different ecologically specialized species in the Kujalnikian and Gurian deposits of the northern part of the Black Sea

Typical species of the Kujalnikian ostracods are *Cyprideis ruggierii* Dec., *Aurila notata* (Reuss), *Amnicythere spectabilis* (Mark.), *Loxoconcha bulgarica* Car., *Xestoleberis* (*Xestoleberis*) *chanakovi*, *Candona* (*Eucandona*) *balatonica* Dad., *Cypria arma* (Schn.) (Dykan, 2006, 2016 a). Kujalnikian ostracod associations had a brackish water-freshwater-marine composition: brackish water species accounted for 57 %, freshwater – 31 %, marine – 12 % of the total number of species (Fig. 3).

Gurian deposits are embedded low down in the marine Quaternary deposits and they are mosaically distributed between isobaths 10-90 m in the northwestern and northeastern shelf of the Black Sea. They are represented by silts and clays with a total thickness of up to 20 m.

Gurian ostracods total 11 genera and have a poor species composition (17 species). They are presented by Miocene-Pliocene relics, which accounted for 94 % of the total: *Loxoconchissa* (*Loxoconchissa*) *bairdi* (G.W. Müll.), *Loxoconchissa* (*Loxocaspia*) *babazananica* (Liv.), *Bacunella dorsoarcuata* (Zal.), *Pontoniella acuminata* (Zal.), *Tyrrhenocythere amnicola donetziensis* Dub., *Tyrrhenocythere azerbaidjanica* (Liv.), *Camptocypria acronasuta* (Liv.), *Camptocypria gracilis* (Liv.), *Amnicythere palimpsesta* (Liv.), *Cyprideis torosa* (Jones), *Cypria candonaeformis* (Schw.), *Ilyocypris gibba* (Ramd.), *Il. bradyi* Sars, *Advenocypris centropunctata* (Suz.), *Cryptocyprideis bogatschovi* (Liv.), *Darwinula stevensoni* (Brady & Rob.). The index species of the beginning of the Gurian is *Amnicythere postbissinuata* (Neg.) (Dykan, 2016 a) (Table 1). Gurian ostracod associations had a brackish water-freshwater composition: brackish water species dominated (accounting for 69 % of the total number of species), with freshwater ostracods comprising 31 %; Fig. 3).

The Pliocene/Quaternary boundary, as defined by ostracods between the Kujalnikian and Gurian horizons in the northern part of the Black Sea, is based on the change in taxonomic composition of ostracods, with the disappearance of Pliocene species and the appearance of new Quaternary ones. Ten species disappeared in the Kujalnikian: *Cyprideis pontica* Krstič, *Euxinocythere* (*Maetocythere) crebra* (Schn.), *Amnicythere mironovi* (Schn.), *Camptocypria lobata* (Zal.), *Loxoconcha subcrassula* Suz., *Loxoconcha verticalitercostata* Dyk., *Xestoleberis* (*Xestoleberis*) *cellulosus* Vek., *Xestoleberis* (*Pontoleberis*) *communis* G.W. Müll., *Candona* (*Candona*) *expressa* Karm., *Ilyocypris caspiensis* (Neg.): and one species, *Amnicythere postbissinuata,* appeared in the Gurian (Figs. 4, 5).

Also, the biostratigraphic marker of the Kujalnikian in the Black Sea is *Cyprideis pontica* Krstić, 1968 (Dykan, 2016 b). The brackish-water

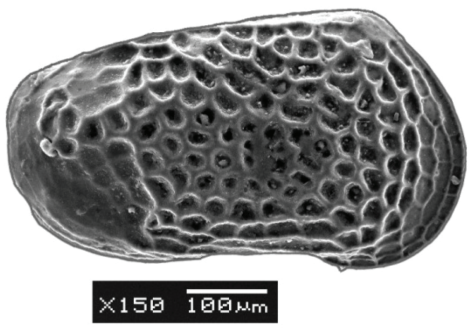

Fig. 4. Index species of the Gurian *Amnicythere postbissinuata* (Neg.), collection No. 2567-5-132/9, right valve, female, adult, Gurian horizon, Taman Peninsula, Akhtanizivsky station

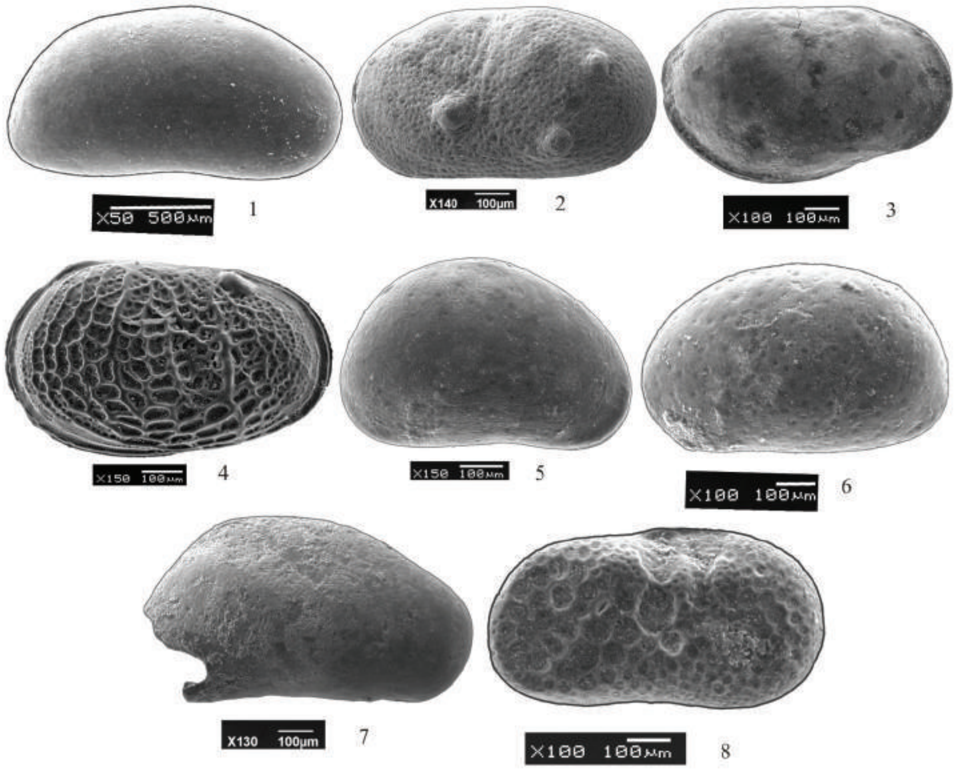

Fig. 5. Characteristic species of the Pliocene that disappeared at the Kujalnikian/Gurian boundary:
1 - *Camptocypria lobata* (Zal.), collection No. 2567-64/21, left valve, adult, Kimmerian horizon, northeastern part of the Black Sea; 2 - *Cyprideis pontica* Krstić, collection No. 2567-6/2, left valve, female, adult, Kimmerian horizon, northwestern part of the Black Sea; 3 – *Loxoconcha subcrassula* Suz., collection No. 2567-21/16, left valve, female, adult, Kujalnikian horizon, northwestern part of the Black Sea; 4 – *Loxoconcha verticalitercostata* Dyk., collection No. 2567-6/17, left valve, female, adult, Kimmerian horizon, northwestern part of the Black Sea; 5 - *Xestoleberis* (*Xestoleberis*) *cellulosus* Vek., collection No. 2567-86/20, right valve, female, adult, Kujalnikian horizon, northwestern part of the Black Sea; 6 - *Xestoleberis* (*Pontoleberis*) *communis* Müll., collection No. 2567-81/19, left valve, adult, Kujalnikian horizon, northwestern part of the Black Sea; 7 - *Candona* (*Candona*) *expressa* Karm., collection No. 2567-5-1/26, right valve, adult, Kimmerian horizon, Taman Peninsula, Zaliznyy Rih section; 8 - *Ilyocypris caspiensis* (Neg.), collection No. 2567-5-129/26, right valve, adult, Kujalnikian horizon, Taman Peninsula, Akhtanizivsky station

species *Cyprideis pontica* has a narrow stratigraphic range (in the upper half of the Middle Miocene-Pliocene) and a widespread geographic distribution within Western and Eastern Europe (Pannonian Basin, Dacian Basin, Euxinian Basin of Paratethys), and the Mediterranean region. The stratigraphic position of the species *Cyprideis pontica* in the Mediterranean region (eastern Mediterranean Basin, Crete and

Table 1. Stratigraphic position of *Cyprideis pontica* Krstić in Parathetys-Mediterranean region

Period	Epoch	MEDITERRANEAN BASIN (ATNTS2004)	PANNONIAN BASIN (SCU, 2012)	DACIAN BASIN (SCU, 2012)	EVKSINIAN BASIN (SCU 2012)
QUATERNARY	LOWER PLEISTOCENE	CALABRIAN (1.806)	LOWER PLEISTOCENE	LOWER PLEISTOCENE	GURIAN
NEOGENE	PLIOCENE	GELASIAN (2.588)	RUMUNIAN	RUMUNIAN	KUJALNICIAN
		PIACENZIAN (3.600)			
		ZANCLEAN (5.332)	DACIAN	DACIAN	KIMMERIAN
	MIOCENE	MESSINIAN (7.246)	PONTIAN	PONTIAN	PONTIAN
		TORTONIAN (11.608)	PANNONIAN	MAEOTIAN	MAEOTIAN
		SERRAVALLIAN (13.82)	SARMATIAN	SARMATIAN	SARMATIAN
					KONKIAN
					KARAGANIAN
		LANGHIAN (15.97)	BADENIAN		CHOKRAKIAN
					TARKHANIAN

The stratigraphic position of Cyprideis pontica — Pliocene/Quaternary boundery northern Greece) covers the upper Serravallian-Messinian interval (Mostafawi, 1989, 1996); in the Pannonian Basin (Austria, Slovenia, northern and eastern Serbia) the Upper Pannonian-Upper Pontian (Gross et al, 2008); in the Dacian Basin (northern Bulgaria, Romania) the Pontian (Krstić et al, 1989; Olteanu, 1989); and in the Euxinian Basin (Black Sea) (northern shelf, the Indo-Kuban depression) the Sarmatian-Kujalnikian (Dykan, 2016 a, b). The species *Cyprideis pontica* disappears at the boundary of the Late Miocene (Messinian, Pontian) and the Pliocene (Zanclean, Dacian, Kimmerian) (5.33 Ma) in the Mediterranean, Pannonian Basin and Dacian Basin (The Geologic Time Scale, 2012) (Table 1).

of water filtration, there was a reorganization of the morphology of the surface pore channels in the species *Cyprideis torosa*. This involved an increase in the size of the sieve-shaped lamellae, the number of internal pores in these lamellae and the size of the osculum of the inner pore, and a change in the shape of the inner pore on the stack with a rim along the perimeter. As a result of these evolutionary processes, a new morphotype *Cyprideis pontica* was formed within the Paratethys-Mediterranean basins. It occupied a mosaic, ecologically isolated area that coincided geographically or overlapped with the area occupied by the species *Cyprideis torosa* (sympatric evolutionary process) (Fig. 6).

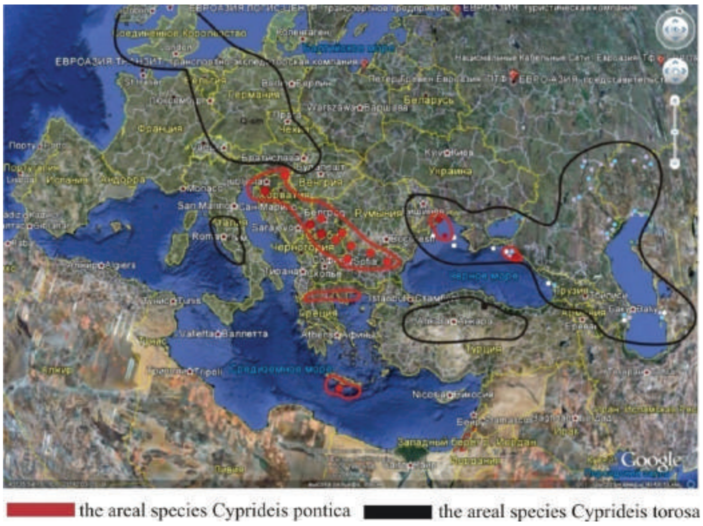

Fig 6. Map of the range of *Cyprideis pontica* Krstić and *Cyprideis torosa* (Jones) in the Paratethys-Mediterranean region (Middle Miocene-Pliocene)

Cyprideis pontica continued to exist during the Sarmatian-Kujalnikian in the Euxinian Basin. High density monotypic populations of the species were formed in the deep-water habitats of the eastern part of the Black Sea (Indo-Kuban depression) during the Sarmatian-Maeotian. The area with *Cyprideis pontica* declined in the Pliocene to the northwestern part of the sea, where this species was still widespread in the shallow coastal biotope, though with a population of low density. *Cyprideis pontica* was rare in the Kujalnikian, its few populations represented only, or mainly by, larvae. The species had disappeared in the Black Sea by the Kujalnikian/Gurian boundary.

Cyprideis pontica is a phylogenetic branch of the species *Cyprideis torosa* - separating from the parent species *C. torosa* in the Late Miocene. As a result of the occupation of a new ecological niche in deeper water biotopes of the shelf and continental slope with a reduced oxygen content, part of the population of *Cyprideis torosa* went through a narrow specialization process. In the process of adaptation to hypoxia and the necessity to increase the volume

The morphology of the shell of *Cyprideis pontica* Krstić has a diagnostic feature (the morphology of the surface pore canals), which allows this species to be recognised in the Neogene deposits (Dykan, 2016 a, b). The surface pore canals have a different shape (rounded, oval, flower-shaped, irregularly elongated, irregularly oval), different sizes (8-42 μm), sieve-typed, deepened in relation to the surface of the valve. The sieve-shaped lamella contains from 110 to 270 internal pores. The internal pores have a staggered shape and a round osculum (302-994 nm in diameter) with a rim along the perimeter. The central pore is located in the centre of the sieve-shaped lamella, deepened in relation to the surface of the valve, with a round osculum (977 nm-1.8 μm in diameter) (Fig. 7).

Conclusions. A monographic study of the Neogene-Quaternary ostracods of the Black Sea, their stratigraphic position and geographical distribution in the Mediterranean-Black Sea-Caspian region allow one to conclude that a change in the taxonomic composition and ecological specialization of ostracods occurred at the Kujalnikian/Gurian boundary in the northern part

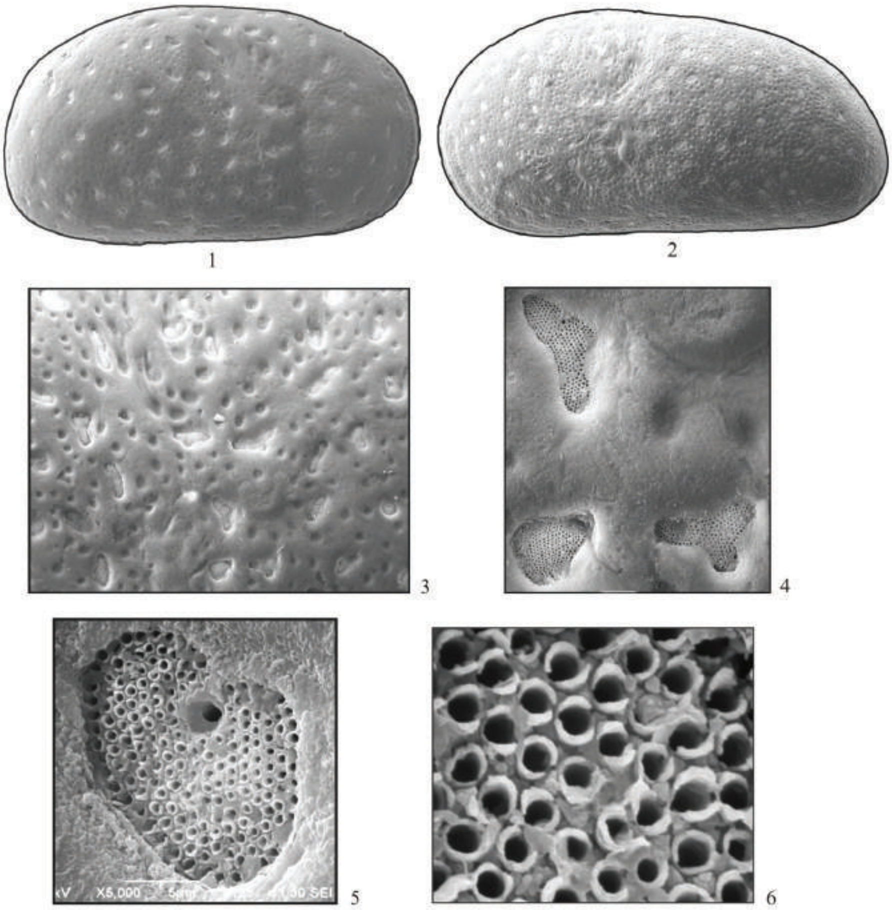

Fig. 7. Morphology of the fossil shell species *Cyprideis pontica* Krstić, 1968: 1 - right valve, female, adult, lateral external view (x 130), Upper Sarmatian horizon, north-western shelf of the Black Sea, drill hole 67; 2 – left valve, male, adult, lateral external view (x 95), Lower Maeotian horizon, north-western shelf of the Black Sea, drill hole 55; 3 – fragment of the outer surface of the shell (x 250); 4 – surface porous canals (x 1000););5 – sieve-shaped lamella of the surface porous canal (x 5000); 6 – internal pores of the surface porous canal (x 13000) (Dykan, 2016)

of the Black Sea. 24% of Pliocene species, including the index species *Cyprideis pontica*, disappeared in the Kujalnikian. Ostracod associations had a brackish water-freshwater-marine composition. In the Gurian, the new species *Amnicythere postbissinuata* appeared and brackish water-freshwater associations formed, with the domination of brackish water species.

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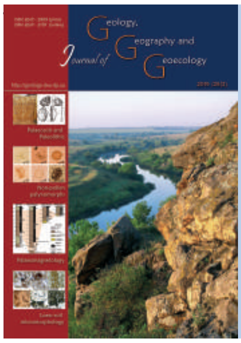

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The Late Pleistocene soils as indicators of the impact of environmental changes on development of pedogenic processes (the study case from the Kryva Luka site, Donetsk area)

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Abstract. The aim of this paper is to reveal connections between Upper Pleistocene soil types and the vegetation, which existed during their formation. Palaeovegetation was reconstructed on the basis of pollen analysis, whereas morphological description of palaeosols and the data from their laboratory study (grain-size and bulk chemical analyses, contents of Corg., $CaCO_3$ and dry salts) were used to reconstruct palaeopedological processes. The Kryva Luka sedimentary sequence was accumulated in a deep palaeogully (the incision of which occurred in early Kaydaky times), where, as a result of high sedimentation rates, well-developed Upper Pleistocene pedocomplexes formed, on one hand, and very good preservation of pollen was thus guaranteed. Several phases of soil development occurred in Kaydaky, Pryluky and Vytachiv times (the Ukrainian Quaternary framework), all represented in the section by individual palaeosols, separated by loess-like beds, or by erosional surfaces. The data collected demonstrates a cyclic pattern of short-period palaeoenvironmental changes during the Late Pleistocene. The last interglacial is related by paleopedological and pollen data to the Kaydaky unit. The pre-temperate stage of the interglacial is revealed in the gully deposits of subunit 'kd_{1a}'. The early-temperate stage corresponds to the Luvisol of subunit 'kd_{1b}', which was formed under broad-leaved woods dominated by oak. The late-temperate stage is recorded in the Greyzemic Phaeozem of the soil 'kd_{3b1}' (by the appearance of hornbeam) and the Mollisol 'kd_{3b2}'. The post-temperate stage of the interglacial and the transition to the early glacial occurred during formation of the uppermost bed of the latter and the incipient soil 'kd_{3c}'. (pedosediments were also accumulated at this time). Both vegetational composition and the soil types reflect a warmer and wetter climate for the temperate part of the last interglacial, as compared to that existing in modern times. The soils of different phases of Pryluky and Vytachiv times were formed during interstadials, with cooler climates than at present. As recorded both in soil types and pollen assemblages, the climates during the early interstadials of Pryluky and Vytachiv times were wetter than now (particularly during the 'pl_{1b1}' phase), but during their late interstadials, the climate was drier than the modern one (particularly during the phase 'pl_{3b2}'). On the basis of TL-dating obtained in sections in western Donetsk area and Central Ukraine, Pryluky times correspond to interstadials and stadials of the early glacial, whereas Vytachiv unit may be related to the middle pleniglacial. Types of cryostructures, connected with loess-like deposits of the stadials, indicate that the studied area in those times was under a severe continental climate, with deep seasonal freezing of the grounds. Nevertheless, the absence of ice pseudomorphs and of pollen of arcto-alpine plants indicates that permafrost was not present. Changes in palaeopedogenic processes (as well as in types of sedimentation) mainly paralleled changes observed in the palaeovegetation. The extent of wooded areas, the role of broad-leaved trees in the forest composition, and the spread of xeric herbal associations had particularly notable effects on the development of pedogenic processes.

Key words: palaeopedology, pollen analysis, short-period palaeoenvironmental changes

Пізньоплейстоценові ґрунти як індикатори впливу змін природного середовища на розвиток процесів педогенезу (на прикладі розрізу с. Крива Лука, Донецька обл.)

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Анотація. У статті наведено реконструкцію динаміки пізньоплейстоценових змін таких компонентів давнього природного середовища як палеорослинність, палеоґрунти і палеокріогенез (які є індикаторами палеоклімату) та показано взаємозв'язки між ними. Дослідження виконано із застосуванням паліногічного і палеопедологічного (зокрема, аналітичних методів) вивчення розрізу верхньоплейстоценових відкладів Крива Лука. У цьому розрізі, розташованому на акумулятивних схилах палеобалки, закладеної на початку кайдацького часу, завдяки значній інтенсивності седиментації, повно представлені фази ґрунтоутворення впродовж кайдацького, прилуцького і витачівського етапів. Показано, що зміна типів педогенезу (а також і седиментогенезу) відбувалася за умов змін рослинності, при цьому особливе значення мала участь у її складі деревних порід (особливо широколистих) і трав'янистих ксерофітів. Останній інтергляціал виявлено в утвореннях кайдацького кліматоліту: його початкову стадію у балкових відкладах 'kd$_{1a}$', кліматичні оптимуми у грунтовій світі 'kd$_{1b1}$ – kd$_{3b2}$', заключну стадію – у грунті (чи у педоседиментах) 'kd$_{3c}$'. Тип і склад рослинності та типи викопних грунтів відображають вологіший і тепліший клімат оптимумів кайдацького етапу у порівнянні із сучасним. Ґрунти прилуцького і витачівського часів формувалися за інтерстадіальних умов, прохолодніших від сучасних. Впродовж фази 'pl$_{1b1}$' клімат був вологішим від теперішнього, а у час 'pl$_{3b2}$ ' – суттєво посушливішим. Відсутність у розрізі пилку кріофітів та наявні форми кріоструктур свідчать, що територія розташування розрізу впродовж стадіалів, виявлених у його відкладах, знаходилася не у зоні багаторічної мерзлоти, але у зоні глибокого сезонного промерзання грунтів за умов суворого континентального клімату.

Ключові слова: палеопедологія, спорово-пилковий аналіз, короткоперіодичні зміни природного середовища

Introduction. Fossil soils, intercalated with loesses in the Upper Pleistocene deposits of Ukraine, are a valuable source of information about past pedogenic processes, which changed (in time and laterally) depending on trends in palaeoenvironmental development. To establish the connection between the climatic and vegetational dynamics of the past and changes in the genetic types and properties of the corresponding palaeosols is an important task in the elaboration of a prognosis for possible future changes of the modern soil cover. This goal is especially actual in the modern time of climatic and environmental instability. The older Pleistocene soils, or soils in the northern-western Ukraine which existed under much more humid climate than at present, may have no genetic correlatives in the modern soil cover of Ukraine. Nevertheless, it is possible to determine the modern analogues of Upper Pleistocene northern steppe-belt soils belt in the southern steppe or the forest-steppe belts of Ukraine. The aim of this paper is to reveal the connection between the changes in palaeosol properties and the reconstructed environments where they were formed. The realization of this aim is founded on the study case of the Upper Pleistocene loess-palaeosol section at Kryva Luka, which includes most of the Upper Pleistocene soil units, enriched in pollen. The latter, together with palaeosols themselves, is the main tool for palaeoenvironmental reconstruction.

In the Donetsk area, Upper Pleistocene soils have previously been studied by M. Veklitch *et al*. (1973), N. Sirenko (1972) and Zh. Matviishina (1982). Fossil pollen was first revealed by A. Artyushenko *et al*. (1973). Palaeoenvironmental reconstructions of the area of Ukraine (including the Donetsk region) have been promoted using palaeosol and pollen studies by N. Sirenko and S. Turlo (1986). All results described were obtained for relatively long-lasting time periods (the interglacial and interstadials), whereas the short-period dynamics of pedogenic processes and vegetational changes were first obtained in the Western Donetsk area by N. Gerasimenko and G. Pedanyuk (1991), N. Gerasimenko (2010, 2011). The additional study was fulfilled by the authors in 2013. The Quaternary framework of Ukraine (Veklitch, 1993) is used for the site stratigraphy. The short-term periodization of the Upper Pleistocene in the Western Donets area, applied in this paper, was outlined by N. Gerasimenko (2010).

Material and methodology. The section at Kryva Luka is located in the right slope of a ravine, which deeply dissects the right bank of the Siverskyi Donets River (48°52′10″ N, 37°54′46″ E, 138 m a. s. l.) to the east of Kryva Luka village, in the northern part of the Donetsk region (Fig.1). The right bank of the river consists here of Cretaceous rock, which were cut during the Upper Pleistocene by a series of deep ravines.

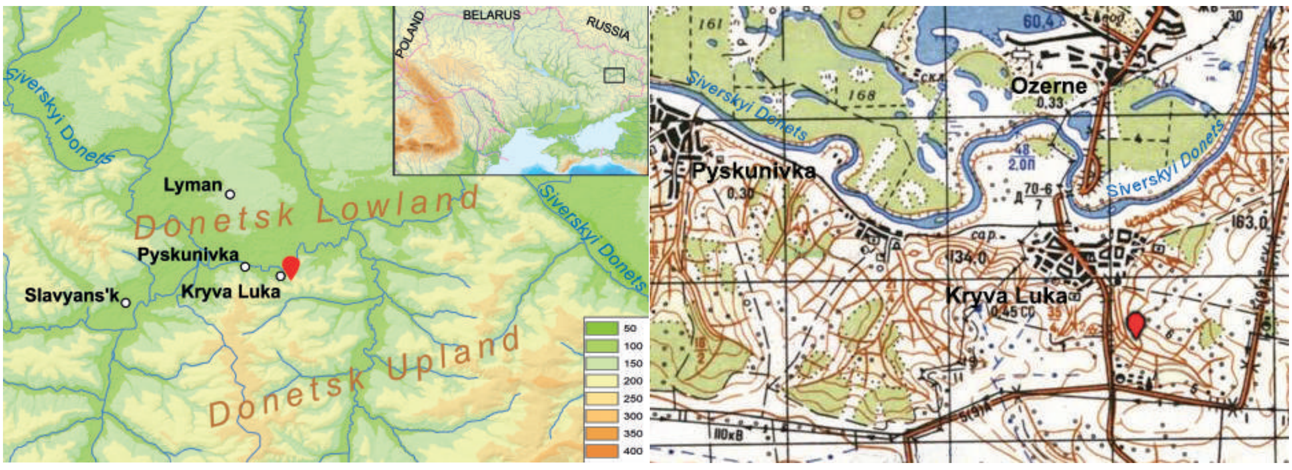

Fig.1. Location of the studied site.

The inclination of the Upper Pleistocene deposits, exposed in the ravine sides, confirms that the palaeoslopes were inherited by Holocene erosional processes. Judging from the stratigraphy of the infilling deposits in the palaeoravines, incisions occurred at the beginning of Vytachiv times (the terrestrial equivalent of MIS 3), and, more commonly, at the beginning of Kaydaky times − the first interglacial after the Dnieper (Saalian) glaciation. The studied section is exposed in the part of the palaeoravine created during Kaydaky times, and later completely filled with younger sediments and palaeosols. At present, the right bank of the Siverskyi Donets is gently sloping in the direction of the river valley. In general, the studied area is located within the NW part of the Donets Upland whose relief is represented by accumulative-denudational hilly plain, deeply dissected by valleys (Vakhrushev *et al*., 2010).

The modern soils are Mollisols, which are not leached of their carbonates (Calcic Chernozems). The modern vegetation of the slopes and plateau is that of mesophytic steppe, comprising diverse forbs and grasses. The dense trees (mainly *Acer, Fraxinus* and *Salix*) cover the bottom of the lower part of the gully, whereas bushes (*Elaeagnus angistifolia*, *Rosa canina, Pyrus* sp.) are scattered on its slopes. The eroded exposed parts of slopes are inhabited by Chenopodiaceae, *Artemisia* and Asteraceae. The high floodplain of the Siverskyi Donets is covered by broad-leaved forest made up of oak, elm and ash, and the distant sandy terraces are occupied by pine woods.

52 samples were collected from the main section (with an interval 10-20 cm) in such a way that each soil genetic horizon was sampled, though the pedosediments and gully alluvium were sampled at a significantly larger interval. Grain-size, bulk chemical and pollen analyses had been carried out for each sample. Contents of C_{org}, CO_2 of carbonates (re-calculated to $CaCO_3$ content) and dry salts were determined. Despite all components of the bulk chemical composition having been obtained, only the contents of R_2O_3 ($Al_2O_3 + Fe_2O_3$) are shown in the summary in Fig. 2, as well as their molecular ratio with SiO_2. According to Veklitch *et al*. (1979), these indices, as well as the clay fraction (< 0, 001 mm) are crucial for the estimating the intensity of clay weathering in soils, whereas their re-distribution in a soil profile allows judgments on the development of translocation processes. The sum of silicate CaO and MgO is provided in order to demonstrate the accumulation of bases in the deposits. The $CaCO_3$ re-distribution indicates the primary and secondary carbonate horizons in the upper part of the section, whereas its lower part does not include any carbonate. The content of dry salts, represented mainly by $CaSO_4$ and $NaHCO_3$, provide evidence that the majority of the soils and other deposits were not solonized. All chemical analyses were carried out according to standard methodologies, whereas grain-size analysis was done by the Kachinsky 'pipette' method. With the exception of the main section, several additional excavations have been dug up and down the course of the ravine.

As the studied section is located in a kind of a 'sediment trap' in the gully, the accumulation rates of deposits were rather high and pollen-bearing beds were buried quickly, which prevented these microfossils being oxidated. At least 300-400 well-preserved pollen grains were counted in each sample. Re-deposited Neogene palynomorphs occur only at one level (Neogene deposits are exposed at the top of the gully). Sample processing for pollen analysis completely corresponds to the method described in Gerasimenko *et al*., 2019 in this volume. The two surface pollen samples, taken from the top bed of the Mollisols near the gully, differ from the pollen spectra that would be expected from the vegetational zone of mesophytic steppe, in that they have very high percentages of Chenopodiaceae pollen (30-40%). The common percentages of these in grassland is <30% (according to V. Grichuk, 1989). This anomaly can be clearly explained by over-representation of Chenopodiaceae pollen, produced by the ruderal plants from this family (different species of *Chenopodium*), observed at present on the eroded slopes of the ravine. This fact should be taken into account when interpreting spectra of the fossil taxa from the section. Arboreal pollen (10-15%), present in the surface samples, include *Pinus sylvestris* (dominates), *Betula, Quercus, Acer* and arboreal Rosaceae. The sum of pollen of broad-leaved trees in the steppe associations is ≤ 5%, which also should be taken to consideration when interpreting fossil spectra. The percentages of *Pinus sylvestris* pollen (9-12%) are unusually low for an open landscape, which means that this long-distance wind-blown pollen is 'swamped' by the abundant pollen coming from the local steppe vegetation, which there produces dense ground cover. Pollen grains were identified with the aid of pollen atlases (Kupriyanova, Alyeshina, 1972, 1978; Reille, 1995) and the reference pollen collection of the Geography Faculty of the Taras Shevchenko National University of Kyiv. The reconstructions of past vegetation are based on the methodological principles elaborated by V. Grichuk (1989), N. Bolikhovskaya (1995) and L. Bezys'ko *et al*. (2010). In the pollen diagram (Fig. 3), those abbreviations are used: AP – arboreal pol-

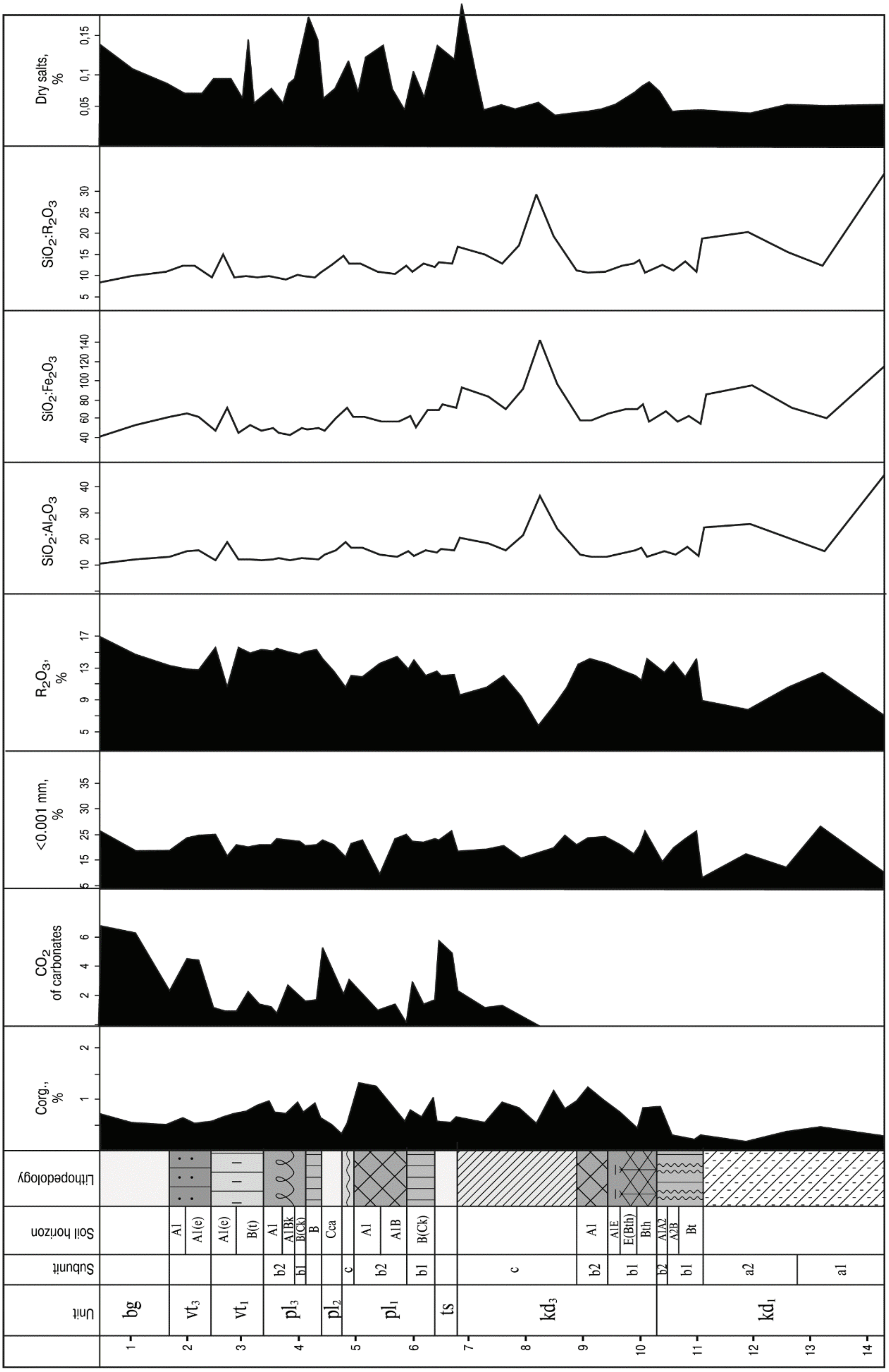

Fig. 2. Main chemical and grain-size characteristics of the deposits of the Kryva Luka site.

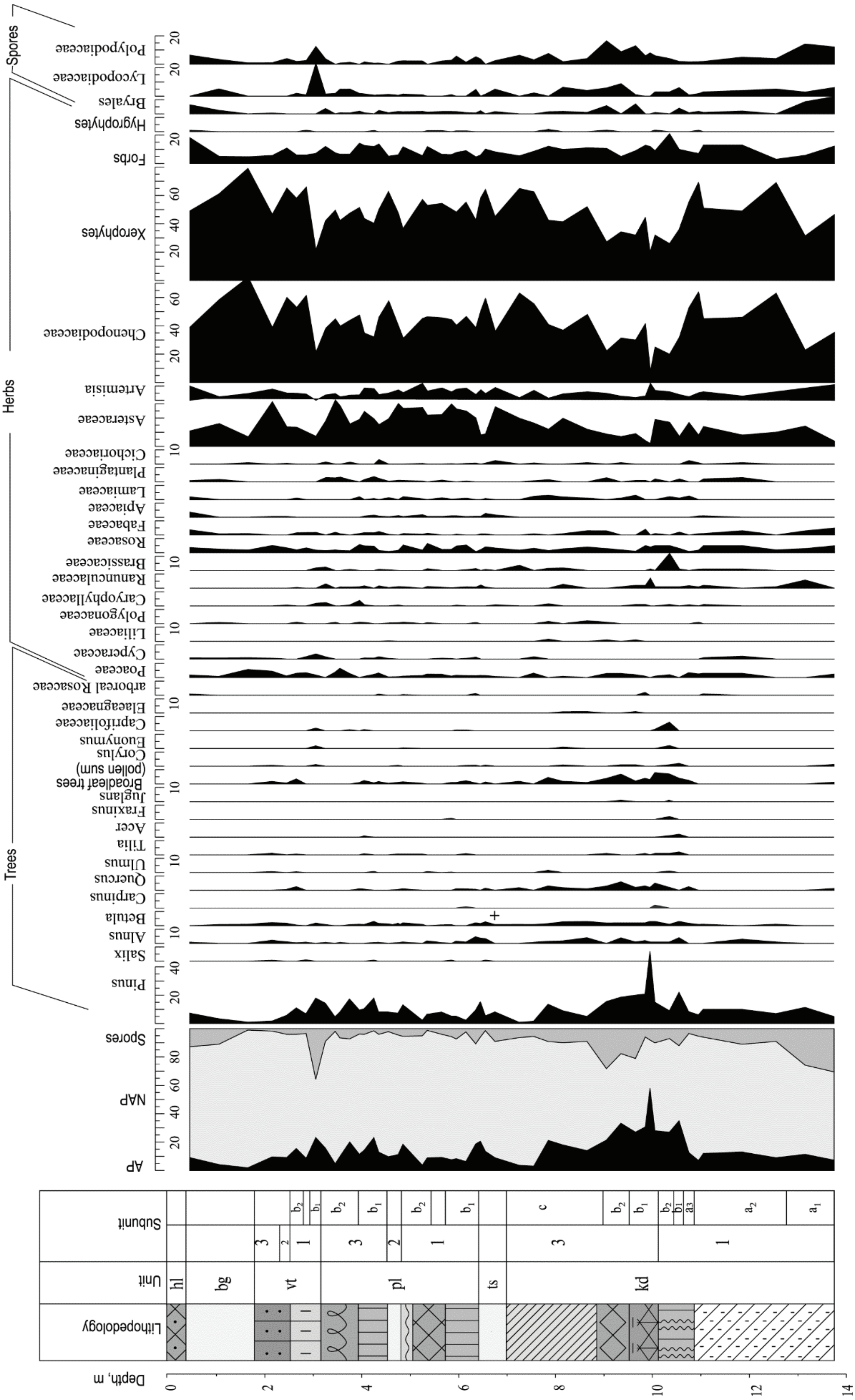

Fig. 3. Pollen diagram of the deposits of the Kryva Luka site. '+' – presence of pollen of *Betula* sect. Nanae et Fruticosae.

len, NAP − non-arboreal pollen. Asteraceae pollen is not included in the sum of forbs because of its over-representation, controlled by the local development of erosional processes and, thus, the disturbed soil cover.

Results. The section includes from the top to bottom those units. ***The Holocene*** (0.0-0.3 m) is represented by the A1C horizon of the truncated Mollisol (a grey loam, with granular-crumbly structure, and $CaCO_3$, penetrating along the root casts).

The Bug (bg)unit (0.3-1.8 m) is a loess, densely penetrated with thin carbonate veins and including humiferous warm routes in its upper part – C(A1)k horizon of the Mollisol. Thin fissures filled in with the loess dissect the underlying Vytachiv soil. The C_{org} content is low (0.5-0.7%) and that of $CaCO_3$ is very high (14-15%). The significant content of R_2O_3 is controlled by the impact of the Holocene pedogenic processes, and it decreases downwards, as well as the content of clay particles (from 26 to 18%). The sum of CaO and MgO is high (6.1%), whereas the content of dry salts, represented mainly by calcium sulfates and hydrocarbonates, is medium (from 0.14 to 0.09% downwards).

Pollen assemblages from the Bug unit is dominated by NAP (81-97%), with Chenopodiaceae pollen being most abundant (53-77%). Pollen of Asteraceae and *Artemisia* is well noticeable (up to 11-19% of each), whereas Poaceae and forbs occur less frequently (up to 4-6% of each). The increase in pollen of forbs in the uppermost bed is connected with the transition to the Holocene soil at this level. The AP (2-8%) is dominated by *Pinus sylvestris* though few grains of *Betula pendula*, *Alnus glutinosa* and arboreal Rosaceae occur. The TL-date from the lower part of the unit is 26±3 ka BP (Gerasimenko, Pedanyuk, 1991).

The Vytachiv (vt) unit (1.8-3.20 m) consists of two palaeosols. The upper one (1.80-2.50 m) – ***vt$_3$*** – is a Calcaric Cambisol, with darker A1 and brownish A1B horizons. The soil structure is not well-developed, whereas carbonates are seen through the whole soil profile. In its upper part, they are secondary forms but in the primary A1Bk horizon, the bright spots of farinaceous carbonates are abundant. The C_{org} content is slightly higher in A1 horizon (0.65%) than in A1B, and the distribution of carbonates and dry salts is opposite. The contents of R_2O_3 and clay fraction is higher than in Bug loess, and the sum of CaO and MgO is much lower (1.8%). The lower soil (2.50-3.20 m) – ***vt$_1$*** – is also a Calcaric Cambisol but with the features of lessivage processes (the content of clay particles and, especially, R_2O_3 is smaller in the middle part of the soil profile (A1E horizon) than in its lower part (Bt horizon). The A1 and A1E horizons have the low content of secondary carbonates, where in the lower part of the Bt horizon, there is a small increase (5%) in $CaCO_3$ (probably connected with several phases in this soil development). The development of lessavage processes is also confirmed by prismatic structure of the bright-brown compacted Bt horizon. There is a network of thin fissures, filled in with loess-like material, which opens from the surface of this soil. This indicates some phase of aridification and wind-blown dust accumulation that occurred between the two main pedogenic phases of the Vytachiv time. There is the erosional level at the base of the 'vt$_1$'soil – a thin layer of gravel grains and crumbles of the Cretaceous rocks.

Pollen assemblages of the two Vytachiv soils are somewhat different. The 'vt$_3$' soil has a typical steppe pollen spectra (AP 8-10%, NAP 88-89%, spores 2-4%), whereas the 'vt$_1$' soil includes both steppe and forest-steppe spectra (the AP up to 24%). The AP from the 'vt$_3$'soil includes a few (but diverse) pollen of *Alnus glutinosa, Betula pubecens, Salix, Pinus sylvestris, Tilia cordata, Ulmus* sp*., Corylus avellana* and *Rhamnus cathartica.* The NAP is dominated by Chenopodiaceae and Asteraceae but their percentages are lower than in Bug loess. Pollen of *Artemisia*, Poaceae and Roasceae is noteworthy, whereas the other forbs are rare. The AP from the 'vt$_1$'soil differs in different horizons of soils. The pollen assemblage from the A1E horizon is the richest in palynomorphs of broad-leaved trees (mainly *Quercus*), whereas the pollen spectra from the Bt horizon are either of a steppe type (without pollen of broad-leaved taxa), or of a forest-steppe type (with pollen of *Corylus avellana, Euonymus* and *Sambucus*. Here the percentages of Polypodiaceae and Lycopodiaceae (*Lycopodium annotinum, Diphazium complanatum*) spores strongly increased at the expense of the drop in pollen sum of xerophytes.

The Pryluky (pl) unit is represented by a well-developed thick pedocomplex (3.20-6.40 m), consisting from two palaeosols ('pl$_3$'and 'pl$_1$') separated by a thin loess subunit 'pl$_2$'. The upper ***'pl$_{3b2}$' soil*** (3.20-4.0 m) includes A1 and A1Bk horizons, both grey but significantly lighter in colour than the modern Mollisols, crumbly and non-compacted, with abundant carbonate pseudomycelium in A1Bk horizon. The upper boundary of the soil is dissected by the wedges (some of them 1.4 m in depth), filled in with loess. The lower boundary is disturbed by shallow ground wedges (0.2 m in depth), filled in with the soil material. Taking in account the degeneration of humus matter in palaeosols, this soil is enriched in organic carbon (0.9-1%).

It has a high position of carbonate horizon, the relatively high sum of CaO and MgO (up to 3.6%). The content of dry salts (0.16%) increased at the level below the humiferous profile. In the pollen assemblage of this soil, AP constitutes only 5-18%, whereas NAP is 82-94%. The AP is dominated by *Pinus sylvestris*. A very few pollen of *Betula pubescens, Alnus glutinosa, Rhamnus cathartica* and *Sambucus* sp. occur. In the NAP, Chenopodiaceae is less abundant than in the Vytachiv soils at the expense of the increase in pollen of Poaceae and forbs.

Below the 'pl$_{3b2}$' soil (4.0-4.40 m), the remnants of the preceding soil formation is revealed – the B(t) horizon of the ***'pl$_{3b1}$' soil***, brown-coloured, compacted, prismatic (but without glance films on ped surfaces). The carbonate pseudomycelium (obviously secondary) is less frequent, but in the Ck horizon of this soil, the content of $CaCO_3$ reaches 12%. Dry salts is washed down from the overlying soil. The content of R_2O_3 and clay fraction in the soils of the 'pl$_3$' subunit is similar to that in the Vytachiv unit, but without their re-distribution in the soil profiles. The pollen spectra from the 'pl$_{3b1}$' soil are both of steppe (the lower and upper beds) and forest-steppe (the middle beds) types. Besides the AP, represented in the 'pl$_{3b2}$', pollen of broad-leaved taxa (*Quercus, Ulmus, Acer* and *Tilia cordata*), *Sambucus* and arboreal Rosaceae occur. The NAP is similar to those of the 'pl$_{3b2}$' soil, and the content of spores are miserable on both soils.

The thin loess-like ***subunit 'pl$_2$'*** (4.4-4.7 m) is the Ck horizon and the level of accumulation of dry salts, washed down from the overlying soils. It has the low content of C_{org} in its lower part, whereas in the upper part, root casts and warm routs include some humus material. The content of R_2O_3 and clay fraction is much smaller than in all overlying soils and similar to that in the Bug loess. The pollen assemblage of this subunit is dominated by NAP, and namely by Chenopodiaceae and Asteraceae, whereas the pollen percentages of grasses and forbs are very low. No pollen of broad-leaved pollen is found.

The 'pl$_1$' subunit consists of two palaeosols. The upper one ***'pl$_{1b2}$'*** (4.7-5.85 m) is a well-developed Mollisol, dark-grey in its A1 horison and brownish-grey in A1B horizon. The material of A1 horizon is granular-crumbly, loose, enriched in C_{org} (1.4%) and, in its upper part, includes soft nodules of $CaCO_3$ (the secondary carbonate horizon). The own carbonate horizon of this soil, represented by the pseudomycelium and small infrequent nodules of $CaCO_3$, is located in the lower part of A1B horizon and in the Ck horizon below the humiferous part of the soil profile. The A1B horizon has prismatic structure. It is more compacted and more enriched in R_2O_3 and clay fraction than A1 horizon. The lower boundary of the soil is uneven – with short 'tongues' of humiferous material (0.2 m in depth) and very thin veins, inclined oppositely to the general downhill sloping of the soils. The pollen assemblage of the soil is of a steppe type (AP 5-12%), with the high percentages of Chenopodiaceae and Asteraceae in the NAP but still a diverse composition of pollen of forbs. The AP includes a very few pollen grains of *Quercus, Tilia cordata, Corylus avellana, Euonymus* sp. and arboreal Rosaceae.

Below the described Mollisol, the B horizon of Cambisol ***'pl$_{1b1}$'*** (5.85-6.4 m) is located which differs by its bright brown colour and prismatic structure (without glance films on peds surfaces) of the compacted material. It includes less of C_{org} than the Mollisol, the contents of R_2O_3 and clay particles are the same as in the A1B horizon of the 'pl$_{1b2}$' soil. The B horizon is overlapped by the Ck horizon of the overlying soil but the spots of the primary material, leached from carbonates, are traced. The content of dry salts is much lower than in the overlying deposits. Pollen spectra of this horizon are of steppe and forest-steppe types (in the forest-steppe spectrum from the bottom of the horizon, pollen of *Pinus sylvestris, Alnus glutinosa* and *Betula pubescens* is more abundant than in the steppe spectra). A very few pollen of broad-leaved taxa are presented in all spectra and include *Quercus, Fraxinus, Tilia cordata, Corylus avellana, Sambucus*, and arboreal Rosaceae. The presence of a few grains of *Carpinus betulus* is a special feature. The NAP composition is similar to that in the overlying deposits, but the small peak in Polypodiaceae spores is observed.

The Tyasmyn unit (6.4-6.8 m) is a light-yellow loess (in places up to 0.7 m thick), loose, porous, filled in with carbonates in root casts, with multiple krotovinas. The thin ground wedges in a raw opened from its lower boundary and dissect the underlying deposits. The C_{org} content is low (0.3-0.5 %) and $CaCO_3$ content is high (5-8%). The loess does not differ from the overlying soils in the contents of R_2O_3 and clay fraction, obviously because of the impact of the following pedogenic processes on this thin layer, but the sum of CaO and MgO is higher than in the soils (4%). The pollen assemblage is dominated by NAP (85-88%) of the same composition as in the overlying deposits. The AP (10-14%) consists of *Pinus sylvestris* (dominates), a few *Betula pendula* and *B*. sect. Nanae et Fruticoase, *Alnus glutinosa*, and, at one level, a few grains of broad-leaved taxa (*Quercus* sp. and *Corylus avellana*).

The Kaydaky unit (6.8-14.2 m) includes well-developed pedocomplexes, pedosediments and gully alluvium. The upper part of the unit is represented by pedosediments of subunit ***'kd$_{3c}$'*** (6.8-8.9 m) – the alternation of brownish-grey and dark-grey sandy loams, which includes thin (< 5 cm; rarely up to 10 cm) sand layers. The deposits are thinly bedded and gently inclined downslope. In their upper part, the pedosediments are penetrated by carbonate pseudomycelium ($CaCO_3$ from 7% to 1% downwards), and, at the level around 7 m, the peak in dry salts content (mainly calcium sulfates) occurs. Below this level, the content of dry salts in the Kaydaky unit is very low. The content of C_{org} increased downwards (up to 1.2%) in parallel with the predominance of dark-grey re-deposited soil material. The contents of R_2O_3 and clay fraction is lower than in the overlying and underlying soil deposits because of a strong increase in sand fraction in the pedosediments.

There is no point in establishment of pollen assemblages in pedosediments as they include re-deposited pollen. Nevertheless, two palynologically different parts of these pedosediments are traced. The upper brownish-coloured beds (6.8-7.8 m) has the very low AP (4-9%), represented mainly by *Pinus sylvestris* (a few grains of *Alnus, Betula* and *Quercus*). The percentages of Chenopodiaceae pollen here are the same as in the overlying deposits. The lower darker-coloured beds (7.8-8.9 m) are richer in AP (up to 21%) which includes *Alnus, Betula, Quercus, Ulmus, Corylus, Euonymus* and Elaeagnaceae. The percentages of Chenopodiaceae in the NAP are less than in the overlying deposits.

In the excavation, located higher up in the course of the ravine, the pedosediments above the Kaydaky pedocomplex are absent, and the latter is overlain by the incipient soil 'kd$_{3c}$' (0.3 m thick). It is light-brown in colour, not-compacted, and dissected by the wedges filled in with the Tyasmyn loess (up to 0.2 m in width in their upper part and 0.7 m in depth). The C_{org} content in the soil is low (0.6%), as well as that of dry salts, whereas the content of $CaCO_3$ is high (7%). The pollen assemblage of the incipient soil is dominated by NAP (75%), in which the percentages of Chenopodiaceae, Asteraceae and the sum of other forbs are approximately equal. *Pinus sylvestris* dominates the AP, but pollen of *Alnus glutinosa, Betula pubescens, B. pendula, Quercus* sp., *Tilia cordata* and *Euonymus* sp. occur.

In the main excavation, the Mollisol '***kd$_{3b2}$***' (8.9-9.4 m) is partly truncated by the overlying pedosediments but still has very high contents of C_{org} (1.2-1.3%) and R_2O_3 (12-14% %). It is leached from carbonates and dry salts. The soil material is dark-grey silty loam, loose, with granular-crumbly structure, and the gradual transition downward. Higher up in the course of palaeogully, this soil is 0.8 m thick, with A1 and A1B horisons. The A1 horizon is penetrated by the secondary carbonate pseudomycelium which disappears downward, but in the lowermost part of the A1B horizon, the own carbonate horizon of the soil is located (large spots of loose carbonates). The pollen assemblage of the truncated leached Mollisol is of a forest-steppe type (AP 23-33%, NAP 50-52%, spores 17-25%). The AP is dominated by *Pinus sylvestris* but differs from all overlying deposits by the higher percentages of pollen of broad-leaved trees, particularly of *Quercus robur*. A few grains of *Tilia cordata, Corylus avellana, Cornus mas* and *Juglans regia* are present. The other AP includes *Alnus glutinosa, Betula pubescens,* and one pollen grain of *Picea* occurs in the uppermost soil bed. In the NAP, the percentages of Chenopodiaceae pollen decrease (20-35%) as compared to the overlying soils. The maximum of Polypodiaceae spores (up to 15-20%) is observed.

The soil '***kd$_{3b1}$***' (9.4-10.2 m) is a Luvic Greyzemic Phaeozem, completely leached of carbonates. The A1E horizon (9.4-9.5 m) is a grey loose silty loam, with SiO_2 powder. The E(Bth) horizon (9.5-9.8 m) is whitish from SiO_2, with the lenses completely filled in with it. Prismatic structures occur rarely. The Bth (9.8-10.2 m) horizon is dark-brown, compacted, with perfectly developed blocky-prismatic structure, with glance colloidal films on the ped surfaces. The dark colour of these films indicate translocation of organic matter, together with clay particles and R_2O_3. The visual signs of eluviation-illuviation in the soil is confirmed by the analytical data. The content of clay fraction in the Bth horizon is 12% larger than in the E horizon, and the content of R_2O_3 follows the same pattern. The content of C_{org} is equally high (0.9%) in A1E and Bth horizons that testifies its translocation. The sum of CaO and MgO is very low (1.5-2%).

Pollen spectra from this soil are of a forest-steppe type, and one bed of the Bth horizon has pollen spectrum of a forest type (AP 63%, NAP 30% and spores 7%). *Pinus sylvestris* dominates the AP, particularly in the forest spectrum. Pollen of small-leaved and broad-leaved trees is well noticeable. The broad-leaved taxa include pollen of *Quercus robur, Carpinus betulus, Tilia cordata* and *Corylus avellana*. Pollen percentages of Chenopodiaceae remain not significant, whereas Polypodiaceae spores are noteworthy.

The '***kd$_{1b}$***' soil (10.2-11.1 m) is a Luvisol, which is characterized by a stronger clay translocation than the Phaeozem but without organic matter illuviation. The A1E horizon is a very thin (10.2-10.3 m) and transformed by translocation processes from the overlying Greyzemic Phaeosem, but the SiO_2 powder from the primary pedogenic processes is present. The Btf horizon (10.3-11.1 m) is bright-ochre-brown, with a kind of marble-like colouration, prismatic, compacted, with orange-brown glossy films of the ped surfaces, with punctuations of Fe-Mn hydroxides, and with a very small content of C_{org}. The redistribution of clay fraction and R_2O_3 is well-expressed, and their contents are rather high, despite this soil was formed on sandy deposits.

The pollen assemblage of the soil includes 23-35% of AP, 53-66% of NAP and 6-12% of spores. Only the lowermost bed of Bth horizon has a steppe type spectrum (AP 13%, NAP 84%, spores 3%). This fact can be a result of transformation of the upper bed of the underlying subunit by translocation processes. The AP, besides pollen of *Pinus sylvestris* and small-leaved trees, includes pollen of broad-leaved taxa – *Quercus robur, Tilia cordata, Ulmus, Acer, Fraxinus, Corylus avellana*, and one pollen grain of *Juglans regia.* Pollen of bushes also includes *Euonymus, Viburnum* and *Sambucus*. In the upper part of the soil, pollen of Chenopodiaceae practically disappears, and pollen of forbs reaches its maximum.

The ***'kd$_{1a}$'*** subunit (11.0-14.2 m) is represented by the palaeogully alluvium – bedded sandy silts and sands, which sloping the same direction as the modern gully thalweg does (but with much larger inclination). The thickness of the beds varies from 3 to 20 cm. The sands are yellowish-brown, mainly small-grained, though, in places, coarse (particularly at the base of the subunit). The loams are greyish-brown, sandy, with manganese punctuations. The lower boundary is sharp, erosional, cut into Cretaceous rocks. The brown loamy beds can be slightly enriched in R_2O_3 (up to 12%). The subunit includes two pollen assemblages, both with pollen spectra of a steppe type. The upper one 'kd$_{1a2}$' (11.0-12.4 m) has very high percentages of Chenopodiaceae pollen (up to 77%), whereas the AP includes only *Pinus sylvestris* and a few *Alnus glutinosa, Betula pubescens* and arboreal Roasaceae. The lower assemblage 'kd$_{1a1}$' (12.4-13.8m) is characterized by the high percentages of spores (up to 29%), the occurrence of a few pollen of broad-leaved trees (*Quercus* and *Corylus*) and the smaller percentages of Chenopodiaceae pollen than the overlying subunit.

Interpretation. At the beginning of ***Kaydaky times***, strong erosion caused an incision in the Cretaceous chalk, and intense accumulation of the gully alluvium started. Judging from the inclination of bedded sands and silts, as compared to that of the modern thalweg, the palaeogully slope was sharper than at present. Pollen data indicates that the incision started at a time when the first broad-leaved taxa (oak and hazelnut) appeared in the vegetation, Polypodiaceae ferns spread, as well as plants of Chenopodiaceae, though they were less abundant than later. This phase can be compared with the time span '***kd$_{1a}$***' in other areas, a period at the transition from the penultimate glaciation to the last interglacial (Gerasimenko, 2006). The upper part of the gully alluvium, less enriched in R_2O_3 and clay, was formed in a treeless area (only a few alder near the river and Rosaceae bushes in the gully). Ferns almost disappeared, and Chenopodiaceae plants became most abundant. All of these indicate a much more arid and cooler climate than during the preceding phase. The same climatic dynamics are revealed in Central Ukraine during the second phase of the pre-temperate stage of the last interglacial – '***kd$_{a2}$***' (Gerasimenko, 2006). A parallel can be traced between these phases and the Allerød interstadial and the Young Dryas stadial, which preceded the beginning of the modern Holocene interglacial. It has been proved (Sidorchuk *et al*., 2008) that the incision of Holocene rivers and gullies also started during the transition from the last glaciation to the modern interglacial. The last phase of the pre-temperate stage of the interglacial – '***kd$_{a3}$***'– is indicated by the pollen found in the lowermost bed of Btf horizon of the 'kd$_{1b1}$' Luvisol. At that time a few oaks re-appeared and Chenopodiaceae became much less abundant, which indicates some increase in warmth and humidity.

The temperate stage of the interglacial had started by the time the erosional processes in the gully stopped, and soils developed under the woodland, whose spread obviously was larger than at present. Alder and *Betula pubescens* framed the river course; and pine appeared on the sandy and chalky rocks. Diverse broad-leaved trees (oak, elm, lime-tree, maple, and, later on, ash-tree and walnut), as well as mesophilic bushes (such as hazelnut, spindle-tree, viburnum and elder) grew in the gully. The minimum of Chenopodiaceae and the maximum of forbs indicate that the upper parts of slopes and the plateau were covered by mesophytic steppe. During this time translocation processes developed in the Luvisols. The climate was warmer and much more humid than at present. This phase, '***kd$_{1b1}$***', is related to the first (early temperate) climatic optimum of the interglacial. During the next phase, '***kd$_{1b2}$***', some humus accumulation started, forming the A1E horizon of the Luvisols, and there was a decrease in the diversity of broad-leaved trees (oak dominated). This phase might reflect some cooling (indicated by the disappearance of walnut).

The next phase in the development of the vegetation is revealed in the lowermost bed of the Bth horizon of the Greyzemic Phaeozem. It was marked by the maximum spread of pine in the area, probably controlled by the enlargement of chalk exposures in the slope of the River Donets. The presence of eroded slopes is also evidenced by the increase in Chenopodiaceae pollen and the appearance of *Elaeagnus angustifolia*. The relatively high content of coarse silt ('loess fraction') at this level (33%, as against 16-19% below) indicates the strengthening in the region of aeolian processes. The new silt input allowed the Phaeozem to develop without transforming the underlying Luvisol with its translocation processes. During this time, the areas with broad-leaved woods became smaller, and they consisted only of oak and lime. All of this indicates the increase in the continentality of the climate during the short '$\boldsymbol{kd_2}$' time period.

During the formation of the Greyzemic Phaeozem (the phase'$\boldsymbol{kd_{3b1}}$'), erosional processes lessened, and the gully was occupied by broad-leaved taxa − oak (dominant), hornbeam, hazelnut and walnut. Chenopodiaceae became much less abundant, and ferns and club-mosses spread. It was the second (late temperate) optimum of the interglacial, with a warmer and wetter climate than nowadays. At present, hornbeam does not grow in Eastern Ukraine. The '$\boldsymbol{kd_{3b2}}$' Mollisol has a strong humus accumulation, which could not have formed under a forest canopy. Thus, the gully slope studied was covered by herbs and grasses. Broad-leaved trees (oak and lime) and ferns grew at the gully bottom. The change in pedogenic processes and the disappearance of highly mesophilic arboreal taxa indicate that the interglacial climate became drier, but it was still more humid than at present, as modern Mollisols are not leached.

The end of the interglacial (the post-temperate stage) is not well recorded in the studied sequence because of the affect of erosional processes, followed by accumulation of pedosediments '$\boldsymbol{kd_{3c}}$'. Nevertheless, changes in lithology and pollen enable one to trace the trend in environmental development. The lower pedosediments is similar to the material of the 'kd_{3b2}' Mollisol in both the content of $C_{org.}$ and the absence of $CaCO_3$, but it differs significantly in its impoverishment in clay and, particularly, in R_2O_3. The latter features were controlled by erosional processes, which are clearly indicated by the increase in the sand fraction, as well as the sharp increase in ruderal plants, particularly Chenopodiaceae. The upper pedosediments were not formed as a result of the redeposition of 'kd_b' soils, as they have a high content of carbonates and, in their uppermost beds, even of dry salts. The pollen data demonstrate that these deposits were accumulated in treeless landscapes (only a few oak occurred in the gully). Chenopodiaceae or Asteraceae dominated the steppe associations. A study of the chemistry and pollen of the poorly developed 'kd_{3c}' soil, located higher up in the course of the palaeogully, give evidence that these pedosediments were formed through re-deposition of the material of the 'kd_{3c}' soils. Thus, in the studied area, the very end of the interglacial and the transition to the early glacial was very arid and rather cool.

During ***Tyasmyn times***, soil formation ceased at the site despite the fact that at first the vegetation's composition was similar to that during the 'kd_{3c}' phase, with a few oak and hazelnut persisting in the gully. Erosional processes weakened, as it evidenced by the decrease in sand (8-28%) as compared with the upper 'kd_{3c}' pedosediments (47-50%), and an increase in the input of coarse silt. The intense accumulation of carbonates indicates an arid climate (though some of them were a result of $CaCO_3$ leaching from the overlying soil). The area became treeless (only some pines on chalky rocks and a few alder near the water). Chenopodiaceae and Asteraceae dominated steppe vegetation, whereas the role and diversity of forbs significantly diminished. Later on, the arid climate became cold: a few shrub birches grew, and broad-leaved taxa completely disappeared. The fissures in raw, dissecting the underlying deposits, indicate deep seasonal freezing of the ground, under a severe continental climate.

Several drastic environmental changes characterized ***Pryluky times***. A first phase, '$\boldsymbol{pl_{1b1}}$', was marked by formation of a Cambisol. Clay weathering and leaching of carbonates, typical for this soil, indicate a relatively warm climate, which provided moisture in the gully. Arboreal vegetation grew here, whereas steppe occupied the plateau. Forbs became more abundant and diverse than during Tyasmyn times, though Chenopodiaceae still dominated in the eroded parts of the slope. The few trees in the gully included oak, lime, ash, and hornbeam, with ferns growing under them. The existence of mesophilic trees and the spread of mesophytic herbs and ferns indicate a semi-humid climate, which was wetter than at present.

A Mollisol formed during the next phase '$\boldsymbol{pl_{1b2}}$'. As compared to the Cambisol, it differs by its enrichment in humus, the relatively high position of its carbonate horizon, and the lower content of clay and R_2O_3 in its A1 horizon. The prismatic structure in its Bk horizon may indicate that it was formed in the material of the preceding Cambisol. The plateau around the gully was completely treeless. Low percentages of pine pollen do not allow one to surmise the growth of pine trees in the vicinity of the site, as a long-distance pollen transport much be inferred. A very few oak, lime and hazelnut grew near the bottom of the gully, but not in the studied site. The more extensive spread of xeric herbs and less abundant broad-leaved species that are found now indicate that the climate of that time was somewhat cooler and drier than today.

The formation of a loess-like bed during the phase '$\boldsymbol{pl_2}$' reflects further aridification. Humus accumulation stopped, and the content of coarse silt increased, the opposite trend to that of clay particles. Only alder and *Betula pubescens* grew near the water, and a few Rosaceae bushes on slopes. Xerophytization of steppe coenoses is reflected in the spread of Chenopodiaceae and lesser numbers of forbs. The humus 'tongues' along the lower boundary of the underlying soil, as well as thin fissures in raw, dissecting the soil's upper boundary, indicate a continental climate with dry summers and very cold winters. The next phase, '$\boldsymbol{pl_{3b1}}$', is represented only by the remnants of a Cambisol, its B horizon, overprinted by the Ck horizon of the overlying soil; and its own carbonates are deeply leached from the soil profile. In general, the content of carbonates is lower and that of R_2O_3 higher than above and below in the section, which indicates some clay weathering. The change in the vegetation, as compared with the preceding phase, is rather distinct. The spread of forbs and a lessening of Chenopodiaceae indicate that mesophytic steppe occupied the plateau. A few broad-leaved trees (oak, elm, maple, and lime) appeared in the gully, and pine grew on chalk rocks. The semi-humid steppe climate was similar, but somewhat drier, than that of phase '$\boldsymbol{pl_{1b1}}$'.

The palaeosol developed during the phase '$\boldsymbol{pl_{3b2}}$' is less enriched in humus than the '$\boldsymbol{pl_{1b2}}$' Mollisol, and it has a larger content of $CaCO_3$ and the higher position of carbonate horizon. Calcium sulphates and potassium hydrocarbonates were deposited during its formation, but, later on, they were washed downward. The rather high content of R_2O_3 is inherited from the underlying soil. The '$\boldsymbol{pl_{3b2}}$' soil was formed in a treeless steppe, dominated by Chenopodiaceae on the eroded slopes, and with more grasses on the plateau than during the preceding phases, when forbs were more important. Pine grew sporadically on chalk. It is suggested that the '$\boldsymbol{pl_{3b2}}$' soil is a kind of Kashtanozem, with weak, deep solonization. Such soils form in an arid climate.

The deposits of ***Uday times*** are truncated, as evidenced by the erosional level at the base of the Vytachiv unit. In the lower reaches of the gully, the light-brown coloured Vytachiv alluvium is exposed, overlain by the thick Bug loess. In the studied section, the Uday loess survives only in deep ground wedges that dissect the Pryluky soils. Smaller humus 'tongues', filled with 'pl_{3b2}' Kastanozem at the lower boundary of this soil, demonstrate the first phase of frost wedging that occurred at the beginning of the Uday times. Later the soil was affected by stronger wedging under a continental climate, with very severe winters.

At the beginning of ***Vytachiv times***, lessivage processes developed in the Cambisol (with the re-distribution of R_2O_3 and clay within the soil profile). In this time, mesophytic steppe covered the plateau. Pine spread on the chalk, and groves of small-leaved trees grew in the gully, with a rich ground cover formed from club-mosses and ferns. The appearance later of oak, a few hazelnut and spindle-tree indicates that the climate became warmer (the south-boreal). At the same time, the sharp decrease in mesophytic herbs and, particularly, the disappearance of spore plants and the extensive spread of herbal xerophytes on the steppe show that the warming was followed by aridification. Trees retreated in the lower part of the gully, whereas in the studied locality, calcium carbonate accumulated and transformed the leached soil in the Calcaric Cambisol '$\boldsymbol{vt_1}$'. Thin fissures, opening from the top of this soil and infilled with loess, indicate a further increase in climatic continentality, obviously during the '$\boldsymbol{vt_2}$' phase, represented in the other section by a thin loess bed (Gerasimenko, Pedanyuk, 1991; Gerasimenko, 2010). During the '$\boldsymbol{vt_3}$' phase, a typical Calcaric Cambisol was formed under the steppe. The role of xeric herbs and grasses was larger and that of forbs smaller than during '$\boldsymbol{vt_1}$' soil formation. The climate was arid, but not cold. Pine disappeared from the slopes, but in the wet gully, buckthorn and a few broad-leaved species (elm, lime and hazelnut) grew. Both phases of Vytachiv soil formation were relatively warm.

During ***Bug times***, pedogenic processes ceased, and coarse silt ('loess fraction') accumulated much more than in the underlying soils. The enrichment in $CaCO_3$ and impoverishment in R_2O_3 indicate an arid and cold climate. The area was treeless (only a few alder and *Betula pubescens* grew near the river). Xeric herbs in the steppe vegetation reached their maximum. Nevertheless, the phase, represented in the studied section (dated to 26±3 ka BP), was not the coldest of Bug times. The absence of cryoturbations and of pollen of arcto-boreal plant species does not allow the interpretation of a periglacial climate.

Conclusion. Studies of lithology and palynology applied to deposits at Kryva Luka have demonstrated multiple short-period environmental and climatic changes during the Late Pleistocene. The palaeogully's sediment trap was also a pollen trap, and this pollen allows reconstruction of short-lasting phases in vegetational development. Usually it is not an easy task to interpret palynological assemblages from steppe coenoses. On the other hand, the position of the section in a palaeogully, where intense erosion occurred on its slopes, caused an over-representation of pollen from ruderal plants (particularly Chenopodiaceae) that had has to be taken into account when interpretating the palynology.

The interglacial climate, which was warmer and wetter than now, existed only during Kaydaky times, when Luvisol and Greyzemic Phaeozem developed on the slopes of the gully. The modern southern limit of disconnected patches of Greyzemic Phaeozems extends to more than 200 km north from Kryva Luka. In the climatic optima during Kaydaky times, the area was located in the forest-steppe realm, with the highest Late Pleistocene incidence of broad-leaved species. Mesophilic hornbeam occurred in woodland. The southern limit of its distribution is now located about 450 km north from the studied locality. Thermophilic walnut grew sporadically, and its occurrence in the vegetation of Kaydaky times has been recorded elsewhere in Ukraine (Sirenko, Turlo, 1986; Bolikhovskaya, 1995; Gerasimenko, 2010). Pollen assemblages from the site, located in the modern steppe belt of eastern Ukraine, differ from the typical last interglacial succession in western and northern Europe, in having large percentages of herbal pollen. Nevertheless, considering the succession within the AP in the lower and middle part of the Kaydaky unit – *Pinus*+*Betula*+*Alnus* – *Pinus*+*Quercus* − *Quercus*+*Ulmus*+*Tilia*+*Corylus* – *Quercus*+*Carpinus*+*Tilia* – *Pinus*+*Alnus*+*Betula* +*Picea* − *Pinus*+*Alnus*+*Betula*, one can see the similarity with the last interglacial succession. Thus, we correlate Kaydaky times with the last interglacial, as has been suggested previously (Rousseau *et al*., 2001; Gerasimenko, 2006; Matviishina *et al*., 2010; Haesaerts *et al*., 2016), though a contrary opinion has been also suggested in Ukraine − on a correlation of early Pryluky time with the MIS 5e (Gozhik *et al*., 2000; Boguckyj *et al*., 2002; Lindner *et al*., 2006).

According to the data obtained from the Kryva Luka site, forest soils and forest vegetation never spread in the area as extensively as they did during Kaydaky times. During later phases of soil formation ('pl_{1b1}', 'pl_{1b2}', 'pl_{3b1}', 'vt_1' and 'vt_3') broad-leaved species rarely grew in wooded gullies, though they did not occur during the driest pedogenic phase ('pl_{3b2}'), when Kastanozems formed. Hornbeam grew sporadically in the gullies during 'pl_{1b1}', when Cambisols formed on their slopes. All the above-mentioned phases of soil formation are related to interstadials, with that of the 'pl_{1b1}' phase having had the mildest climate. TL-dates of 75.0±4 ka BP and 57.5±3 ka BP were obtained from the Uday loess unit and the lowermost soil of the Vytachiv unit, respectively, and 90±5 ka BP from the Tyasmyn unit in other sites in the western Donetsk area (Gerasimenko, Pedanyuk, 1991; Gerasimenko, 2011). Thus, the Pryluky interstadials are compared with those of MIS 5, whereas the interstadials of Vytachiv times are correlated with MIS 3.

Stadials, represented by loess beds, are those from Tyasmyn, middle Pryluky and Bug times. Pollen of broad-leaved species is absent in these deposits. It is also absent in the other two levels – between subunits 'vt_3' and 'vt_1', and within subunit 'pl_{1b}'. The same have been revealed in the other east Ukrainian sites (Gerasimenko, Pedanyuk, 1991; Gerasimenko, 2006, 2010) that enables the suggestion on the existence of stadials at the corresponding times − 'vt_2', and between 'pl_{1b1}' and 'pl_{1b2}' phases. Cryoturbation and desiccation fissures were formed during the aforementioned phases, indicating a cold continental climate. Nevertheless, cryoturbation types and their sizes, and the absence of pollen of arcto-alpine species (with the exception of one level within the Tyasmyn unit), do not allow the reconstruction of permafrost in the studied area. The absence of pollen of cryophytes in the other sections of the Donetsk area (Artyushenko *et al*., 1973; Gerasimenko, 2011) enables the suggestion to be made that during these stadials, ground wedges developed in deeply frozen soils under a very severe winter climate.

The comparison of palynologically based vegetation reconstruction with the lithopedosequence at Kryva Luka, characterized by an intense sediment accumulation and pedogenic processes, demonstrates the very good correspondence in the palaeoclimatic interpretations derived from the palaeosol types and the reconstructed vegetation. The direct correlation between characteristics of the palaesols and the composition of the coeval vegetation, which is one of the most important factors affecting soil formation, proves the importance of palaeosols as reliable palaeoenvironmental and palaeoclimatic indicators.

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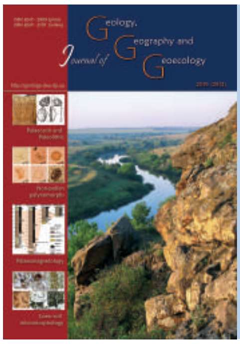

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Palaeoenvironmental changes during the Middle and Early Upper Paleolithic in the Upper-Tysa Depression, Ukraine (the Sokyrnytsya and Ruban' sites)

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Abstract. The aim of the study is the reconstruction of palaeoenvironments of the Middle and Early Upper Palaeolithic in the Upper-Tysa Depression, related to short-period Upper Pleistocene changes. Stratigraphical, palaeopedological, pollen and archaeological methodologies have been applied in the study of several excavations at the Sokyrnytsya 1 and Ruban' sites. Intense translocation processes (during formation of Luvisols and Albic Luvisols) during Late Pleistocene warm phases and Holocene, frequently transformed the material of underlying cold-phase non-soil sediments. The last are revealed in the lower horizons of palaeosols by their pollen assemblages, indicative of a periglacial climate, and by the levels with cryoturbations. The pollen succession of the last interglacial is found in the well-developed Kaydaky Luvisol. The presence of beech growing during the second half of the interglacial is a special feature of Transcarpathia. Above, two interstadials and two stadials are revealed in the early glacial. At Sokyrnytsya 1, Middle Palaeolithic first appeared at the very end of the last interglacial (when boreal forests dominated), and it is traced through sediments of the early glacial interstadials. The small collections of artefacts and the absence of specialized features on them do not allow them to be assigned to a specified technological-typological complex. During the interstadials of the early glacial ('pl1' and 'pl3'), Luvisols and Cambisols developed beneath woodland, dominated by pine, but with admixture of deciduous trees, under a south-boreal climate. The cultural level at Ruban', located in the transitional horizon from the late Pryluky soil to the Uday loess unit, is related to the Quina-type industry. Its analogues are quite common in Western Europe, but up to now have not been known to the east of the Carpathians. At that time, broad-leaved trees disappeared; the climate became cooler and drier. The presence of dry seasons is indicated by a level with abundant Fe-Mn concretions. At Sokyrnytsya 1, the Early Upper Palaeolithic non-Aurignacian cultural level is found in the Vytachiv unit (Middle Pleniglacial, around 38 - 39 ka BP). It is characterized by a technological-typological complex which has its analogue only in Eastern Europe (Kostenki XIV). In Vytachiv times, woodland, dominated by small-leaved trees, alternated with open landscapes of forbs and sedges. The climate was transitional from south-boreal to boreal. The Upper Palaeolithic level, which also is not related to a distinctive culture, is located above the level of the Bug (Late Pleniglacial), cryoturbations which deeply dissect the Vytachiv unit. The presence of both West European and East European archaeological industries and the exceptional palaeoenvironmental features of the studied area demonstrate its importance in the European context.

Key words: lithopedostratigrpahy, palynology, short-period environmental phases, cultural levels.

Природні зміни впродовж середнього і раннього верхнього палеоліту у Верхньо-Тисненській улоговині, Україна (стоянки Сокирниця 1 і Рубань)

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Анотація. Реконструкція короткоперіодичних змін палеоекологічих умов середнього і раннього верхнього палеоліту у межах Верхньо-Тиської западини виконана на основі стратиграфічного, палеопедологічного, палінологічного та археологічного вивчення пізньоплейстоценових відкладів багатошарової стоянки Сокирниця 1 і середньопалеолітичної стоянки Рубань, а також порівняльного аналізу результатів їхнього дослідження із матеріалами з одновікових стоянок прилеглих територій. Встановлено специфічні риси будови розрізів району, зумовлені постседиментаційним перетворенням відкладів холодних етапів нисхідними процесами ґрунтоутворення під час формування бурих лісових лесивованих і підзолисто-буроземних ґрунтів наступних теплих етапів. Виявлена циклічність екологічних змін впродовж останнього зледеніння – чергування трьох інтерстадіалів із лісо- та лісостеповими ландшафтами південно-бореального і бореального клімату із стадіалами, коли поширювалися відкриті ландшафти перигляціального типу. Простежено специфічні риси розвитку рослинності, притаманні останньому міжзледнінню у Закарпатті. На стоянці Сокирниця 1 середньопалеолітичні культурні шари виявлено починаючи від верхів кайдацького міжльодовикового кліматоліту до верхньоприлуцького (останній інтерстадіал раннього гляціалу). На стоянці Рубань у перехідному горизонті від верхньоприлуцького до удайського кліматолітів встановлено середньопалеолітичну індустрію типу Кіна, поширену у Західній Європі, але наразі не виявлену на схід від Карпат. У витачівському кліматоліті (38-39 т. р. т.) виявлено культурний шар із техніко-типологічним комплексом раннього верхнього палеоліту, який не належить до оріньяку. Подібні комплекси простежені лише у Східній Європі (Костенки XIV).

Ключові слова: літо-педостратиграфічний аналіз, палінологія, короткоперіодична палеогеографічна етапність, культурні шари.

Introduction. The important task of the Quaternary stratigraphy and palaeogeogrpahy is to reveal the geological age of the Paleolithic cultures and to reconstruct the Ancient Humans' environments. A comparison of environments of the coeval cultures in different parts of Ukraine and the adjacent areas allows us to find out the impact of environmental changes on the distribution of the Paleolithic cultures and their changes in time. The area of Transcarpathia is of a particular interest in this respect as the connecting chain between Eastern and Central Europe. The aim of this study is to reveal changes in soil-sedimentation processes and vegetation through the time of Middle and Early Upper Paleolithic existence in the Upper-Tysa Depression. The ecotones of this area, transitional between the lowland and adjacent mountains of the Volcanic Carpathians, are particularly sensitive to climatic changes, reflected in palaeovegetation and palaeopedogenic processes.

By the end of the 1960es, two Paleolithic sites were known in the Transcarpathia: Mala Gora and Pavlova Gora (Skutil, 1938). V. Petrun' (1972) has gathered the Early and Middle Palaeolithic artefacts on the surface at Rokosove. The systematic search for Palaeolithic sites, which had been started in the Transcarpathia by the team of V. Gladilin in 1969, has led to the discovery of several dozens of locations with Palaeolithic artefacts, and the Molochnyi Kamin' Cave and Beregove 1 sites were excavated. Nevertheless, the archaeological map of the Transcarpathia looked much poorer in comparison with the adjacent areas where hundreds of Palaeolithic locations, including stratified sites, were known. The discovery of the multi-layered stratified Palaeolithic site at Korolevo (1974) was a fundamentally new step in the archaeological study of the region, which is a junction between the Palaeolithic realms of Central and Eastern Europe (Kulakovska, 1989; Gladilin, 1985; Gladilin, Sitlivy, 1990). The site first pointed at the geological age of the appearance of the early humans in the area of Ukraine. Ten Palaeolithic levels were recorded *in situ*. The collections of stone artefacts from different levels reflected the great variability of technical and typological traditions. At present, eight stratified Palaeolithic sites are known in the Transcarpathia: Korolevo 1, Korolevo 2, Beregove 1, Sokyrnytsya 1, Shayan 1, Malyi Rakovets' IV, Ruban' open-air sites and the cave site Molochnyi Kamin'.

The first studies in detail of stratigraphy, lithopedology and palynology of the Palaeolithic sites Korolevo 1 and Beregove 1 (Fig. 1) have been fulfilled by the team of O. Adamenko (Adamenko, Grodetskaya, 1987; Adamenko *et al*., 1989). The multi-layered site Korolevo 1 is located on the high Lower Pleistocene terrace of the Tysa. Seven loess units and six palaeosol units of the Ukrainian stratigraphic framework (Veklitch et al., 1993) had been identified there, with M/B boundary located within the lowermost Martonosha soil. The paleoclimatic implication of the pollen data corresponded well with the glacial (loess) – interglacial (palaeosol) cycles. The new high-resolution pedostratigraphical study of Korolevo 1, with the application of OSL-dating and correlation with MIS, has been carried out by P. Haesaerts and L. Koulakovska (2006). The Beregove 1 site is situated in the III^rd^ (the Late Pleistocene) terrace of Tisa, and it includes three loess and three soil units

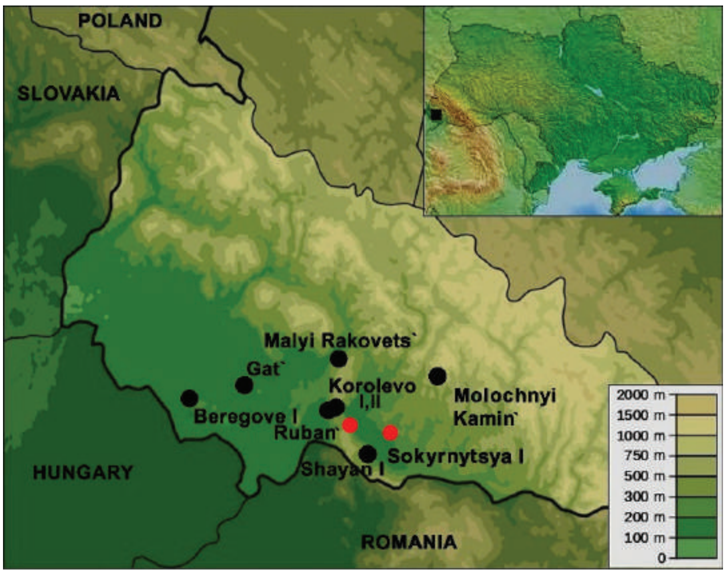


Fig. 1. The sites' location

above the alluvial gravels. Pollen data from Vytachiv unit (the terrestrial equivalent of MIS 3) at Beregove 1 (Yurchenko, 2017) has shown the temporal variability of the vegetation during this time, which indicates the existence of two interstadials, with distinct climatic optima, separated by a stadial. The pedostratigraphy of the Upper and Middle Pleistocene and palaeogeographical reconstructions, based on palaeopedology, have been carried out by Zh. Matviishina and S. Karmazinenko in the multilayered Malyi Rakovets IV site (Stepanchuk *et al*., 2013; M.Yamada and S. Ryzhov, Eds., 2015), which is located on the slope of the Vygorlat-Hutinsky Ridge of the Carpathian Mountains, adjacent to the Upper-Tysa Depression. The Gat' site is located in the oldest terrace of Tysa, and it includes 20 units (Gerasimenko, Vozgrin, 2011) of Ukrainian stratigraphical framework of the Pleistocene. In this section, the Lower and Middle Pleistocene units are represented much more completely than the Upper Pleistocene, which deposits consist mainly from welded palaeosols. The complete pollen succession from the pedocomplex of Pryluky − Kaydaky units, which are regarded as the terrestrial equivalents of MIS 5 (Rousseau *et al*., 2001; Gerasimenko, 2006a), was obtained only from the Sokyrnytsya 1-A site (published in Russian, Gerasimenko, 2006b). The stratigraphical subdivision of the Sokyrnytsya section was first fulfilled together with Zh. Matviishina (Usik *et al*., 2006). Morphological features of the palaeosols at Ruban' have been described in Kulakovska *et al*. (2018). The significant similarity of the Middle and Upper Pleistocene pedocomplexes at Korolevo 1, Sokyrnytsya 1-A and Ruban', which is demonstrated in this paper, allows their correlation and the environmental reconstruction for the Middle and Early Upper Palaeolithic in the Upper-Tysza Depression.

Material and methods. The Sokyrnytsya 1 site was discovered and excavated in 2000-2004 (Usik, 2001; Usik *et al*., 2003-2004). The most important point Sokyrnytsya 1-A includes several archaeological levels and horizons of findings. The Middle Palaeolithic Ruban' site was discovered and excavated in 2005 – 2008 (Kulakovska *et al*., 2018). The sites Sokyrnytsya 1 (48°7′55″N, 23°24′6″E, 230-240 m a. s. l.) and Ruban' (48°9′29″N, 23°11′18″E E, 206-213 m a.s.l.) are located in the high Early Pleistocene terraces of the Tysa River within the Upper-Tysa Depression. The latter, protected from both sides by the ridges of the Volcanic Carpathians, is one of the warmest parts of the Transcarpathia, with the very high annual precipitation (1000-1500 mm). The modern soil cover consists of Albic Luvisols and Gleyic Fluvisols, and the natural vegetation is represented by oak-beech woods and mesophytic herbal associations. The local vegetation of the sites is completely changed by human activity, and it consists of forbs and grasses, surrounded by bushes and ferns. The lithopedostratigrpahic descriptions of both sections have been carried out according to the Quaternary stratigraphic framework of Ukraine, based on the stratigraphy of Korolevo 1 as the reference site (Adamenko *et al*., 1989; Haesaerts *et al*., 2007). The ^{14}C dates in this paper are uncalibrated.

46 samples, taken with the interval 5 cm from the Sokyrnytsya I-A section, have been palynologically analyzed. The sample processing includes those steps: boiling in a 10% solution of HCl, disaggregation in a 15% solution of $Na_4P_2O_7$ in order to remove clay particles, removal of the secondary carbonates with HCl, boiling in a 10% solution of KOH to dissolve organic matter, treatment in a heavy liquid (CdI_2 and KI, specific gravity 2.0) in order to separate palynomorphs from silt particles. Despite the pollen frequencies were low in the majority of the samples, 100-200 palynomorphs were registered in each of them, and pollen preservation was good. Re-deposited palynomorphs were practically absent. Pollen grains were identified with the aid of pollen atlases (Kupriyanova, Alyoshina, 1972, 1978; Bobrov *et al*., 1983; Reille, 1995). Pollen diagram is represented in Fig. 2, and these abbreviations are used: AP – pollen of trees and shrubs, NAP − pollen of herbs, grasses and sedges, and PZ – pollen zone. The reconstructions of past vegetation are based on the methodological principles elaborated by V. Grichuk (1989) and N. Bolikhovskaya (1995). Their studies of surface samples have proved the under-representation of palynomorphs of broad-leaved trees in pollen assemblages, which allows the reconstruction of domination of broad-leaved trees in the vegetational cover if ≤ 20% of their pollen is counted (from AP sum) in the corresponding pollen spectrum.

The large thickness of deposits (including loess units) at Korolevo 1 is controlled by its location in the palaeogully cutting the old terrace. At Sokyrnytsya 1-A and Ruban', located on the flat (or gently sloping) terrace surfaces, sedimentation rates during the Quaternary were much lower, and, thus, the non-soil units were significantly re-worked by translocation pedogenic processes, as it also has been shown in the other areas of Ukraine (Gerasimenko, 2006a). This is the reason why the material, which is visually related to the Btf soil horizons, was, in fact, formed during the preceding cold phase (judging from its pollen spectra of a periglacial type, or by the findings of the Paleolithic material). The comparison of palaeopedological and pollen data is most important for the proper palaeoenvironmetal interpretation. In this respect (as no pollen diagram is available for the Korolevo 1), the

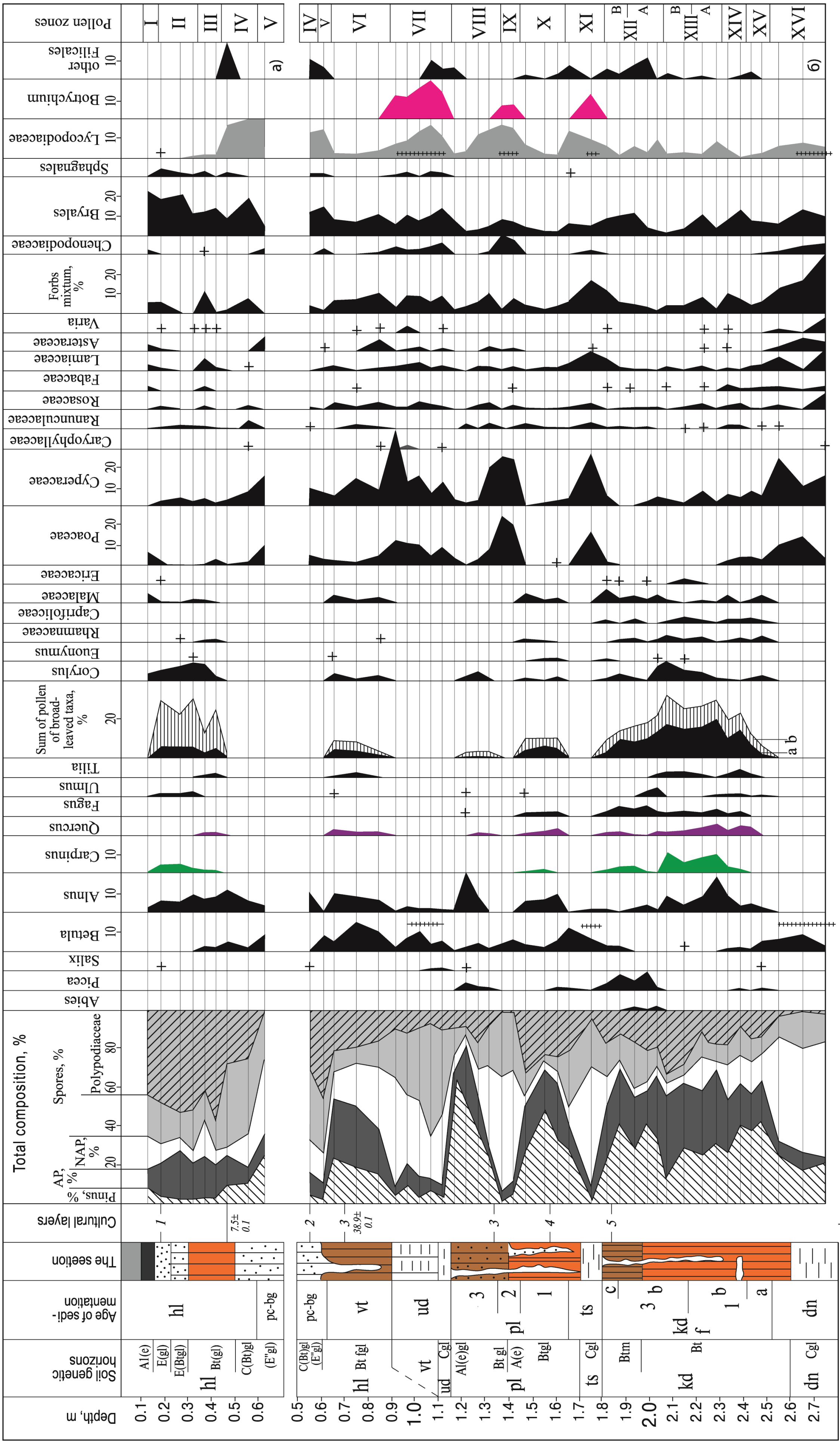


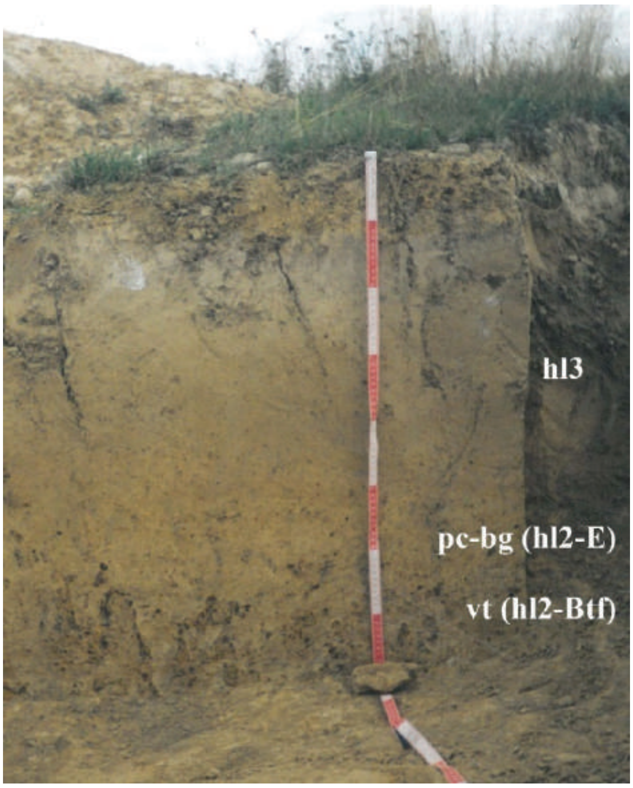
Fig. 2. Pollen diagram of the Sokyrnytsya 1-A site: a) excavation 3, b) excavation 1. Legend: 1 – pollen of Betula sect. Nanae et Fruticosae, 2 – spores of arcto-boreal and arcto-alpine species of Lycopodiaceae. The curves inside the Fig.: a – perventages counted from the total sum, b – percentages counted from the AP sum.

Sokyrnytsya 1-A site is the key section for the studied area.

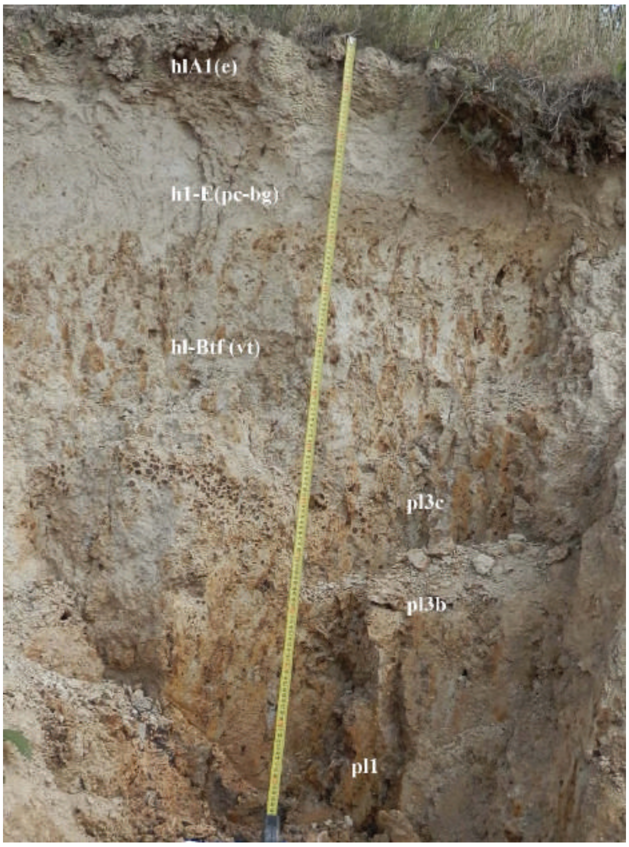
The Holocene (hl). In both Sokyrnytsya 1 site and the majority of the Ruban' sections, the Holocene unit is partly truncated. The complete profiles of the Holocene soils were studied in a few sections (*e.g.* the excavation 3 at Sokyrnytsya 1-A, Fig.3a), where these soils are undisturbed and represented by a pedocomplex from the upper Luvisol and the lower Albic Luvisol. Pollen assemblage of the A1(e) horizon of the Luvisol corresponds well to the local surface pollen sample and the modern vegetational composition. The characteristic features are the predominance of spores (57-74%, mainly of Polypodiaceae), the presence of pollen of herbs and bushes, and very low percentages of broad-leaved trees (PZ I, Fig.2a). The pollen assemblages of soil genetic horizons E(gl), E(Btgl) and the upper part of Bt(gl) are also dominated by fern spores, but the AP increases, and it includes pollen of broad-leaved taxa, particularly *Carpinus* and *Corylus* (PZ II). A few artifacts of cultural level 1 are found *in situ* in the upper part of E(gl) horizon only in the excavation 3 of Sokyrnytsya 1-A. The absence of diagnostic features in these artifacts and their small number does not allow the cultural assignement of this level.

In the lower part of the Bt(gl) horizon, pollen of *Quercus* and *Tilia* is more abundant than *Carpinus*, and some increase in NAP is observed (PZ III). The Egl horizon of the Holocene Albic Luvisol (Cgl horizon of the upper Luvisol) has abundant Fe-Mn punctuation, and it includes PZ IV and PZ V. In PZ IV, pollen of broad-leaved trees disappeared, *Alnus* dominates the AP, and Lycopodiales became significant among the spores. In PZ V, NAP, consisting mainly from Poaceae and Cyperaceae, dominates; AP includes *Pinus sylvestris* and small-leaved trees; Polypodiaceae spores disappear. PZ IV and V (Fig. 2b) are represented in the same soil genetic horizons in the excavation 1 at Sokyrnytsya 1-A (Fig.4b) where the upper part of the Holocene pedocomplex is disturbed by human impact.

The striking difference between PZ IV and V indicates that the material of the lower part of Egl horizon of the Albic Luvisol was formed under different climatic conditions than its upper part, and, thus, it has different age. It is confirmed, on one hand, by the ^{14}C date 7,560±150 yrs BP (Usik *et al*., 2004), indicating the Holocene age of its upper beds, and, on the other hand, by the presence in its lower beds of the cultural level 2 which includes the Upper Palaeolithic artefacts. The small collection from this level and the



a)



b)

Fig. 3. The sections of the Holocene and the upper part of Upper Pleistocene deposits, undisturbed by human impact: a) the upper part of the Holocene pedocomplex in the excavation 3 at Sokyrnytsya 1-A. The Btf horizon of the lower Holocene soil is formed in the material of Vytachiv unit; b) the Holocene and Upper Pleistocene deposits in the excavation of the middle part of the slope at Ruban'.

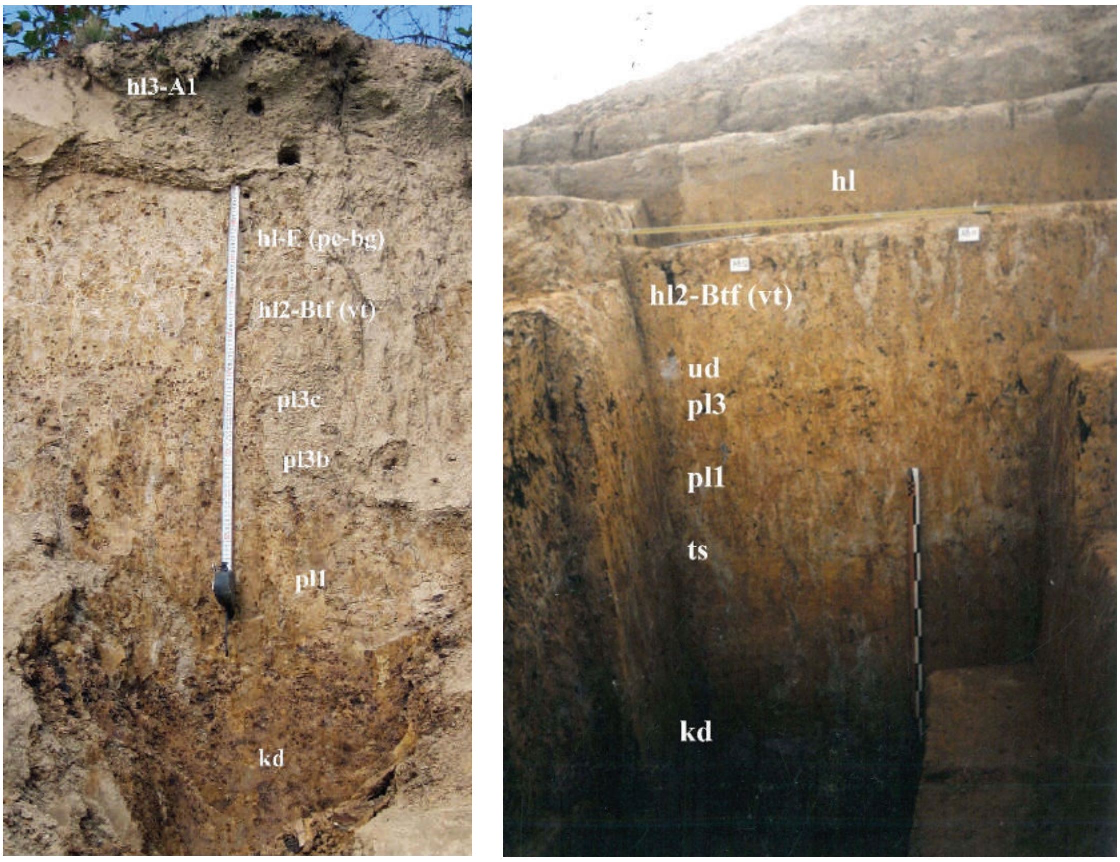


Fig. 4. The Holocene and Upper Pleistocene deposits: a) at Ruban' (the upper part of the slope); b) at Sokyrnytsya 1-A (the flat surface of the terrace, truncated from the top).

absence of diagnostic features in the artefacts do not allow its cultural attribution. ***Prychernomorya-Bug (pč-bg) units***. The domination of NAP, the occurrence of only boreal trees in the AP of the lower part of the Egl horizon, the presence of frost fissures, deeply dissecting the underlying Vytachiv unit both at Sokyrnytsya 1-A and Ruban' (Fig. 3, 4), and the presence of the Upper Paleolithic artefacts allow the suggestion that this material was formed under the climate of a stadial. During the Holocene, it was affected by eluvial pedogenic processes. At the Upper Paleolithic site Shayan 1, the similar lithostratigrpahic unit has been ^{14}C-dated between 19,850±400 and 27,700±800 ka BP (Usik *et al*., 2004). At Korolevo 1, the primary loess-like carbonate material is preserved in places at this level, and it is TL-dated to the Upper Pleistocene (Adamenko *et al*., 1989). Such ages prove that the primary material was deposited during the 'pc-bg' times. The similarity in the lithomorphology allows the suggestion that the same horizon at Ruban' also was formed during these times.

At Korolevo 1, Sokyrnytsya 1-A and Ruban', ***Vytachiv (vt) unit*** is transformed by the translocation processes during the formation of the Holocene Albic Luvisol, and visually it represents Btfgl genetic soil horizon. The characteristic features of this brown horizon is the presence of a huge amount of small Fe-Mn nodules (in the upper part also Mn films), the marble-like colouration and the combination of prismatic structure and platy texture. Films of Mn hydroxide on the horizontal plate surfaces indicate that the lamination was formed before mobilization of manganese in the humid Holocene climate, and, thus, during the cold 'pč-bg' times. It is confirmed by the irregularity both of the upper boundary (see above) and the lower transition of the unit ('tongues' filled with the soil material). In the main part of the Vytachiv soil (0.6-0.8 m), AP dominates (PZ VI), consisting mainly of *Betula* and *Alnus*, though pollen of *Quercus, Tilia* and *Corylus* occur. The percentages of spores (28-31%) are much lower than in the overlying deposits. The NAP includes mainly Cyperaceae and forbs. The pollen data indicate that these deposits were formed during an interstadial. The charcoal from the cultural layer 3 (0.6-0.85 m at Sokyrnytsya 1-A) yielded eleven ^{14}C dates indicating its age between 38,200±450 and 42,150±500 ka, the average date of 38,800±110 (Usik *et al*., 2004). This allows the suggestion that it was formed during the Middle Vytachiv interstadial, dated 38-36 ka uncal ca BP (Gerasimenko, 2006a). Despite the Vytachiv soils at Ruban' and Sokyrnytsya 1-A are morphologically similar, their secondary transformation by the Holocene illuvation processes

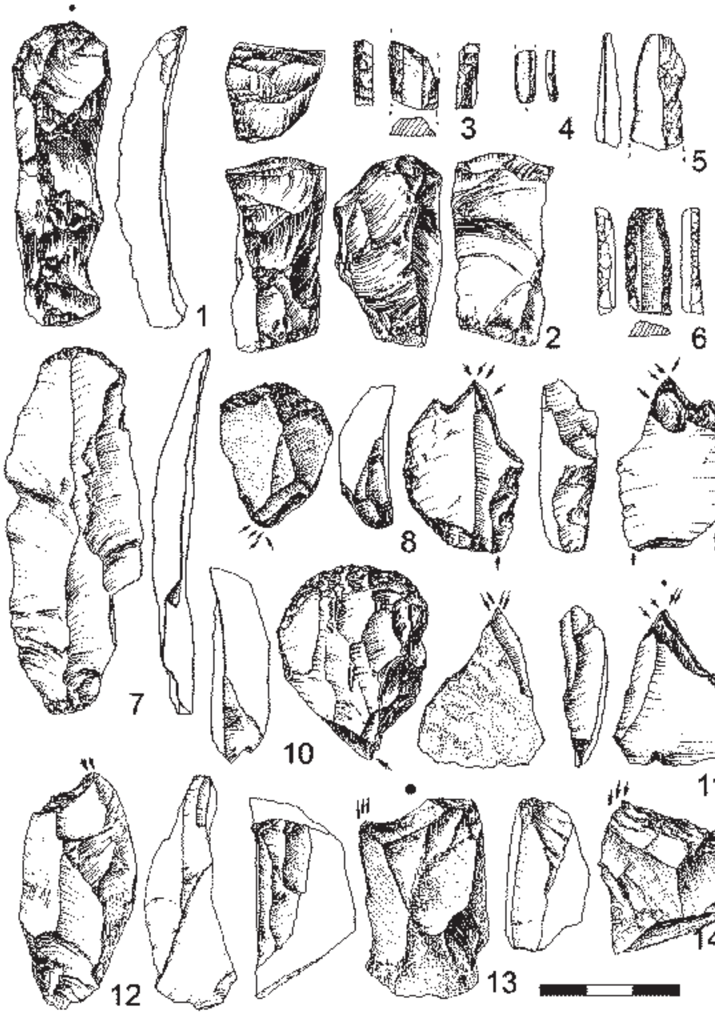


Fig. 5. Sokyrnytsya 1-A, cultural level 3, the Early Upper Paleolithic, tools: 1, 2, 7 – end scrapers; 3-6 – microliths, 8, 10 – end scrapers/burins; 9, 11-14 – burins.

allows the presumption that the different interstadial (or interstadials) of the Vytachiv time might be represented in this level at Ruban'.

In the cultural level 3, mainly quartzite pebbles were used for reduction. In the collection, there are samples of andesite raw material, typical for the Early Upper Palaeolithic at Korolevo 1. The primary flaking is focused on production of blades from parallel volumetric cores (cylindrical, sub-cylindrical, pyramidal, *etc*.), mainly with a soft hammer. The collection includes the typical crested blades and core tablets. Burins predominate over end scrapers in the tool kit. Dihedral burins are more common than those on truncation. Burins are often multifaceted, made on massive blanks. End scrapers are represented by simple type, on retouched blades and flakes, as well as those combined with burins. The Aurignacian forms are rare and atypical. Dufour bladelets are absent. Microliths are made on bladelets and microblades with lateral and bilateral dorsal retouch. Thus, the level 3 represents the specific Upper Palaeolithic industry.

The lower part of Vytachiv unit at Sokyrnytsya 1-A (0.8-0.9 m) includes PZ VII (AP 6-20%) which strongly differs from PZ VI by the increase in NAP (21-59%) and spores (35-66 %), the disappearance of pollen of broad-leaved taxa and the presence of palynomorphs of arcto-alpine and arcto-boreal species (*Betula* sect. Nanae et Fruticosae, *Lycopodium lagopus, Diphazium alpinum,* and, particularly, *Botrychium boreale*). Pollen of Chenopodiaceae first became noteworthy. The pollen assemblage from the underlying ***Uday (ud) unit,*** represented by a thin light-grey loam, belongs to the same PZ VII. Thus, the lower beds of Vytachiv unit (the Bt-Cgl soil horizon) were formed during a stadial climate of the Uday time, and they have been transformed by pedogenic processes later. The network of long fissures-in-raw, filled in with the Uday material, dissects the underlying Pryluky soils both at Sokyrnytsya 1-A and Ruban'. The TL-data from the lower part of the same soil at Korolevo 1 are around 60 ka BP (Adamenko *et al*., 1989) that fits to chronological attribution of the Uday unit in Ukraine.

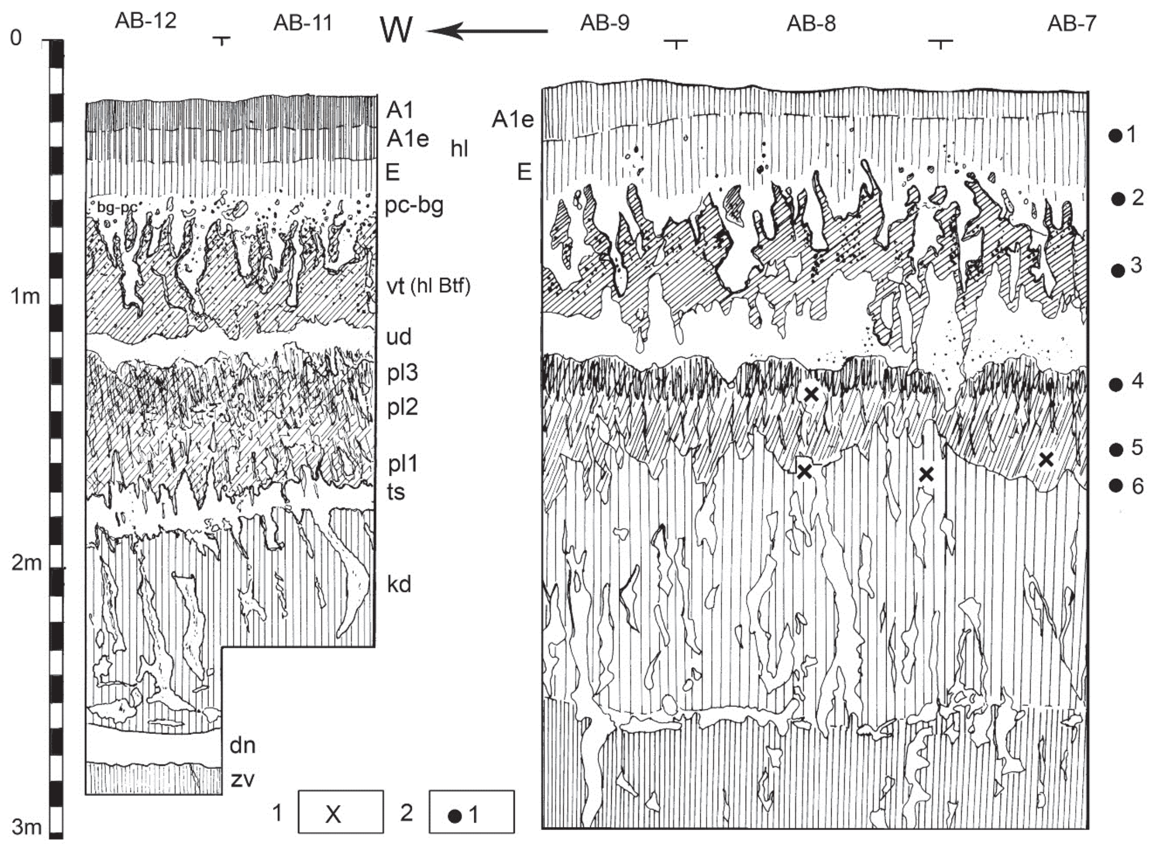


Fig. 6. Sokyrnytsya 1-A, excavation area 1, northern wall, stratigraphical position of cultural levels. 1 - position of artifacts in the section; 2 – position of the cultural levels.

Pryluky (pl) unit at Sokythytsa 1-A and Ruban' is a pedocomplex, consisting of two soil subunits ('pl_3' and 'pl_1'), separated by a thin non-soil loam ('pl_2'). The level of ground wedges is connected with the 'pl_2' subunit (see Fig. 4). Subtypes of the Pryluky Luvisols depend on their position in palaeorelief but, in general, these soils are brighter (with reddish-brown tints) than the overlying deposits, and strongly mottled in colour (black manganese spots alternate with ochre iron-hydroxide and bluish-gley spots). At the Sokyrnytsya 1-A site, which is located on the relatively flat surface and topographically higher than the Ruban' site, the Pryluky soils have short profiles and very high content of clay particles. These factors caused the strong surface moistening of the upper beds of the soil 'pl_3', which is reflected in the abundance of thick manganese films on the ped surfaces. The short-profile Pryluky soils were observed only in the topographically highest excavation from eleven of them in the Ruban' geological profile, stretched along the gentle slope to the gully, which dissects the terrace. Downslope, because of the increase in sedimentation rates, the thicknesses of Pryluky unit became larger, particularly of 'pl_3' subunit, which consists there of two soils – 'pl_{3c}' and 'pl_{3b}'. The position on the slope provided the better water drainage of these soils than at Sokyrnytsya 1-A, and, thus, manganese hydrooxides are concentrated in the abundant small nodules at the top of the thin 'pl_{3c}' Cambisols. The 'pl_{3b}' soils are the thicker Luvisols, with the darker A1(e) horizon and the bright-brown Btf horizon, and with discrete relatively small Mn films. In places, the 'pl_3' subunit is completely dissected by wedges, filled in with the Uday material.

At Sokyrnytsya 1-A, PZ VIII (1.15-1.4 m) from the 'pl_3' subunit has a strong predominance of AP (68-82%). The majority of the AP belongs to *Pinus sylvestris*, though *Alnus* is rather abundant (up to 20%) and *Picea* appears (1-4 %). Only a few pollen grains of broad-leaved taxa (*Quercus, Ulmus, Fagus* and *Corylus*) occur, whereas in the uppermost level of the subunit, only pollen of boreal trees is present. Polypodiaceae dominate spores, and palynomorphs of arcto-boreal species disappear. Such pollen assemblage is typical for a cool interstadial. The artifacts from the depth 1.20-1.40 m mark cultural level 4. Their morphological features are associated with the Middle Paleolithic techno-complex.

The Middle Palaeolithic cultural level at Ruban' is located in the top layer of the 'pl_{3c}' soil (Fig. 7). The archaeological collection from this level contains 953 artefacts, among which quartzite raw material predominates. The other raw materials are argillite and, more rarely, andesite. The collection includes cores, flakes, blades, tools, chips and fragments, indicating a complete cycle of primary flaking and manufacture of tools, which took place directly in the location. The blank production, based on radial, sub-crossed, orthogonal and Kombeva's methods, was sed sporadically. These systems of blank production resulted in domination of short and thick flake, triangular in a cross-section. These flakes were used as a main blank for the majority (52%) of tools. Blades are rare and, obviously, were produced unintentionally. The striking platforms of blanks are mainly thick, cortical or unprepared.

The collection of tools (5.8% from the sum of artifacts) demonstrates a definite dominance of the side scrapers (52%), which are usually represented by convexes − simple (19%), diagonal (16%) and transverse (4%). The working edge of tools is frequently formed by the scaled stepped retouch (the so-called «Quina», or «Semi-Quina»). Many tools have the so-called «back», often natural, which presents a striking platform, or an edge of a core. These types of scrapers are very similar in design (Fig. 8). The other types of side scrapers, such as déjeté, double and ventral, occur very rarely. The collection also includes denticulates (4%), notches (7%) and retouched flakes (27%). Thus, the Ruban' site technology can be described as non-Levallois, non-blades, non-faceted. The analysis

Fig. 7. Ruban': a) position of the subunit 'pl_{3c}' in the excavation on the slope, which was truncated by the quarry; b, c - position of the Middle Paleolithic cultural level in the excavation of the archaeological site (also truncated); d) the Middle Paleolithic: scapers.

of the typology (selection of the blanks, secondary flaking, the ratio of types of tools) allows the assignment of the collection at the Ruban' to a circle of the Middle Palaeolithic industries of the Quina type.

The 'pl_2' loam at Sokyrnytsya 1-A includes PZ IX which differs from PZ VIII by the sharp decrease in AP (5-11%) compensated by the increase in NAP (58-64%). Pollen of *Picea* and broad-leaved taxa is absent. The NAP consists mainly of Poaceae and Cyperaceae, though Chenopodiaceae pollen also appears. Arcto-boreal species of Lycopodiales and *Botrychium boreale* dominate the spores, and Polypodiaceae are not present. The 'pl_1' Luvisol at Sokyrnytsya 1-A is not strongly enriched in manganese segregations, but in the soils at Ruban', their A1 horizons include a huge amount of Fe-Mn concretions, which are larger and more frequent than in the Vytachiv soils. The better drainage of these Luvisols at Sokyrnytsya 1-A than at Ruban' might be explained by formation of the first ones on the less clayey Tyasmyn loams which are absent at Ruban' sections. At Sokyrnytsya 1-A, PZ X (1.45-1.65 m) from the 'pl_1' soil is dominated by AP (69-50%), and the spore percentages are larger than in the 'pl_3' soil (27-51%). *Pinus sylvestris* predominates the AP (26-47%), but the percentages of pollen of broad-leaved taxa are higher than in the 'pl_3' soil – *Quercus* and *Fagus* (each 2-4%) and a few grains of *Carpinus* and *Ulmus*. Pollen of bushes are diverse – *Corylus*, *Euonymus, Frangula* and arboreal Rosaceae. Polypodiaceae strongly dominate the spores. The cultural level 5 which includes the Middle Palaeolithic techno-complex is located at the depth 1.53-1.63 m.

Tyasmyn (ts) unit at Sokyrnytsya 1-A is a pale-grey loam (0.1 m thick) with irregular lower transition – narrow wedges (0,5 m in depth) and shallow pocket-like downward intrusions. The narrow wedges with gleyed non-soil material are also open from the level below the 'pl_1' soil at Ruban'. At Sokyrnytsya 1-A, the Tyasmyn loam includes PZ XI, which has a very low AP (up to 8%), represented mainly by *Betula* sect. Nanae et Fruticosae. The majority of NAP consists of Cyperaceae, Poaceae and Lamiacaeae. The spores are dominated by arcto-alpine Lycopodiales and *Botrychium boreale*.

Kaydaky (kd) unit is represented in both sites studied by the thick Btf horizon of Luvisol (Fig. 4, 8). Ochre-brown colour of the soil indicates the high content of iron hydroxides that is typical for the warm facies of Luvisols. Glossy massive reddish-brown cutans of illuviation cover the surface of blocky-prismatic peds. Manganese punctuation is much less abundant than in the overlying deposits. The platy texture of the soils (up to the depth 0.6 m from their surface) is of particular interest. The lamellas intersect gley spots in the soils, and, thus, they were formed as the result of cryolamination, which occurred after the pedogenisis. At Sokyrnytsya 1, the gley spots (up to 0.1 m in width, up to 0.4 m in length) are particularly prominent, and despite they frequently are vertical, their horizontal forms also occur, and there is no level from which they open systematically. Thus, they are not frost wedges or desiccation fissures. Most likely, they represent the development of gley processes in organic remains of the former tree roots.

All PZ from the Kaydaky soil at Sokyrnytsya 1-A are dominated by AP (50-69%). They are as follows (from top to bottom). PZ XII from the uppermost part of the soil differs by the presence of *Picea* pollen (up to 9%). It is subdivided into two subzones on the basis of presence of *Abies* and the higher percentages of pollen of broad-leaved trees in the lower part (PZ XII-A). Broad-leaved taxa are represented mainly by pollen of *Fagus* and *Carpinus.* Pollen of arboreal Rosaceae is most abundant among bushes. Bryales spores share dominance with Polypodiaceae, and NAP percentages are extremely low (4%). The Middle Palaeolithic level 6 is located at the top of Kaydaky soil (the depth about 1.8 m).

PZ XIII differs from PZ XII by the increase in pollen of broad-leaved trees (20%), *Alnus* (up to 18%), and the disappearance of dark conifers. PZ XIII is also subdivided into subzones – the upper one (XIII-B) has the maximum of *Carpinus* and *Corylus* pollen (both up to 12%), *Tilia platyphyllos* and Ericaceae are present, whereas in the lower PZ XIII-B, the decrease in *Corylus* is compensated by the increase in *Quercus* pollen. Palynomorphs of *Frangula* and *Viburnum* are noteworthy in both subzones, as well as high percentages of Polypodiaceae spores (up to 39%). The next PZ XIV has the lower percentages of AP and of pollen of broad-leaved trees (10-14%), compensated by some increase in NAP. In the AP, pollen of *Quercus* predominates (3-6%), pollen of *Carpinus, Fagus, Ulmus, Tilia* and *Corylus* constitute each 1-2%. PZ XV differs by the further decrease in pollen percentages of broad-leaved trees (2-6%), represented by *Quercus* (predominates), *Ulmus* and *Tilia*, by the disappearance of *Carpinus, Fagus*, and the presence of a few *Picea* pollen.

Dnieper (dn) unit is represented as a thin light-grey loam only at Sokyrnytsya 1-A, but both at Sokyrnytsya 1-A and Ruban', the underlying Luvisol of Zavadivka unit is distorted by the posterior cryogenic structures and textures of the Dnieper time (particularly by the platy textures). At Sokyrnytsya 1-A, the Dnieper unit includes PZ XVI. The pollen assemblage from the lowermost Bt-C horizon of the Kaydaky soil also belongs to this PZ. This indicates that the upper

Fig. 8. The lower Pryluky and Kaydaky soils at Sokyrnytsya 1-A (a) and Ruban' (b).

beds of Dnieper unit were re-worked here by translocation processes of the Kaydaky pedogenesis. PZ XVI is dominated by NAP (54-59%) which includes forbs, Cyperaceae, Poaceae and few Chenopodiaceae. AP (23-31%) consists of *Pinus sylvestris* and *Betula* sect. Nanae et Fruticosae. The spores are dominated by Bryales and arcto-boreal species of Lycopodiales.

Interpretation. The Middle Palaeolithic first appeared in the Upper-Tysza Depression during the formation of the soil correlated by P. Haesaerts and L. Koulakovska (2006) with MIS 7. In Ukraine, the terrestrial equivalent of MIS 7 is regarded either as Kyadaky unit (Veklitch *et el*., 1993; Gozhik *et al*., 2000; Lindner *et al*., 2006), or as Potyagaylivka unit (Gerasimenko, Matviishina, 2007; Matviishina *et al*., 2010). The latter was earlier considered as the uppermost soil of the Zavadivka unit *sensu lato* (Veklitch *et el*., 1993) because the Upper Middle Pleistocene soils in Ukraine frequently are represented by a single very thick pedocomplex, or by one welded soil. In Transcarpathia, the Middle Palaeolithic culture has been discovered in Zavadivka unit at Malyi Rakovets IV (Yamada and Ryzhov, Eds., 2015). At the Sokyrnytsya 1-A site (cultural level 6), the Middle Palaeolithic first appeared at the very end of the ***Kaydaky time***, when the formation of the interglacial Luvisols was finishing. The light pine woods, with ferns in the ground cover and arboreal Rosaceae in the undergrowth, dominated the landscapes. Spruce and a few broad-leaved trees (particularly beech) grew in wet locations. It was the end of the interglacial. The main features of pollen succession of this interglacial is similar to that of the Eemian (Mikulian), namely, the change of Quercetum mixtum by Carpinetum forest, the *Corylus* culmination, the appearance of *Abies* and *Picea* at the transition between the late-temperate and post-temperate stages of the interglacial. The Kaydaky soils both at Sokyrnytsya 1-A and Ruban' show morphological features characteristic for the much warmer climate than during the formation of all overlying soils. This facts and stratigraphical position of this interglacial below the two interstadials, palynologically determined within Pryluky unit, confirms the suggestion that Kaydaky unit is a correlative of the Last Interglacial (marine substage 5e), as it has been proposed earlier (Rousseau et al., 2001; Gerasimenko, 2006; Matviishina *et al*., 2010; Haesaerts *et al*., 2016). The other suggestion exists on correlation of Kaydaky unit with MIS 7, and Pryluky unit with MIS 5 (Veklitch *et al*., 1993; Gozhik *et al*., 2000;

Lindner *et al*., 2006). At the sections studied in this paper, Pryluky unit is represented by the two interstadials, which cannot be compared with Kaydaky unit by the level of development of pedogenesis and by the abundance in pollen of broad-leaved taxa. The vegetation of the last interglacial in the Upper-Tysa Depression had its particular features, obviously controlled by the very high precipitation in this area (the extensive spread of beech) and high temperatures (the limited spread of fir and spruce). The spread of beech during the last interglacial in the Transcarpathia is also shown in the Korolevo 1 site (Pashkevich, 1984) and the Gat' section (Gerasimenko, Vozgrin, 2011).

The sharp reduction in arboreal vegetation occurred during the ***Tyasmyn time***, when sedges, grasses and some forbs dominated the landscapes (PZ XI). Arcto-boreal and arcto-alpine species of birch, club-mosses and *Botrychium* grew extensively that indicates a periglacial climate. The development of cryogenic processes is reflected in frost wedges and very well expressed secondary platy cryotexture in the Kaydaky soils. This time span is correlated with the first stadial of the Early Glacial (substage 5d).

During the ***formation of the lower Pryluky soil (pl$_1$),*** landscapes were dominated by mixed woods, which included pine, birch, broad-leaved taxa (oak, beech, hornbeam, hazel) and those bushes as spindle-tree, buck-thorn and arboreal Rosaceae (PZ X). Ferns formed the ground cover. Alder grew in the valleys. The Luvisols were the dominant soil type, and they were periodically intensely gleyed in the low relief positions (the Ruban' site). The climate was rather warm, as well as during the 1st interstadial of the Early Glacial in Central Ukraine, where it has been correlated with substage 5c (Rousseau *et al*., 2001; Герасименко, 2006a; Haesaerts *et al*., 2016). The spread of broad-leaved trees during this interstadial occurred both in Eastern and Western Europe (Bolikhovskaya, 1995; Woillard, 1978). The existence of Middle Palaeolithic during this time is proved at Sokyrnytsya I-A (the cultural level 5). The Middle Palaeolithic cultural layer IV at Malyi Rakovets IV, located in the brightest reddish-orange part of the Btf horizon of the welded Pryluky-Kaydaky soil (Ryzhov *et al*., 2015), might be also related to this time.

The ***Middle Pryluky stadial (pl$_2$)*** was characterized by almost complete disappearance of arboreal vegetation – only a few birches occurred (PZ IX). The open landscapes were occupied by sedges, grasses, arcto-alpine and arcto-boreal club-mosses and *Botrychium*. Chenopodiaceae first became noteworthy in the ground cover, whereas ferns did not grow. Depending on the relief, xeric coenoses alternated with cryomeso- or cryohygrophytic associations. The periglacial climate of this 2nd stadial of the Early Glacial (the equivalent of substage 5b) was drier than that of the 1st stadial. In the Eastern Ukraine, xerophyte *Artemisia* dominated during this time (Rousseau *et al*., 2001). The soil formation ceased, whereas erosional and cryogenic processes developed intensely and deformed the underlying 'pl$_1$' soil, particularly in several localities at Ruban'.

During ***formation of the upper Pryluky soils (pl$_3$)***, the landscapes were dominated by light pine woods, with an admixture of spruce, birch and a few broad-leaved taxa (hornbeam, oak, hazelnut and beech). Alder formed the flood-plain woods. The ground cover of the woods consisted of ferns and club-mosses (PZ VIII). At the end of the 'pl$_3$'time, broad-leaved trees disappeared. This interstadial was cooler that the preceding one that caused the decrease in evaporation and the appearance of excessive moisture in the grounds. As the result, mobilization of manganese occurred in the soils producing abundant Mn films on the structural plains of peds. The cooler climate that during the preceding interstadial is also found in the 'pl$_3$' soils of Central Ukraine which are correlated with the 2nd interstadial of the Early Glacial, the terrestrial equivalent of the marine substage 5a (Roussaeu *et al*., 2001; Gerasimenko, 2006a). The climate was transitional from boreal to south-boreal, but at the very end of soil formation (the phase 'pl$_{3c}$'), it became colder, typically boreal. Pedological and pollen characteristics of the 'pl$_3$' soils correspond very well to those of the upper layer of the IInd soil at Korolevo 1 (Adamenko *et al.*, 1989; Pashkevich, 1984). Pollen data from this soil indicate the spread of boreal forest from pine (including stone pine), fir and larch. The Middle Palaeolithic existed at Sokyrhytsya 1-A (the cultural level 4) during the warmer part of this interstadial. The Middle Palaeolithic cultural level at Ruban' appeared at the very end of the 'pl$_3$' time − during its coolest phase 'pl$_{3c}$', at the transition to the cold Uday phase. In Central Ukraine (Roussaeu *et al*., 2001; Gerasimenko, 2006a), the 'pl$_{3c}$' incipient soils are correlated with the weak Ögnon interstadials, established by Woillard (1978).

The Palaeolithic collections from the Kaydaky – Upper Pryluky units at Sokyrnytsya 1-A lack cores. At the same time, the flakes, produced by hard hammer, have scar patterns (centripetal, convergent, etc.), the shape and striking platforms usual for the Middle Palaeolithic. Single tools such as the transversal convex side scraper (level 4), the simple convex side scraper with a natural back (level 5) and a flake with inverse retouch (level 6) are also quite typical for the Middle Palaeolithic.

The Middle Palaeolithic industry at Ruban' occurs in the top layer of the 'pl_{3c}' soil. The industry of this type was first ascertained in France (the site La Quina). A very specific type of tools of this industry is a massive scraper with the back and the Quina retouch. The working edge of this tool was formed by several rows of the retouch of a 'scaled' type, which reach a dorsal side of a flake. Thus, a working edge of this tool is stepped in a cross-section (Bordes, Bourgon, 1951). The industry of Ruban' site is completely analogous to those of the sites Korolevo I (level II), Malyi Rakovets' IV (level II) and the small collection from the Rokosovo. Nevertheless, at the Korolevo 1, this level is located in Uday unit, whereas at Makyi Rakovets', it is observed both in the very thin Uday unit (Stepanchuk *et al*., 2013, Fig.20) and in the top layers of Pryluky unit (the same book, fig.34). Thus, the carriers of the described industry existed in the Upper-Tysa Depression and the adjacent low mountain ridges from the end of the Pryluky times through the following Uday times.

During the ***Uday time,*** the drastic cooling occurred. The spread of sedges and *Botrychium boreale* reached its maximum (PZ VI) in the open landscapes, where grasses, arcto-boreal and arcto-alpine species of club-mosses, some forbs and xeric Chenopodiaceae also grew. The coenoses were similar to those of the modern subalpine belt of the Carpathian Mountains but differed by some spread of steppe elements. The periglacial climate existed that is also confirmed by the growth of shrub birches and the development of cryogenic processes. At Korolevo 1, Uday unit is represented by a thin loess (Adamenko *et al.*, 1989) that indicates the development of aeolian processes in the region.

During the ***Vytachiv interstadial***, represented in the Sokyrhytsya 1-A site (the Middle Vytachiv, around 38-39 ka BP), forest-steppe landscapes existed (PZ VI), with domination of south-boreal woods. The latter consisted mainly from arboreal birches and alder, with small admixture of pine and broad-leaved taxa (oak, lime and hazelnut). The forest ground cover was formed by ferns, and bushes became more abundant than during the pl_3 interstadial. Diverse forbs and sedges grew in the open landscapes. Judging from the pollen data, the climate was drier that during the Pryluky interstadials and this is confirmed by the presence of Fe-Mn nodules in the Vytachiv soil. They indicate a contrast changes in the precipitation (Veklitch *et al*., 1979), and, thus, there existed dry seasons during this interstadial. The pedological characteristics of the Vytachiv soil at Sokyrnytsya 1-A are well correlated with those of the I[st] soil at Korolevo 1 (Adamenko *et al.*, 1989). According to the pollen data (Pashkevich, 1984), oak-pine forest dominated but the spread of open landscapes points to some aridity. The Transcarpathian Lowland was covered by oak-pine woods, alder groves and meadows from sedges and forbs (Gerasimenko, Vozgrin, 2011). The presence of open landscapes favoured the protracted Early Upper Palaeolithic occupation at Sokyrnytsya 1-A (the main cultural level 3 of the site).

The rich in artefacts level 3 represents the non-Aurignacian industry, which is characterized by the typical Upper Palaeolithic tradition of blade production with the system of predominantly parallel unidirectional reduction, commonly used after the crest preparation on cores. Rejuvenation of cores with the so-called 'core tablet technique' and the usage of a soft hammer are frequent. The tool-kits are completely typical for the Upper Palaeolithic. At the same time, there are no cores and tool types ("carenated", "nosed", "Dufour"), typical for the Aurignacian, or their specific 'guiding' types that enables allocation of this collection to the individual culture. At present, the industry of the level 3 at Sokyrnytsya 1-A can be regarded as the 'unspecific' Early Upper Palaeolithic. The level 3 by its technical and typological indicators is correlated with level IVb at Kostenki 14 and the level Ia at Korolevo 1 (Monigal *et al*., 2006; Usik *et al*., 2006). The latter is located in the lower layers of Vytachiv unit. Thus, the described industry might exist in the studied area during the Early and Middle Vytachiv times. The last are correlated with Hengelo interstadial of Western Europe (Hammen, van der, 1995).

The next phase of environmental development, represented at Sokyrnytsya 1-A, belongs to a stadial with periglacial climate reflected in the strongest cryoturbations of the Vytachiv soils and in pollen data. The last indicates to domination of open landscapes with club-mosses, green mosses, sedges and some Chenopodiaceae (PZ V). At the beginning of the phase (judging from pollen from the material of the wedges infilling), ferns still grew but later on, they completely disappeared. Nevertheless, arboreal birches and alder persisted in the most protected habitats. As it had been shown above (the chapter 'Results'), this phase belongs to ***the Bug-Prychernomorya times*** (MIS 2). The pollen data from the Korolevo 1 site (Pashkevich, 1984) indicate that around 25 ka BP, the described area was occupied by sparse conifer woods (pine and larch). The absence of pollen of arcto-boreal and arcto-alpine vegetation, which would be expected for the Late Pleniglacial, might be explained by non-continuous sedimentation in the sites studied, where the deposits of the LGM had been truncated. The Upper Palaeolithic existed at Sokyrnytsya 1-A at the beginning of the described phase (the cultural level 2).

The Holocene. The first half of the Holocene (before 7.5 ka BP) was characterized by the spread of woods and development of intense translocation processes which lead to transformation of the material of ‘pc-bg’ and ‘vt’ units into the texture-differentiated profile of Albic Luvisol. At Sokyrnytsya 1-A, the formation of this soil was finished around 7.5 ka BP, or (more likely) this Albic Luvisol was truncated. The next phase of environmental development, palynologically detected in the Btf horizon of the upper soil of the Holocene pedocomplex in excavation 3 of Sokyrnytsya 1-A (PZ III), was characterized by the strongest spread of Polypodiaceae ferns, broad-leaved trees (oak, lime and hazelnut) on the terrace and alder groves in the valley. Such strong predomination of ferns (or herbs) over arboreal vegetation during the Holocene is normally typical for forest clearance (Kremeneckiy, 1991; Bezus’ko *et al*., 2010), which in this case could occur at the second half of Atlantic (the Northgrippian). Thus, human impact on the vegetation started in the studied area approximately at the same time as in the belt of broad-leaved forest of the plain area of Ukraine.

The obtained results demonstrate multiple environmental changes in the studied area during the existence of Middle and Upper Palaeolithic which are well correlated with those established both in Eastern and Western Europe (Fig. 9). During the last glacial, the changes had a cyclic pattern – the alternation of the interstadials (with south-boreal and boreal climates) with the stadials (with periglacial climate) during. The deposits of the LGM and the coldest phase of the penultimate (Saalian) glaciation are not represented in the studied section, as well as the Early Atlantic optimum. Nevertheless, the morphological features of the last interglacial soil indicate that it was formed in the warmer climate than the ‘hl_2’ Albic Luvisol.

Conclusion. The area of the Upper-Tysa Depression is most important both for its archaeology and for palaeoenvironmental interpretations. For instance, concerning the Middle Palaeolithic, industries of the Quina type are quite common in Western Europe, but up to now they have been unknown to the east of the Carpathians (Kulakovska, 2003). The Early Upper Palaeolithic industry represented at Sokyrnytsya 1-A has the analogue in Eastern Europe (Kostenki XIV) but has not been described in Western Europe (Usik *et al*., 2006). These facts prove the importance of the Transcarpathian Palaeolithic in the European context. The Late Pleistocene and Holocene environments of the Upper Tysa Depression are also rather specific, as there are not many areas in Europe that show its combination of high temperatures and high precipitation during the Pleistocene warm phases and the Holocene. Intense translocation and gleying processes in the forest soils of the region frequently resulted in the transformation of the underlying non-soil deposits, those accumulated during Pleistocene cold phases. This lead to the formation of the Pleistocene-Holocene sequences, consisting from welded soils, and this hampers the stratigraphical subdivision. The frequent position of archaeological sites on slopes, where erosional processes lead to the truncation of both paleosols and loesses, contributes to the difficulties in interpreting the stratigraphy. Thus, the profiles-transects of the Pleistocene deposits should be studied (like, for instance, eleven excavations at Ruban’). Pollen study is a necessary tool in stratigraphical subdivision and palaeoenvironmental reconstruction, as pollen assemblages indicate the primary environments, which existed prior to pedogenic processes transforming their parent rocks. The local palaeoenvironmental features are characteristic for the area studied, *e.g.* the formation of Fe-Mn concretions at the top of the majority of the palaeosols; the presence of thick films of manganese hydroxides, atypical for the Upper Pleistocene in other areas; the absence of Mollisols, characteristic for European plains; the spread of beech during the last interglacial and early glacial interstadials; limited growth of fir and spruce as compared to Central Europe, *etc*.). Nevertheless the main environmental phases of the Late Pleistocene in the Upper-Tysa Depression are well correlated with those in both Eastern and Western Europe (Fig.9).

In the sites studied, Middle Palaeolithic first appeared at the very end of the last interglacial, pollen succession of which is found in Kaydaky unit, represented by the most well developed Luvisol (of the warm facies) in the section. At that time, sparse pine woods included also some spruce and deciduous trees (including broad-leaved taxa). The Middle Palaeolithic continued into the early glacial interstadials, palynologically determined in subunits ‘pl_1’ and ‘pl_3’. During the corresponding time intervals, mixed woods consisted mainly of pine, particularly during the second interstadial. Among the deciduous taxa, small-leaved trees dominated over broad-leaved. The small collections of artefacts from Middle Palaeolithic levels and the absence of indicative features in them does not allow their assignment to certain technological-typological complexes.

In the Upper-Tysa Depression, the absence of Middle Palaeolithic in Tyasmyn and Uday units, and in Middle Pryluky subunit which were formed in open periglacial landscapes (beneficial for the Middle Palaeolithic in the other regions of the plain area of Ukraine), could be connected with the very high humidity and the very thick winter snow cover. In the

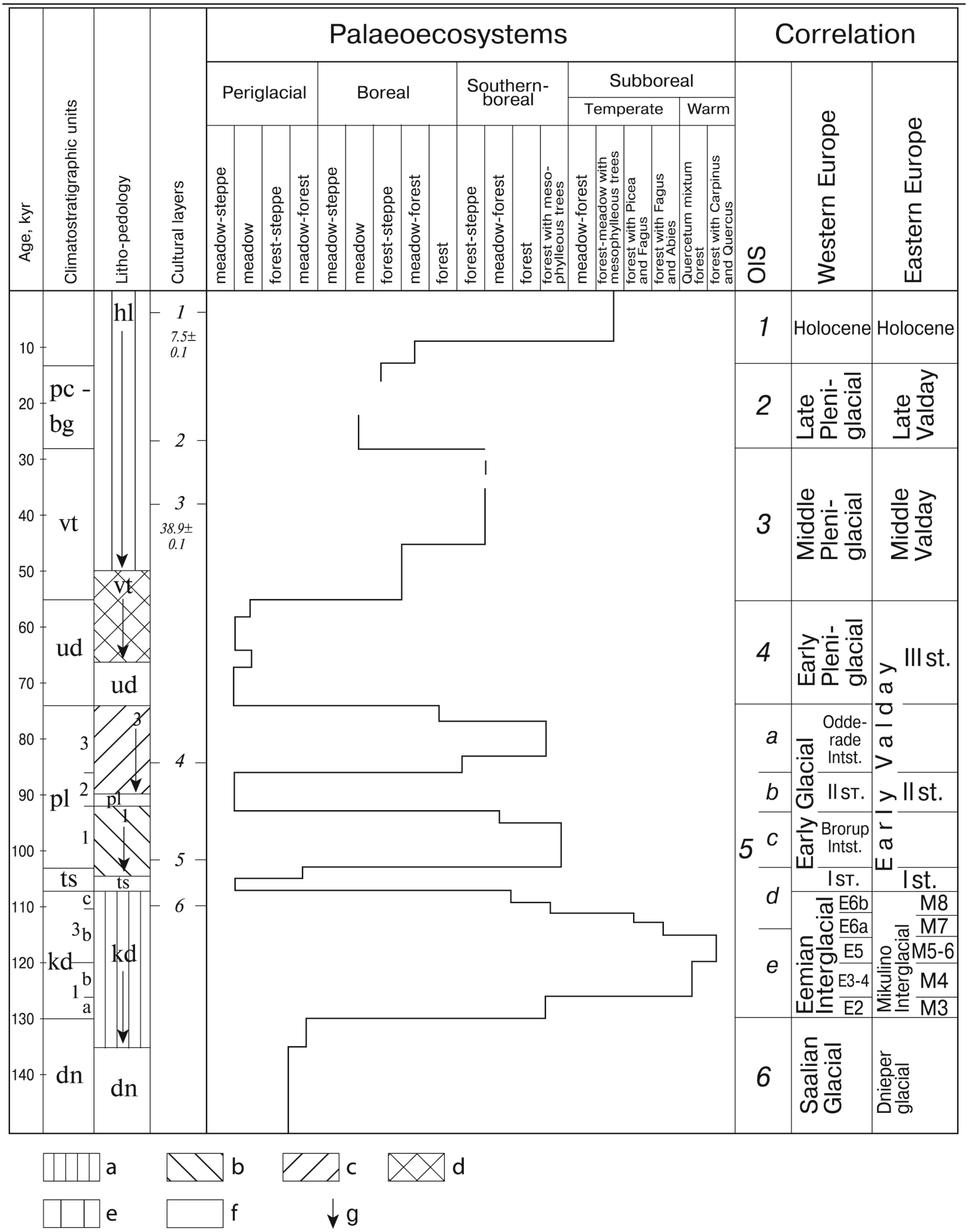


Fig. 9. Environmental changes in the Upper-Tisa Depression during the Late Pleistocene and Holocene (the study case of the Sokyrnytsya 1-A site) and the correlation with the glaciochronological frameworks of Western and Eastren Europe. Legend: a – Luvosil of warm facies, b – Luvisol of temperate facies, c – Gleyed Luvisol of boreal facies, d - Cambisol, e – Albic Luvisol, f – non-soil loam, g – translocation processes (modified from Gerasimenko, 2006) .

topographically higher and better drained localities (at Korolevo 1 and Malyi Rakovets' IV), the Middle Palaeolithic artefacts are found in the Uday unit. At the very end of the substage 'pl_3', the horizon of the Fe-Mn concretions indicates frequent dry seasons. During this time, the Quina Middle Palaeolithic culture existed both in the Upper-Tysa Depression and on adjacent mountain ridges.

During early and mid Vytachiv times, the reduction of woodland was balanced by the spread of mesophytic steppe. In the woodland, small-leaved trees dominated over pine and broad-leaved trees (mesophilous hornbeam and beech were absent). Judging from the last fact and the greater extent of herbs compared to ferns, the climate of the mid Vytachiv times was better for occupation by Palaeolithic people. Early Upper Palaeolithic (non-Aurignacian) culture of an unspecific type existed around 38 - 39 ka BP that has analogues only in Eastern Europe (Kostenki XIV). In the open landscapes at the beginning of cold 'pc-bg' times, Upper Paleolithic cultures existed in the Upper-Tysa Depression, but at Sokyrnytsya 1, artefacts are rare and do not allow their assignment to a specific cultural type.

During the Atlantic (the Northgrippian), well-developed Albic Luvisols could be formed only under woodland, but at the end of this period, forest clearance lead to the spread of ferns. The second half of the Holocene (the Meghalyan) was marked by the appearance of hornbeam in the oak-lime woods, whereas translocation processes still were active in the soils. During the formation of a humus horizon, the spread of meadow and mesophytic steppe associations and the further reduction of the forests in the studied area indicate the increase in human impact.

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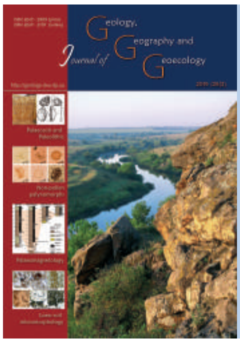

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On the lower boundary of the Quaternary System in the Azov-Black Sea Basin

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Abstract. The data on the lowering of the lower boundary of the Quaternary System below the Gelasian Stage at 2.588 million years are presented in the paper. In Azov-Black Sea basin this boundary takes place within the middle of the Kuyalnikian Regionalstage and related to the magnetostratigraphic boundary Gauss-Matuyama and should be drawn under the deposits of the upper Kuyalnikian regionalsubstage, Taman layers of the Akchagylian, alluvium X terrace of the Dnister, Danuba, Prut rivers, the Haprovian layers of the Priazovie and under sediments of the Siverian stage in the loess-soil series of the Ukraine. Below there lie the deposits of the Bogdanivkian stage and the lower Kuyalnikian rocks. The deposits of the Lowerkuyalnikian regionalsubstage, upper and lower Poratian beds and sediments of the Bogdanivkian, Kizlyarkian and Jarkian stage in the loess-soil series related to Piacencian stage and Upper Pliocene. Kuyalnikian deposits in the Odessa (Kryzhanivka) region are the upper part of the Upperkuyalnikian regionalsubstage, above the Tamanian beds and correlations with a Beregovian stage in the loess-soil series. Beginning of the maximum Akchagylian transgression in the Black Sea coincides with a sharp cooling Climate period (2,5-2,6 million years) and compares with the Middle Akchagylian transgression of the Caspian basin. Signs of the late Akchagylian mollusks at the basal beds of the Kuyalnikian of the Priazovie requires additional research, as at that time the formation of the lower Poratian deposits took place in a (with Rugunio lenticularis) Warm climate. The most probable version is the invasion of Akchagylian mollusks during the cocking in Ajdarian time. The author opinion on the reasoning of the lowering of the boundary and the problems of its use in geological mapping are also stated.

Key words: Dniester River Valley, Priazovie, Pliocene, Quaternary, stratigraphy

Про нижню границю четвертинної системи в Азово-Чорноморському басейні

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Анотація. В статті приведені матеріали щодо зниження нижньої границі четвертинної системи під відклади гелазійського ярусу в 2.588 млн. років. В Азово-Чорноморському басейні ця границя розміщується в середині куяльницького регіоярусу і співпадає з магнітостратиграфічною границею Гаус-Матуяма і буде проводиться під відкладами куяльницького регіопід'ярусу, таманськими верствами акчагилу, алювієм X терас Дніпра, Дунаю, Прута, хапровськими верствами Приазов'я і і відкладами сіверського етапу лесово-грунтової серії України. Нижче залягають відклади богданівського етапу та нижньокуяльницькі відклади. Відклади нижньокуяльницького регіопід'ярусу, верхньо- і нижньопоратських верств, богданівського, кизилярського і ярківського етапів лесово-грунтової серії співставляються з п'яченцським ярусом і віднесені до верхнього пліоцену. Куяльницькі відклади району м. Одеса (Крижанівка) складають верхню частину верхньокуяльницького регіопід'ярусу (над таманськими верствами) і співставляються з берегівським етапом лесово-грунтової серії. Початок максимальної акчагильської трансгресії в Чорному морі співпадає з різким похолоданням клімату (2.5-2.6 млн. років) і співставляється з середньоакчагильською трансгресією в Каспійському басейні. Ознак пізньоакчагильської трансгресії в Азово-Чорноморському басейні не виявлено. Знахідки акчагильських молюсків в самих низах куяльнику Приазов'я потребує додаткових досліджень, оскільки в цей час відбувалось формування нижньопоратських відкладів (з Rugunio lenticularis) при теплому кліматі. Найбільш ймовірним є варіант інвазії акчагильських молюсків при похолоданні в айдахський етап лесово-грунтової серії. Викладено також думку автора про обгрунтування пониження нижньої границі і проблеми її застосування при геологічній зйомці.

Ключові слова: куяльник, пліоцен, стратиграфія, Приазов'є, долина Дністра.

Introduction. The question of the lower boundary of the Quaternary System has been considered by the geological community on many occasions. In 1839, Charles Lyell, author of the name «Pleistocene», proposed to define the lower boundary in marine sediments, if the assemblage of marine organisms contains 90% of modern species. With the development of Quaternary geology, the identification of glacial and interglacial deposits, the rhythmicity of subareal formations became of primary importance in solving the problems of boundaries, which involved the climatic component. So in 1948, at the 18th International Geological Congress (IGC) in London, it was proposed to draw the lower boundary of the Quaternary System under the marine Calabrian deposits, in which the first Arctic species of molluscs and foraminifera appeared in the Mediterranean Sea. In the continental sediments, this boundary had to bee placed under the deposits of the Villafranchian Stage. However, the proposed version of the lower boundary was adopted only during the 27th IGC, which was preceded by detailed work on the choice of the Calabrian stratotype. The argument has already clearly outlined the climatic paradigm, such as penetration into the Mediterranean basin of cold-water migrants from the Atlantic (in particular, *Arctica islandica*), the appearance of the Pretiglian spore and pollen assemblage in the Quaternary deposits of Western Europe, which marked the global cooling in the Northern Hemisphere. The appearance of the Villafranchian association of large mammals was also mentioned. The section “Vrika” was chosen as the Global Point, In this section, the lower Quaternary boundary is positioned above the subchron Oldway - 1.81 million years (Ma). Later studies have shown that the migration of marine species of fauna from the North Atlantic (such as *Arctica islandica*) and the occurrence of Pretiglian assemblage of pollen took place much earlier than 2 million years ago, and the Calabrian corresponds only to the upper Villafranchian.

Supporters of the lowering of the Quarternary lower boundary have chosen a significant cooling-(ice age) of about 2.5 million years, which corresponded to the critical point of the evolution of the Earth’s climate system, namely the appearance of glaciation in the Northern Hemisphere. This argument was the main one of the proposed options (Head, Gibbard, Salvator, 2008; Finney, 2010) and endorsed by the Executive Committee of the International Union of Geological Sciences. The changes in the International Stratigraphic Scale (ISC) for the Neogene and Quaternary systems were ratified. According to these changes, the lower boundary of the Quaternary System is drawn in the section of the Global Stratotype and the Global Point (GSSP) of the Gelasian Stage “Monte san Nicola” on the southern shore of the island of Sicily near the city of Gala, 1 m above the magnetostratigraphic boundary of Gauss - Matuyama, at the beginning of the “warm” isotope stage of IOP. Above this boundary the extinction of carbonate nanno-fossils *Discoaster pentaradiatus* and *D. surculus* is recorded. In the justification of the abovementioned idea, we should note the beginning of loess sedimentation in China, human development and practical considerations.

Thus, stratigraphy of the Quaternary System has a clearly expressed climatic paradigm, as opposed to the stratigraphic one, which is incorporated in the construction of the ISS. On the one hand, this approach to the Quaternary System is justified, taking into account the frequency of glaciations, interglaciations, formation of loesses and buried soils, regressions and transgressions. Selection on this basis of climatostratigraphic subdivisions is the basis for regional stratigraphic schemes, and the development of the isotope-oxygen scale (MIS) has proved the global nature of climate changes. However, no matter how perfect climatostratigraphic subdivisions are, without biostratigraphic, paleomagnetic and absolute age data, they do not solve one of the main tasks of geological survey - the correlation of glacial and interglacial subdivisions of different regions and sedimentation environments. As an example, we can cite the age identification of the Don moraine, which was compared with that of the Dnieper moraine. However, after the processing of the paleontological material, in particular, the remains of small mammals, the difference in age of the abovementioned moraines was proved. Such examples are also known in the stratigraphy of loess formations.

Returning to the question of the validity of the definition of the Quarternary lower boundary by the climatic factors, there is no guarantee of a re-examination of the problem. After all, significant cold fluctuations are observed at the boundaries of 3.2, 3.4 million years (not to mention 5.5 million years), glaciation of Greenland - 3.3 million years, the data on the beginning of loess sedimentation in 2.8 million years. At the same time, we must admit that addition of the Gelasian Stage to the Quarternary System can serve as an example of a combination of climatic and biostratigraphic criteria, which we will discuss in the following sections of this article.

Discussion of the problem of the lower boundary of the Quaternary System in the Azov-Black Sea Basin. In accordance with the approved lower boundary of the Quaternary System at 2.588 million years in the Azov-Black Sea Basin, it takes place within the middle of the Kujalnikian Regio-stage (Gozhik, Matoshko, 2011), the upper part of which belongs to the Pleistocene, and the lower part - to the Pliocene.

In this paper there is no possibility and need to discuss all the papers on the Kujalnikian Stage, so we focus on the main localities where freshwater molluscs, mainly unionids and viviparids, have been found. The choice of these mollusks is dictated by directional evolution during the Pliocene, with broad migration on the background of global climate change. All this is the basis for the subdivision of the Kujalnikian deposits and correlations with the Akchagilian and alluvial deposits in the river valleys of the southern part of the East European Platform.

The "Kujalnik Beds" were discovered by I.F. Sintsov (1875) near the city of Odessa, where they overly with erosion the Pontian and Meotian deposits. After processing the paleontological material, he subdivided these beds into 2 horizons: the lower horizon - with the marine and freshwater molluscs and the upper one - with the freshwater ones. Among the freshwater molluscs a new species of viviparid was established - *Viviparus subconcinus* Sinz., which occurs both in Kujalnikian and in the coeval alluvial deposits. I.F. Sintsov (1877, 1897) assigned the lower and upper horizons to the new (upper) Pliocene.

The stratigraphic position of the Kujalnikian deposits has long been controversial. E. Andrusov (1897) placed them above the ore-bearing layers of the Kerch-Taman region.

N.P. Mikhailovsky (1902, 1905), studying the deposits near Pakveshi village at the Galizga River, which overlie Kimmerian rocks, mentioned a fauna somewhat different from that described by I.F. Sintsov around the city of Odessa. Considering the Kujalnikian deposits in the rank of the stage, he believed that the beds of the Galizga represent the lower horizon of the Kujalnikian Stage, and that the deposits described by I.F. Sintsov belong to the upper Kujalnikian (Mikhailovsky, 1909).

V.D. Laskarev (1912) compared the upper horizon with the remains of mammals with the Villafranchian Stage. T.A.Mangikian (1929) believed that there were no grounds to distinguish two horizons within the section of the Kujalnikian deposits in Odessa region due to the identity of the freshwater mollusc assemblage in both of them. The new species distinguished by Magnikian (*Unio tanphilievi, U. kujalnicensis, U. alexeevi, Viviparus pseudoachetinoides kujalnicensis*) later were mentioned, as a rule, by other researchers from the Kujalnikian deposits of the Azov Sea area.

An important stage of the knowledge of Kujalnikian deposits was the study of V.N. Krestovnikov (1928). He established and described several new species of molluscs: *Limnocardium limanicum, Pachydacna subkujalnicensis, Dreissenssia theodori kubanica* and *Valvata vanciana*, which became characteristic of the lower Kujalnikian deposits (in the understanding of N.P. Mikhailovsky) of the Taman and Kuban regions.

A.G. Eberzin (1931) discovered deposits with the Akchagiliuan mollusc *Avimactra subcaspia* in the Crimea and included them in the Tamanian Horizon, which, in his opinion, could not be older than the upper horizon of the Kujalnikian Stage. The Akchagilian molluscs were discovered by IM Gubkin (1931) in the overlying ore-bearing strata of the area of Durnoselivka village and adjacent territories of the Taman Peninsula. Having subdivided the strata into 3 horizons, he noted that the Kujalnikian molluscs as well as the Kimmerian ones are characteristic for the lower horizon, the Kujalnikian and the freshwater ones – for the middle horizon, and the Akchagilian and Kujalnikian ones - for the upper one. It is important for us to emphasize that in the middle horizon among the freshwater molluscs Gubkin identified *U. tamanensis* and the gastropods similar to those occurred in the Paludinian beds of Slovenia. He considered the upper horizon to be the youngest Kujalnikian described by V.N. Krestovnikov (1928) and that it corresponded to the upper horizon of the Kujalnikian.

G.I Molyavko (1948) significantly expanded knowledge of the distribution area of the Tamanian deposits of A.G.Eberzin in the Crimea and noticed the presence there of large debris of unionids of the Levantinian appearance.

Generalization of data on the Kujalnikian sediments of the Azov-Black Sea region was performed by A.G. Ebersin (1940). He assigned the Krasnodarskian Horizon with *Unio sturi* Horn., the Tamanian Horizon with *Avimactra subcaspia* Andr. and the Kujalnikian Stage with *Limnodacna limanica* Krest. to the Upper Pliocene.

The second most important region of the distribution of the Kujalnikian deposits is the Priazovie, where they were studied mainly using drilling data, which were rarely accompanied by the collection of paleontological material.

G.I. Molyavko (1950) established the distribution of Kujalnikian deposits within the limits of the Lower Dnipro and Melitopol district, the Prisivash and the Crimea. The Kujalnikian deposits are represented by mainly clays with interlayers of clayey sands and only in the Lower Dnipro area - by sands, inequigranular at the base with pebbles of sedimentary and crystalline rocks (the facies of erosion). In the upper part of the section the remnants of molluscs were practically not collected, but in the lower part the following fossils were found: *Dreissena theodori* Andr. *var kubanica* Krest., *D. polymorha* Pall., *D. fogti* Ebers., *Prosodacna sinzovi* Ebers., *P. subkujalnicensis* Krest., *Limnocardium skadovkaense* Ebers., *Momodacna cf sibrigeli* Sinz., *Unio* sp., *Viviparus subconcinus* Sinz., *Valvata* sp., *Lithoglypus* sp. Subsequent studies of the Kujalnikian sediments revealed the remnants of freshwater molluscs also in the upper horizon, among which *Viviparus subconcinus* Sinz, *Planorbarius* sp., *Planorbis* sp., *Valvata* sp. and others were identified.

The discovery of the "Levantinian" unionids in the Lower Kujalnikian deposits of the Azov Sea area, described by G.I.Molyavko and Yu.I.Selin (1957), was extremely important. In the area of the villages of Botievo and Orlovka *Unio cf. rumanus* Cob., *U. lenticularis* Sabba, *Unio* sp., *Dreessena polymorpha* Pall., *Melanopsis* sp., *Viviparus* sp., and *Valvata* sp were found in the cores of boreholes. The presence of sculptured unionids and melenopsids of the Levantine appearance gave the authors the basis for correlation of the Kujalnikian deposits with the lower horizon of the Levantinian (Poratian) Stage.

In the Skadovsky district the valve of *Unio bielzi* Czek was found in the sandy strata of the borehole at the depth of 90 m near the village of Karga. In the same area, according to the data of the abovementioned authors, at the depth of 85.1 m A.G. Ebersin identified the Kujalnikian molluscs *Pachydacna kujalnicensis* Krest., *Limnocardium limanicum* Krest. and the fragments of gastropods of the Levantinian appearance (emphasized by us).

Detailed investigations of the Kujalnikian and Kimmerian sediments performed by V.M. Semenenko (1960, 1966, 1975, 1987) significantly supplemented the data on the distribution and species composition of marine and freshwater molluscs. He distinguished two horizons in the Kujalnikian strata. The upper one is most clearly represented in the Melitopol region, where in the clays, sometimes sandy ones, and siltstones *Unio kujalnicensis* Mang., *Unio tenphilievi* Mang., *Viviparus subconcinus* Sinz., *V. bethinicus* Mang. and others were discovered , that is, the species typical for the Kujalnikian deposits of Odessa region. The lower horizon of the Kujalnikian here contains *Limnocardium limanicum* Krest., *Pachydacna kujalnicensis* Andr., *P. subkujalnicensis* Krest., *Prosodacna* cf. *miser* Ebers., *Didacnomya vulgaris* Sinz. In a generaralized list of fauna of the lower Kujalnikian, V.M. Semenenko (1987) indicated the following freshwater molluscs: *Dreissena theodori kubanica* Krest., *Dr. rostriformys* Desh., *Potomida neustruevi* Andr., *Unio lenticularis* Sabba., *U. cf. rumanus* Cob., *U. krajovensis slanicensis* Teiss., *Viviparus ex gr. turritus* Bog., *V. aff. subconcinus* Sinz., *Lithoglyphus neumayri* Sabba, *L. acutus* Cob., *Bithynia uncotinovici* Brus., *B. spoliata* Sabba, *Melanopsis esperoides* Sabba. *U. neustruevi* and U. *lenticularis* are of particular interest. Unfortunately, there was no indication which part of the lower Kujalnikian contained the abovementioned unionids.

In the basal part of the Kujalnikian deposits of the Northern Priazovie V.M. Semenenko (1975, 1987) registered the remains of *Avimactra subcaspia* Andr. and *Cárdium dombra* Andr., which raises the question of the time of the first migration of Akchagilian molluscs to the Black Sea.

The Kujalnikian deposits in the Steppe Crimea with *Limnocardium limanicum* Krest., *Dreissensia theodori kubanica* Krest., *Viviparus sinzovi* Pavl. and *Unio* sp. overlie the Pontian, and on the Kerch Peninsula - the Kimmerian rocks. In the Indole and Chigerchinska troughs above the Tamanian strat,a A.G. Ebersin (1940) discovered the fragments of *Didacna* ? cf. *digressa* Livent - the marker of the Gurian layers of the Black Sea. In the Steppe Crimea above the Tamanian layers, G.I. Molyavko (1938) identified greenish waxy clay with numerous *Coretus, Planorbis, Limnaea, Dreissena* and smooth *Unio* (Tjup-Dzhankoian beds).

According to V.M. Semenenko, the Lower Kujalnikian deposits of the Azov Sea area and Western Georgia are directly magnetized and belong to the Gauss era. The Upper Kujalnikian, Tamanian and Tjup-Dzhankoian beds are inversely magnetized and correspond to the lowermost part of the Matuyama epoch, as well as the middle- upper Akchagilian deposits of the Caspian Sea basin.

From the material above, it follows that a number of issues concerning the Kujalnikian deposits are still controversial. These are their subdivision, correlation with the Akchagilian and Tjup-Dzhankoian layers, the volume of the upper Kujalnikian and its correspondence to the Tamanian Horizon, appearance of the Akchagilian molluscs in the Azov-Black Sea region and the definition of the lower boundary of the Kujalnikian Regio-Stage in the continental formations (Semenenko, 1987; Vernigorova, 2016). In this regard, let us discuss the geological, paleontological and climatic factors of these problems.

First of all, let us consider the structure of the reference section of the Kujalnikian deposits near the village of Kryzhanivka, described in detail by M.F. Veklych (1968). The upper horizon, defined by I.F. Sintsov (1877), is represented by the eluvial, lacustrine and alluvial deposits (Fig. 1), which M.F. Veklych compared with the Berezanian stage of the formation of the loess-soil series of Ukraine. At the base of the horizon there are inequigranular sands with the interlayers of gravels and pebbles (erosion facies), in which the remains of small mammals of the Odessa complex (Shevchenko, 1965) corresponding to the early stage of the Tamanian faunal assemblage have been discovered. The freshwater molluscs were found both in the alluvial and lacustrine sediments. However, in the alluvial deposits, rheophilous molluscs dominate, and in the lacustrine deposits – stagnophilous ones. Among the rheophiles that evolved more rapidly during the Pliocene, we should note *Unio kujalnicensis* Mang., *U. tanphilievi* Mang., *U. alexeevi* Mang., *Viviparus subconcinus* Sinz., *V. sinzovi* Pavl., *V. pseudoachatinoides* Desh., *Melanopsis esperoides* Sabba., *Bithynia vucatinoviei* Brus., *B. spoliata* Sabba. The lower horizon of I.F. Shintsov, compared by M.F. Veklych (1968) with the Beregovian stage, is represented by marine, alluvial-marine and lagoon-swamp formations (Fig. 1). The remains of small mammals were collected from the gravel interlayers and distinguished as the Kujalnikian assemblage (Shevchenko, 1965), which belongs to the Haprovian faunal assemblage. The freshwater molluscs discovered in the alluvial-marine and marine sediments are mainly rheophilous and have almost the same composition as in the upper horizon. Characteristic forms, *Unio kujalnicensis* Mang., *U. tanphilievi* Mang.and *Viviparus subconcinus* Sinz., are distributed far beyond the stratotype (Kryzhanivka village) from the Priazovie to the Taman Peninsula (the Taman beds), the Pskepus River valley, Akchagilian of the Volga region. I.Ya.Yatsko (1954) discovered *Unio rumanus* Tourn. and *Limnoscapha semiornata* Bolgin. together with *Unio kujalnicensis* at the base of the Kujalnikian eastwards of the Tiligul estuary, which gave grounds to suggest the proximity of the

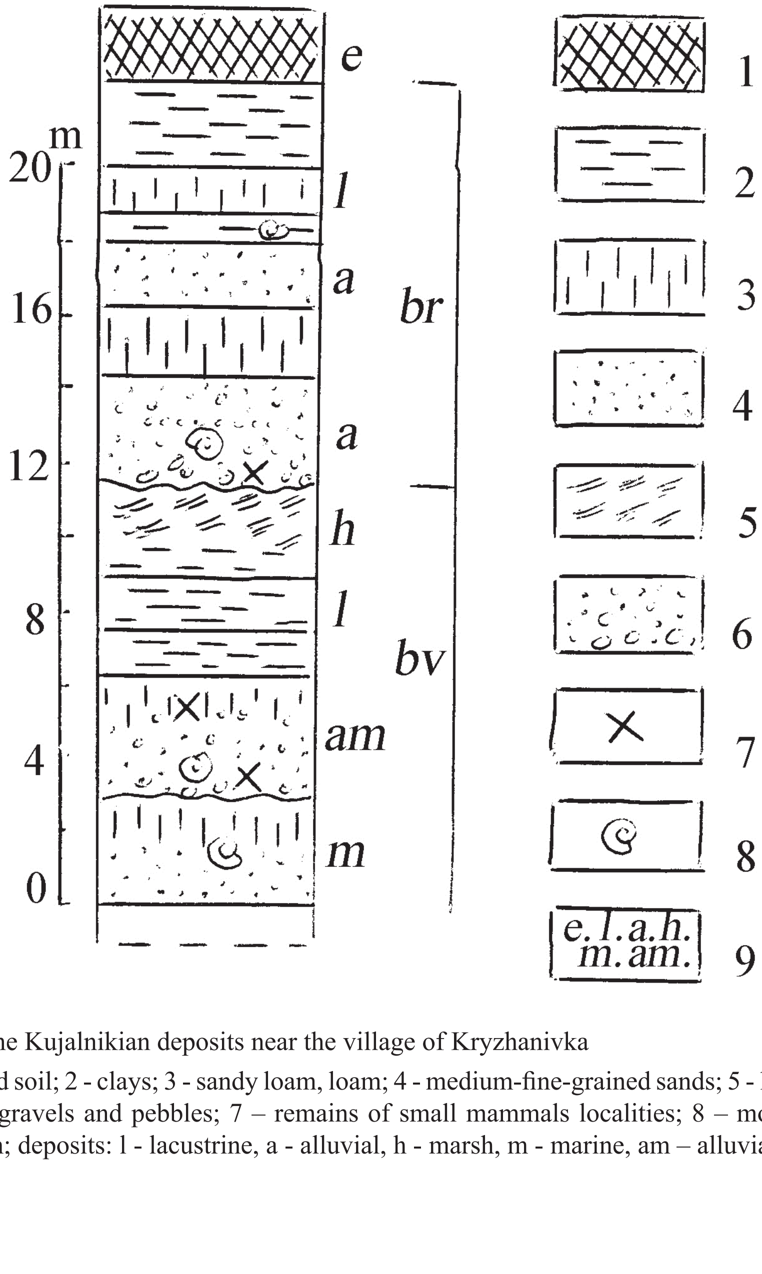

Fig. 1. Section of the Kujalnikian deposits near the village of Kryzhanivka

1 - red-brown buried soil; 2 - clays; 3 - sandy loam, loam; 4 - medium-fine-grained sands; 5 - lagoon-marsh soil formations; 6 - inequigranular gravels and pebbles; 7 – remains of small mammals localities; 8 – molluscs' localities; 9 - genetic indices: e - eluvium; deposits: l - lacustrine, a - alluvial, h - marsh, m - marine, am – alluvial- marine.

Kujalnikian Stage to the Dacian.

Deposits of the upper and lower horizons have inverse magnetization (Matuyama), and only at the boundary between them is there a zone of directly magnetized rocks (Tretiak, Volok, 1976), which can be compared with the subchron Oldway (1.77-1.95 million years). Taking into account the paleontological and paleomagnetic data, M.F. Veklych (1982) identified the age of the Berezanian phase as 1.90-1.61 million years, and the Beregovian at 2.430-1.90 million years.

Freshwater molluscs from the Lower Kujalnikian sediments of the Azov Sea area deserve special attention due to the occurrence of unionids characteristic of the lower and upper Poratian strata. Their belonging in the stratotype area to the NSM11 Zone - *Moldavunio lenticularis - Valachunio iconomianus*, identifies the age of 3.7- 2.7 million years (Andreescu, 2009). The early Poratian species *Moldavunio (= Rugunio) lenticularis* Sabba belongs to the NSM11a Subzone, and the late Poratian species *Pelendunio (= Rytia) bielzi* Czek belongs to the NSM11c Subzone. According to the paleomagnetic data, the NSM11 zone is comparable to the Gauss epoch, in which, as noted earlier, the Lower Kujalnikian deposits are placed. Accordingly, *M. lenticularis* should correspond to the lower part, and *P. bielzi* - to the upper part of the Kujalnikian Regio-Stage. Besides Wallachia (Romania), *M. lenticularis* was found in the Lower Poratian (= Lower Levantinian) deposits of the lower part of the Prut River. M.I. Andrusov (1963) described *Unio lenticularis* Sabba var *samarica* and *U. neustruevi* Andr. var. *geometrica* from the deposits of the Wolf's gully of the Volga River area

The Upper Poratian deposits which contain the remains of *Pelandunio bielzi* Czek., unconformably (with erosion) overlie the Dacian rocks in the Danube River valley and are placed in the stratigraphic scheme above the Lower Poratian. Besides the lower reaches of the Prut and the Danube rivers (Ripa Skortselska and Dolynske), *P. bielzi* was described from the middle-upper Paludinian beds, of Slavonia, Pelendavian Substage of Romania, the lower Kujalnikian of the Priazovie, the Don Valley near the station of Nagavska (so-called the Nagava beds). The late Poratian species were recorded also in alluvium of XI (Vadyluivodska) terrace of the Dniester River (Chepalyga, 1967).

Viviparus turritus Bog., the characteristic form of the Kinel beds of the Volga River region, was found in the lower Kujalnikian of the Priazovie and the Upper Poratian near the village of Dolinske (the Danube River Valley). Numerous remains of late Poratian viviparids such as the sculptured *V. bifarcinatus* Bielz. and *V. rudis strossmayerianus* Brus. , as well as those with smooth shells *V. turritus* Bog., *V. sinzovi* Pavl., *V. craiovensis* Poz. and *V. proserpinae* Bog. occurred in inequigrained sands with gravel near Dolynske. As the sculptured viviparids were not found in the younger deposits, it is logical to admit that a significant cooling preceded the formation of the Upper Poratian deposits.

Bogatschevia (=Unio) tamanensis Ebers. and *B. bugasica* Ebers are characteristic forms of the Tamanian Horizon. The narrow stratigraphic range of *B. tamanensis* is the basis for correlation of the marine Tamanian and middle Akchagilian deposits with the alluvial ones. The continental (terrestrial) equivalents of the Tamanian beds are the alluvial deposits of the Psekups River near the Saratovska stanytsya, Haprovian beds of the Priazovie, alluvial deposits of the X terrace of the Dniester River (the Rashkivska, Ferladanska), the Danube River (Kotlovynska), the Prut River (the Roshska). The remains of small mammals of the deposits correlated with the Tamanian Horizon belong to the Haprovian faunal assemblage.

The Romanian researchers (Andreescu, 2009; Andreescu et al., 2010) assigned the deposits with *Bogatschevia tamanensis* and with boreal *Unio kujalnicensis* to the Wallachian Regio-Substage in the 2.4-2.0 million years range, *Bogatschevia sturi* Hornes was dated as 1.8- 1.6 million years. The presence of *B. sturi* in the alluvium of the IX terrace of the Dniester and Danube river valleys and the Lower Apsheronian deposits of the Kuban does not contradict that.

Detailed analysis of the spore-pollen complexes of the Kujalnikian and subaeral deposits of the Priazovie, represented by O.A.Sirenko (2017), showed that the upper Kujalnikian corresponds to the Beregovian stage, the middle Kujalnikian – to the Siver stage, under which the magnetostratigraphic boundary Gauss - Matuyama is fixed. Thus, the lower boundary of the Quaternary System of 2,588 million years is drawn under the Siver deposits. Below lie the deposits of the Bogdanovkian Stage and the lower Kujalnikian rocks. At the same time, Sirenko came to the conclusion that the essential cooling took place at the beginning of the Siver stage, with which we associate the invasion of the Akchagilian molluscs into the Black Sea, which most likely occurred between 2.6 and 2.4 million years. This is the time of maximum Akchagilian transgression in the Azov-Black Sea Basin, whose traces were found on the shores of the Dardanelles Strait (Taner, 1970).

As for the occurrence of the Akchagilian molluscs at the base of the Lower Kujalnikian in the Priazovie, it was obvious that this could have happened at the end of the Pontikipaean time, when there was a

Table 1. Subdivision chart of the Kujalnikian deposits

Age (Ma)	ISC: System	ISC: Stage	Polarity chron	Regional: Stage	Regional: Substage	Regional: Climatolites	Azov-Black Sea Basin		Alluvium sediments terraces	Fresh – water Molluscs
1.8	Quaternary	Cal	C1			*br*	Lower Gurian		IX Boshernitsa	*Margaritifera arca, Bogatschevia sturi, Unio apsheronicus*
2.0		Gelasian	C2n	Kuialnikian	Upper	*bv*	Upper Kuialnikian	Tjup-Dzhankoian beds	X Ferladany	*Planorbarium corneus, Planorbis, Limnea, Valvata, Unio*
2.2								Kujalnikian beds of Odessa		*Unio kujalnicensis, U. tanphilievi, Viviparus subconcinus, Limnoscapha, semiornata*
2.4						*sv*		Tamanian beds	XI Vady Luj Vode Upper Poratian beds	*Bogatschevia tamanensis, Unio kujalnictnsis,Dreissensia theodori kubanica, Rugunio lenticularis samarica*
2.6 / 2.8		Piacencian	C2An-1n		Lower	*bd*	Lower Kuialnikian	Galizgian beds		*Pristinunio pristinus, P. davilai, Rytia bielzi, Viviparus turritus, V. bifacinatus*
3.0						*kz*		Beds with Akchagilia ?	Lower Poratian beds	*Rumanunio rumanus*
3.2 / 3.4 / 3.6			C2An-3n			*jr*		Bachteria beds		*Rugunio lenticulaxis, Plicatibaphia flabellatiformis, Ebergininaia neustruevi*

significant cooling, recorded in the deposits of the Aidar stage of the loess-soil series of Ukraine.

Conclusion. An analysis of the available material makes it possible to draw the following conclusions. The lower boundary of the Quaternary System should be drawn under the deposits of the upper Kujalnikian, Taman layers of the Akchagilian, alluvium of the X terrace of the Dniester, Danube and Prut rivers, the Haprovian layers of the Priazovie and under the sediments of the Siver stage in the loess-soil series. This boundary of 2.588 million years is related to the magnetostratigraphic boundary of Gauss - Matuyama (Table 1). The Kujalnikian deposits in the Odessa region are the upper part of the upper Kujalnikian Substage, above the Tamanian beds.

The lower boundary of the Kujalnikian Regio-Stage takes place at the level of 3.6 million years, separating the cold Aidar stage and the Yarkov - the warmest in the Late Pliocene, to which the formation of the lower Poratian deposits belongs. The upper part of the lower Kujalnikian is compared with the accumulation of the upper Poratian deposits and the Bogdanovkian stage of soil formation. The climate cooling and activation of erosion activity took place between the accumulation of the lower and upper Poratian.

The beginning of the maximum Akchagilian transgression in the Black Sea coincides with a sharp cooling period (2.5-2.6 million years) and compares with the middle Akchagilian transgression of the Caspian basin. Signs of the late Akchagilian transgression in the Azov-Black Sea basin were not registered, however, according to paleomagnetic data at the Voyevodino section, it can correspond to the time of sedimentation of the Tjup-Dzhankoy sediments.

Occurrence of the Akchagilian molluscs at the basal beds of the Kujalnikian of the Priazovie requires additional research, as at that time the formation of the lower Poratian deposits took place in a warm climate. The most probable version is the invasion of Akchagilian molluscs during the cooling in the Kyzylyarian time.

Drawing the lower boundary of the Quaternary System at 2.588 million years created a number of inconsistencies in conducting geological surveys. Previously, the Kujalnikian deposits in full volume had been shown on the geological map, but by the current position of the abovementioned boundary, the upper Kujalnikian would be represented on the map of the Quaternary deposits, and the lower Kujalnikian- on the geological map. At the same time, it should be noted that 70% of the territory has already been surveyed and geological maps of scale 200,000 published. The remaining geological sheets will have a different loading and will cause some difficulties in the modeling of the geological structure of the regions and sedimentary basins in the future.

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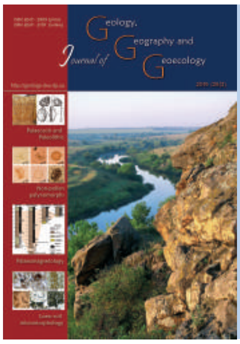

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Refined magnetostratigraphic position of the Shyrokyne unit in loess sequences from Central Ukraine

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Abstract. The youngest geomagnetic polarity reversal, the Matuyama–Brunhes boundary (MBB), which occurred 780 kyr ago, is a "golden spike" in the age calibration of sediment sequences. The use of palaeomagnetic method as a stratigraphic tool in the study of loess sequences from Ukraine originated some 50 years ago. One major problem in using the available data is the contradictory position of the MBB in different stratigraphic units, which affected historic evolution of the chronostratigraphic models of the Quaternary in Ukraine. The most important units in this regard are the Shyrokyne and Martonosha units, in which the MBB had been defined most often. This paper provides the careful analysis of the previous magnetostratigraphic data and new preliminary results from key loess-palaeosol sections in Central Ukraine. Shyrokyne palaeosol complex in four loess-palaeosol sections located in the Middle Dnieper and Podolia regions has been palaeomagnetically studied. It is shown that the transition zone of the Matuyama–Brunhes palaeomagnetic reversal is most likely located at the base of the soil complex. In the Vyazivok section the MBB has been found in the lowermost part of Shyrokyne palaeosol sh_1. Preliminary palaeomagnetic studies of the Stari Kaydaky section reveal that the MBB cannot be defined at least above sh_1 subunit. Medzhybizh and Holovchyntsi sections were deposited after the Matuyama–Brunhes reversal; however, the palaeomagnetic informativeness of the part of studied strata is doubtful. Magnetostratigraphic position of the Shyrokyne unit below the MBB in some previous studies is explained by methodological reasons and inconsistent chronostratigraphic models. The paper substantiates that normal magnetic polarity zone in the Pryazovya loess and upper part of the Shyrokyne soil is not associated with the influence of secondary processes on the palaeomagnetic record.

Key words: magnetostratigraphy, Matuyama–Brunhes boundary, palaeomagnetic method, loess-palaeosol sequence, Pleistocene, marine isotope stage 19.

Уточнене магнітостратиграфічне положення широкинського горизонту у лесових серіях Центральної України

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Анотація. Наймолодша геомагнітна інверсія полярності, границя Матуяма–Брюнес (МБ), що відбулася 780 тис. р. тому, є «золотим цвяхом» у віковому калібруванні осадових серій. Використання палеомагнітного методу як стратиграфічного інструменту при дослідженні лесових серій України бере початок близько 50 років тому. Однією з головних проблем використання наявних даних є суперечливе положення границі МБ у різних стратиграфічних горизонтах, що позначилося на історичному розвитку хронотратиграфічних моделей четвертинного періоду в Україні. Найбільш важливими підрозділами у цьому контексті є широкинський та мартоноський горизонти, в яких границя МБ визначалася найчастіше. У цій статті проведено ретельний аналіз попередніх магнітостратиграфічних даних та нових попередніх результатів ключових лесово-ґрунтових розрізів у Центральній Україні. Широкинський ґрунтовий комплекс досліджено палеомагнітним методом у чотирьох лесово-ґрунтових розрізах, що знаходяться у Середньому Придніпров'ї та на Подільській височині. Показано, що перехідна зона палеомагнітної інверсії Матуяма–Брюнес найімовірніше розташована у підошві ґрунтового комплексу. У розрізі В'язівок границю МБ було знайдено у нижній частині широкинського ґрунту sh_1. Попередні палеомагнітні дослідження розрізу Старі Кайдаки свідчать про те, що границя МБ не може бути визначена принаймні вище підгоризонту sh_1. Відклади розрізів Меджибіж і Головчинці сформувалися після інверсії Матуяма–Брюнес; однак, палеомагнітна інформативність частини досліджених шарів сумнівна. Магнітостратиграфічне положення широкинського горизонту нижче границі МБ у деяких попередніх роботах пояснюється методологічними причинами та непослідовними хроностратиграфічними моделями. У статті обгрунтовано, що зона прямої полярності у приазовському лесі та широкинському ґрунті не пов'язана із впливом вторинних процесів на палеомагнітний запис.

Ключові слова: магнітострaтиграфія, границя Матуяма–Брюнес, палеомагнітний метод, лесово-ґрунтова серія, плейстоцен, морська ізотопна стадія 19.

Introduction. Loess sequences, alternating loess and palaeosol horizons, are unique continental formations of the Quaternary. They contain one of the most complete records of global changes in the climate of this geological period, in particular, glaciations and interglaciations of the last million years, and are significantly widespread, mostly at intermediate latitudes of the Northern Hemisphere (Evans and Heller, 2003; Buggle, 2011). For this reason, loess sediments are carefully studied by various methods of environmental research, including the palaeomagnetic method.

The Matuyama–Brunhes polarity reversal, which occurred 780 kyr ago (Tauxe et al., 1996) is the key benchmark of correlation of loess-palaeosol sequences of the Quaternary, defining the Lower–Middle Pleistocene boundary. In deep-sea sediments, this reversal is fixed in the interglacial marine isotope stage (MIS) 19 (Tauxe et al., 1996).

Loess-palaeosol exposures along Dnieper, Sula and Southern Bug rivers in Central Ukraine reveal a complex succession of Quaternary palaeoenvironments over the past 0.7–1.2 million years (Veklich, 1982; Bolikhovskaya and Molodkov, 2006; Matviishyna et al., 2010; Buggle, 2011). For magnetologists the most important unit in the loess sequences is the Shyrokyne horizon (hereinafter the stratigraphic terminology is used in accord with the Stratigraphic Framework of the Pleistocene of Ukraine (Veklich et al., 1993)) – palaeosol complex consisting of three subunits: brown clayey soils of earlier optimum sh_1 and later optimum sh_3, and uncommon loess-like loam subunit sh_2 (Gozhik and Gerasimenko, 2011; Sirenko, 2017). Previously the Matuyama–Brunhes transition zone was defined by colleagues from the Institute of Geophysics (Tretyak et al., 1987; Tretyak et al., 1989; Tretyak and Vigilyanskaya, 1994; Vigilyanskaya, 2000, 2001a, 2001b, 2002) in wide range of sections most often in the lowermost sh_1 subunit. According to their generalized Pleistocene Magnetostratigraphic Scale of Ukraine (Tretyak and Vigilyanskaya, 1994), which is based on the palaeomagnetic studies of almost 60 sections in Ukraine, Moldavia and Pryazovya, the Matuyama–Brunhes boundary (MBB) is located in the Shyrokyne horizon (according to stratigraphic nomenclature of (Veklich et al., 1984)), the age of which was estimated at 730 kyr. Thus, the Shyrokyne unit should be evidently correlated with MIS 19 (Bogucki et al., 2012).

However, in the stratigraphic models, which are proposed for the Ukrainian Quaternary, the chronological placement of the Shyrokyne unit is different. It is generally argued that this pedocomplex and the respective interglaciation occurred during 0.85–1.2 Ma (Matviishyna et al., 2010) and corresponds to MIS 25 (Veklich, 1995, cited in Bolikhovskaya and Molodkov, 2006) or 21–33 (Lindner et al., 2006). Therefore, the younger Martonosha palaeosol unit is placed either in MIS 19–23 (Veklich, 1995, cited in Bolikhovskaya and Molodkov, 2006) or 17–19 (Lindner et al., 2006). Theoretical correlation with marine oxygen isotope stages of stratigraphic schemes of Ukraine, resulting from the different opinions on the chronological placement of the Shyrokyne and Martonosha units, is given in (Bakhmutov et al., 2017).

The above frameworks are based in turn on initial contradictory magnetostratigraphic data (Tretyak and Volok, 1976; Tretyak, 1980, 1983; Tretyak et al., 1980, 1986; Veklich, 1982), in which the MBB had been defined in the Berezan, Shyrokyne, Martonosha, Sula and Lubny units. Eventually, the normal polarity zone within Przyazovya loess and the upper part of the Shyrokyne soil units had been interpreted by geologists as Jaramillo event (0.98 Ma) and the MBB had been placed at the top of the Martonosha soil unit, which became the basis for following palaeogeographic reconstructions (Veklich, 1987; Lindner et al., 2004; Lindner et al., 2006; Matviishyna et al., 2010; Gozhik and Gerasimenko, 2011 and others). However when considering them, surprising unanimity in position of the MBB in several key Pleistocene sections is troubling. For example in (Lindner et al., 2004, fig. 2) the MBB in the Vyazivok section had been defined based on only one sample with anomalous polarity at the base of Sula loess (Veklich, 1982, fig. 26), and in the Roxolany section (Lindner et al., 2004, fig. 3) – one sample of reversed polarity in Martonosha soil (Tretyak, 1980, fig. 1; Tretyak, 1983, fig. 6.5). It should be recognized that most of previous results (Tretyak and Volok, 1976; Tretyak, 1980, 1983; Tretyak et al., 1980, 1986; Veklich, 1982; Veklich, 1987), carried out without effective minimization the acquisition of present-day viscous magnetization, and defined abundant magnetic events therein, cannot be taken as reliable as any stratigraphic correlations based in them (Bakhmutov and Hlavatskyi, 2016).

However, later in several sections of Southern Ukraine and Ukrainian Shield the MBB was found exactly at Martonosha horizon level (Bakhmutov et al., 2005; Sirenko et al., 2008; Slivinskaya et al., 2012), which supports the existing charts. In addition, in the Roxolany section, one of the key loess sequences of the Black Sea area, the MBB was defined recently at the contact of two soils (Bakhmutov and Hlavatskyi, 2014a, b), which were stratified by (Gozhik et al., 2007; Bogucki et al., 2013) as the Lubny and Martonosha units.

In order to resolve the problem of inconsistency between different stratigraphic positions of the MBB in loess cover of Ukraine, the most complete sections of the Quaternary should be investigated. In this study initial results, focusing on determination the MBB in key loess-palaeosol sequences of the Middle Dnieper area at Vyazivok and Stari Kaydaky are given. Additionally, new results of palaeomagnetic study of the Podolian Upland sequences – the Lower Palaeolithic sites – at Medzhybizh and Holovchyntsi are presented.

Geological setting. The *Vyazivok* section is located in the village of Vyazivok (49°33’ N, 32°98’ E) about 8 km south of Lubny of Poltava oblast on the western bank of the Sula River, a tributary of the Dnieper (Fig. 1). It represents one of the most complete Quaternary records in Ukraine and the longest section studied within Dnieper Lowland. It is characterized by 59-meter sequence of several well developed palaeosols which alternate with thick loess units. The section was studied earlier by (Veklitch et al., 1967; Matviishyna et al., 2001; Rousseau et al., 2001). The detailed description of the section which the author was guided in rock sampling is presented in (Matviishyna et al., 2001). The Shyrokyne unit in the Vyazivok section is represented by two subunits. The lower subunit sh_1, which is 1.15 m thick, consists of two substages: greyish-brown clayey soil sh_{1b1} and reddish-brown sandy-clayey soil sh_{1b2}. The upper soil subunit sh_3, which is 2.35 m thick, is chocolate-brown soil, composed of clay, more compact, prismatic, with abundant carbonate concretions at the base of soil.

The *Stari Kaydaky* (or *Stari Kodaky*) section (48°22’ N, 35°07’ E) is located south of Dnipro at the Dnieper River. The sequence comprises eight major loess-palaeosol couples. It was stratified by (Veklich and Sirenko, 1972) and was declared as reference Pleistocene section of Ukraine. The uppermost part of the section (from the Lubny unit to the Holocene unit) had been studied in particular by rock magnetic methods (Buggle et al., 2008, 2009, Buggle, 2011) and it was correlated with loess sequences of Danube basin. The Shyrokyne unit in studied exposure at Stari Kaydaky is not less than 8 m thick, which is almost twice as much its thickness in the stratotype sequence at Shyrokyne (4.5 m) (Veklich and Sirenko, 1972). It includes three subunits: subunit sh_1, which is at the minimum 3.9 m thick, subunit sh_2 (0.55 m thick) and the upper soil sh_3 (3.6 m thick). The lower subunit sh_1

Fig. 1. Location of studied sections on the map of Ukraine.

consists of the solid chocolate-brown soil, composed of clay, compacted, prismatic, with rare carbonate concretions at the base of soil, and the upper dark humus subhorizon. The middle subunit sh_2 includes thin reddish-brown loam and dark humus layer. The upper subunit sh_3 is brown clayey soil.

The *Medzhybizh-A* section (49°25' N, 27°23' E) is located in the village of Medzhybizh about 33 km east of Khmelnytskyi on the nothern bank of the River Southern Bug. Loess sequence covers the time interval from the Shyrokyne unit to the Holocene, and lies on the marine sediments of the Sarmatian time (Stepanchuk et al., 2014). It is famous archaeological site of the Lower Palaeolithic. Archaeological artifacts were found in the palaeosols of the Zavadivka, Lubny, Martonosha and Shyrokyne stratigraphic units (Stepanchuk et al., 2014, 2016). The Shyrokyne horizon is very thin (a few tens of centimeters) and is composed of sandy clay.

The *Holovchyntsi-1* section (49°25'E, 27°29'N) is located 1.3 km north of the village of Holovchyntsi and 7.5 km east of Medzhybizh-A section on the northern bank of the River Southern Bug. The section is the southern part of the current Holovchynskyi granite quarry. It was investigated by archaeologists from the Lower Palaeolithic expedition of the Institute of Archeology of the National Academy of Sciences of Ukraine in cooperation with geologists (Yu.M. Veklich, S.P. Karmazinenko, A.V. Nadvirnyak) for the first time in 2015. Initially, studied soil horizons, which are 3 m thick, were attributed by geologists to the Zavadivka or Lubny unit. Conclusions based on topography and stratigraphy of the location, as well as artifact typologies, clearly indicated the discovery of a new Lower Palaeolithic location in the region (Vetrov, 2016). Research was continued in 2016–2017 under the guidance of V.N. Stepanchuk. According to new stratigraphic interpretation of Zh.M. Matviyishina and S.P. Karmazinenko the palaeosols were already stratified as the Shyrokyne horizon and it was possible to establish a preliminary conclusion about the oldest artifacts found in Ukraine – 0.9–1.2 Ma. The interpretation of stratigraphic subdivision by Zh.M. Matviyishina and S.P. Karmazinenko has been used in this paper.

Sampling and methods. Samples for palaeomagnetic studies in the Vyazivok section have been collected in 2014–2015. 173 oriented rectangular blocks were taken from the whole sequence, which were cut into 692 oriented cubes with an edge of 2.0 cm. Samples from Shyrokyne horizon have been processed in 2014 from 2 exposures (Zupynka 1 and Zupynka 2) which represent the same units of the Lower Pleistocene.

In 2015 a total of 81 blocks were taken from the Medzybizh-A section and in 2017 – 17 blocks from the Holovchyntsi-1 section. Considering the loose state of the oriented rectangular blocks selected in the Medzhybizh-A section, it was not possible to make stable cube samples for magnetometric measurements. It was possible to make only a few oriented samples mostly from the lowermost part of the section.

Samples from Shyrokyne palaeosol in the Stari Kaydaky section have been collected over two field seasons during 2017–2018. It was difficult to reach the primary exposure because of a thick deluvium layer. 26 oriented rectangular blocks were taken. For now 65 oriented cubes from the uppermost part were cut from 11 rectangular blocks, taken in 2017. Sampling density is about every 10–20 cm.

Palaeomagnetic measurements were carried out in the laboratory of the Institute of Geophysics of the National Academy of Sciences of Ukraine (Kyiv). Partly the measurements were performed in the laboratories of Palaeomagnetism Department of the Institute of Geophysics of the Polish Academy of Sciences (Warsaw) and The Ivar Giæver Geomagnetic Laboratory hosted by the Centre for Earth Evolution and Dynamics at the University of Oslo (Oslo).

The natural remanent magnetisation (NRM) was measured using JR-6, JR-6A magnetometers and SQIUD 2G Enterprises magnetometer accompanied by an alternating field demagnetizer. All samples were subjected to stepwise thermal demagnetization (THD) up to 240–350° C and alternating field demagnetization (AFD) in fields of up to 100 mT. All measurements have been performed inside the magnetically shielded rooms to minimize the acquisition of present-day viscous magnetization.

Directions of characteristic remanent magnetization (ChRM) component has been calculated by multicomponent analysis of the demagnetization path (Kirschvink, 1980), using Remasoft 3.0 software (Chadima and Hrouda, 2006). Polarity zones were built in MPS program (Man, 2008).

Brief overview of previous results and new preliminary data. ***Vyazivok section.*** Previously the Vyazivok profile had been palaeomagnetically studied in the 1970's (Veklich, 1982). In one sample at the lowermost level of the Sula loess (the samples below were not selected) anomalous polarity had been established. It was announced that the MBB lies at the top of the Martonosha palaeosol, and it had long been thought that the Martonosha unit belongs to Matuyama chron. This conclusion was the basis for futher correlation charts of the Quaternary in Ukraine and neighboring territories (Lindner et al., 2004).

The whole sequence had been studied by (Vigilyanskaya, 2001b; composite palaeomagnetic section is in fig. 9 in (Matviishyna et al., 2001)). 233 samples were thermally demagnetized up to 250° C and 132 samples were demagnetized by alternating field up to 50 mT. The MBB was clearly defined in Shyrokyne palaeosol.

Preliminary results of palaeomagnetic and rock magnetic study of the Vyazivok section were published by author of this study with co-authors in (Hlavatskyi et al., 2016b). Most of the samples from the Shyrokyne unit and surrounding Pryazovya and Illichivsk loess units containe a high-coercivity component, removed totally only by 80–100 mT field demagnetization. In some cases it could not be destroyed even by 100 mT alternating field or 300°C temperature. According to thermomagnetic analysis the main carriers of NRM in studied rocks are magnetite and hematite. Paramagnetic minerals also play a significant role in the magnetic properties of this loess-palaeosol sequence (Hlavatskyi et al., 2016b).

Samples demagnetized by alternating field and temperature have similar positive inclination and northerly declination values for the depth interval 51.5–56.2 m. Only in two specimens above 56.2 m (from upper part of the Shyrokyne unit), which were thermally demagnetized, was a full reversal of directions observed. Other samples keep steady inclinations in average at 66°. However, data from samples below suggest a major polarity change at a depth of 56.2 m which is interpreted as evidence of the Matuyama–Brunhes polarity boundary. Samples below this level have mean ChRM inclination direction -52° and declination direction 181°. The Jaramillo subchron cannot be identified in the Vyazivok section.

Thus, the MBB was found at a depth of approximately 56.2 m in the lowermost Shyrokyne soil sh_1. After removal of viscous component, loess and soil samples display the presence of a stable hard component carried mainly by hematite.

Stari Kaydaky section. For the first time the Stari Kaydaky section was studied by A.N. Tretyak and L.I. Vigilyanskaya and the MBB was determined in the Shyrokyne palaeosol (V.G. Bakhmutov and N.P. Gerasimenko, personal communication, 2018). But any publications of A.N. Tretyak and L.I. Vigilyanskaya concerning palaeomagnetic research of the Stari Kaydaky profile cannot be found in the Institute of Geophysics library filing cabinet, as there are no appropriate references in their works. Only composite palaeomagnetic section is available. Probably, this section was studied before 1994, because Stari Kaydaky outcrop is marked as studied section on the map, attached to Pleistocene Magnetostratigraphic scale of Ukraine (Tretyak and Vigilyanskaya, 1994).

Preliminary investigations by V.G. Bakhmutov in 2006 (personal communication, 2018), in which high precision measurement equipment (including 2G Enterprises magnetometers) had been used, could not detect the geomagnetic polarity change of the MBB. The studied part of the profile included interval from the top of the Shyrokyne unit (uppermost part with a thickness of 1.5 m) to the Holocene soil. In all layers, including top of sh_3 subunit as the overlying Pryazovya loess and Martonosha palaeosol units, exceptionally normal polarity was observed.

Works on demagnetization of samples of the lowermost layers are currently in progress. For now, a pilot collection of 24 specimens from the entire thickness of the sh_3 and sh_2 subunits, and from upper humus subhorizon of sh_1 subunit have been treated by temperature up to 300°C. Since most of the specimens were fragile, they cannot be heated to temperatures above 300°C and few steps of demagnetization at temperatures 210, 240, 270 and 300°C have been carried out. After stepwise THD objectively one stable component is observed on the orthogonal vector diagrams (Fig. 2a,b), which is not totally removed by temperature of 300°C. Probably the secondary component overprint was demagnetized at temperatures lower than 210°C, but incomplete demagnetization also is possible. In most samples the component, which was accepted as characteristic, decays linearly towards the origin, with only normal directions indicating the formation of studied subunits during the Brunhes chron.

Average value of bulk magnetic susceptibility is 310×10^{-6} unit SI, which is the same as in the Shyrokyne unit of the Vyazivok section (318×10^{-6} unit SI). These values indicate typical for loess-palaeosol series of Ukraine concentration of magnetic minerals.

Full details of the further palaeomagnetic data from the Stari Kaydaky section require a separate paper and will be presented in future submissions.

Medzhybizh and Holovchyntsi sections. Complex rock magnetic and palaeomagnetic studies of the Medzhybizh-A and Holovchyntsi-1 loess-palaeosol sections for the first time were performed by (Bakhmutov et al., 2018) in order to determine the suitability of these objects for palaeomagnetic study and the establishment of magnetostratigraphic markers.

The deposits of the Medzhybizh-A and Holovchyntsi-1 sections are characterized by low values of magnetic susceptibility, which indicates an insignificant content of magnetic minerals, especially in the Medzhybizh-A section (in average 82×10^{-9} m^3/kg, in contrast to 178×10^{-9} m^3/kg in the Holovchyntsi section, Fig. 3). Investigated sections by rock mag-

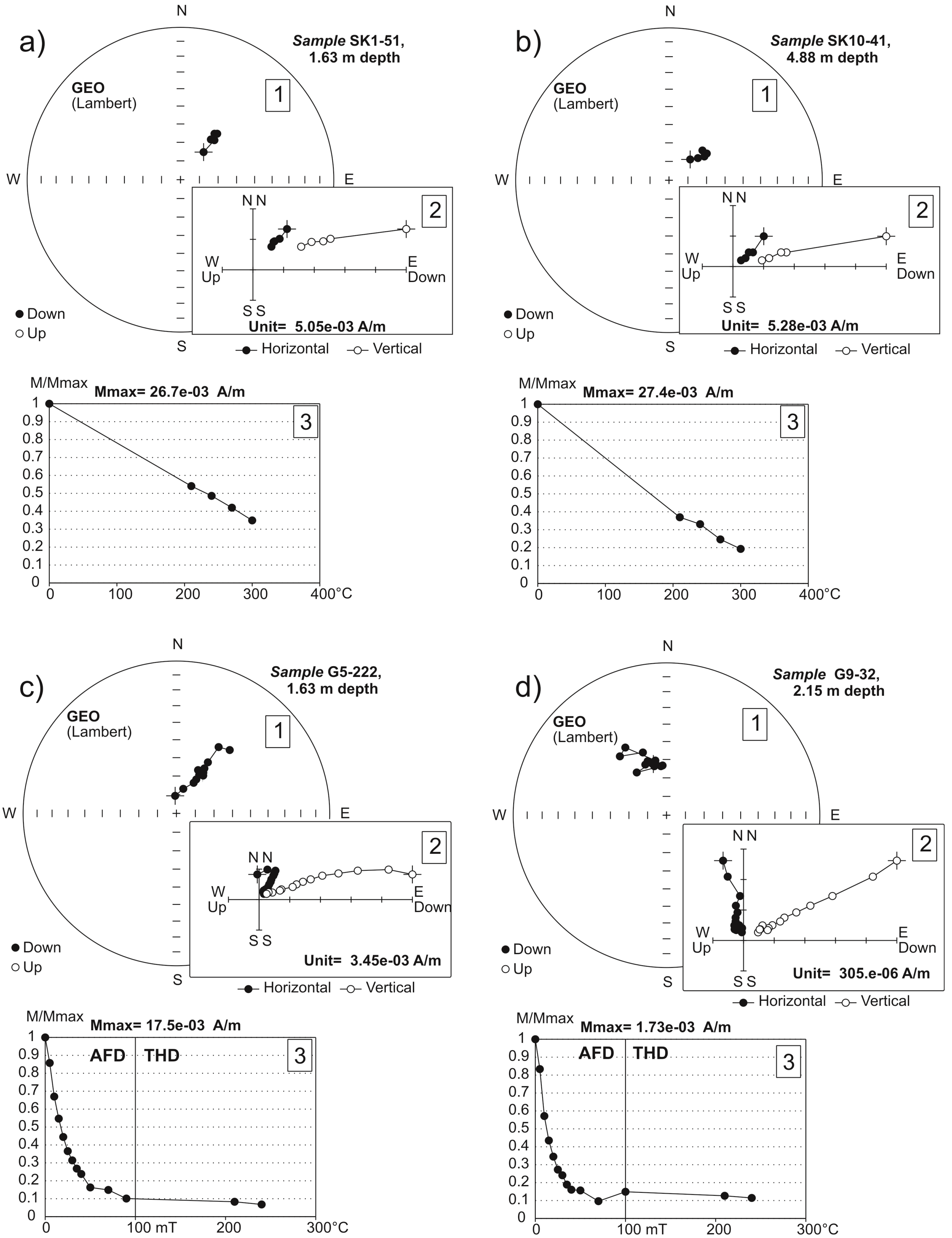

Fig. 2. Examples of stepwise thermal (a, b) demagnetization of soil samples from the Shyrokyne unit in the Stari Kaydaky section, and alternating field and following thermal (c, d) demagnetization of soil samples from the Shyrokyne unit in the Holovchyntsi-1 section.

1 – stereographic projections of demagnetization directions, *2* – orthogonal demagnetization projections, *3* – intensity decay curves of NRM.

netic characteristics are closest to the sections of the Volynian Upland, and refer to the intermediate "Chinese" type of formation of magnetic properties with an admixture of the "Alaskan" mechanism (Hlavatskyi et al., 2016a; Bakhmutov et al, 2017).

Most of the samples from both sections have visually disturbed texture, which is confirmed by anomalous data on the anisotropy of the magnetic susceptibility. In interpretation of (Bakhmutov et al., 2018), it reflects the orientation of ferrimagnetic grains due to currents, slope processes, winds etc. Samples, in which the primary magnetic texture is not broken, were selected for further laboratory palaeomagnetic studies.

In order to determine characteristic component of NRM a pilot collection of the samples from both sections has been demagnetized by stepwise AFD up to 100 mT (using cryogenic SQUID magnetometer 2G Enterprises with an in-line alternating field demagnetizer), and THD up to 240–350°C. Most of the samples show ChRM directions of normal polarity (Fig. 2c, d). Below the soil horizon sh_3 in the Holovchyntsi-1 section the NRM and ChRM values decrease in average to 1×10^{-3} mA/m and 0.5×10^{-3} mA/m, respectively (Fig. 3), and the samples show a large scatter of the ChRM directions with predominantly anomalous polarity.

Taking into account the secondary changes in the deposits, the minimum values of the remanent magnetization in the soil, the small thickness of the section as a whole, it is not possible to reliably determine the primary component of the magnetization in the deposits within the lowermost layers. Statistical characteristics of NRM and ChRM after demagnetization by magnetic field and temperature are shown in fig. 3 in (Bakhmutov et al., 2018). The average values for the directions of the NRM and ChRM components within sh_3 subunit agree within 95% and 99% confidence limits and indicate a direction close to the current geomagnetic field in the area (Fig. 3).

The results of palaeomagnetic studies turned out to be uninformative for the most layers of the Medzhybizh-A section and for the lowermost part of the Holovchyntsi-1 section (sh_1 subunit) because of

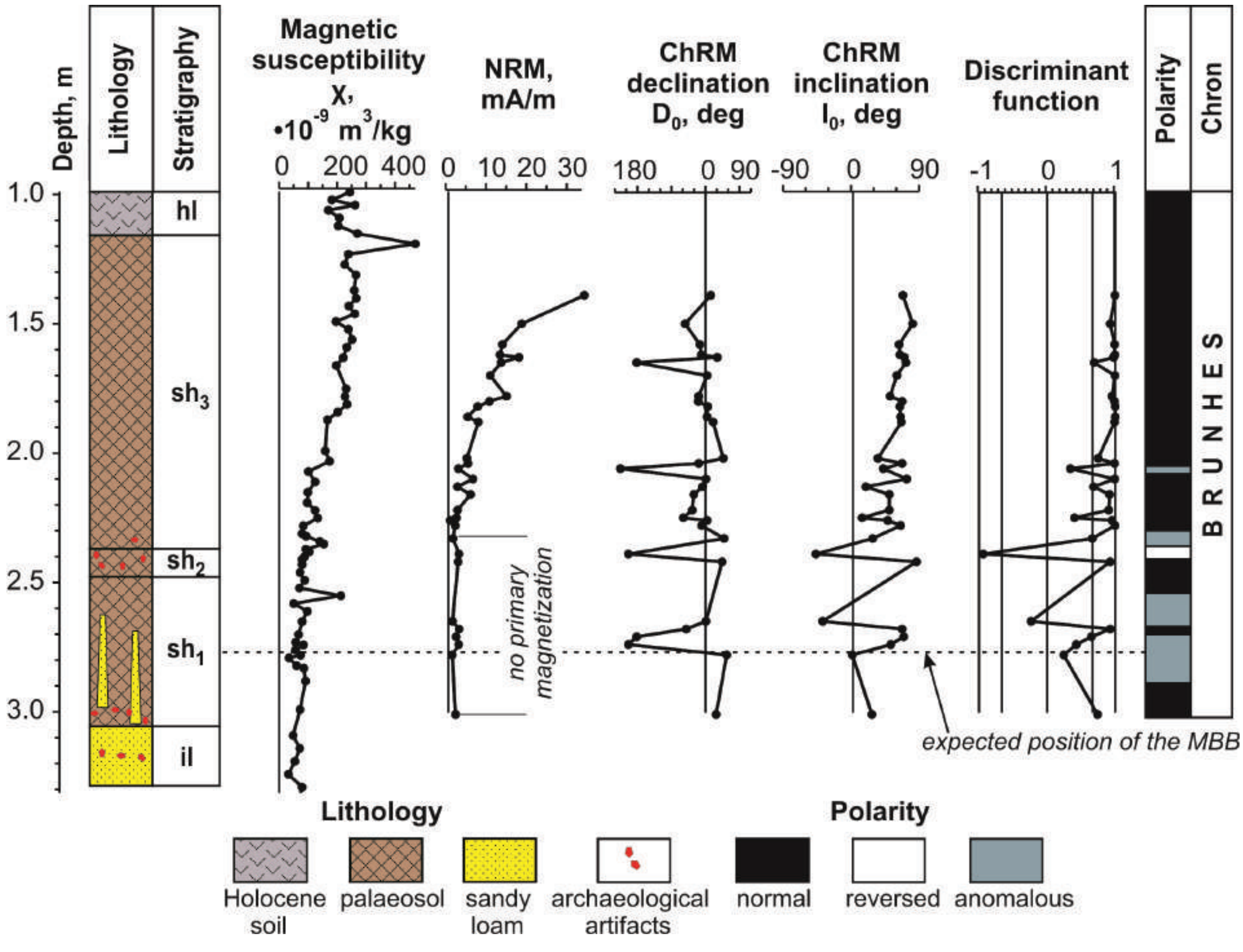

Fig. 3. Results of palaeomagnetic study of the Holovchyntsi-1 section: lithostratigraphy (Matviishyna and Karmazinenko, 2017), magnetic susceptibility, normal remanent magnetization, ChRM directions, discriminant function and palaeomagnetic chart.

the almost complete absence of ferrimagnetic material and the disturbance of the sedimentary magnetic texture of the rocks. The entire loess-soil stratum of the Medzhybizh section according to preliminary data can be attributed to the Brunhes chron, i.e. the age of the rocks in the section does not exceed 780 kyr. In the Holovchyntsi-1 section the Matuyama–Brunhes boundary also was not clearly identified. The polarity is reliably allocated only in the upper soil sh_3.

Discussion. Preliminary palaeomagnetic data obtained in key Pleistocene sections of the Middle Dnieper region in contrast to most of current palaeogeographic reconstructions (Veklich, 1995 cited in Bolikhovskaya and Molodkov, 2006; Matviishyna et al., 2010; Gozhik and Gerasimenko, 2011) and in agreement with the earlier conclusions in (Tretyak and Vigilyanskaya, 1994; Vigilyanskaya, 2001a, b) and the latter correlation model (Bogucki et al., 2012) manifest the position of the MBB in the lowermost part of the Shyrokyne pedocomplex. In the Vyazivok section the MBB was found in the Shyrokyne palaeosol subunit sh_1, which is in full agreement with previous data, obtained by Vigilyanskaya (2001b). Preliminary investigations, obtained by V.G. Bakhmutov in 2006 and ongoing study of Stari Kaydaky profile cannot indicate evidence of the MBB boundary at least above sh_1 subunit (Fig. 4).

The Medzhybizh-A section and the lowermost part of the Holovchyntsi-1 section from Podolia region are characterized by low concentration of ferrimagnetic material, the destruction of the primary sedimentary magnetic texture, which makes them unsuitable for qualitative magnetostratigraphic studies. Additionally, the Medzhybizh-A section has very small thickness of stratigraphic units (Fig. 4). A zone of normal polarity, probably the Brunhes chron, has been reliably determined in the uppermost part of the Holovchyntsi-1 section (sh_3 subunit). The palaeomagnetic veracity of the remaining investigated layers is questioned. Unfortunately, reliable data on the MBB and, correspondingly, data on the age of any layers with artifacts in the Medzhybizh-A and the Holovchyntsi-1 sections more than 780 kyr have not been obtained from the results of palaeomagnetic studies.

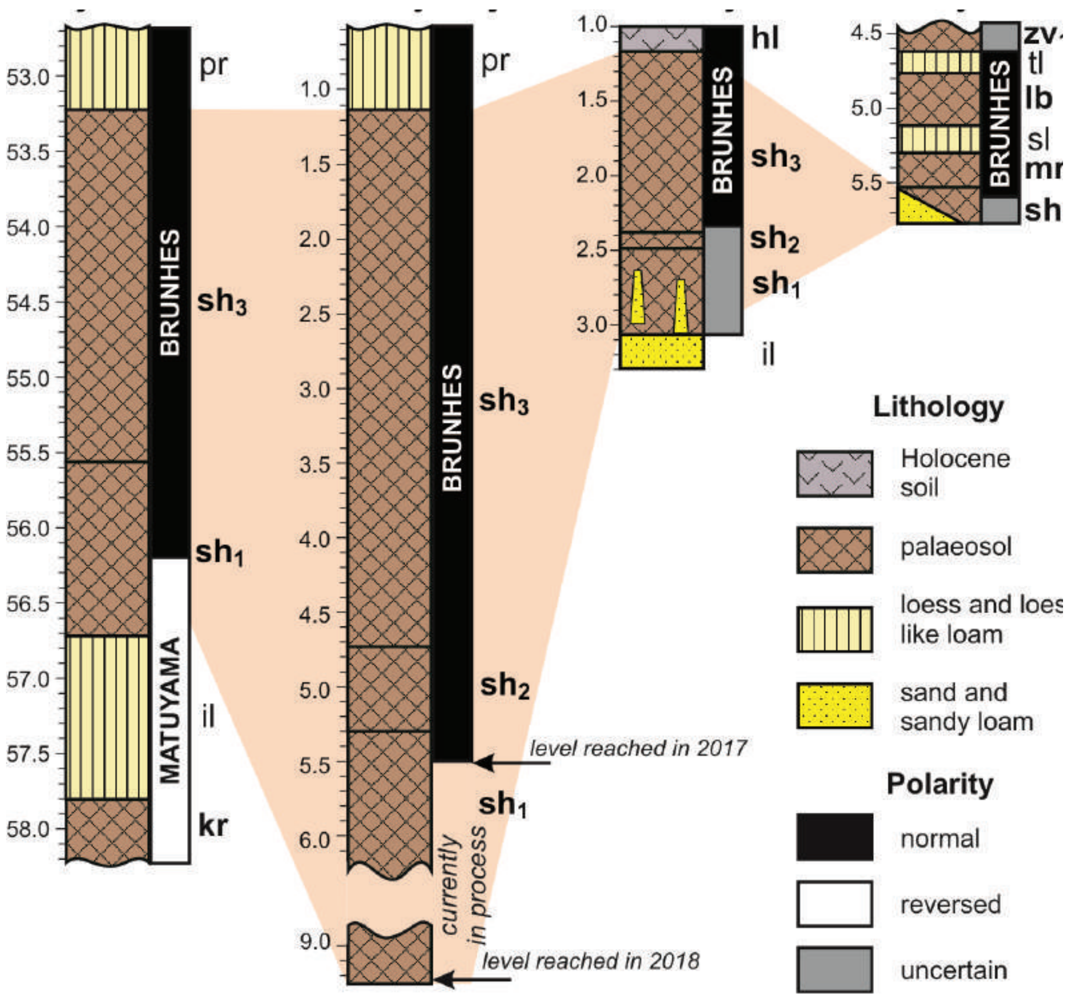

Fig. 4. Comparison chart of Shyrokyne palaeosol complex in the Vyazivok, Stari Kaydaky, Holovchyntsi and Medzhybizh sections.

These results further supports that the Shyrokyne palaeosol unit should be comparable to the marine oxygen isotope stage 19 (as well as in (Bogucki et al., 2012)) rather than 25 (Veklich, 1995, cited in Bolikhovskaya and Molodkov, 2006) or 21–33 (Lindner et al., 2006).

Inconsistencies in the stratigraphic position of the MBB in the Shyrokyne and Martonosha units relative to the national stratigraphic scheme (Veklich et al., 1993) in different studies could be caused by following factors: 1) ambiguous physical definition of the palaeoclimatic boundaries; 2) the relatively low sampling resolution of some previous studies; 3) methodological difficulties in determination of the ChRM component; 4) inconsistent or incorrect stratigraphic subdivisions of Pleistocene loess-palaeosol series in some studies. They are not evidently associated with the influence of secondary magnetization processes on the palaeomagnetic record because of a huge distance between the Shyrokyne and Martonosha units in the Middle Dnieper sequences (3–13 m). Even for thick Chinese loess sequences lock-in effect exceed not more 2–3 m (Tauxe et al., 1996; Zhou and Shackleton, 1999; Spassov et al., 2003; Liu et al., 2008). Since the MBB was defined in loess series of Ukraine much more often in palaeosol, it should be stratigraphically the same horizon.

Furthermore, the determination of the position of the MBB in loess sections should take into account the fact that loess sediments are affected by soil formation processes less than compared to soils (Bolshakov, 2008). Therefore, the overprinting effect of chemical magnetization in loess is less significant. Thus, loess can serve as a barrier against palaeomagnetic lock-in depth due to secondary chemical processes. In other words, if the Matuyama–Brunhes reversal is synchronous with the formation of a part of soil horizon, the palaeomagnetic record of the reversal in general cannot be displaced appreciably below the boundary between the soil and underlying loess (Bolshakov, 2008). The Pryazovya loess unit below the Martonosha unit in the Vyazivok and Stari Kaydaky sections has completely normal polarity, which excludes secondary processes overprint on the palaeomagnetic record in above layers. Notably, in earlier works (Veklich, 1982; Veklich, 1987), in which the MBB had been placed in the Martonosha unit, the entire underlying Pryazovya loess has normal polarity and it was mistakenly attributed to Jaramillo excursion.

Magnetic and palaeomagnetic characteristics of the key sections of the Ukrainian loess sequences composed of various types of loess-palaeosol horizons should be carefully studied and an integrated palaeogeographic analysis of the sediments should be conducted in order to compare climatic conditions of the formation of loess and soil units located around the MBB in different sequences. Clarifying the question of stratigraphic position of the MBB in key loess series of Ukraine allows recognizing the most objective chronostratigraphic marker and would help to correlate them with other loess sequences across Eurasia.

Conclussions.

Using multiple tools of measurements in different palaeomagnetic laboratories, the MBB was identified in the Vyazivok section at the Shyrokyne lowermost palaeosol sh_1 subunit.

In the Stari Kaydaky section the MBB cannot be defined at least above Shyrokyne sh_1 subunit. Further study is currently in progress to identify polarity reversal in underlying layers.

Among studied sections in Podolian Upland only the uppermost part of the Holovchyntsi section (subhorizon sh_3) has been turned out to be acceptable for palaeomagnetic studies, in which the Brunhes chron of normal polarity has been reliably determined. The palaeomagnetic informativeness of the rest of the studied strata is questionable.

In the present Ukrainian stratigraphic system the chronological setting of the Shyrokyne and Martonosha units is regarded in different ways. It appears most reasonable (at least in studied sequences) to correlate the Shyrokyne complex with MIS 19, and the Martonosha unit with MIS 17. This correlation supports the stratigraphic model of (Bogucki et al., 2012).

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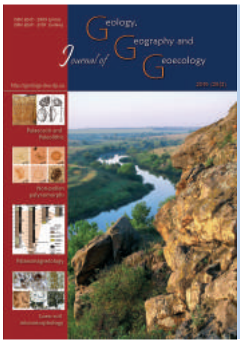

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Pleistocene soils of the Azov Lowland, Ukraine

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Abstract. With the aim to reconstruct the Pleistocene soils in Azov Lowland (geological sections near the villages of Bezimenne and Melekine Donetsk region), we carried out palaeopedological research. The Paleopedological method was used, which consisted with a detailed analysis of the morphological (color, structure, granulometric composition, humidity, composition, neoplasms, inclusion, transition between horizons, border) and micromorphological (skeleton, plasma, color, aggregation, porosity, organic and clay parts, mineral skeleton, tumors, microstructure) features. Paleopedological studies of Pleistocene soils have allowed to determine the types of these deposits and to follow the dynamics of changes in soil conditions: - warm-temperate with signs and close to subtropical, when formed reddish cinnamon (kr$_{b1}$), reddish brown (kr$_{b2}$), cinnamonish-brown (sh$_{b1}$), reddish cinnamon (sh$_{b2}$), dark-colour (meadow reddish cinnamon) merged (mrb2 + mr$_{b1}$), reddish cinnamon, brownish, fused saline soils (mr$_{3}$) Kryzhanivka, Shyrokyno and Martonosha soils, which are distinguished by reddish shades of coloring of the profiles, are the most ferruginous, clay, with a large number of nodules witch concentration of organo-iron-clay material; - moderately-warm transition to subtropical – red-brown saline (lb$_{b2}$), dark-colour (brownish-cinnamonic) fused (lb$_{b2}$ + lb$_{b1}$) heavy loam Lubny soils, with are less clayed, ferruginous and formed in meadow-steppe and steppe conditions (brownish-gray with cinnamonish shades of coloring profiles, the presence of moleholes, complex microaggregation); - moderately variable – humid close to subtropical – cinnamon and cinnamon saline (zv$_{b1}$), reddish-cinnamon saline (zv$_{b2}$), heavy loam Zavadivka soils, which are a transitional variant to temperate climates, although some of the features of the lower Pleistocene soil formation are retained (ferrugination, presence of segregated clusters organo-clay and clay materials, microortshteins); - moderately-warm equally humid – cinnamon-brown (kd$_{b1}$), ordinary chernozems (kd$_{b2}$), cinnamonish-gray saline (pl$_{b1}$), chernozem saline (pl$_{b2}$), brown steppe (pl$_{c}$), heavy and medium loam Kaydaky and Pryluky soils, characterized by the grayish shades of coloring of profiles, the presence of moleholes, carbonates, complex microaggregates, pores and are closest to modern soils; - moderately-warm subarid – cinnamonish-brown (vt$_{b2}$) heavy loam Vytachiv soils formed under the influence of turf (the presence of crust, carbonate, complex microaggregates) and brown-liked (cinnamonish-brown color of the profile, spatial structure of clays) of soil formation processes and have no analogues in modern soil cover; - moderately-continental and more arid (dry) – chernozems saline (df$_{b2}$), brown saline (df$_{c}$), desert-steppe fulvous (df$_{c}$), medium loam Dofinivka soils, with clear features of xeromorphism (low profile power, its carbonate, lack of signs of organo-mineral materials) replacing.

Key words: paleopedology, Pleistocene, palaeosol morpho-, and micromorphology.

Плейстоценові ґрунти Приазовської низовини території України

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Анотація. З метою реконструкцій плейстоценових ґрунтів на території Приазовської низовини (геологічні розрізи біля сіл Безіменне і Мелекіне Донецька область) нами були проведені палеопедологічні дослідження. При їх дослідженні був застосований палеопедологічний метод, що полягав у детальному аналізі їх морфологічних (забарвлення, структура, гранулометричний склад, вологість, складення, новоутворення, включення, перехід між горизонтами, межа) і мікроморфологічних (скелет, плазма, колір, агрегованість, пористість, органічна і глиниста частини, мінеральний скелет, новоутворення, мікроструктура) особливостей. Проведені палеопедологічні дослідження плейстоценових ґрунтів дозволили встановити типи цих відкладів та прослідкувати динаміку змін умов їх ґрунтоутворення: - тепло-помірних з ознаками і близьких до субтропічних, коли формувалися червонувато-коричневі (kr$_{b1}$), червонувато-бурі (kr$_{b2}$), коричнювато-бурі (sh$_{b1}$), червонувато-коричневі (sh$_{b2}$), темноколірні (лучно-червонувато-коричневі) злиті (mr$_{b2}$+mr$_{b1}$), червонувато-коричневі буруваті злиті солонцюваті (mr$_{3}$) крижанівські, широкинські і мартоноські ґрунти, які вирізняються червонуватими відтінками забарвлення профілів, є найбільш озалізненими, глинистими, із великою кількістю ооїдоподібних стяжінь органо-залізисто-глинистої речовини;

- помірно-теплих перехідних до субтропічних – червоно-бурі солонцюваті (lb_{b2}), темноколірні (бурувато-коричневі) злиті (lb_{b2}+ lb_{b1}) важкосуглинкові лубенські ґрунти, є менш оглиненими, озалізненими і формувалися у лучно-степових і степових умовах (бурувато-сірі з коричнюватим відтінком забарвлення профілів, наявність кротовин, складна мікроагрегованість); - помірних змінно-вологих близьких до субтропічних – коричневі і коричневі солонцюваті (zv_{b1}), червонувато-коричневі солонцюваті (zv_{b2}) важкосуглинкові завадівські ґрунти, які представляють собою перехідний варіант до ґрунтів помірного клімату, хоча зберігають деякі риси нижньоплейстоценового ґрунтоутворення (озалізненість, наявність сегрегаційних скупчень органо-глинистої і глинистої речовини, мікроорштейнів); - помірно-теплих рівномірно вологих – коричнювато-бурі (kd_{b1}), чорноземи звичайні (kd_{b2}), коричнювато-сірі солонцюваті (pl_{b1}), чорноземи солонцюваті (pl_{b2}), бурі степові (plc) важко- і середньосуглинкові кайдацькі і прилуцькі ґрунти, які характеризуються сіруватими відтінками забарвлення профілів, наявністю кротовин, карбонатів, складних мікроагрегатів, пор і є найбільш близькими до сучасних ґрунтів; - помірно-теплих субаридних – коричнювато-бурі (vt_{b2}) важкосуглинкові витачівські ґрунти, що формувалися під впливом дернового (наявність кротовин, карбонатність, складна мікроагрегованість) і буроземоподібного (коричнювато-буре забарвлення профілю, лускувата структура глин) ґрунтоутворювального процесів і не мають аналогів у сучасному ґрунтовому покриві; - помірно-континентальних і аридніших (сухих) – чорноземи солонцюваті (df_{b2}), бурі солонцюваті (df_c), бурі пустельно-степові (df_c) середньосуглинкові дофінівські ґрунти, з чіткими рисами ксероморфізму (мала потужність профілю, його карбонатність, відсутність ознак перерозподілу органо-мінеральних речовин).

Ключові слова: палеопедологія, плейстоцен, ґрунти, морфо-, мікроморфологія.

Introduction. The Pleistocene soils, which started to develop about 2.6 million years ago, are one of the most important indices for palaeogeographical reconstructions of this period. They are peculiar natural indicators, phenomena and «monuments» of the ancient natural conditions of the time of their formation. No wonder the fossil soils are considered as a kind of archaeological paleogeographic information. Paleopedology, the branch of paleogeography (the science about the ancient geographic sphere and the nature of the Earth's surface), which studies ancient (fossil) soils, deals with the study of fossil Holocene, Pleistocene, Pliocene and more ancient soils and deposits (Veklych e. a., 1979).

Prerequisite for conducting paleopedological studies of Pleistocene soils in the Azov Lowland is the presence on the Azov Sea of the outskirts of the Pleistocene and somewhere more ancient Neogene deposits. Since the Azov lowland is a stratotype region of the Pliocene-Pleistocene deposits in the southern part of Ukraine. Paleopedological investigations on this territory (sites near Mariupol, Shirokine village) were conducted by M.F. Veklych, N.O. Sirenko, Zh.M. Matviishyna (Veklych, 1968, 1982; Veklych, Sirenko, 1972; Veklych e. a., 1973) and later by the author (Karmazinenko, 2013, 2014, 2017).

Matherial and methods of research. In the study of Pleistocene soils in the Azov Lowland, a paleopedological method was used which based on the study of morphology (color, structure, granulometric composition, humidity, composition, neoplasm, inclusion, transition between horizons, boundaries) and micromorphological (skeleton, plasma, color, aggregate, porosity, organic and clay portions, mineral skeleton, neoplasms, microstructure) of the features of ancient deposits (Veklych e. a., 1979; Karmazinenko, 2010; Matviishyna, 1982).

In order to reconstruct the Pleistocene soils in the Azov Lowland, the author carried out field paleopedological research of Pleistocene soils of Kryzhanivka (kr), Shyrokyno (sh), Martonosha (mr), Lubny (lb), Zavadivka (zv), Kaydaky (kd), Pryluky (pl), Vytachiv (vt), Dofinivka (df) stratigraphic horizons (Veklych e. a., 1993; Gozhik e. a., 2012) of the villages of Bezimenne (5 clearings) and Melekine (7 clearings) of the Donetsk region. It should be noted that in order to clarify the genesis of the Pleistocene soils, we first used a micromorphological analysis (200 thin section with undisturbed structure were analyzed under a polarization microscope).

Results and their analysis. On the basis of the results of Paleopedological (morphological and micromorphological) studies of Pleistocene soils of Kryzhanivka (kr), Shyrokyno (sh), Martonosha (mr), Lubny (lb), Zavadivka (zv), Kaydaky (kd), Pryluky (pl), Vytachiv (vt), the Dofinivka (df), stratigraphic horizons (Veklych e. a., 1993; Gozhik e. a., 2012), a change of paleogeographic conditions during the specified stages in the Azov lowlands was observed.

Kryzhanivka horizon (OIS – 53-41 (Veklych e. a., 1993; Gozhik e. a., 2012). Kryzhanivka age formation were studied near village Melekine. They represented by soils of climatic optimum: reddish-brown (kr_{b2}) and reddish-cinnamon (kr_{b1}). Characteristic features of their morpho- and microstructure are: reddish shades of coloration, ferrugination (studied soils, among all the studied are most ferruginous), clayed, in the microstructure the presence of segregation of clay and iron-clay material, impregnation of the plasma by microcrystalline calcite.

The upper reddish-brown soil of the climatic optimum (kr_{b2}) in its microstructure reflects the signs of the processes of some transition to steppe of landscapes (the development of simple and complex microaggregates, intense penetration of plasma by microcrystalline calcite in the lower part of the profile). Although, the presence of nodules with concentration of iron-clay material, microortshteins in soils is evidence of an alternating humid regime during their formation (Fig.1).

2012). By paleopedological data on the territory of the Azov Lowland were characterized with reddish-cinnamon (sh_{b2}) and cinnamonish-brown (sh_{b1}) soils, which as Kryzhanivka, are subarid soil formation.

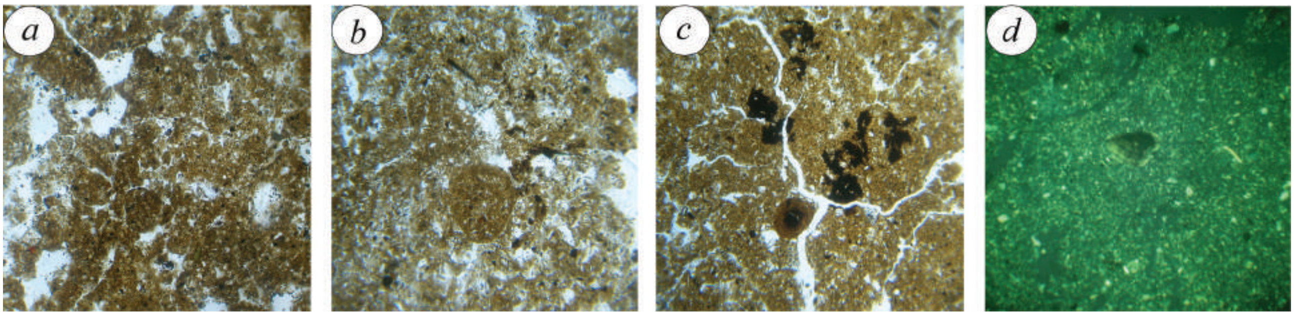

Fig.1. Microstructure of reddish-brown (kr_{b2}) Kryzhanivka soil (village of Melekine): *a* – round form of accumulation of iron-clay material; *b* – segregation of iron-clay material; *c* – iron-manganese stains and microortshteins on the background of iron-clay plasma; *d* – plasma infiltration by microcrystalline calcite (*a-c* – nic. ||, *d* – nic. +, magnification 100)

Lower reddish-brown soil (kr_{b1}) reflects somewhat damper conditions of its formation compared to the upper ones. It is more ferruginous, clayed, in the microstructure, signs of reorientation of clay and iron-clay material with concentrations of ferruginous mull humus in the bundles and lumps are defined. Clay and iron-clay plasma in the lower part is more impregnated with microcrystalline calcite, as well as more intensely colored with oxides and hydroxides of iron and manganese near pores (Fig.2).

The upper reddish-cinnamon soil (sh_{b2}), investigated in the section village Melekine, is somewhat lixiviated from carbonates (in the lower part their number increases – carbonate-clay plasma is impregnated with microcrystalline calcite) and is characterized by a nuttish-prismatic structure, an argillaceous composition, in the form of blocks with a large number of nodules witch concentration of organo-clay material (Fig.3). The type of the profile, the intensive ferrugination, claying, which is most defined in the middle part of the profile, the features of lixiviation indicate the signs of warmer and humid conditions of soil formation, compared with the Martonosha and Lubny soils of the lower Pleistocene.

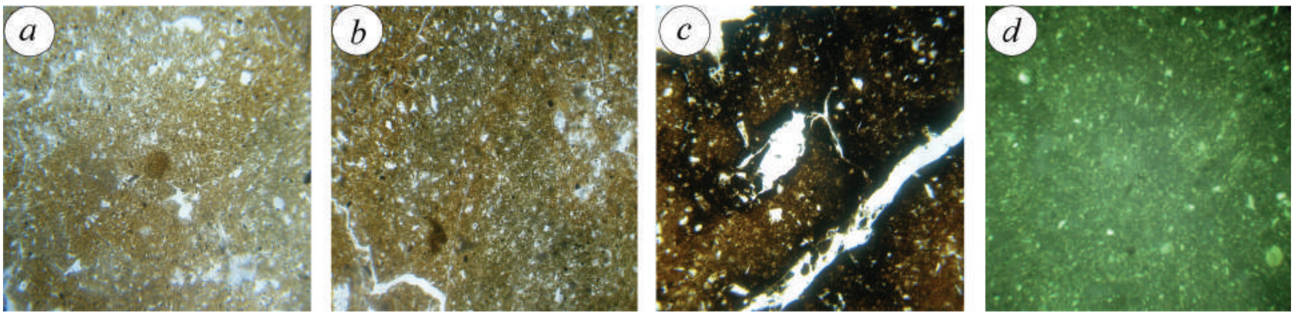

Fig. 2. Microstructure of reddish-brown (kr_{b1}) Kryzhanivka soil (village of Melekine): *a, b* – signs of displacement of clay and iron-clay material; *c* – concentration of clay material impregnated with hydroxides and iron oxides and manganese near pores; *d* – plasma penetration by microcrystalline calcite; (*a-c* – nic. ||, *d* – nic. +, magnification 100)

The indicated signs (capacity of the profile, clay composition, ferrugination, reddish shades in color) show that formation of Kryzhanivka soil was in a warm, moist (change-humid), close to arid subtropical climate. But at the same time, the soils reflect the intensification of the processes of steppe growing in landscapes (if compare with the northern territories where reddish, red-brown, alkali free forest and meadow soils were formed), they changed with more steppe differences – red-brown (kr_{b2}) and reddish-cinnamon (kr_{b1}) carbonated.

Shyrokyno horizon (OIS – 35-21) (Gozhik e. a.,

The lower cinnamonish-brown soil (sh_{b1} – the vil. of Bezimenne) differs from the reddish-brown (sh_{b2}) stronger profile (1.50m), is much clayed, ferruginous, carbonate, with a significant development of complex microaggregates of the I-II order, the presence of nodules with concentration of organo-clay, clay and iron-clay material (their formation is probably connected with meadow processes and with periodic

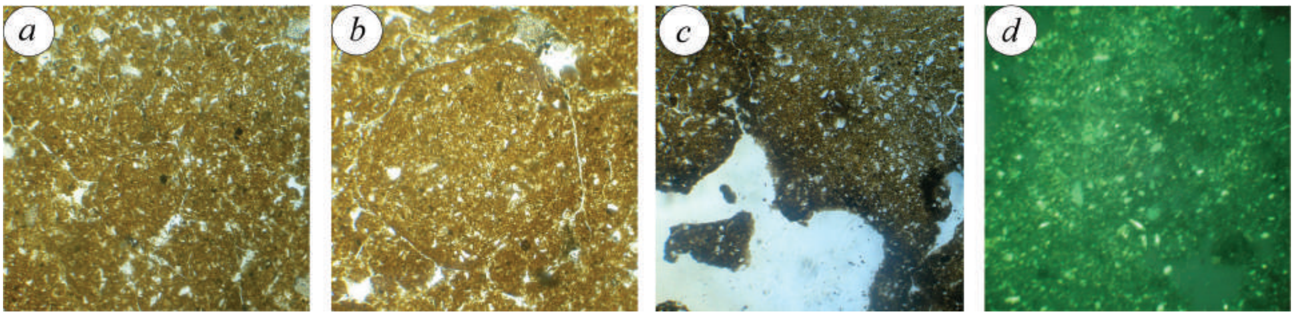

Fig. 3. Microstructure of reddish-cinnamon (sh_{b2}) Shyrokyno soil (village of Melekine): *a* – segregational clusters of organo-clay material separated by pores; *b* – large (0,7 mm) cluster of iron-clay material; *c* – carbonate-clay plasma, paintwork pores with oxides and hydroxides of iron and manganese; *d* – uniform concentration of grains of microcrystalline calcite in plasma; (*a-c* – nic. ||, *d* – nic. +, magnification 100)

excess moisture), iron-clay microortshteins (processes of redistribution of iron oxides and manganese, pulling them to the edges of pores-cracks), microcrystalline calcite (Fig.4). All these signs indicate a somewhat wetter conditions for the formation of this soil.

Shyrokyno soils are quite close to the Martonosha signs, but they are characterized by a more intense reddish tinge of the color of the profile, they are more ferruginous (iron-clay plasma), clayed (the number of nodules witch concentration of organo-clay, clay and iron-clay material is much larger). In comparison with the soils which were formed to the north, the studied soils of the Azov Lowland is differed in a higher position of the carbonate horizon, the presence along with the blocks of aggregate microconsolidations and the impregnation of the plasma by microcrystalline calcite in the middle and lower parts of the profiles, indicating somewhat arid conditions of the warm-moderate close to subtropical climate.

Martonosha horizon (OIS – 19-17) (Gozhik e. a., 2012). On the territory of the study during the Martonosha period soils, as in well as the Shyrokyno and Kryzhanivka time, are characterized by a reddish tinge of the color of the profile, are clayed, ferruginous.

Near village of Melekine dark-colored fused soils (2.0m thickness) were developed. They are characterized by a dark gray with a reddish tinge color of the profile, are more clayed and ferruginous compared with the Lubny and form one polygenetic profile in which some soil formation stages ($mr_{b2}+mr_{b1}$) are combined. The meadow-reddish-cinnamon dark-colored soil of the climatic optimum mr_{b2} is lixiviated from carbonates ("washed" carbonates accumulate in cinnamonish-brown loess-liked material (Pikgl (mr_{b2})), with carbonate concretions, light carbonate-clay plasma and clusters of microcrystalline calcite), with gypsum and shows signs of nettish orientation of clay with spots of manganese in the lower part (Fig.5). The material of the reddish-light-brown dark-colored soil of the climatic optimum, mr_{b1}, is more ferruginous (enriched in iron and aluminum compounds), clayed (presence of clay particles) and with carbonate (concretions) compared to the upper (mr_3). For the soil also characterized by a lesser manifestation of the signs of reorientation of clay and skeletal material and some gleying (meadow formation conditions).

In Martonosha time in the section village of Bezimenne were investigated reddish-cinnamon-brownish fused saline soils (1.0m) mr_3 substrage, with features of the steppe (in the upper and middle

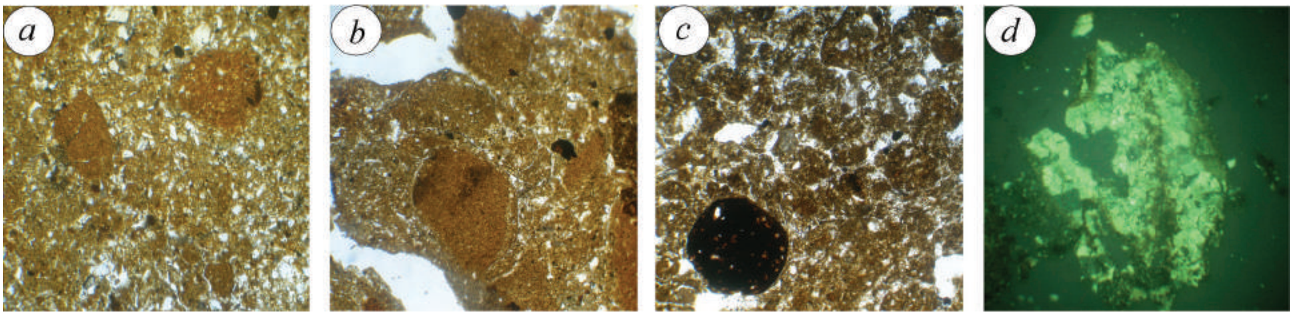

Fig. 4. Microstructure of cinnamonish-brown (sh_{b1}) Shyrokyno soil (village of Bezimenne): *a* – uniform impregnarit of plasma by iron-clay material, nodules, clusters of iron-clay material; *b* – round segregational clusters of clay and iron-clay material; *c* – iron-manganese microortshteins, uniform plasma impregnation with humus and its rounded clusters; *d* – accumulation of fine-crystalline calcite grains (*a-c* – nic. ||, *d* – nic. +, magnification 100)

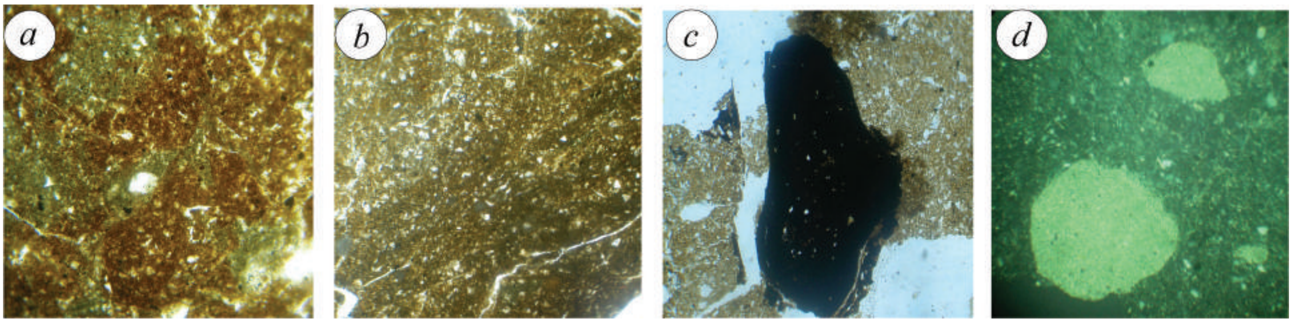

Fig. 5. Microstructure of dark-colored (meadow-reddish-cinnamonic) fused – mr_{b2} + mr_{b1}) Martonosha soils (village of Melekine): *a* – rounded clusters of iron-clay material; *b* – displacement of clay and skeletal material; *c* – iron-manganese microortshteins elongated form; *d* – the rounded concentration of microcrystalline calcite in a plasma; (*a-c* – nic. ||, *d* – nic. +, magnification 100)

sections of the profile – the development of complex microaggregates to the III order and the nodules witch segregations of the organ-iron-clay material, the isolation of calcite in plasma, and about pores throughout the profile) and meadow (in the bottom – the presence of glayed micro-sections and gypsum, slight movement of clay) soil formation (Fig.6).

Compared to the Kryzhanivka and Shyrokyno, the Martonosha soils are characterized by less thickness of soil profiles, with a lack of well-defined genetic horizons, are not so ferruginous (though they are noticeably enriched in hydroxides of iron and aluminum) and clayed, with less number of nodules with concentration of organo-iron-clay material. The soils also have dark brown and reddish-dark-cinnamonic color (the highest intensity of reddish coloration in the middle part of the profile), compactness, fusion, high clayed with microforms of some mobility of clays, manganese and iron along the pores with the impregnation of plasma by microcrystalline calcite. All this determines their high viscosity in the humid state and fusibility, density and cracks in drying. Increased Martonosha soil hydromorphism is due, apparently, not only to the abundance of atmospheric precipitation, but also to the close occurrence of ground water. Soils of different stages often form a polygenetic profile and reflect an increase in signs of xerophyticity that was characteristic of the conditions of the southern and southeastern parts of Ukraine. All these features indicate the conditions of formation of these enriched, composed in the form of blocks with organo-clay soils, when the climatic conditions were warm-temperate and close to subtropical ones (warmer in comparison with the Zavadivka and especially the Lubny soils). Probably in the first half of the optimum the climate was relatively humid, in the second – the variable-humid, close to the climate of the current alternating-humid subtropics, but with clearly detected hydromorphy of landscapes. This contributed to the development of meadow processes (the formation of powerful profiles with high mineral dispersion), which, in combination with periodic arrigation, rising to the final phase of the Martonian time, caused the fusion of these soils.

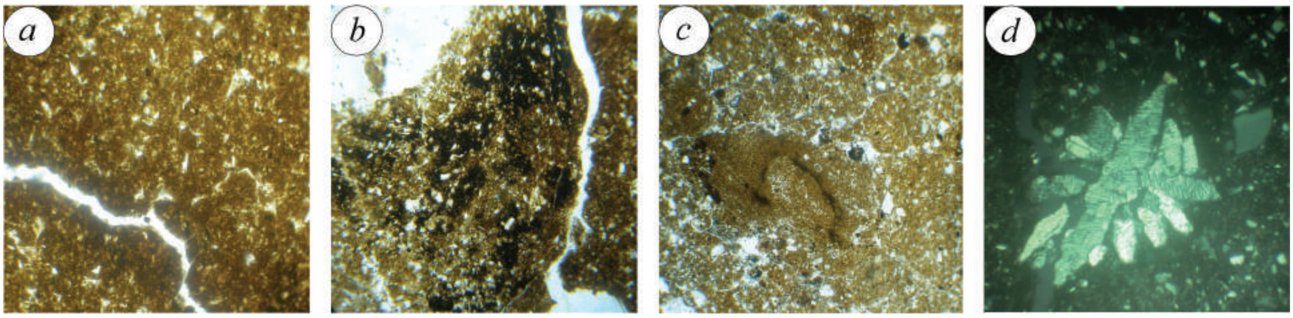

Fig. 6. Microstructure of reddish-cinnamonic fused saline (mr_3) Martonosha soil (vil. of Besimenne): *a* – rounded clay segregation separated by pores; *b* – iron-manganese stains; *c* – signs of the of iron-clay material transfer; *d* – concentration of gypsum in the pores; (*a-c* – nic. ||, *d* – nic. +, magnification 100)

Lubny horizon (OIS – 15-13) (Gozhik e. a., 2012). Lubny soils, as well as Martonosha, are characterized by the active development of soil formation processes, but in more moderate and more contrasting climatic conditions. This is confirmed by the formation of the soil of the sub-boreal climate on most of the territory of Ukraine at that time, and only in the steppe (including the territory of the Azov lowlands), the Lubny soils had some features of the subtropical. The soils of the Lubny horizon are very well expressed in the studied sections, they are characterized by brownish-gray shades of color of their profile, but always with a cinnamonic tint. Only in the Lubny soils in the lower Pleistocene complex microaggregates is developed and humus is concentrated in the humon. They also noted the features that are characteristic to the Kryzhanivka, Shyrokyno and Martonosha soils: some material clayed (more intensively in the middle part of the profile), with compact building, it is characteristic nodules witch concentration of organo-clay material (apparently associated with meadow processes), visible features the movement of clays (mainly within the genetic horizons), iron and manganese in the form of a large number of microortshteins, darker coloration of the pores, simultaneously with the isolation of calcite and gypsum.

The reddish-brown saline soil of the climatic optimum lb_{b2} (vil. of Melekine) has a cinnamonish-brown-reddish coloration of the whole profile (the clayed and density of the middle part), the presence of gypsum concentrations. Micromorphology of the soil is characterized by a manifestation of signs of reorientation of clay material, the presence of clear blocks with concentration of organo-clay material, microortshteins in the middle and lower parts of the profile, which are signs of raining processes and salinization in the formation of soil, due to periodic processes of excess moisture. The presence of complex microaggregates (although their number is negligible), the saturation of carbonates (the impregnation of plasma by microcrystalline calcite and gypsum with its concretions) are signs of the influence of steppe conditions and salinity in the formation of this soil.

In the section of the village of Besimenne an unidentified brown-cinnamonic, dark-colored saline soil, which is characterized by a polygenetic profile (lb_{b2}: He, Hpki, Pks and lb_{b1}: Hpk, Pk), was detected. The climate of the climatic optimum (lb_{b2}) is characterized by the signs of steppe soil formation (lumpy-granular structure, the presence of moleholes and wormholes, the development of complex microaggregates to the third order separated by pores and nodules witch concentration of organo-clay material in conjunction with the impregnation of the plasma by microcrystalline calcite). At the same time, its profile is saline in the middle part, with the traces of reorientation of clay and the presence of a significant amount of microortshteins (Fig.7). The lower soil of the climatic optimum lb_{b1} reflects the features of meadow-steppe signs of soil formation and differs in the smaller development of complex microaggregates, but with more iron-manganese microortshteins (periodicity in moisture).

The definite signs indicate that climatic conditions in the territory of the Azov lowland during

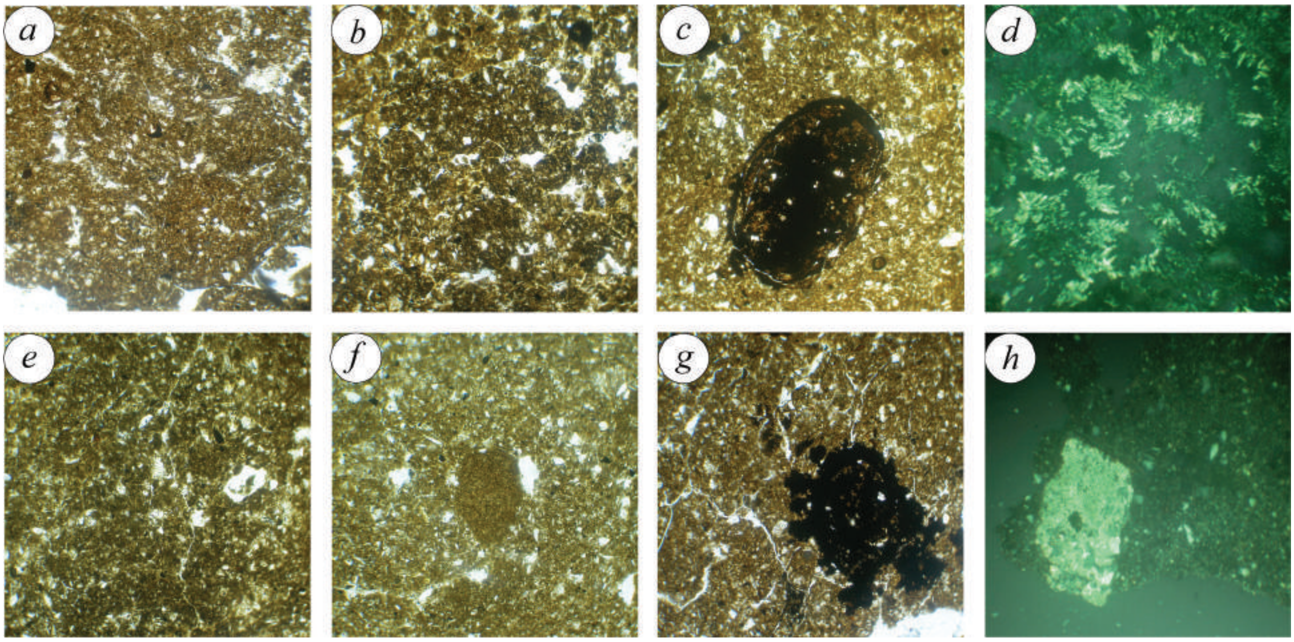

Fig.7. Microstructure of dark-colored (brown-cinnamonic) fused (lb_{b2} + lb_{b1}) Lubny soil (village of Bezimenne): *a* – round segregational clusters (0,2mm) of iron-clay material; *b* – complex rounded microaggregates of the I-II order, separated by pores; *c* – uniform impregnation of the plasma with clay, iron-manganese microortshteins (0.5mm) of concentric microstructure; *d* – small crystals of gypsum; *e* – complex microaggregates of II order, separated by pores; *f* – round segregation of clay material; *g* – there are blocks separated by pores, iron-manganese stain; *h* – concentration of micro- and small-crystalline calcite in a pore; (*a-c, e-g* – nic. ||, *d, h* – nic. +, magnification 100)

the formation of the Lubny soils were quite warm, close to subtropical ones (ferrugination, claying and carbonation of the profile), but more moderate and not as warm as in the Zavadivka and Martonosha times. The soils are clayed and ferruginous, but to a lesser extensively than Martonosha and differ from them in grayish shades of coloring profiles. The studied soils are saline, with clear blocks and clutches of organo-iron-clay material and features of redistribution of clays within the genetic horizons. The soil lb_{b1} (vil. of Bezimenne) is characterized by a deeper playcing of the carbonate horizon and a large number of microortshteins. The lower soil of the climatic optimum (lb_{b1}) was definitely formed in meadow-steppe conditions, and the upper (lb_{b2}) – steppe.

Zavadivka horizon (OIS – 11) (Gozhik e. a., 2012). In Zavadivka time were investigated reddish-cinnamonic saline (zv_{b2}), brown saline (zv_{b1}) the villages of Melekine and cinnamonic soils are also the climatic optimum zv_{b1} (vil. of Bezimenne).

The reddish-cinnamonic saline soil (vil. of Melekine) of the climatic optimum zv_{b2} is characterized by a reddish (ferruginous) shade of the color of the profile, a prismatic-nutty structure, a significant amount of carbonate nodules and concentrations of gypsum. Micromorphology of the soil is characterized by the presence of a significant number of segregational clusters of organ-iron-clay material, complex microaggregates of the I-II orders, and the impregnation of the plasma in the carbonate horizon by micro- and small-crystalline calcite (Fig.8).

The cinnamonic saline soils with the chernozem-like profile of the climatic optimum zv_{b1} (vil. of Melekine) differs from the reddish-cinnamonic saline soil zv_{b2} by greater claying, density of profile with cracking pores and drosses of gypsum and manganese puncturing. They are also less ferruginous, aggregated (less complex microaggregates of the I-II order and the separation of organo-clay material on the background of a dense block microstructure with cracking pores) and carbonate and shows signs of a slight reorientation of the material (jet orientation of the clay substance, the presence of disaggregated microdistricts and zones depleted on clay – Fig.9). Such signs of the soil indicate its formation in more humid conditions compared with the upper reddish-cinnamonic saline soil (zv_{b2}).

Besides brown saline soils (vil. of Melekine) we also had researched cinnamonic soil of climatic

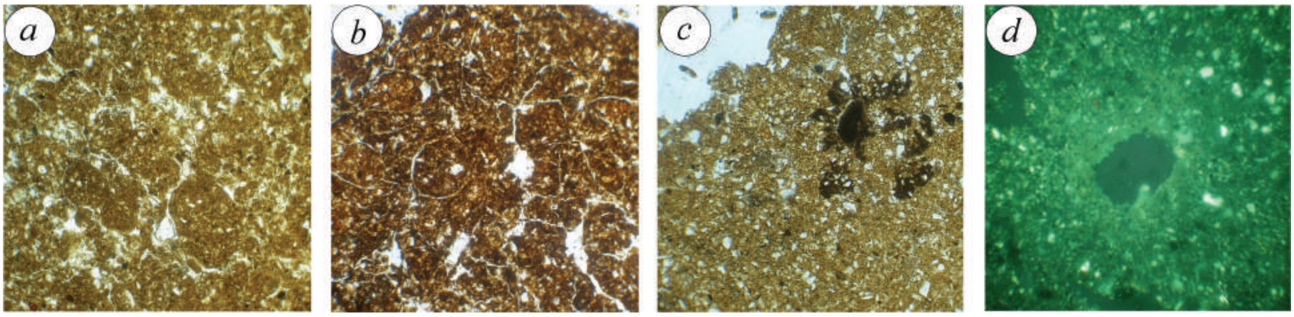

Fig. 8. Microstructure of reddish-cinnamonic saline (zv_{b2}) Zavadivka soil (village of Melekine): *a* – nodular segregational clusters of organo-clay material; *b* – iron-clay plasma, rounded segregational clusters of iron-clay material, separated by pores; *c* – dense packing of skeleton grains in clay plasma, spots of manganese; *d* – concentration of microcrystalline calcite in the plasma and near the pores; (*a-c* – nic. ||, *d* – nic. +, magnification 100)

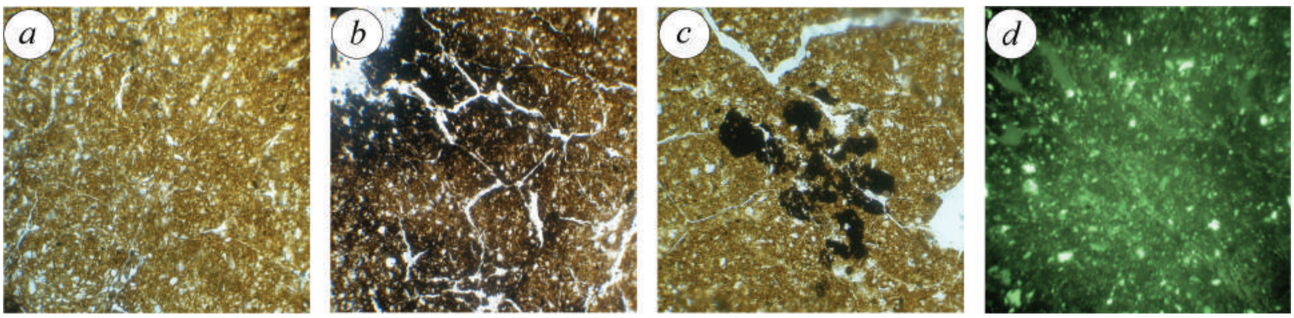

Fig. 9. Microstructure of brown saline (zv_{b1}) Zavadivka soil (village of Melekine): *a* – isolation of organo-clay in the form of simple and complex microaggregates of I-II order, separated by twisted pores; *b* – segregation of organo-clay impregnated with oxides and hydroxides of iron and manganese, separated by pores; *c* – iron-manganese stains; *d* – dusty-plasma microstructure, jet orientation of clay material; (*a-c* – nic. ||, *d* – nic. +, magnification 100)

optimum zv_{b1} (vil. of. Bezimenne), with a clear horizon of carbonates (carbonates in the form of concretions) and without gypsum. Compared to the soils formed in the north, cinnamonic soils reflect us the features of some soils characteristic for the southern part of Ukraine (the development of complex microaggregates to the III order, the gradual decrease of humus with depth, the presence of the carbonate horizon with carbonate-clay plasma which uniformly impregnated with microcrystalline calcite) and some waterlogging (a significant number of segregation clusters of organo-clay and clay materials, the presence of microortshteins).

(vil. of Melekine), is characterized by a brown-gray coloration of the profile, lumpy structure, the presence of quinces, moleholes and carbonates in the form of veins and nodules. Micromorphologically, the soil is characterized by such microindications (Fig.10): complex microaggregates and porosity (the development of complex microaggregates to the third order, separated by a system of winding pores), various isolation of carbonates (plasma infiltration by microcrystalline calcite, its concentration near pores). Compared to the northern sections, the soil reflects the features of some steppe processes (shortened profile – 0,60m, the presence of complex aggregates,

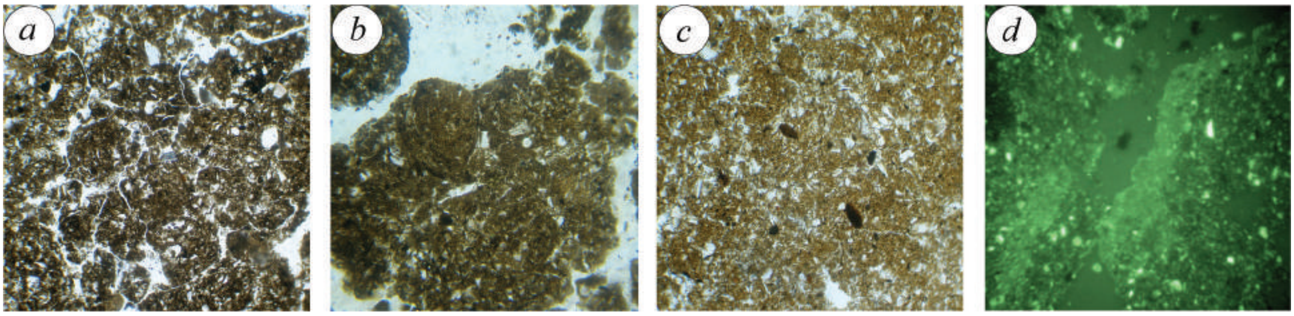

Fig. 10. Microstructure of Kaydaky ordinary chernozem (kd_{b2}) (village of Melekine): *a* – humus-clay plasma, complex microaggregates of II-III order, separated by pores; *b* – plasma impregnation with humus, isolation (0.2mm) of organo-clay material; *c* – carbonate-clay plasma, small microortshteins; *d* – concentration of microcrystalline calcite in the plasma and near the pores; (*a-c* – nic. ||, *d* – nic. +, magnification 100)

Probably, during the Zavadivka time in the Azov Lowland, the climatic conditions were warmer, even hot, in comparison with modern ones (large ferrugination of soils, often their saline). Although compact structure and inhomogeneous coloration of the profile is characteristic for the Lower Pleistocene (Martonosha, Lubny) soils, in the Zavadivka soils it is also preserved. Probably the soils were formed in moderate variable-humid (in the presence of periods of drying), close to subtropical climatic conditions and represent a transitional version to temperate climates, which became widespread in the post-Dnieper times.

Kaydaky horizon (OIS – 7) (Gozhik e. a., 2012). During the Kaydaky time there were more sharp climatic changes caused by Dnieper glaciation. It’s influence also affected the development of soil cover. Instead of the subtropical soils that were distributed in the Pliocene, and in the south and in the Early (Martonosha, Lubny horizon) of the Pleistocene, the temperate continental climate of the Kaydaky period begins to form similar to the modern ones. On the territory of the Azov Lowland, we have investigated the soils of the optimal stage: ordinary chernozem (kd_{b2}) – village of Melekine and Bezimenne and cinnamon-brown soils (kd_{b1}) – village of Melekine.

Ordinary chernozem of climatic optimum kd_{b2} impregnation of the plasma by microcrystalline calcite). The climate of the climatic optimum, kd_{b2}, according to it’s morpho- and microstructure features is most closely related to modern zonal soils (chernozem, the usual) that are developing in this territory, although the climate at that time was definitely a bit more evenly humid.

The lower, cinnamonish-brown soil of the climatic optimum kd_{b1} (village of Melekine) is characterized by a combination of meadow germs (the development of segregation clusters of organo-clay material, signs of weak mobility of silt, plasma penetration by oxides and hydroxides of manganese and its isolation in the form of spots and microortshteins) and steppe (small power, poorly differentiated profile, clear grayish tint in the background of light brown color, complex microaggregating, plasma penetration by microcrystalline calcite in the middle and lower part of the profile) processes of its formation. From the upper (kd_{b2}) soil, it is differed by less complex microaggregates and carbonates (Fig.11).

According to paleopedological data, it can be concluded that the climatic conditions of the Kaydaky time in the territory of the Azov lowland, as well as for the whole of Ukraine, have changed. In the first half of the optimum the soils of the forest-grass

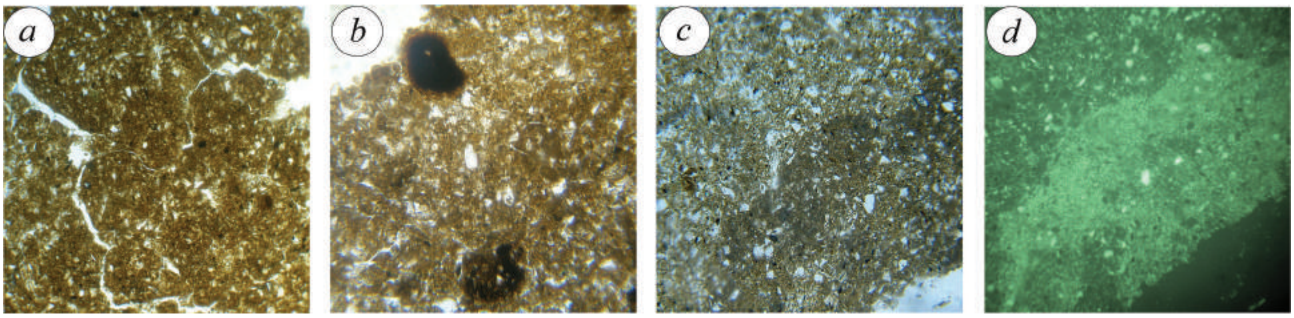

Fig. 11. Microstructure of cinnamonish-brown (kd_{b1}) Kaydaky soil (village of Melekine): *a* – rounded segregational clusters of organo-clay material separated by pores; *b* – dense packing of grains of the skeleton in clay plasma, iron-manganese microortshteins; *c* – plasma impregnation with microcrystalline calcite; *d* – concentration of microcrystalline calcite in the plasma and near the pores; (*a-c* – nic. ||, *d* – nic. +, magnification 100)

genesis were formed. By the end of the stage, the climate has changed considerably in the direction of continentalization – soils of the chernozem type are developing in the soil cover (kd_{b2}). But the increased meadowness of these chernozems indicates conditions that are more damp than the modern southern zone of chernozem soil formation on the territory of Ukraine. In general, Kaydaky soils reflect more contrasting warmly-moderate conditions of their formation, have a well-formed profile with the genetic horizons of soils of the boreal, sub-boreal type of temperate-warm and temperate continental climate. The features of the upper climatic optimum (kd_{b2}) resemble the profile of modern soils, but those formed in slightly more evenly humid conditions. Kaydaky soils are most similar to the soils that are currently forming in Ukraine, although some of their features indicate a more humid conditions for their formation, while others are more warm.

The cinnamonish-gray saline soils of the climatic optimum pl_{b1} (village of Melekine and Bezimenne) are characterized by the following signs of morpho- and microstructure (Fig.12): dark gray coloration of the profile with a distinct cinnamonish tinge, lumpy-nutty structure, clayed, fusion, well formed carbonate-gypsum horizon, the development of complex microaggregates to the III order, separated by pores, the dispersed state of humus, the presence of microortshteins, grains of micro- and small crystalline calcite and gypsum of leafy-plaster form. In the upper part, due to the saline, the soil shows signs of a slight nettish orientation of the clay material. The presence and concentration of a large number of microortshteins indicates a certain periodicity in the moisture of these soils. Apparently, the soils were formed in the conditions of a southern meadow grass steppe of moderately warm climate and combine some of the properties of chernozem and chestnut soils.

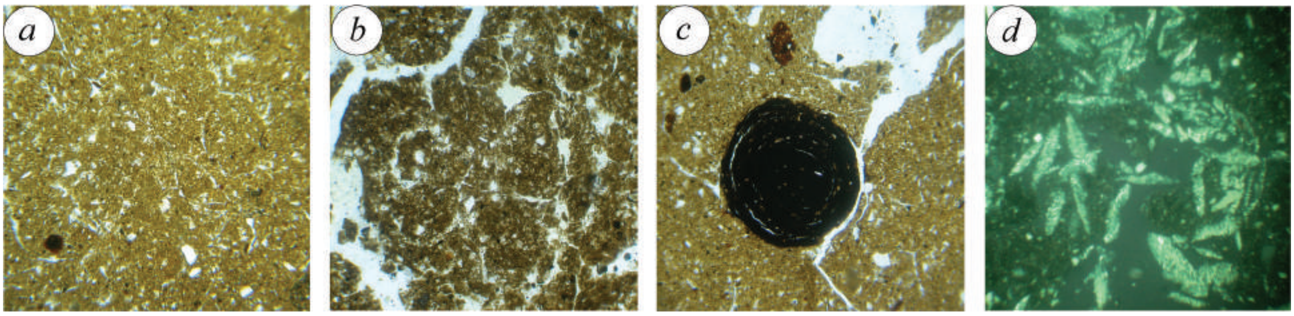

Fig. 12. Microstructure of cinnamonish-gray saline (pl_{b1}) Plyluky soil (village of Melekine): *a* – clay plasma of the base, simple and complex microaggregates of the II-III order of a rounded form, separated by thin winding pores; *b* – round segregation of organo-clay material separated by pores; *c* – concentric glandular manganese microortshtein; *d* – concentration of small plaster crystals in plasma; (*a-c* – nic. ||, *d* – nic. +, magnification 100)

Pryluky horizon (OIS – 5) (Gozhik e. a., 2012). On the territory of the Azov lowland, we were found hear vil. of Bezimenne the svit of Pryluky soils (cinnamonish-gray saline – pl_{b1}, chernozem saline – pl_{b2}, brown steppe – pl_{c}) and cinnamonish-gray saline soils of the climatic optimum pl_{b2} (village of Milekine).

The chernozem saline of climatic optimum pl_{b2} (village of Bezimenne) is dark gray with a brown tinge with profile color, lumpy structure, the presence of moleholes and carbonates in the form of impregnation and mycelium. The soil, in contrast to the corrosion-gray saline soils (pl_{b1}), is better microagregated over the entire profile (complex microaggregates of the

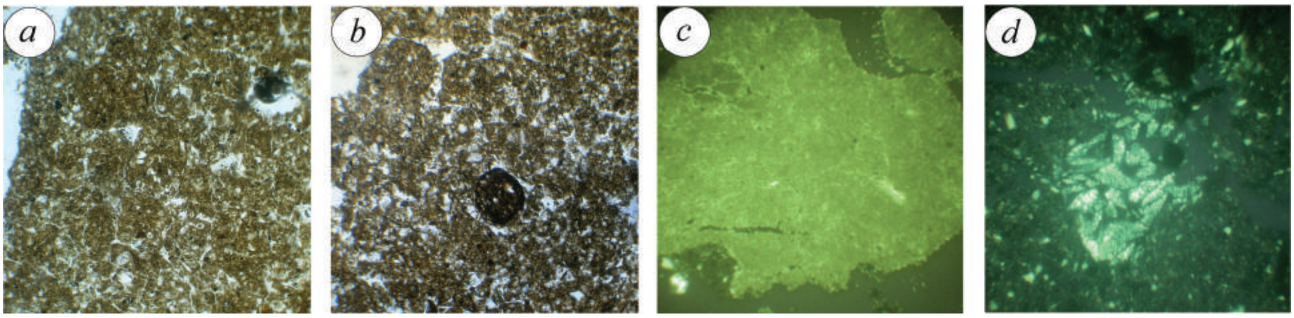

Fig. 13. Microstructure of Pryluky (pl_{b2}) chernozem saline (village of Bezimenne): *a* – uniform impregnation of the plasma organo-clay material, simple and complex microaggregates of I-II order, separated by pores; *b* – complex microaggregates of the III order, round form (0,15mm), separated by pores, iron-manganese microortshtein (0,15mm); *c* – cluster of microcrystalline calcite; *d* – concentration of gypsum in the pores; (*a-c* – nic. ||, *d* – nic. +, magnification 100)

I-III order) with the presence of micro- and small crystalline calcite grains in carbonate-clay plasma, but less porous (a small number of gypsum crystals in the upper and lower parts of the profile – Fig.13).

The brown weaclydeveloped steppe soil of the final stage pl_c (village of Bezimenne) is characterized by poor development of complex microaggregates of the I-II order, uniform saturation of the plasma by microcrystalline calcite.

Pryluky soils – cinnamonish-gray saline (pl_{b1}), chernozem saline (pl_{b2}), brown steppe (pl_c) reflect conditions of a moderately warm climate (wetter and warmer in comparison with modern ones) of the southern grassland steppe. Soils, forming the suit of soils (pl_{b1} + pl_{b2} + pl_c) reflect changes in conditions of moderately warm climate during the stage. The most humid conditions were during the formation of cinnamonish-gray saline (pl_{b1}), somewhat less humid – chernozem saline (pl_{b2}) and much less moist – brown steppe (pl_c) soil. Pryluky soils, as well as Kaydaky are the closest to the soils that are currently forming in Ukraine, although some features indicate a more humid conditions for their formation, while others are more warm. In comparison with the Kaydaky, Pryluky soil formation took place in somewhat more steppe conditions, although in one moderately warm zone, but in more arid conditions (compared to the northern territories). Natural zones of Ukraine at the modern time, in comparison with the Kaydaky, were displaced to the south.

Vytachiv horizon (OIS – 3) (Gozhik e. a., 2012). In the Vytachiv time, the cinnamonish-brown (similar to chestnut) clay optimum vt_{b2} soils (sections the villages Melekine and Bezimenne) were investigated.

Morphologically, the soils are characterized by a cinnamonish-brown coloration of the profile, a considerable clayed of its middle part, with carbonates in the form of impregnation, white bilozirka other and concretion. Under a microscope for soil material, the development of simple and complex microaggregates of the III order is characteristic, as wele us the concentration of the organo-clay material, the spatial structure of the clay, the presence of microortshteins, and the saturation of the plasma by microcrystalline calcite (Fig.14).

Such morpho- (cinnamonish-brown coloring, profile reduction and its riching in carbonates, high absorption, especially in the middle part) and micro sign (the presence of nodules) of soils indicate their development in fairly warm and relatively humid conditions. It is possible that the moisture of these soils was periodic: in the humid season, the

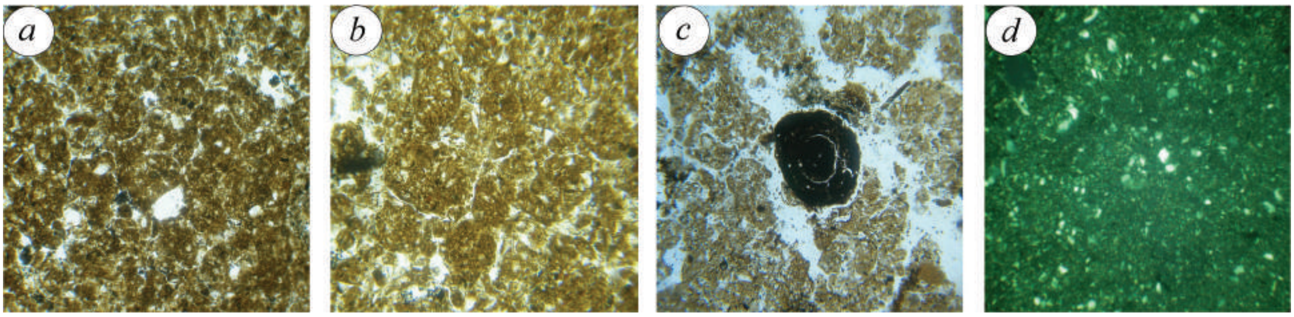

Fig. 14. Microstructure of cinnamonish-brown (vt_{b2}) Vytachiv soil (village of Melekine): *a* – simple and complex microaggregates of the I-III orders of round form (0,12mm), separated by pores; *b* – nodules with segregations of organo-clay material; *c* – iron-manganese microortshtein (0.25mm); *d* – dusty-plasma microstructure, uniform concentration of microcrystalline calcite in plasma; (*a-c* – nic. ||, *d* – nic. +, magnification 100)

soil-forming process proceeded in the direction of brownzems formation, and in dry period under the steppe type. Such periodicity of humidification is confirmed by micromorphological data (development of concentration of organo-clay material, concentric microortshteins, along with plasma by microcrystalline calcite). However, the insignificant power of the Vytachiv soils (0.70m), the presence of moleholes, high degree of carbonatisation with the isolation of the carbonate horizon indicates rather dry conditions of formation. Probably the Vytachiv soils in this territory have developed in rather warm conditions of periodically arid temperate and warm subarid climate and have no analogues in the modern soil cover.

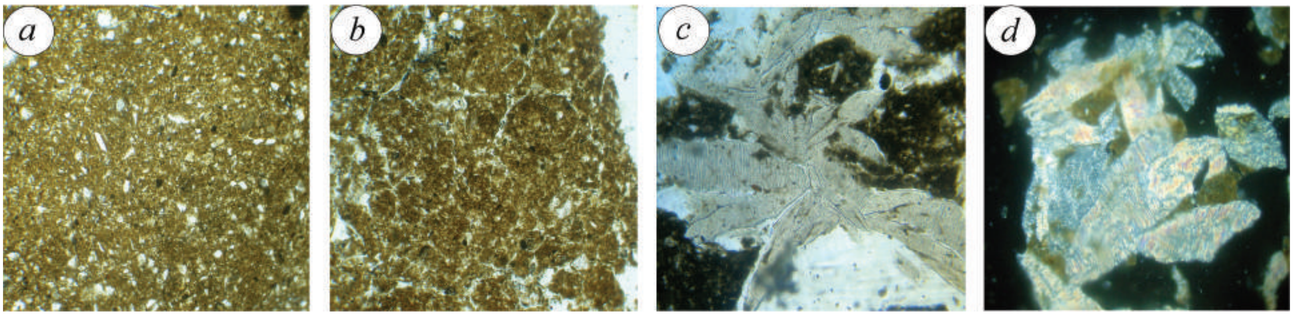

Fig. 15. Microstructure of the Dofinivka (df_{b2}) chernozem saline (village of Melekine): *a* – compact packing of grains of the mineral skeleton in the humus-clay plasma; *b* – simple and complex microaggregates of the III order (0,1mm), separated by pores; *c* – large crystals of gypsum; *d* – tabular crystals of gypsum; (*a, b* – nic. ||, *c, d* – nic. +, magnification 100)

Dofinivka horizon (OIS – 2) (Gozhik e. a., 2012). The morpho- and micromorphological properties of the Dofinivka soils reflect the features of the Pleistocene trends to climate aridisation. This is confirmed by the formation of the chernozem of saline soils (df_{b2}), steppe brown saline soils and brown desert-steppe soils in the final stage (df_c) of the Dofinivka soil formation.

The Dofinivka climatic optimum soil df_{b2} chernozem saline (village of Melekine) is characterized by a dark gray color, the presence of moleholes, wormholes, carbonates and niddles of gypsum, the development of simple and complex of I-II order microaggregates, microcrystalline calcite impregnation of plasma, and the presence of tabular gypsum (Fig.15). Compared to the Pryluky saline soils, the chernozem of the Dofinivka time are even with more quatity of gypsum content and have the influx of humus in the middle part of the profile, can see some redistribution of iron oxides and manganese, which are distinguished in the form of thin films along the edges of the pores in the background as well as a whole of the carbonate-clay plasma. Ale this is a confirmation of its formation in conditions of insufficient moisture with clear features of xeromorphism.

In the final (df_c) stage of the Dofinivka soil formation there were formed: low-power (0.30m) fulvous saline soils (simple and complex microaggregates of the II order, uniform impregnation of the plasma by microcrystalline calcite and gypsum) were investigated in the section the villages of Melekine and brown desert-steppe soils (light-boring color, powdery forms of carbonates, spongy microstructure, simple and complex to the II order microaggregates, separated by pores, plasma infiltration by microcrystalline calcite – Fig.16) – vil. of Melekine, Bezimenne.

The morpho-and micromorphological properties of the Dofinivka soils reflect the features of the Pleistocene's subsequent climate aridization.

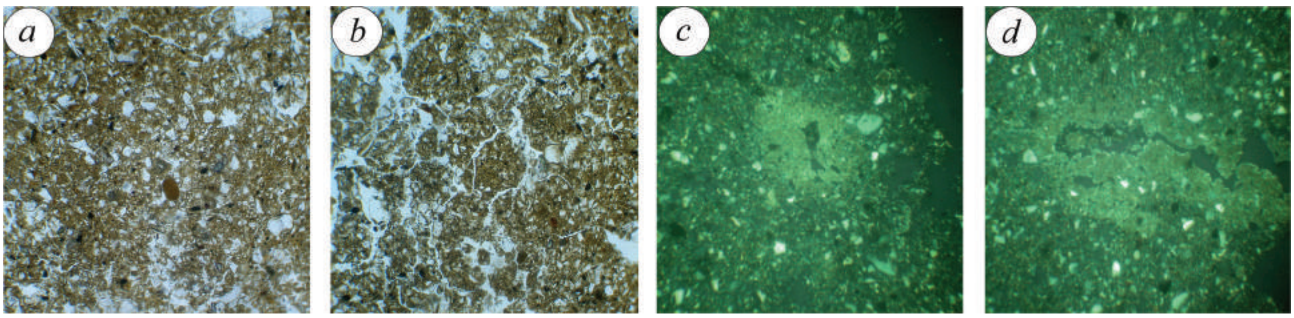

Fig.16. Microstructure of brown desert-steppe (df_c) Dofinivka soil (villag. of Melekine): *a* – compact building, dense packing of grains of mineral skeleton in carbonate-clay plasma; *b* – complex microaggregates of the II order, separated by winding pores; *c* – dusty-plasma microstructure, concentration of microcrystalline calcite in the pores; *d* – concentration of microcrystalline calcite in a pore; (*a, b* – nic. ||, *c, d* – nic. +, magnification 100)

Insufficient moisture has led to the formation of chernozem, which had clear features of xeromorphism (without signs of redistribution of organo-mineral substances by profile), their profiles are carbonate, often with gypsun. Xerophytization of conditions has been especially intensified in the final stage of the Dofinivka soil formation (the formation of brown desert-steppe soils). The Dofinivka soils, in comparison with modern ones, have a higher aridity of the conditions for the formation of a temperate dry continental climate, but warmer compared with the Prychernomorsk time.

Paleopedological results obtained by the author in person (Karmazinenko, 2013, 2014, 2017) and the usage of literary data (Veklych, 1982, 1987; Krokhmal, Rekovets 2010; Sirenko, Turlo 1986) made it possible not only to reconstruct the Pleistocene soils, but also to follow the change of paleogeographic conditions (types of soils, general types of vegetation, faunistic complexes, and climate) during the Dofinivka, Vytachiv, Pryluky, Kaydaky, Zavadivka, Lubny, Martonosha, Shyrokyno and Kryzhanivka stages in the Azov Lowland (Table 1).

Conclusions. Paleopedological studies (using micromorphological analysis) of the Pleistocene soils of the Kryzhanivka, Shyrokyno, Martonosha, Lubny, Zavadivka, Kaydaky, Pryluky, Vytachiv and Dofinivka stratigraphic horizons near the villages of Bezimenne and Melekine in the Azov Lowland made it possible to determine their morpho- and micromorphological features, to establish the types of these deposits and to reconstruct the paleogeographical conditions of the time of their formation:

- Kryzhanivka (reddish-cinnamon – kr_{b1}, reddish-brown – kr_{b2}), Shyrokyno (cinnamonish-brown – sh_{b1}, reddish cinnamon – sh_{b2}) and Martonosha (dark-colored (meadow-reddish-brown) merged – mr_{b2} + mr_{b1}, reddish-cinnamon brownish fused saline

Table 1. Paleogeographic conditions of the Pleistocene in the Azov lowland (Veklych, 1982, 1987; Krokhmal, Rekovets 2010; Sirenko, Turlo 1986.)

Stage	The type of soils which studied palaeopedologically by the author sites (vil. of Bezimenne, Melekine)	The general types of vegetation (Sirenko, Turlo 1986)	Faunistic complexes for large mammals (Krokhmal, Rekovets 2010)	Climate (average annual temperature, ° C: January / July; annual rainfall, mm (Veklych, 1982, 1987; Sirenko, Turlo 1986)
df	chernozem saline (df_{b2}), brown saline (df_c), brown desert-steppe (df_c)	grass-graze-polynomial-loboda steppes	Upper paleolithic (*Mammuthus primigenius*)	moderate dry (-6- -9 / +17-+18; 300-400)
vt	cinnamonish-brown (vt_{b2})	grass-gravel steppes and ravine forests		moderately warm subarids (-3--5 / +18-+20; 350-450)
pl	cinnamonish -gray saline (pl_{b1}), chernozem saline (pl_{b2}), brown steppe (pl_c)	grass-gravel steppes		moderately warm (0-+1 / +21-+22; 450-700)
kd	cinnamonish-brown (kd_{b1}), chernozems ordinary (kd_{b2})	grass-gravel steppes and ravine forests	Khazar (*Mammuthus chosaricus*)	moderately warm (-2- -3 / +20-+21; 550-700)
zv	cinnamon (zv_{b1}), reddish-cinnamon saline (zv_{b2})	forest-steppe with broadleaf pine forests with elements of Pliocene flora with grass-mixed grass steppes	Singh (*Palaeoloxodon antiquus*)	moderately variable and humid close to subtropical (0-+2 / +22-+23; 400-600)
lb	reddish-brown saline (lb_{b2}), dark-colored fused (lb_{b2} + lb_{b1})	forest-steppe with broadleaf-pine forests with elements of Pliocene flora and meadow steppes	Tiraspol (*Archidiskodon trogontherii*)	moderately warm transition to subtropical (-1-+1 / +21-+22; 550-900)
mr	dark-colored merged (mr_3 + mr_2 + mr_1), reddish-cinnamon fused saline (mr_3)	forest-steppe with broadleaf-coniferous forests with elements of the Pliocene flora and mesotic steppes		warm-moderately close to subtropical (+1-+2 / +22-+23; 650-750)
sh	cinnamon (sh_{b1}), reddish-cinnamon (sh_{b2})	forest-steppe with broadleaf-coniferous forests with elements of heat-loving flora and meadow-steppe herbaceous vegetation	Taman (*Archidiskodon meridionalis tamanensis*)	warm-moderate close to subtropical arid (+1-+3 / +22-+24; 550-650)
kr	reddish-cinnamon (kr_{b1}), reddish-brown (kr_{b2})	forest-steppe with broadleaf coniferous forests including elements of heat-loving flora and grassy steppes	Pseudo (*Archidiskodon meridionalis meridionalis*)	warm-tempered with signs of subtropical (+2-+4 / +22-+23; 500-600)

– mr_3) soils, which are distinguished by reddish shades of color, are the most clayed, ferruginous with a large number of nodules which concentration organ-iron-clay material; the bixed morpho- and micromorphological features indicate that such types of soils could only be formed in the heat-temperate with signs of subtropical or climatic conditions close to them;

- Lubny (red-brown saline – lb_{b2}, dark-colored (brownish-cinnamon) fused – $lb_{b2} + lb_{b1}$), heavy loam soils, are less clayed, ferruginous, different by brown-gray a brownish tinge with the color of their profiles, the presence of moleholes, complex microagregation; such features of the morpho- and microstructure of these soils are evidence of their formation in the meadow-steppe and steppe conditions of a moderately warm transition to a subtropical climate;

- Zavadivka (cinnamon and cinnamon saline – zv_{b1}, reddish-brown saline – zv_{b2}), heavy loam soils, which are a transitional variant to the temperate climate, although some features of the lower Pleistocene soil formation remain (ferrugination, presence of segregation clusters of organo-clay and clay materials, microortshteins) and probably formed in moderate variably-wet close to subtropical climatic conditions;

- Kaydaky (cinnamonish-brown – kd_{b1}, chernozems ordinary – kd_{b2}) and Pryluky (cinnamonish-gray saline – pl_{b1}, chernozems saline – pl_{b2}), brown steppe – pl_c), heavy and medium loam soils are characterized by grayish shades of their profiles coloring, presence moleholes, carbonates, complex microaggregates, pores; the listed signs indicate that these soils were formed in moderately warm, uniformly humid climatic conditions; they are the closest to the modern soils that are currently distributed in the territory of Ukraine;

- Vytachiv (cinnamonish-brown – vt_{b2}) heavy loam soils formed under the influence of turf (the presence of moleholes, carbonate, complex microaggregates) and brownzem-liked (cinnamonish-brown coloration of the profile, spatial structure of clays) of the soil forming processes of a moderately warm subarid climate and have no analogues in the modern soil cover of our country;

- Dofinivka (chernozem saline – df_{b2}, brown saline and brown desert-steppe – df_c), medium loam soils, with clear features of xeromorphism (low profile power, its carbonaceous nature, absence of signs of organo-mineral material redistribution), formed in moderately continental and more arid (dry) climatic conditions compared with modern ones.

The established types of Pleistocene soils, their morphological and micromorphological features reflect changes in paleogeographic conditions from Kryzhanivka, Shyrokyno, Martonosha, Lubny and Zavadivka paleogeographical stages, soils formed in warm-temperate climatic conditions with signs of subtropical or close to them. The established types of soils of the Kaydaky, Pryluky, Vytachiv and Dofinivka stages are evidence of their formation in temperate climates.

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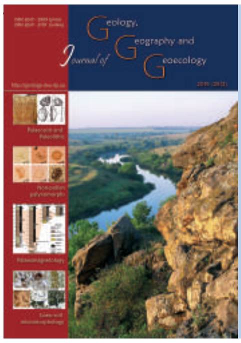

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Micromorphological peculiarities of the Pleistocene soils in the Middle Pobuzhzhya (Ukraine) and their significance for paleogeographic reconstructions

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Abstract. The basic micromorphological features of fossil Pleistocene soils of the Middle Pobuzhzhya region are revealed. The early Neopleistocene (Shyrokyne, Martonosha, Lubny) and Middle Pleistocene Zavadivka soils are characterized by bright brownish, reddish and brownish colors of plasma, compact composing structural separations in the form of cleave blocks with densely packed nodular formations of ferruginous matter, cracksman ship of the mass, a significant amount of ferruginous, manganese and carbonate new formations. In the soils of the early optimum of the Kaydaky stage, signs of the eluvial-illuvial processes were observed (impoverished on the thin clays and humus fields with the «washed» grains of the mineral skeleton, the destroyed microaggregates in the eluvial and the impregnation of the plasma by calomorphic clays in the form of streaks, films, streams in the illuvial horizons). In the Pryluky soils there is a well-expressed microagregation of the mass, a branched net of twisted pores, humus coagulation in the humus and humus transition horizons, various forms of carbonate new formations as the impregnation and plasma cementation by microcrystalline calcite, presence of isolated crystals of crypto-, micro- and small crystalline calcite. The specific individual features of the Vytachiv soils are cleave block microstructure, the presence of the nodular concentric organo-iron-clay formations, and microorsteins. Dofinivka soils are characterized by a loose microstructure, fuzzy rounded microaggregates, a developed system of twisted pores, and enrichment of mass on carbonates. In order to clarify the genetic types of fossil Pleistocene soils of the Middle Pobuzhzhya, identification of the signs of elementary soil formation processes was carried out on the basis of micromorphological analysis data. The significance of the results of micromorphological researches for paleogeographical reconstruction is outlined. It has been established that certain groups of soil formation processes are characteristic for fossil soils of separate paleogeographical stages. In the soils formed up to the Dnieper glaciation (Shyrokyne, Martonosha, Lubny and Zavadivka), signs of processes of claying, rubbification, ferralization, cleaving were displayed, but weakly expressed humus formation, though carbonization were diagnosed. In the soils formed after the maximum glaciation (Kaydaky, Pryluky, Vytachiv, Dofinivka), signs of the such processes as humus formation, podzolization, lessive, leaching, damp-meadow soil formation on floodplain, migration of carbonates, etc., are established. It is processes which are predominating in the modern soils of the territory of Ukraine. Assertaintment of elementary soil-forming processes, diagnosed in multi-annual fossil soils, have made it possible to identify their genetic types and as a result, to reconstruct the soil cover in separate stages of the Neopleistocene, to establish regional patterns of evolutional stadial changes and the natural environment in the Pleistocene on the territory of the Middle Pobuzhzhya.

Key words: Pleistocene, fossil soils, micromorphology, soil formation processes, paleogeography.

Мікроморфологічні особливості плейстоценових ґрунтів Середнього Побужжя та їх значення для палеогеографічних реконструкцій

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Анотація. Виявлено основні мікроморфологічні особливості викопних плейстоценових ґрунтів території Середнього Побужжя. Для ґрунтів раннього неоплейстоцену (широкинських, мартоноських, лубенських) і середньоплейстоценових завадівських, ґрунтів характерні яскраві буруваті, червонуваті та коричнюваті відтінки забарвлення плазми, компактне складення маси, структурні виокремлення у вигляді злитих блоків із щільно упакованими нодульними утвореннями залізисто-глинистої речовини, тріщинуватість маси, значна кількість залізистих, манганових і карбонатних новоутворень. У ґрунтах раннього оптимуму кайдацького етапу зафіксовано ознаки елювіально-ілювіальних процесів (збіднені на мул і гумус ділянки з «відмитими» зернами мінерального скелета, зруйновані мікроагрегати у елювіальних горизонтах; у ілювіальних – просочення плазми коломорфними глинами у вигляді натеків, плівок, потічків). У прилуцьких ґрунтах проявляється добре виражена мікроагрегованість маси, розгалужена сітка звивистих пор, скоагульованість гумусу типу муль у гумусових і гумусово-перехідних горизонтах, різноманітні форми карбонатних новоутворень у вигляді просочень та цементації плазми мікрокристалічним кальцитом, виокремлення кристалів крипто-, мікро- та дрібнокристалічного кальциту. Специфічними індивідуальними ознаками витачівських ґрунтів є блокова мікробудова, наявність нодульних стяжінь органо-залізисто-глинистої речовини, мікроорштейнів. Дофінівські ґрунти вирізняються пухкою мікроструктурою, нечіткими округлими мікроагрегатами, розвинутою системою звивистих пор, карбонатність маси. З метою уточнення генетичних типів викопних плейстоценових ґрунтів Середнього Побужжя проведено ідентифікацію ознак елементарних ґрунтоутворювальних процесів на основі даних мікроморфологічного аналізу. Окреслено значення результатів мікроморфолоічних досліджень для проведення палеогеографічних реконструкцій. Встановлено, що для викопних ґрунтів конкретних палеогеографічних етапів характерні певні групи ґрунтоутворювальних процесів. У ґрунтах, які формувались до дніпровського зледеніння (широкинських, мартоноських, лубенських та завадівських) діагностовано ознаки процесів оглинення, рубефікації, фералітизації, злитизації, слабко вираженого гумусоутворення, карбонатизації. У ґрунтах, що сформувалися після максимального зледеніння (кайдацьких, прилуцьких, витачівських, дофінівських), установлено ознаки тих самих процесів (гумусоутворення, опідзолення, лесиважу, вилуговування, олуговіння, міграції карбонатів тощо), які переважно властиві сучасним ґрунтам території дослідження. Діагностовані у різновікових викопних ґрунтах елементарні ґрунтоутворювальні процеси надали змогу ідентифікувати генетичні типи викопних плейстоценових ґрунтів і як наслідок – реконструювати ґрунтові покриви у окремі етапи неоплейстоцену, встановити регіональні закономірності еволюційних змін ґрунтів і природного середовища у плейстоцені на території Середнього Побужжя.

Ключові слова: плейстоцен, викопні ґрунти, мікроморфологія, ґрунтоутворювальні процеси, палеогеографія.

Introduction. Micromorphological studies of Pleistocene fossil soils are an important trend in contemporary world researches. It is evidenced by a large number of international publications on this topic, that initiated micromorphological studies in the 40's of the twentieth century. The Austrian scientist V. Kubiena (1938), who formulated the main methodological principles of micromorphology, proved the importance of using micromorphological analysis for the development of soil diagnostics and systematics (Kubiena, 1970). Significant contribution to the development of micromorphology was made by R. Brewer (developed a classification of soil microstructure components) (1964), B. Baratt, E.A. Fitzpatrick and others. The first Russian-language works, in which the methodology of micromorphological research of modern soils was covered, became monographs of O.I. Parfenova and K.A. Yarilova (1962, 1977). General theoretical and practical questions of micromorphological researches were developed by I.P. Gerasimov, G.V. Dobrovolsky, S.V. Zonn, V.O. Targulian, M.I. Gerasimova, S.V. Gubin, S.O. Shoba, E.I. Gagarina and others. Under the microscope, modern soils were studied by I.I. Feofarova, E.K. Nakaidze, L.K. Tselishcheva, B.P. Gradusov, T.F. Urushadze, V.V. Medvedev, A.M. Poliakov, A.I. Romashkevich, N.I. Matynian, N.A. Bilova and al.

Micromorphological studies of fossil Pleistocene soils of European part of Russia conducted by T.D. Morozova. Micromorphological peculiarities of microstructure components, with access to the genesis of Quaternary deposits, were considered by O.A. Chichagova (composition of humus), N.G. Glushankova (microforms of humus), T.A. Halcheva (forms of carbonates). Micromorphological signs of cryogenesis were studied by L.A. Gugalinskaya. Questions of Pleistocene soil formation in the basin of the upper Don, using micromorphological data, were studied by A.I. Tsatskin. Micromorphological data in the study of Quaternary deposits of France was used by Y.B. Jamagne; England – P. Bullock; Czech and Slovakia – L. Smolikova; Poland – T. Madeyska, P. Mroshec, T. Mroshec; Central Asia – N.G. Minashina; China – R.A. Kemp, A. Bronger; Canada – P.G. Jungerius; New Zealand – Y.B. Dalrympl and others. Micromorphological studies of deposits older than the Quaternary, conducted by V.I. Chalyshchev, A.P. Feophilova et al.

In Ukraine, for the first time, a micromorphological analysis for the study of fossil Pleistocene soils and loesses was used by M.F. Veklych (1958). To find out the individual peculiarities and issues of the genesis of the Pliocene and Pleistocene fossil soils and sediments successfully uses the micromorphological analysis Zh.M. Matviishyna (Veklych et al, 1979; Matviishyna, 1992; Matviishyna et al, 2010). The question of the Pleistocene evolution of soil coverings and landscapes, based on paleopedological data with widespread use of micromorphological analysis, is reflected in later publications by Zh.M. Matviishyna and her students (Matviishyna, Parkhomenko, 2008; Matviishyna et al., 2009; Matviishyna, Doroshkevych, 2011; Doroshkevych, Matviishyna, 2012). The features of zonal changes of Upper-Pleistocene and modern soils, based on micromorphological data, are covered in the monograph by S.P. Karmazynenko (Karmazynenko, 2010). Paleogeographical reconstruction of the Pleistocene nature, carried out on the basis of paleopedological data with the active use of micromorphological analysis, is devoted to the monograph of S.P. Doroshkevych (Doroshkevych, 2018) on the territory of Pobuzhzhya.

Materials and methods of research. The basis of the study is the complex paleopedological method, the main task of which is to reconstruct the paleoenvironment of the ancient soils formation. An important role during paleopedological investigation is given by micromorphological analysis, which demonstrates good efficiency in the study of fossil soil through the diagnosis of ancient elementary soil formation processes.

During the study, as a stratigraphic basis, we used a scheme of paleogeographic stage for the plain territory of Ukraine (Veklych M.F. et al, 1993). It is this scheme that remains unified for Ukraine today, although, over the past 20 years, many issues have emerged that require clarification and improvement. In particular, the issues of absolute age (especially for the late Pleistocene horizons), the affiliation of the horizons to the Pleistocene units, the establishment of the lower bound of the Pleistocene, etc., are very acutely debated. According to the stratigraphic code (Stratigraphic ..., 2012), the Pleistocene (Neopleistocene) is divided into 16 paleogeographic stages, the stages of Eopleistocene are not considered in the work.

Regarding the territory of the Middle Pobuzhzhya, there are several approaches to the allocation of its boundaries: tectonic (within the boundaries of the Ukrainian shield, from Medzhybizh to Alexandrovka), geomorphological and hydrological (from Vinnitsa to Aleksandrovka) (Denysyk H.I. et al, 2002), landscape (Medium-Pobuzhzhya Highland region according to modern physics-geographical division into districts) (National Atlas of Ukraine, 2007), etc. From the standpoint of paleogeographic studies, in our opinion, the most expediently to study the territory that developed on a common tectonic basis, that's why under the Middle Pobuzhzhya, we consider the territory of the basin of the Southern Bug river within the boundaries of the Ukrainian shield (Figure 1).

Fig. 1. Territory of Middle Pobuzhzhya within Ukraine

During the last 10 years, we have investigated 17 new sections of the Pleistocene deposits (11 of which are within natural outcrops and quarries, 6 on archaeological sites (Doroshkevych, 2018; Zalizniak et al, 2013; Matviishyna, Doroshkevych, 2011; et al). These are sections near the city of Medzhybizh and the village of Trebukhivtsi (Khmelnytsky region), villages of Bezimenne, Stryzhavka, Yakushyntsi, Sabariv, Raihorod and Tyvriv (Vinnytsia region), Uman cities (Cherkasy region), villages of Andriivka, Korobchyne (two sections), Likareve (section Vyss), Ozerove, Troianove (Kirovograd region), cities of Pervomaisk and the village of Pankratove (Mykolaiv region) (Figure 2, 3).

Results and their analysis. According to modern physic-geographical division into districts, the territory of the Middle Pobuzhzhya is located within three natural zones: broadleaf forests, forest-steppe and steppe. Each of these zones has its typical natural features (National Atlas of Ukraine, 2007). Particularly interesting is the estate of modern soil cover, which is considered as a kind of indicator of modern physic-geographical conditions. After all, the formation of one or another genetic type of soil from on the interaction of the main natural factors of soil formation: the lithological composition of soil formation bed rocks, geomorphological position, climate, vegetation, geological age and duration of soil formation. All these factors, in turn, predetermine a specific set of elementary soil formation processes under the influence of various interactions under which a certain genetic type of soil is formed.

Accordingly, modern zonal soils of the Middle

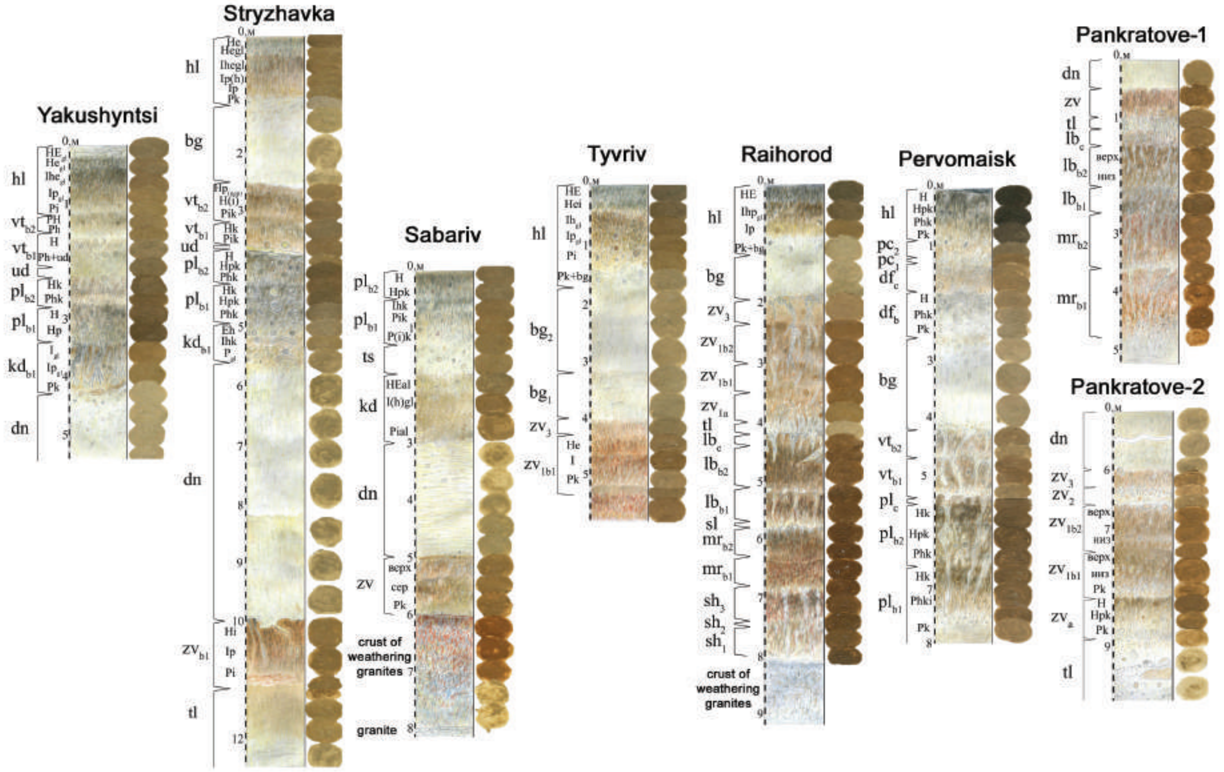

Fig. 2. The field scetches of the section with samples of natural material of the Middle Pobuzhzhya Pleistocene deposits (after Zh. Matviishyna). (On the top – name of the section. From left to right: indexes of the stratigraphical horizons; genetic horizons; deep in m; lithological column; samples of the natural materials).

Pobuzhzhya is represented by light gray, gray and dark gray podzolized, chernozems degrated, podzolized, typical (in the forest-steppe zone) and chernozems ordinary (in the steppe zone). Locally distributed sod, sod-podzolic, meadow-chernozem, meadow, peat-swampy and other azonal soils (National Atlas of Ukraine, 2007). The modern genetic types of soils are the basis for paleogeographic reconstruction, peculiar standards for comparison with the genetic types of fossil soils in the studied sections of the Pleistocene deposits. Performed reconstruction of the natural conditions of the territory of Middle Pobuzhzhya in Pleistocene are based on paleopedological data, that is, peculiar «records» about the natural conditions of the past, preserved in the form of specific properties and features of fossil Pleistocene soils, soils rocks, loesses and other layers.

As you know, the formation of any genetic type of soil depends of the nature soil formation processes. Possessing knowledge about manifestation of soil formation processes, one can observe their diagnostic features under a microscope, which provides an opportunity to restore the chronology of soil formation processes to clarify the genesis of deposits and to conduct genetic identification of the soils.

Separate possibilities of micromorphological diagnostics of elementary soil formation processes, based on their own and of precursors data, are shown in Table 1.

To solve the problems of paleogeographical reconstruction, we used the data of micromorphological analysis as part of the complex paleopedological method. In particular, the method of micromorphological research has been adapted to detect the diagnostic features of primary soil formation processes in the fossil soils of the Middle Pobuzhzhya in order to find out the issues of the genesis of deposits (Doroshkevych, Matviishyna, 2012).

The signs of the following groups of elementary ones have been found in the fossil Pleistocene soils of the Dofinivka (df), the Vytachiv (vt), the Pryluky (pl), the Kaydaky(kd), the Zavadivka (zv), the Lubny (lb), the Martonosha (mr) and the Shyrokyne (sh) soil-forming processes (SFP) (classification of groups by Rozanov, 2004) (Figure 4).

Biogenic-accumulative SFP (humus formation, humus accumulation, bedding, peat formation, etc.) caused by direct influence of living organisms, products of their life activity and dead remains (Figure 4 a-d). In thin sections with undisturbed structure under microscope biogenic and accumulative processes are characterized by dark, dark brown or brown humus-clay plasma, structural formations in the form of simple and complex microaggregates, well-defined

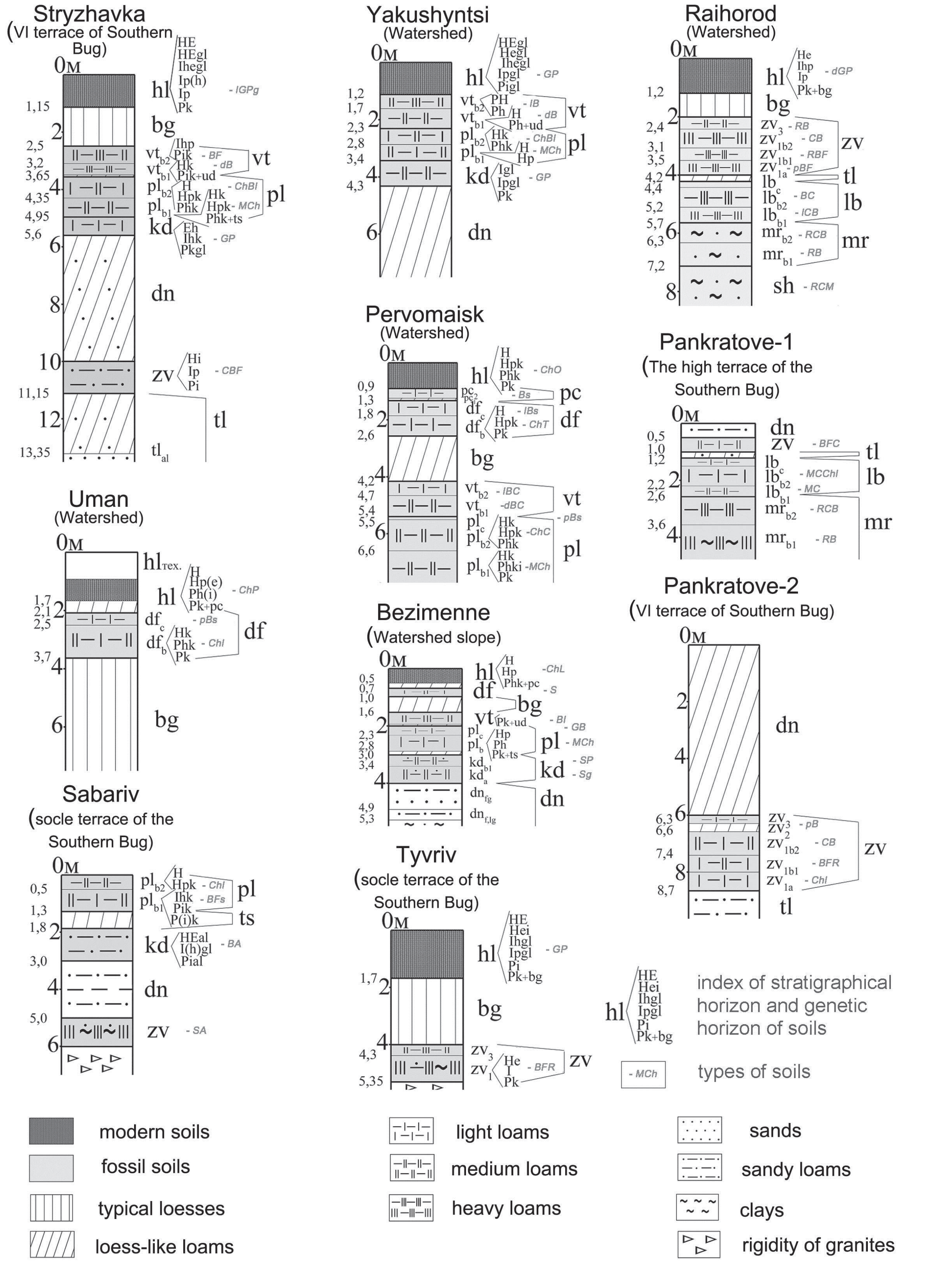

Fig. 3. Lithologic-stratigraphical columns of separate sections of the Pleistocene deposits of the Middle Pobuzhzhzhya.
Types of soils: S – sod; SP – sod- podzolic; Sg – sod gleyed; GP – grau podzolized; lGPg – light-grau podzolic gleyed; dGP – dark-grau podzolic; GB – grau-brown; Bl – brown-liked; BF – brown forest; BFC – brown forest cinnamonish; BFR – brown forest reddish; CBF – cinnamon-brown forest; RB – reddish-brown; RBF – reddish-brown forest; RCB – reddish-cinnamon-brown; RCM – reddish-cinnamonish meadow; BFs - brown forest with sign of steppe; dB – dark-brown; dBC – dark-brown cinnamonish; BC – brown cinnamonish; CB – cinnamonish-brown; lB – light-brown; lBC – light-brown cinnamonish; lCB – light-cinnamonish brown; pBF – pale-brown forest; pBs – pale-brown steppe; pB – pale-brown; Bs – brown steppe; MC – meadow cinnamon; BA – brown alluvial; Chl – chernozem-liked; ChP – chernozem podzolized; ChL – chernozem leaching; ChT – chernozem typical; ChO – chernozem ordinary; MCh – meadow chernozem; ChBl – chernozem brownzem-liked; ChC – chernozem cinnamonish

Table 1. Micromorphological diagnostics of soil formation processes in fossil Pleistocene soils of the Middle Pobuzhzhya (Doroshkevych, 2018)

Elements of microstructure	Micromorphological signs and traces of ancient soil formation	Conditions, processes of formation
Microstructure	Compact, dense, merged, with rounded clutches of organo-clay substanses	Soil formation took place under favorable climatic conditions, where there was a sufficient amount of moisture and heat. Properties for the Lower Pleistocene soils
	Cubs, loose, soft, grains of the skeleton are proportional to each other	Soil formation - in relatively arid conditions, a fairly warm climate. The microstructure is characteristic for rocks of light granulometric composition, characteristic of Upper Pleistocene soils, as well as forests ones
Aggregation	Aggregates	They are formed by biogenic-accumulative processes caused by direct influence of living organisms, products of their vital activity, as well as cracking at drying of soil mass, microsedimentation, microerosion
	Complex grainy microaggregates of II-IV order, black or almost black, separated by a grid of vorticular pores	The presence of humic acids in the composition of organic matter, high saturation of soil mass in the basics. In the overwhelming majority it is the products of the life of worms (excrements). Characteristic of the humus horizons of chernozem. Complex microaggregates of chernozem type are observed in the horizons df, pl, kd_{b2}, lb of soils
	Simple and complex (to the third order) microaggregates of dark color	Actual for gray forest soils
	Fuzzy micro aggregates of dark or brownish color	Intrinsic to podzolic soils, in the eluvial horizon often acquire puff formation
	Oval, simple and complex (to the third order) micro aggregates	This is mainly faecals of mites fauna. Own chestnut soils. It is characterized by zonal southern soils of Dofinivka and Pryluky time
	Tightly packed structural isolations of the 1st-2nd order	Actual brown soils
	Cleave blocks	Formed in the case of reloading of soils, when the surface of the cracks converge as a result of swelling and form a cleave mass. Variable wet-dry conditions. Characteristic of vt, zv, mr soils
Porosity	Branched net of pores	Active livelihoods of soil biota and favorable conditions for soil aeration. Properties for forests and soils of chernozem type
	Pores-cracks	They are formed for successive swelling of clay mass under humid conditions, and then compression due to the drying of the soil mass. Intrinsically enriched soils
Optical orientation	Optical orientation of clay substances	The course of illuvial processes
	Isolation of clay substances in the form of scaled gutters, incrustations on the walls of pores, clay streams, impregnation of plasma by the calomorphic clays	Formation of soils of washing (podzolic, pseudo-podzolic, brown forest, gray forest, red and yellow earth) or periodically humid regimen of wetting (solonetses, tacier, malt). The mentioned signs occur in the fossil soils of the forest genesis
	Transparent and bright streaks	The processes of podzolizations. These traits for characteristic of podzolic and turf-podzolic soils
	Influxes are enriched on finely dispersed humus and clay particles	The process of podzolization and lessive. Signs are characteristic for gray forest soils
	Influxes of red color, not transparent, much ferruginous, occur throughout the profile	Processes of lessive (illimerizations). Actual for brown forest soils
	Impoverished on mulles and humus («washed») microplots	The course of eluvial processes of moving organo-clay substances down the profile. Manifested in eluvial horizons
	Clay substance that is not oriented or oriented in the form of rings located near individual minerals or aggregates	Complicated conditions for the course of illuvial processes and leaching
	There is not expressed optical orientation of clay substances	Formation of soils under constantly dry conditions (grayzems, typical loesses, southern zone of the Dofinivka soil formation
Organic matter	Dispersed brown humus, which is closely combined with clay	Characteristic for soils of forest genesis, of Early Pleistocene
	The organic substance is coagulated in the form of clots and lumps, which are combined into complex microaggregates	Intense biogenic and accumulative processes. Particularly good expressed in the chernozems-liked soils, gray forest of Middle and Late Pleistocene soils
	Brown humus in the form of cinnamon or light clots	Displays the effect of relatively arid climate, closed to dry-steppe

Elements of microstructure	Micromorphological signs and traces of ancient soil formation	Conditions, processes of formation
New formation of easily dessolved salts	Needled calcite-lublinit	Characteristic for soils with intensive seasonal migration of carbonates
	Micro-calcite, concentrated on the walls of pores	Relatively fast, intense evaporation and high concentration of carbonates in the soil solution
	Fine-grained calcite, concentrated on the walls of pores	Gradual evaporation and slight migration of carbonates
	Increased carbonate content	Dryer conditions characteristic of steppe type soils
	Insignificant carbonate content	More wet conditions of soil formation, which are characteristic for forest types of soils
	Gypsum	Display of hotter climatic conditions
Iron and manganese neoplasms	Presence of ferruginous and manganese new formations	Surface or ground soils overwetting. Processes related to release, migration and concentration of hydroxides of iron and manganese
	Microorsteins	Seasonal changes in the humidity conditions
	Compact microfiber with clear edges	Formed in ungleyed or deeply gleyed sod-podzolic soils
	Friable microorsteins with fuzzy, blurred edges	Formed in gley soils
	Ferruginations of walls pores	Encreasing gleying in the illuvial horizon
Other	Carbonate-clayey loess particles are commensurate with the seeds of primary minerals, wrapped with transparent films and membranes, separated by a developed pore net	Characteristic for typical loesses
	The accumulation of sand-aleurite particles, micro-polygons in the form of rings, sorting of sand and large alyurite particles	The course of cryogenic processes, the existence of freezing-thawing out conditions

inter- and inside-aggregate cavity space with a developed net of pores and cracks. Organic matter in the soil mass is in the form of humus (of coagulated, dispersed, coprolite, microbial mass, weakly, medium or strongly depleted residues of tissues of plants or animals, organo-mineral compounds, etc.).

Eluvial SFP (podzolisation, illimerization, leaching, etc.) are associated with the destruction or transformation of soil material in the eluvial horizon with the subsequent removal from it of products of destruction (transformation) into the lower disposed horizons (Figure 4 e-h). In the thin sections from the eluvial horizons of fossil soils, the dominance of the skeleton particles over the plasma is observed, the destroyed composite microaggregates are found, the «washed» (without clay films) seeds of primary minerals, which in some fields are cemented with amorphous plasma (by humus, silica). In the illuvial horizon there are signs of the removement of organo-clay substances in the form of numerous scalene streaks of polynite (calomorphic clays) on the walls of pores and cracks, films around the grains of the mineral skeleton.

Illuvial-accumulative SFP is the processes associated with the accumulation of substances in the middle part of the genetic profile of eluvial-illuvially differentiated soils (Figure 4 i-l). Depending on the type of accumulated substances (silt, humus, carbonates, iron oxides, aluminium, etc.), the processes are also distinguished. For example: clay-illuvial, humus-illuvial, carbonate-illuvial, feruginous-illuvial and the like. Under the microscope, illuvial-accumulative processes are diagnosed with various forms of influxes and streams confined to the cavity space, with films around the grains of the skeleton and other new formations of the polynite (calomorphic clays).

Hydrogen-accumulative SFP is a group of processes that are related to the influence of ground water on the formation of a soil profile with various forms of gyps, calcite, easily soluble salts new formation, etc. (Figure 4 m-p). In the thin sections with undisturbed structure of fossil soils, diagnostic signs of enriching on gypses processes (micro, fine, medium grained, rhombus, lensliked and other gyps new formations), carbonatization (crypto-, micro- and small-grained calcite, lublynite, etc.) can be detected, salinization (forms of easy soluble salts), ore formation (spots, flakes, films, diffuse rings, microorsteins, incrustations and other forms of iron and manganese hydroxides), meadow formation processes (high content of humus, in the lower part of the profile – gray-blue spots of hydroxides, iron, microorsteins, leaching of mass from carbonates, etc.).

Metamorphic SFP is a group of processes for the transformation of rock-forming minerals inside

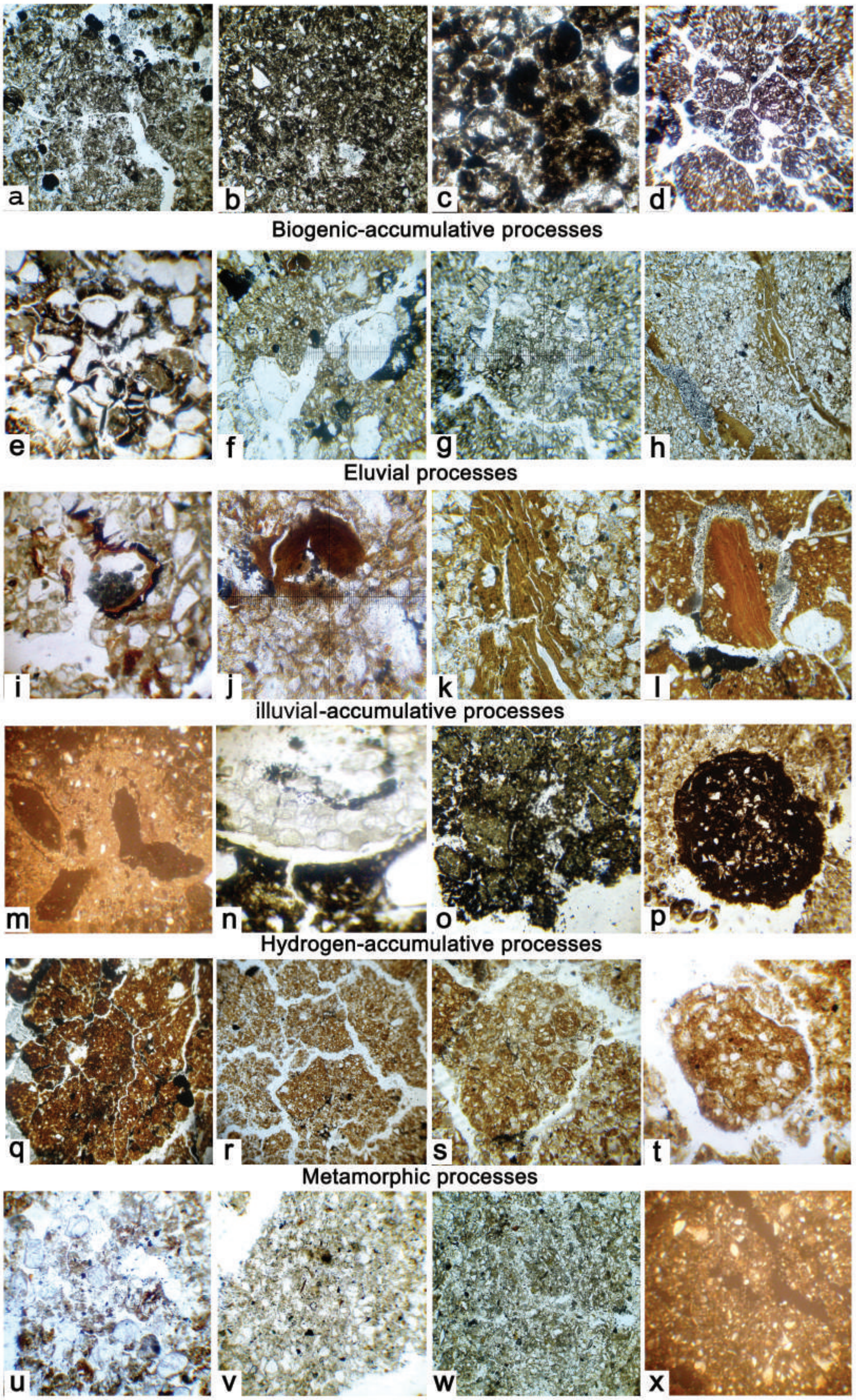

Fig. 4. Certain typical micromorphological diagnostic features of the main groups of soil formation processes in the differ aged Pleistocene soils of the Middle Pobuzhzhya processes:

Biogenic-accumulative: a) complex microaggregation of chernozem of brownzem-liked (pl_{b2}; Yakushyntsi) /magn. 100/; b) microstructure of the humus horizon of meadow chernozem (pl_{b1}; Yakushyntsi) /magn. 100/; c) humus coagulated in the form of humons in the humus horizon of meadow chernozem (pl_{b1}; Yakushyntsi) /magn. 400/; d) coprolites of rain worms combined in the complex microaggregates, separated by a net of twisted pores, in the humus horizon of the meadow chernozem (pl_{b1}; Pervomaisk) / magn. 70/ (nic.||).

Eluvial: e) microstructure of the humus-eluvial horizon of sod-podzolic soils (kd_{b1}; Bezimenne) /magn. 70/; f, g) «washed» grains of the mineral skeleton are cemented with amorphous plasma in the eluvial-humus horizon of gray podzolized soil (kd_{b1}; Stryzhavka) /magn. 80/; h) new formations of polynite (calomorphic clay) in the form of scaly streaks on the pore walls (kd_{b1}; Yakushyntsi) /magn. 100/ (nic.||).

Illuvial-accumulative: i) manganese-ferruginous-clayey calomorphic clay formation on the walls of pores of sod-gleyd soil (kd_a; Bezimenne) /magn. 70/; j) scale influx of calomorphic clays in the brown podzolized forest soil (kd_{b1}; Stryzhavka) /magn. 400/; k) the influx of calomorphic clays in the illuvial horizon of gray podzolized soil (kd_{b1}; Yakushyntsi) /magn. 400/; l) terruginous-clayey influx of calomorphic clays in the pore of reddish-brown meadow soil (sh; Raihorod) /magn. 100/ (nic.||).

Hydrogen-accumulative: m) concentrations of microcrystalline around the pore in the lower part of the brown soil (vt_{b2}; Medzhybizh) /magn. 70/; n) microconcentration of fine crystalline calcite in the pore of brown soil (vt_{b2}; Vyss) /magn. 140/; o) films and flakes of hydroxides of iron and manganese in reddish-cinnamonish brown soils (mr_{b2}; Raihorod) /magn. 100/; p) dense glandular-manganese concentric microorstein in dark brown soil (vt_{b1}; Yakushyntsi) /magn. 100/ (n-p – nic.||, m – nic. +).

Metamorphic: q) cinnamon-brown ferruginous-clay plasma, with a small fraction of the dusty grains of the skeleton, in the reddish-brown meadow soils (sh; Raihorod) /magn. 100/; r) cleave block microstructure of brown forest soils (zv_{1b1}; Raihorod) / magn. 40/; s) the ferruginous-clay substance is segregated into nodular formations, which are tightly packed in cleave blocks in brown forest soils (zv_{1b1}; Raihorod) /magn. 100/; t) the nodule of the ferruginous-clay substance from the middle part of the brown soil (vt_{b2}; Ozerove) /magn. 140/ (nic.||).

Micromorphological features of loesses sediments: u) microstructure of the Prychernomorya loess, the proportion of loess particles with seeds of primary minerals, large calcite crystals (Pervomaisk) /magn. 140/; v) the seeds of primary minerals are commensurate with the loess particles, covered with carbonate-clay films (Bezimenne) /magn. 140/; w) friable microstructure of the Dnipro loess (Yakushyntsi) /magn. 100/; x) dust-plasmic microstructure of the Uday loess, mass is impregnated with microcrystalline calcite (Korobchyne) /magn. 70/ (u-w – nic.||, x – nic. +).

of sediments («in situ»), without eluvial-illuvial redistribution of components in the soil profile (Figure 4 q-t). The metamorphic processes of soil formation are best displayed in the soils of the Early and Middle Pleistocene. Can see under the microskope signs of enrichment on the iron hydroxides processes (reddish, brownish, and yellowish-brown tints of the plasma) of claying (an decreasing in the percentage of mineral skeleton grains – an increasing proportion of plasma mass, a dense microstructure in the form of cleave blocks, mass compactness, sharp edges of pores-cracks), cleavisation (dense block microstructure, segregation of organo-clay substances into nodular formations in side of the middle of fused blocks), rubbification (specific cinnamonic color of plasma, films and spots of iron oxides, goethite and haematites grains) inside soils weathering (corrosion mineral grains) and others.

Under a microscope in the thin sections from the typical loess horizons there are no signs of the above-mentioned soil formation processes. Loesses are characterized by a dust-plasmic elementary microstructure, a loose mass composition, a carbonate-clayey plasma, a developed system of cavities, and the seeds of primary minerals coated with transparent carbonate-clay films and shells that are commensurable with the loesses particles (Figure 4 u-x).

Summarizing the above, it should be noted that the micromorphological analysis, through the study of soil samples in thin sections with undisturbed structure, provides the opportunity to consider the soil as a system at the microscopic level. It is known that the formation of one or another type of soil depends on the nature of the manifestation of soil formation processes, which are the result of the joint action of the main factors of soil formation. Possessing knowledge about the natural peculiarities of certain primary soil forming processes, one can determine their diagnostic features under a microscope. This, in turn, makes it possible to restore the chronology of the soil formation processes in the Pleistocene sediments, to identify signs of diagenesis and the stage of development of the soil, to establish a genetic type of soil and to carry out paleogeographical reconstruction. In many cases, the micromorphological data can also be used for stratigraphic purposes, since the different age-old Pleistocene horizons are characterized by their individual specific singularizes.

Paleopedological studies of different age-old Pleistocene soils, carried out on the territory of the Middle Pobuzhzhya, with the active use of micromorphological data, allowed to obtain the following results.

The Shyrokyne horizon is correlated with 37-21 isotopic-oxygen stages (Matviishyna et al., 2010; Lindner et al, 2004), Balashovsky (Velychko et al., 1997) and Mikhailovsk horizons (Rekovez, 1994), Late Raiver (Veklych, 1968), Gunz-Mindel (Veklych, 1990). Presented by the deposits of the first warm stage of the Pleistocene, which have a rather limited distribution, since they are found at high geomorphological levels of watersheds and, in the form of an alluvium of the warm phase, compose the VIII floodplain terrace. Deposits of the subaerial facies consist of heavy-sandy-clayey eluvial-deluvial formations of the aqual of fossil soils suits, the deposits of the subaqual facies are sands, sandy loams, loams, gravel, and the like.

The Shyrokyne deposits are investigated in the section of Raihorod, where the thickness of sediments is relatively conditionally divided into three soils suits. In the thin sections from Shyrokyne soils, by means of a micromorphological analysis, the processes of intensive claying (reduced proportion of primary grains of the mineral skeleton, cleave block microstructure, mass compacting, sharp edges of pore-cracks walls), enrichment on hydroxides of iron (cinnamonish, reddish, brownish shades of plasma color) , weathering (a large proportion of medium- and fine-dusty grains of the skeleton, clayey mass), partial leaching, intensive periodic surface and ground moisture (various forms of ferruginous and manganese new formations). Oodic and nodule forms of segregations of organic-ferruginous-clayey substances with concentric building indicate the existence of at least short dry periods, when organo-clay substances could be segregated from ground solutions in round and oval knitting-nodules (Figure 5).

The Martonosha horizon is correlated with 19 to 17 isotopic-oxygen stages (Matviishyna et al., 2010; Lindner et al, 2004), the Gremiachiv and Semilutsk interglacials (Bolihovskaja, 1995), Rzhaksyno soil (Velychko et al, 1997), Illyinsk time (Hlushankova, 2008; Rekovez, 1994), Tegelensk interglacial (Veklych, 1968), Mindel 1-2 (Veklych, 1990). It is widespreaded in the subaeral strata of the Pleistocene deposits at high geomorphological levels of watersheds and their gentle slopes, above the seventh floodplain terrace. Deposits are represented by eluvial-deluvial heavy-loamy soils, often clayey fossil soils. In the subaqual thickness, the Martonosha soils correlate with the lower pack of alluvium of the warm phase of the seventh floodplain terrace.

The Martonosha deposits are investigated in sections of the Pleistocene deposits near villages of Raihorod and Pankratove. In the studied sections, the Martonosha formations are represented by soils suits consisting of two soils of climatic optimum. In the section Raihorod is a reddish-brown soil of substage mr_{b1} and reddish-brownish-brown of substage mr_{b2}; in the section Pankratove – it is a reddish brown meadow of early optimum (mr_{b1}) and reddish-cinnamonish-brown meadow soil of late optimum (mr_{b2}). The soils are monolithic, clay-sandy, dense, gleyed and ferrugenous, with fine silicious-carbonate concretions, the number of which grows in the lower soil.

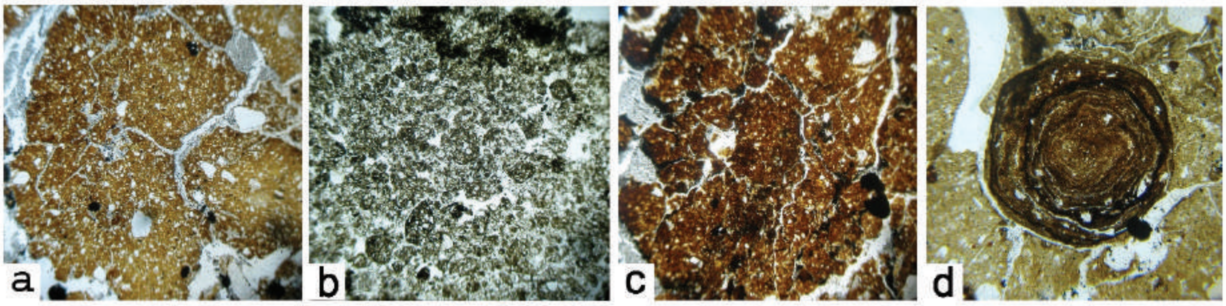

Fig. 5. Microstructure of Shyrokyne soils in the section near the village Raihorod: a) dense block microstructure of the Shyrokyne horizon /magn. 40/; b) structural nodular segregation in the organ-iron-clay plasma /magn. 40/; c) ferruginous-clay plasma in the lower part of the soil /magn. 40/; d) glandular microorstein of a concentric structure in the form of diffuse rings /magn. 100/ (nic. ||).

Macro- and micromorphological features allow us to talk about the formation of the Shyrokyne age soils in the most warm and humid conditions in the Pleistocene, and indicate the similarities of the fossil soils signs with brown and cinnamon ones. At the same time, the relative leaching of the soil profile from carbonates, various forms of ferruginous and manganese new formations are signs of soil formation in sufficiently damp, possibly meadow conditions. We relate the soils of the Shyrokyne time to the type reddish-cinnamonic meadow of warm-temperate climate.

Micromorphological analysis of Martonosha soils fixes their significant claying, cleaving of microstructures in the form of cleave blocks, separated by pores-cracks, the presence of round-oval segregational nodular concentrations of organic-clay substance, indicating on their formation under periodically-changing conditions of moistening. For Martonosha soils, especially of the early optimum, the partial mobility of the most subtle colloidal particles of the silt and their separation in the form of reddish-brown influxes and streams, the filling by the material colloidal substance of pores and impregnation by them of clay material in the middle and lower part of the profiles is characteristic. All these are signs of the course of illuvial and illimerization processes. Soils of the late optimum are characterized by good microaggregacy, which manifests itself throughout the profile. This may indicate an intensive development of biogenic and accumulative processes. Significant claying of the mass and a large number of ferruginous new formations (spots, flakes, microorsteins, diffuse rings) indicate the processes of gleying, enrichment on hydroxides of iron and meadow process development (Figure 6).

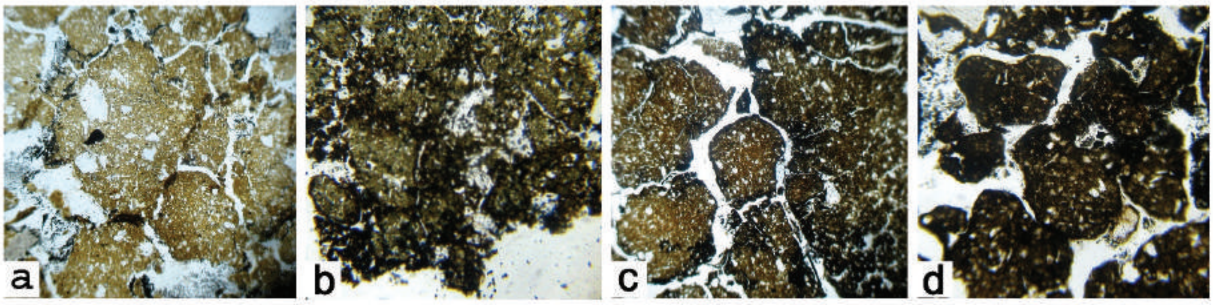

Fig. 6. Microstructure of Martonosha soils in the section near the village Raihorod: a) micro-building in the form of cleave blocks, which are separated by a system of pore-cracks in the soil mr_{b2} /magn. 40/; b) films and flakes of iron and manganese hydroxides outlined ooid-like segregations in the cleave earth mass mr_{b2} /magn. 100/; c) cleave block microstructure mr_{b1}; separate blocks consist of densely packed nodular iron-clay formations; iron and manganese oxides in the form of films are concentrated on the walls of the pores /magn 40/; d) nodule joints of organo-ferruginous-clay substances in soil mr_{b1} /magn. 100/ (nic. II)

Paleopedological data indicate that the climate of Martonosha time was moderately warm, in the first half of the climatic optimum it was wet, but in the second half it was variable-humid. At this time, the climatic conditions were probably close to the changing and wet conditions of modern subtropics, with the summer maximum of humidity, which contributed to the development of the meadow processes (the formation of thick profiles with a high degree of dispersion of the mineral mass), which, in combination with periodic aridity, caused the cleaving of soils.

The Lubny horizon is correlated with 15-13 isotopic-oxygen stages (Matviishyna et al., 2010; Lindner et al, 2004), Muchkap interglacial (Bolihovskaia, 1995), the Voronsky soil complex (Velychko et al, 1997), the Belovezhsky horizon (Rekovez, 1994), the Kromer interglacial (Veklych, 1968). Displaced in the subaerial layers of the Pleistocene deposits at high geomorphological levels of watersheds and their slopes, beginning from the seventh floodplain terrace. In the subaerial straties is represented by eluvial-deluvial deposits – mostly heavy-loamy fossil soils. The stratigraphic equivalent of fossil soils in the subaqual facies is the alluvium of the warm phase of the sixth floodplain terrace.

The horizon is investigated in sections of the Pleistocene deposits of Raihorod, Korobchyne-quarry and Pankratove. Studied Lubny soils in sections are represented by complicated polygenetic formations consisting of two soils of the climatic optimum and the soils-pedosediments of the final stage. In the section, Raihorod a light-cinnamon-brown forest soil of the lb_{b1} substage and brownish-cinnamon substage lb_{b2} are represented; in the sections of the Korobchyne-quarry, this is a cinnamonish-brown forest soil of early optimum (lb_{b1}), dark-cinnamonish meadow weakly saltish soil of late optimum (lb_{b2}) and brownish-cinnamonic dry-steppe soil of the final stage (lb_c); in the section Pankratove it is a meadow-cinnamonic soil of the floodplain facies of the early optimum (lb_{b1}) and meadow-cinnamonic chernozem-liked soil of late optimum (lb_{b2}). The soils are monolithic, dense, enriched on clayes, but to a lesser extent than the Martonosha, enriched on hydroxides of iron, broken by frost-free cracks, inside of which there are hard, hollow in the middle, silicon-carbonate nodules concretions. In the south, gypsum concretions have been detected.

The micromorphological analysis fixes the characteristic features of the Lubny soils – a significant cleaving of the microstructure in the form of blocks, separated by pores-cracks, claying, segregation of the organo-ferruginous-clay substance in the form of ooids-nodules. The latter ones indicate the periodically changing conditions for the formation of soils, when the conditions of intensive moisture environment necessary for the transition of chemicals substances into solutions, were changed in the dry periods, during which the segregation of chemicals from solutions took place. For soils of the early climatic optimum, the partial mobility of the most subtle colloidal particles of the silt and their isolations in the form of influxes and streaks, pore filling, and plasma impregnation in the middle and lower sections of the profiles is characteristic, indicating the course of the illuvial processes. In the soils of the late optimum, good aggregation of the mass is recorded, available carbonate formations (Figure 7).

and of horizon widespread distribution of these deposits indicate intense and long-term soil formation processes that took place during this stage.

In the sections Raihorod and Pankratove, the Zavadivka horizon is represented by the soils of all stages. In the section Raihorod it is a yellowish-brown forest soil of the initial stage, reddish brown forest of early optimum, cinnamonish-brown forest of late optimum and short-profile reddish-brown soil of the final stage. In the context of Pankratove-2, the suit consists of chernozem-liked soil of the initial stage, brown forest reddish soil of early optimum, cinnamonish-brown soil of late optimum, loess-like layer and yellowish-brown soil of the final stage. In addition, Zavadivka soils are investigated in sections Stryzhavka (cinnamon-brown forest), Sabariv (sod-alluvial), Tyvriv (brown forest soil of climatic optimum and soil-pedosediment of the final stage), Medzhybizh (reddish-brown alluvial) and Pankratove-1 (brown forest cinnamonish).

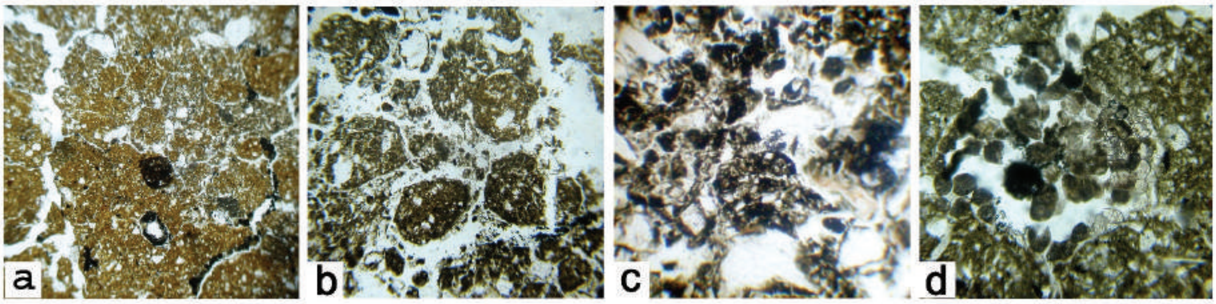

Fig. 7. Microstructure of Lubny soils: a) the blocks are separated by cracking pores in the soil of lb_{b1}, densely packed and with carbonate-clay new formations (section Raihorod) /magn. 40/; b) segregation nodular formations of organo-ferruginous-clay substance in the lb_{b2} section Raihorod /magn. 100/; c) humus-clay soil microaggregates of lb_{b2}, section Pankratove /magn. 70/; d) accumulation of fine crystalline calcite in the pore of the lb_c soil in the section Raihorod /magn. 100/ (nic. II)

The considerable claying and enrichment on iron hydroxides of the mass, a large number of primary minerals weathered grains, indicates not only wet but also sufficiently warm conditions for the formation of Lubny soils. The genetic types of these soils indicate the soil formation under environment of a warm-temperate climate, which is was more temperate that in Martonosha time.

The Zavadivka horizon is represented by the deposits of the first warm stage of the Middle Pleistocene, which correlates with the Lykhvino interglacial (Velychko et al., 1997; Rekovez, 1994), the Mindel-Riss interglacial (Veklych, 1990), 11-7 isotopic-oxygen stages (Matviishyna et al, 2010). Deposits of the Zavadivka stage are widespread in the subaerial straties of the Pleistocene deposits on inter-rivers spaces and their slopes, in the valleys of the rivers since the sixth floodplain terrace. In the subaerial facies eluvial-deluvial deposits are represented by mostly medium-heavy loam fossil soils. The stratigraphic equivalent of fossil soils in the subaqueous facies is the alluvium of the warm phase of the fifth floodplain terrace.

The horizon is investigated in sections of the Pleistocene deposits of Stryzhavka, Sabariv, Tyvriv, Medzhybizh, Raihorod, Korobchyne-quarry, Pankratove-1 and Pankratove-2. Zavadivka deposits are often represented by complex polygenetic soils suits. The structure of the full suit is as follows: zv_a is the soil of the initial stage, zv_{1b1} is the early soil of the optimal stage, zv_{1b2} is the late soil of the optimal stage, zv_2 is the loesses layers (Oril) and zv_3 is the soil of the final stage (Potiahailivsky). The horizon's thickness ranges from tens of centimeters to almost 6 m and averaged around 2 m. Significant thickness

Zavadivka soils are dense, clayed and enriched on iron hidrooxides, secondary carbonated, with ferruginous-manganese films on the edges of structural separations, often broken up by freezing cracks to which confined carbonate new formations, have a differentiated profile. The micromorphological analysis fixes a cleave block microstructure, a significant claying of mass, new formations of polynite (calomorphic clays) in the form of influxes, streaks and streams, plasma impregnation (signs of illuvial processes), gray-blue spots, diffuse rings, microorsteins (signs of gleyiness); unlike of Lubny soils, rounded ooidic segregations of organo-clay substances are fuzzy, weakly concentric, occur less frequently (Figure 8).

Enrichment on iron oxides of soil material in complex with over thickness of profile indicate the formation of cleave soils-pedosediments under the influence of intensive weathering processes in a warm and humid climate. The soils, formed in the early

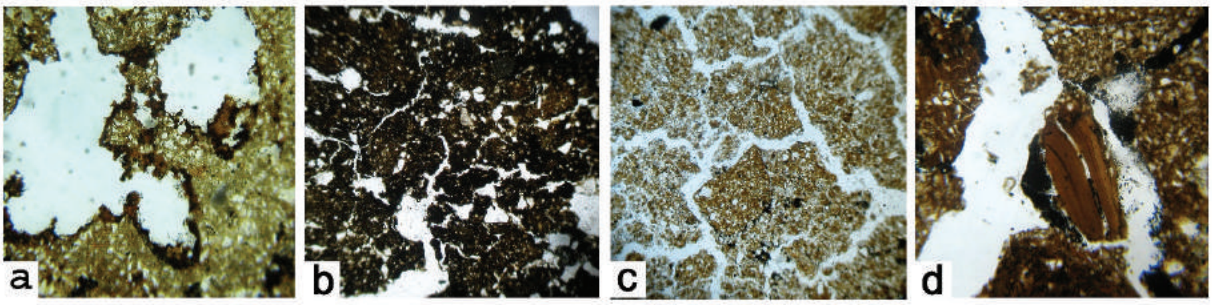

Fig. 8. Microstructure of Zavadivka soils: a) incrustation of pores with hydroxides of iron in the zv_3 soil of the section Raihorod /magn. 100/; b) compact microstructure with a dense packing of grains of the mineral skeleton in a plasma of zv_{1b2} soil section Raihorod /magn. 100/; c) dense blocks are separated by a system of twisted pore-cracks in the zv_{1b1} soil section Raihorod /magn. 40/; d) scaly ferruginous-clayey outflow of polynite in the zv_{1b1} soil, section Raihorod /magn. 100/ (nic. II)

optimum, are mainly of forest genesis, with traits of brown forest soils of warm facies. In the late optimum the soils with transient features from brown forest to brown and reddish-brown were formed. Comparing the micro-morphological features of brown forest-cinnamonish Zavadivka soils with the modern brown forest soils of the Eastern Caucasus, their remarkable similarity (Matviishyna, 1982) is noted, despite of the large differences between the soil-formation bed rocks.

Kaydaky horizon – represented by deposits of the first warm stage after Dnieper glaciation. Stratigraphically it correlates with the first interglacial or the 1-st Warsaw glacial, the Drenthe, the second interstadial of Riss glacial (Veklych, 1968), the Korshiv fossil soil complex (Shelkoplias et al, 1986), or the soil of the first phase of Gorohiv soil formation (Lanczont M. et al, 2015), Saalian the soils of the Mezyn complex (Velychko et al, 1997), the Eemian pedocomplex, the isotope-oxygen substage 5e (Matviishyna et al, 2010). This horizon is widespread in the subaerial strata of the Pleistocene deposits above the fifth terraces, which is represented by eluvial-deluvial sediments – fossil soils. It lies predominantly on the Dnipro deposits, overlapped by thickets of loess and loess liked loams, often by Pryluky soils. On low geomorphological levels and gentle slopes of the watersheds, where favorable conditions for the fossilization of the Kaydaky soil formations were provided, they are represented by the suits of fossil soils. At inter-river spaces and other high lands, the only illuvial horizon of the soil of the early optimum is often remained from the suit of Kaydaky soils, the other part of the profile, as rule, is mainly transformed or reworked by the processes of the Pryluky soil formation. In the subaqual facie the Kaydaky fossil soil is correlated with the alluvium of the warm phase of the IV floodplain terrace.

The horizon is investigated in sections of Pleistocene deposits Bezimenne, Medzhybizh, Stryzhavka, Yakushyntsi, Sabariv, Korobchyne-quarry. The horizon's thickness changes from a dozen centimeters to more than 3 meters. The granulometric composition is mostly medium loam, less commonly-light or heavy.

We studied the following genetic types of Kaydaky soils: sod-podzolic (Bezimenne), sod-podzolic alluvial (Medzhybizh), broun alluvial (Sabariv), meadow-chernozem (Korobchyne-quarry) and illuvial horizons of brown (Stryzhavka) and gray (Yakushyntsi) of forest soils. For sod-podzolic and alluvial soils, the sandy composition is characteristic, small containing of humus substance, the presence of stains of iron hydroxides and claying ortzand layers. In the illuvial horizons of brown and gray forest soils, the micro-morphological features of the illuvial processes (podzolization, illimerization) are clearly traceable: depleted on the mulles and humus fields in the upper part of the profile, the influxes of transparent yellowish calomorphic clays sometimes with inclusions of coarse clay and humus particles in the middle part, signs of gleying and claying, structural separations in the form of blocks separated by wide pores (Fig. 9).

According to paleopedological data, the stage of the Kaydaky soil formation is clearly recorded, manifested in the natural general changes in the soil cover. So, at the initial stage, soddy and turf-podzolic soils were formed; in the substage of the early climatic optimum, the soils of the forest and forest-steppe genesis are soddy-podzolic, brown forest, brown forest gleyey, podzolic and pseudo-podzolic, light gray, gray forest and their varieties, dark gray forest, chernozems podzolized; in the substage of late optimum – soils of sod, meadow or chernozem types: chernozems leached and podzolized, meadow-chernozem, chernozem-like.

During the Kaydaky time, the soils, which were similar to modern ones, began to form in Pleistocene for the first time and were established close to the present soil zones. During this stage there is a stageness of soil formation, which manifests itself in changing

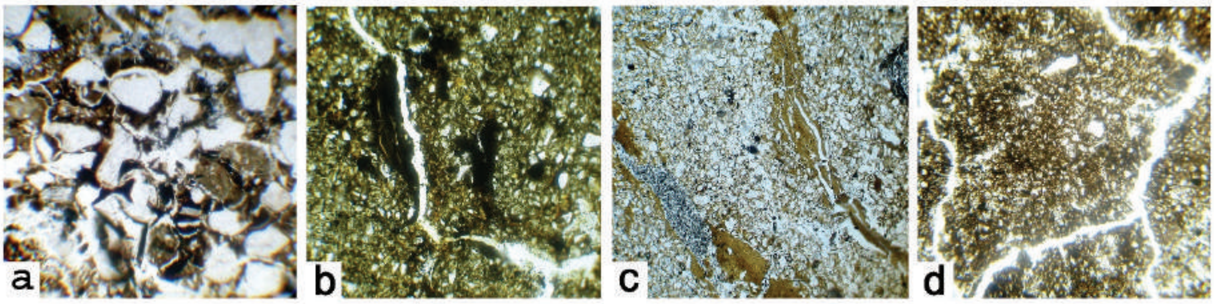

Fig. 9. Microstructure of Kaydaky soils: a) microstructure of eluvial horizon in the kd_{b1} soil, section Bezimenne: alternating «washed» fields with enriched on humus, dark brown clouds /magn. 70/; b) humus-clay dark-colored influxes, enriched by the coarse clays and humus particles of the upper part of the illuvial-humus horizon of the kd_{b1}, section Yakushyntsi /magn. 100/; c) dense microstructure of the Ip_{gl} horizon, the clay substance is mobile, is separated in the form of influxes, films and streams in the kd_{b1} soil, section Yakushyntsi /magn. 100/; d) structural aggregates-blocks, separated by twisted pores in the horizon Pk_{gl} soil kd_{b1}, section Stryzhavka /magn. 80/ (nic. ||)

of the genetic types of soils in time. In the initial stage (kd_a), turf and turf podzolic soils were formed, under the age of the early climatic optimum (kd_{b1}) – the soils of forest and forest-steppe genesis (turf podzolic, brown forest, brown forest glayed, podzolic and pseudopodzolic, light gray, gray podzolic and their gleyed varieties, dark gray podzolic, chernozems podzolized), in the late optimum (kd_{b2}) – the soils are with more developed signs of steppe regime (sod, chernozems leached and podzolized, meadow chernozem, chernozem-like).

Thus, in the Kaydaky time, for the first time in the Pleistocene, not only began to form the soils very similar to the modern ones, but also established the soil zonality most close to the present, which was due to the restructuring of the climate after the Dnieper glacier in the direction of changes in natural conditions from close to subtropical (in the early Pleistocene) to more moderate. Typologically, the soils of the Kaydaky time are more similar to the soils of the subboreal temperate – warm climate, more humid than modern ones.

The Pryluky horizon is represented by the deposits of the warm stage, which is characterized by active processes of soil formation. Stratigraphically correlated with the Eemian, II Mazowetsky interglacial, Riss-Wurm interstadial (Veklych, 1968), Horohiv complex (Shelkoplias et al, 1986; Lanczont M. et al, 2015), is part of the Mesyn complex (Velychko et al., 1997), Brerup-Amersfoort and Odderade, isotopic-oxygen substages of 5 a-c (Matviishyna et al, 2010). In the subaerial strata of the Pleistocene deposits, on the geomorphological levels above the fourth terraces, the horizon is represented by eluvial-deluvial deposits – fossil soils that lie on the Tyasmyn loesses and loess-like loams, often on the Kaydaky soils; are covered with Uday loesses and loess-like loams, or, that is often observed in investigated sections – Vytachiv soils. In the sections the horizon is often represented by soil suits or separate soils. In the subaquale facie, the stratigraphic equivalent of the Pryluky fossil soils is the alluvium of the warm phase of the III floodplain terrace.

The horizon is investigated in sections of the Pleistocene deposits Bezimenne, Medzhybizh, Trebukhivtsi, Stryzhavka, Yakushyntsi, Sabariv, Korobchyne-quarry, Pervomaisk. The thickness of the horizon ranges from 0.5 m to 2,4 m. The granulometric composition is mainly medium loam, and rarely light or heavy. Preferably, the horizon consists of one or two soils of the optimum and the soil of the final stage. Thus, in the first substage of the optimum, the meadow chernozem soils (Bezimenne, Stryzhavka, Yakushyntsi, Pervomaisk), brown forest with signs of steppe (Sabariv) and near to the chernozem ordinary (Korobchyne-quarry) have been developed. For meadow-chernozem soils is characteristic a significant thickness of the soil profile (about 1 m), intense dark gray color, humus «tails» deeply penetrating into the lowering horizons, and the gray-bluish gleyey spots, some times, the existing of layer of meadow carbonates.

The micromorphological analysis records the good microagregation of the entire profile, with the development of complicated microaggregates up to the IV order, separated by the branched system of the twisted pores, coagulation of thin humus (type of mulles) in clear clots and thickening, small lumps, the presence of microorsteines in the lower part of the profile (Fig. 10).

In the second substage of the optimum was investigated chernozems brownzem-like (Medzhybizh, Stryzhavka, Yakushyntsi), chernozem-like soils (Trebukhivtsi, Sabariv) and chernozem-like, brownish soils (Pervomaisk, Korobchyne-quarry). For these soils, there are signs that indicate

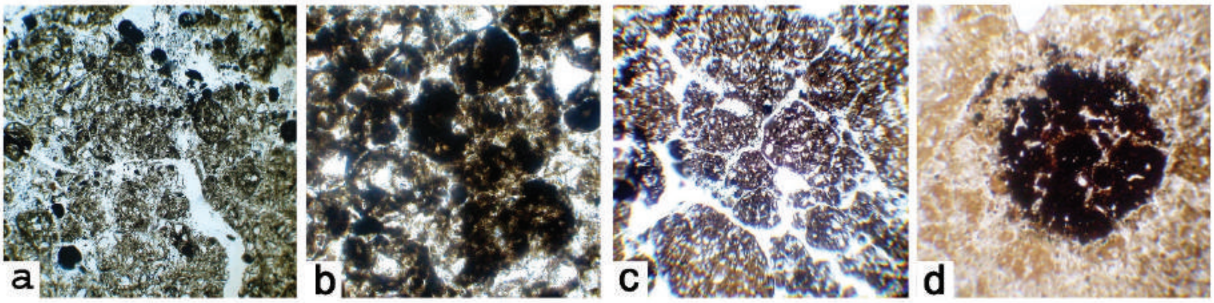

Fig. 10. Microstructure of Pryluky soils: a) complicated microaggregates to IV order are separated by a net of twisted pores and small iron concentrations in the soil, of pl_{b2}, section Yakushyntsi /magn. 100/; b) humus is encapsulated in the form of humons, which form composite microaggregates up to the IV order in the humus horizon of the pl_{b1}, section Yakushyntsi /magn. 400/; c) complex micro aggregates separated by a net of pores in the humus horizon of the soil pl_{b1}, section Pervomaisk /magn. 70/; d) ferruginous manganese microorstein in the lower part of the pl_{b1} soil, section Pervomaisk / magn. 70 / (nic. ||)

their formation in warmer and more arid conditions, in comparison with the soil of the early optimum. High humus containing, various forms of carbonate new formations, more brownish, and in the south even cinnamonish shades of profile color, gradual transitions between genetic horizons, numerous molles and wormholes; in micro-morphology, developed complicated microaggregates, with the cluster and lumps combined with thin humus type mull, absence of signs of redistribution of substances on the profile, plasma cementation by microcrystalline calcite, filling by it of pores – all this indicates the climatic changes in direction more dry steppe conditions in soil formation in the late climatic optimum in comparison with the early.

Short-profile soils were formed in the final stage of the Pryluky soil formation in the transition from warm and wet interglacial to cold and dry periglacial. Sod-carbonate (Medzhybizh), turf (Trebukhivtsi), gray-brown (Bezimenne) and pale-brown steppe (Pervomaisk) soils were prevailed in the soil cover. On dry-steppe conditions of soil formation, under the influence of the weakened sod process, indicates a slight humus mass, short profile, carbonate, mole and worm holes, good microagregation. The small thickness is also due to diagenetic changes in the soil of the final stage, which, at the end of the stage, served as a kind of protective screen for optimum soils.

In Pryluky time types of soils were formed close to modern ones, which, however, are not their complete analogue. During this stage, the stageness of soil formation is clearly recorded, it was manifested in the formation of a soil suits of 1-2 m, consisting as rule, of two soils of the optimal stage and the soil of the final. The soils of the early climatic optimum (pl_{b1}) were formed in the conditions of forest, forest-steppe and meadow-forest-steppe soil formation (brown and gray forest, chernozem leached, meadow chernozem), which as in the late optimum (pl_{b2}) evolved towards the meadow, meadow steppe and steppe soil formation (chernozems brownish, leached, meadow, micellar-carbonate, brownish). In the final stage (pl_c), soil formation was carried out under conditions of a warm dry-steppe regime (turf, grayish-brown chernozem-like, chernozem brownzem-like). Such a set of genetic types of soils is an indicator of warmer as modern and relatively humid temperate climate. Soil zonality, in comparison with the modern, was shifted to the north, especially in the late climatic optimum.

The Vytachiv horizon is represented by the deposits of the warm stage of the late Pleistocene, which stratigraphically correlates with the Bryansk interstadial (Velychko et al., 1997), the Brerup, the interstadial Amersfoort of the Vistulian glacial, the Lower Wurm interstadial (Veklych, 1968), the Dubnivsky soil (Shelkoplias et al, 1986; Lanczont M. et al, 2015), interstadials of Hosselo, Hengelo, Huneborg, Denekamp, 3-rd isotope-oxygen stage (Matviishyna et al, 2010). In the subaerial stratum of the Pleistocene deposits, at the geomorphological levels above the second floodplain terraces, the Vytachiv horizon is represented by eluvial-deluvial deposits – fossil soils that lie on the Uday loesses and loesses-like loams (often, especially on elevated elements of the relief, on the Pryluky soils) and overlap with Bug loesses. In the subaquale facie the stratigraphic equivalent of the Vytachiv soils is the alluvium of the warm phase of the II floodplain terrace.

The horizon is investigated in sections Bezimenne, Medzhybizh, Trebukhivtsi, Stryzhavka, Yakushyntsi, Vyss, Ozerove, Andriivka 4, Korobchyne, Korobchyne-quarry, Pervomaisk. The thickness of the horizon ranges from 0.4 m to 1.0 m. The Vytachiv soils are most densely clayed and enriched on iron oxides among the Upper Pleistocene, have more heavily granulometric (medium-heavy-grained) composition compared to the lower Pryluky and Kaydaky soils, often with sands.

In the investigated sections of the Pleistocene deposits, the Vytachiv horizon represented by 1-3 soils of the suit (Medzhybizh, Stryzhavka, Yakushyntsi, Vyss, Ozerove, Korobchyne, Korobchyne-quarry) or one brownzem-like soil (Bezimenne, Trebukhivtsi, Andriivka 4). The suits mainly consist of dark brown soil of early optimum and brown and light-brown soils of the late. In the south of the Middle Pobuzhzhya (Pervomaisk) the soils get brownish shades. For Vytachiv soils is characteristic enriching on iron oxides and claying of the material, which are largest in the middle part of the profile, high position of carbonate illuvium, insignificant thickness of the soil profile (0.4-0.6 m), significant deformation by the frost-free cracks and solifluctural processes associated with Bug time cryogenic processes, in the south of Pobuzhzhya – the features of saltiness and gypsums.

The micromorphological analysis of 17 thin sections with undisturbed structure allowed to trace the individual diagnostic features of the Vytachiv sediments, which also allows to use micromorphological data for stratigraphic purposes. Thus, the specific feature of their microstructure is the presence of concentric formations of the organo-clay substance in the form of nodules and ooids, as well as ferruginous cells of loess particles that diagnose the periodic segregation of substances and indicate the formation of the soils of the Vytachiv time in contrasting variable-humid-arid conditions (Fig. 11).

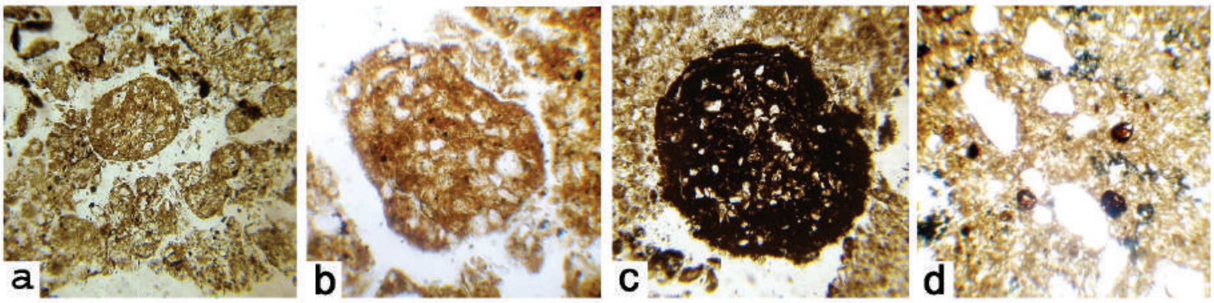

Fig. 11. Microstructure of Vytachiv soils: a) concentric nodules of the ferruginous-clay substance in the humus horizon of the vt_{b1} soil Yakushyntsi /magn. 100/; b) a nodule in the middle of the cinnamonish-brown field, section Ozerove /magn. 140/; c) iron-manganese microorstein of a concentric structure in the soil of vt_{b1}, section Yakushyntsi /magn. 100/; d) small glandular microorsteins in the fused ferruginous-carbonate-clay plasma of the brown-like soil, section Bezimenne /magn. 70/ (nic. ||)

Paleopedological data, such as the gleying and enrichment on iron oxides of soil mass, weathered seeds of primary minerals (feldspars) indicate the formation of Vytachiv soils under favorable conditions for the course of weathering processes; leaching of carbonates rare occurrence of colomorphic clays – on the forest type of soil formation; insignificant thickness of the soil profile – for a relatively short time soil formation; carbonatisation (primary), the presence of mole hollows – the steppe type of soil formation; strong deformity of the upper part of the Vytachiv horizon – on intensive post Vytachiv cryogenic processes; the presence of segregating nodular and ooid forms of organo-clay substances in the microstructure – on contrasting variable-moisture-dry conditions, during which the clay substance could swell in conditions of sufficient moisture, and subsequently, during periods of drought, to segregate in rounded iron-clayey ooid structures. The above features indicate the specific physic-geographical conditions of the Vytachiv soil formation, when periods of good moisture alternated with arid ones. At this time, during wet periods, soil formation could go in the direction of brownzem formation (processes of enrichment on iron oxides, leaching, lessive, podzolization, gleying), and in arid – steppe soil formation (humus formation, migration of calcium carbonates, segregation of iron solutions, etc.). The noticeable cleying and iron enriching of Vytachiv soils indicate a fairly warm climate of the time of their formation. The small thickness of soil profiles, significant capacity carbonates, partial salinity in the south indicate a dryer than the current climate. Such a combination of natural factors is possible only under conditions of a specific climate, rather contrasting, variable-humid to the north and sufficiently arid in the south.

The Dofinivka horizon is of first warm stages after Bug glaciation, which is the marking horizon of the Upper Pleistocene in the non-glacial zone of Ukraine. Stratigraphically, it correlates with Moloho-Sheksnynsky, and Paudorf interstadials, Mazurezky interstadial of the Vistulian glacial, the second interstadiale of the Wurm glacial (Veklych, 1968), the Trubchevsky horizons of the Valdai glaciation

(Velychko et al, 1997), the Rivne soil (Shelkoplias et al, 1986), the middle of the 2nd isotope-acid stage (Matviishyna et al, 2010). It is common in the subaerial strata of the Upper Pleistocene deposits starting from the second floodplain terrace, which is represented by eluvial-deluvial deposits – fossil soils, which lie on Bug loesses and loess-like loams. The stratigraphic equivalent of fossil soils in the subaqual facies is the lower stratum of alluvium of the first flood plain.

The horizon is investigated in sections of the Pleistocene deposits Bezimenne, Uman and Pervomaisk. The horizon's thickness ranges from a few centimeters to more than 1 m. The granulometric composition is mainly light and medium loam. In the north of the Middle Pobuzhzhya, as a separate stratigraphic horizon, it is rather rare, as often it is a relic of modern soil cover or destroyed or transformed by processes of further paleogeographical stages. In the south and south-east – it appears more often and often overlaps with the Prychernomorya loess horizon.

According to paleopedological data, the Dofinivka soils are represented by suits consisting of two soils: the optimum and final stage, or the soil of one of the specified stages. The suits of the soils were discovered and investigated in sections of the Pleistocene deposits near the town of Uman and Pervomaisk. In both cases, the soils of the optimal stage are represented by chernozem soils, and the final one is brown steppe. In the section Bezimenne it is studied one chernozem-like (sod?) soil of optimum. For the investigated soils, the light-medium-grained granulometric composition, carbonate, loose structure and high degree of sorting of the material inherited from the underlying Bug loesses, which are soil-forming rocks, are characteristic. The soils of the final stage were formed directly on the soil of the climatic optimum. The chernozem type of soil formation of optimum confirmes the grayish color of the upper part of the profile, gradual transitions between the genetic horizons, a large number of mole and worm holes, carbonate of mass with new formations which are particularly clearly manifested in the Pk horizon in the form of carbonate mycelium.

According to the micromorphological analysis, for Dofinivka soils, complex microagregates is presented in the form of fuzzy microaggregates of the I-III order, the concentration of humus type mull in clotting and thickening, cementation of plasma by microcrystalline calcite and filling by it of pores, absence of signs of redistribution of humus-clay substance by profile (Fig. 12).

Natural conditions during the Dofinivka stage evolved in the direction of increasing the climate irregularity. The genetic types of drought-bearing fossil soils point to a more continental, colder and dryer climate, especially in the final stage, as compared to modern ones. At this time there is a dominance in the soil cover of carbonate short-profile soils of the steppe, and in the south - dry-steppe and semi-desert genesis.

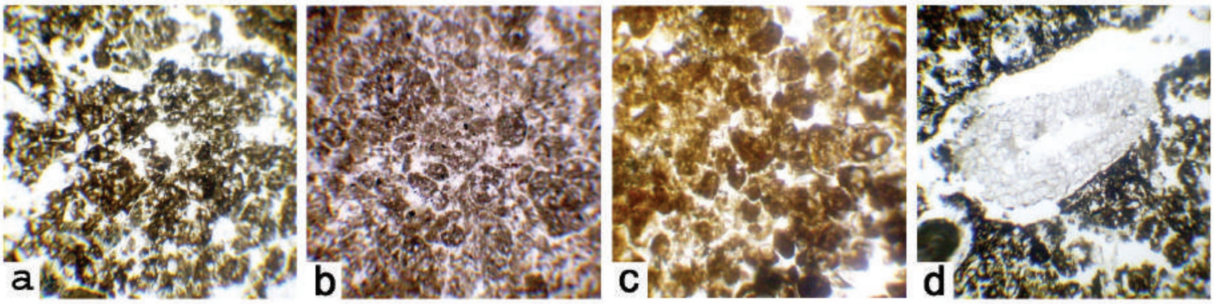

Fig. 12. Microstructure of Dofinivka soils: a) simple and complex microaggregates are separated by a net of twisted pores in the Hk horizon of the chernozem-like soil of optimum, section Uman /magn. 70/; b) simple and complex humus carbonate-clay round microaggregates are separated by a net of twisted pores in the humus horizon of the soil df_b section Pervomaisk /magn. 70/; c) rounded micro aggregates of I-II order are separated by pores, loose microstructure of soil df_c, section Uman /magn. 140/; d) the nodule of fine crystalline calcite in the pore of Hk horizon of chernozem-like (optimum), section Uman /magn. 70/ (nic. ||)

The obtained dat are good correlated with the results of palinological and paleopedological researches by near Pobuzhzhya disposed territory of Ukraine (Sirenko, Turlo, 1986; Gerasimenko, 2004; Sirenko, 2017; et al).

Conclusions. In the Pleistocene soils of the Middle Pobuzhzhya, on the basis of micromorphological research, diagnostic features of soil formation processes were revealed. These features are systematized in groups (biogenic-accumulative, eluvial, illuvial-accumulative, hydrogen-accumulative and metamorphic), which made it possible to find out the issues of the genesis and identification of fossil soil formations, to identify individual micromorphological features of soils of separate stratigraphic horizons, to establish the laws of evolutionary changes soil and perform paleogeographic reconstruction on the basis of paleopedological data.

1. It was found that in unsorted structures of fossil soils *biogenic and accumulative processes* are characterized by dark, dark brown or brown humus-clay plasma, structural formations as simple and complex microaggregates, well-defined inter- and intra-aggregate cavity space, developed pore net, the presence of coagulated or dispersed humus, coprolites, microbial mass, plant tissue residues or animals of varying degrees of decomposition or other organo-mineral compounds. The characteristic features of the *eluvial processes* are the predominance of the skeletal particle over the plasma, halfdestroyed microaggregates in the eluvial horizons of the soils, the «washed» seeds of primary minerals without films, fussy amorphous plasma. *Illuvial-accumulative processes* are diagnosed on the basis of the displacement of organo-clay substance numerous separations of calomorphic clays in form of influxes, stream, films around the grains of the mineral skeleton.

Among the *hydrogene-accumulative processes* in fossil soils, it is possible to diagnose the signs of gypsum enrichment (micro, fine, medium grained, rhombus, lens and other forms of gyps), carbonatization (cryptocristal-, micro- and small-grained calcite concentrations, lublinitis, etc.), salinization (forms of the separation of light-dissolving salts), ore creations processes (spots, flakes, films, diffuse rings, microorsteins, incrustation and other forms iron and manganese hydroxides concentration), meadow processes (high content of mull humus, in the lower part of the profile gray-blue of manifestations of ferrous forms of iron, ferruginous microorsteins, signs of redistribution of clay, carbonates and other salts.

In the thin section under the microscope, especially from the soil of the Early and Middle Pleistocene, there are signs of *metamorphic processes* «in situ» can see, such as iron enrichment (reddish-cinnamonish, yellowish-brown tints of the plasma), claying (reduced proportion of grains of the mineral skeleton – an increased proportion of plasma mass, dense microstructure in the form of cleave blocks, mass compactness, sharp edges of pore-cracks walls), cleaving (dense block microstructure, segregation of organo-clay substances into nodular formations in the middle of cleave blocks), rubbification (brown color of plasma, films and stains of iron oxides, grains of goethite and hematite), intrinsic soil weathering (corrosive grains of the mineral skeleton), etc.

2. It has been established that certain groups of soil forming processes are characteristic for fossil soils of separete paleogeographical stages. In the soils formed prior to the Dnipro glaciation (Shyrokyne, Martonosha, Lubny and Zavadivka), signs of processes of enrichment, rubbification, ferralization, cleaving, weakly expressed humus formation, carbonization, and sometimes enrichment on gyps were diagnosed. For the soils formed after the maximum glaciation (Kaydaky, Pryluky, Vytachiv, Dofinivka), signs of the same processes (humus formation, podzolization, illimerization, leaching, meadow, carbonate migration, etc.), which are characteristic for modern soils of the territory of Ukraine are established.

It is proved that the *individual features* of the microstructure of the Pleistocene soil horizons of the Middle Pobuzhzhya can be used for stratigraphic purposes. The micromorphological features of the Shyrokyne, Martonosha, Lubny and Zavadivka soils are with bright brownish, reddish and brownish shades of plasma color, have compact massing with structural separations in the form of cleave blocks with densely packed nodular formations of ferruginous-clay matter, a considerable amount of ferruginous, manganese and carbonate new formations. In the soil of the early optimum of the Kaydaky and Pryluky stages signs of eluvial-illuvial processes are recorded (depleted on the mulle and humus area with the «washed» grains of the mineral skeleton, the microaggregates in the eluvial horizons are destroyed, but din the illuvial – the impregnation of the plasma by calomorphic clays in the form of streaks, films, streams). In the soils of late optimum of these times, there is a well-expressed microagregation of the mass, a branched net of twisted pores, a cougulated humus in the humus and humus transition horizons, various forms of carbonate evidences as impregnation and cementation of plasma by microcrystalline calcite, grouping of crystals, concentration of crypto-, micro- and fine crystalline calcite. Specific individual characteristics of the Vytachiv soils are block microstructure, numerous nodular concentrations of organ-ferruginous-clay substances, the presence of microorsteins. Dofinivka soils are characterized by a loose microstructure, fuzzy rounded simple micro aggregates, a developed system of twisted pores, and carbonaceous mass.

3. Complex paleopedological studies with wide application of micromorphological data allowed to *identify genetic types of fossil soils* and reconstruct the soil cover of the Middle Pobuzhzhya for eight warm stages of the Pleistocene. Shyrokyne horizon in the study area are represented by the reddish-brown, reddish-dark-brown semi-hydromorphic soils and their meadow species. In the early optimum of Martonosha time, reddish-brown forest, semi-hydromorphic and meadow soils, while in the late optimum – reddish-

cinnamonish-brown semi-hydromorphic and meadow species were formed. Lubny soils are represented by brown forest, light cinnamonish-brown forest (early optimism) and brownish-cinnamonish, meadow-cinnamonish chernozem-like and sod-chernozem (late optimum). Zavadivka stage is characterized by a variety of soil cover. In particular, yellow-brown and brown forest soils formed in the initial stage; in the early optimum – brown forest, yellowish-brown forest (in the north-west), brown forest reddish, cinnamonish soils (in the south-east); in late optimum – brown forest cinnamonish, reddish-brown forest, cinnamonish-brown, leached, brownish-cinnamonish, brownzem-like, meadow; in the final stage – yellowish-brown, reddish-brown and meadow. In the suits of the Kaydaky horizon, the following types of soils were studied: turf and turf-podzolic (in the initial stage); turf-podzolic, brown forest, including gleyed, podzolized and pseudo-podzolized, light gray, gray podzolized, in the south – dark gray podzolized, chernozems podzolized (in the early optimum); turf, chernozems leached and podzolized, meadow chernozem (in late optimum). Within the limits of the Pryluky horizon on the territory of the Middle Pobuzhzhya are found: brown, gray forest, chernozems leached (early optimum); chernozem brownzem-like, leached, meadow, typical, cinnamonish (late optimum); turf, grayish-brown chernozem-like, chernozems brownzem-like (final stage). During Vytachiv time, specific dark-brown soils of early optimum brown and light-brown soils of late optimum were formed. In the north-west of the territory, the Vytachiv soils are often gleyed, close to the grasslands meadow, and in the south and south-east - they get cinnamonish shades, there are solonets species. In the optimum of the Dofinivka time, turf, turf-carbonate and near to chernozem soils formed on the vast territory of the Middle Pobuzhzhya.

4. Identified genetic types of Pleistocene fossil soils and reconstructed soil coverages of the Middle Pobuzhzhya reflect the *dynamic of evolutional soil changes* and, accordingly, *natural conditions* in time and space. From the Early Pleistocene to the Dnipro glaciation, during the Shyrokyne, Martonosha, Lubny, and Zavadivka periods full profiled reddish-cinnamonish, reddish-brown, cinnamonish-brown and brown varieties of soil-pedosediments were formed in weathering favorable to conditions of a moderate, humid, close to subtropical climate.

After the Dnipro glaciation, the genetic types of soils, which are close to modern, close to the modern soil zoning, began to be formed on the territory of the Middle Pobuzhzhya. All types of fossil Kaidaksky soil (soddy-podzolic, brown forest, gray podzolized, meadow-chernozem, chernozem leached, podzolized) indicate that they are formed in slightly more humid conditions of temperate climate compared with modern ones. The genetic types of soils of the Pryluky time reflect the changes in soil conditions from the forest, forest-steppe and meadow-forest-steppe regimes in the early optimum (meadow chernozem, brown forest, gray podzolized, chernozems leached, etc.), in the direction of meadow, meadow-steppe and steppe regimes of soil formation (chernozems, brownzem-like, leached, meadow, micellar-carbonate, cinnamonish) in the late optimum. The soils of Pryluky time were formed in a warmer and evenly humid environment for the modern climate. Specific brown and dark brown soils, analogues which are not present in the modern soil cover of Ukraine, were formed in Vytachiv time in conditions of fairly warm, contrast, change-humidity-arid climate. The Dofinivka soils, which are close to the chernozems, reflect the conditions of a more continental, arid and cooler climate.

5. Changes in *paleogeographic conditions* in the Pleistocene recorded in the soil sediments on the territory of the Middle Pobuzhzhya are subordinated to the basic legularities in the development of nature.

Alternating in subaerial layers of soils (formation of warm stages) with loesses (deposition of cold stages) reflect *rhythmeness*.

The development of natural conditions during the Pleistocene in the direction of aridization and coldness indicate *direction in the development*.

The structure of the most complete soil suits clearly confirms the stage of development stadials – in the initial stage of soil formation, the climate is relatively cold and humid, in the optimum stage – warm and humid, in the final – warm and dry.

Zonal changes in the soil cover of the Pleistocene are manifested both in time and in space (*regionality*). In the early Pleistocene, genetic types of soils, close to subtropical ones, were formed. After the Dnipro glaciation, changes in the natural conditions that occurred in the formation of soils of the subboreal and boreal zones occurred. Spatial zonal changes in the soil of the early Pleistocene were almost non-existent (in the Shyrokyne and Martonosha times) or expressed weakly (Lubny, Zavadivka times). Brighter zonal differences appeared in the post-Dnipro warmer stages. The most suitable for the modern soil zoning was formed in Kaydaky and Pryluky times. The boundaries of natural zones compared with modern ones were displaced to the south in the early optimum of the Kaydaky time, and to the north – in the late optimum of Pryluky. In the Vytachiv and Dofinivka times, the zone was evidenced.

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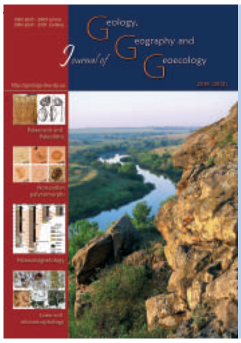

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Non-pollen palynomorphs as indicators of palaeoenvironmental changes: a case study from Lake Chokrak (the Crimean Peninsula)

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Abstract. The paper presents the first study of the non-pollen palynomorphs assemblages of the upper Holocene sediments of hypersaline Lake Chokrak. As has been previously shown, the Crimean saline lakes tend to have low variety and frequencies of non-pollen palynomorphs (Mudie et al., 2011). The upper samples from Lake Chokrak have yielded high pollen frequencies, as well as a relatively diverse assemblage of NPPs, including acritarchs, dinoflagellate cysts, microforaminiferal linings, fungal spores, eggs of *Artemia salina*, ostracod jaws and arthropod parts. Acritarchs are represented mostly by *Sigmopollis* sp., which are abundant in all the studied samples, and by occasional *Micrhystridium* sp. and *Pseudoschizaea circula*. Among the fungal spores, *Podospora*, *Delitschia* and *Sporormiella* have been identified, indicating a former settlement. Three species of dinoflagellate cysts have been identified, *Lingulodinium machaerophorum*, *Impagidinium caspiense* and *Spiniferites* cf. *crusiformis*. These species are found in brackish/marine environments and do not tolerate high water salinity. They could have been transported to the lake by overflowing marine waters over the sand barrier between the lake and the Sea of Azov. Therefore, their appearance in the lake sediments may indicate possible sea-level changes and/or increased wave activity. So far, within the analysed top 2 m of the core, we can distinguish five intervals where dinocysts and microforaminiferal linings are present, possibly indicating increased marine influence, separated by four intervals where few or no brackish species have been found. *Impagidinium caspiense* is a dominant species among the dinocysts in all the samples, except the surface sample, where *L. machaerophorum* is much more abundant. This could indicate the increased salinity and/or higher nutrient loading to the Sea of Azov during the XX century. The allochthonous nature of dinocysts and some other NPPs in the Lake Chokrak sediments can play an important role in reconstructing level changes of the Sea of Azov and depositional environment of the lake, as well as contribute to the interpretation of pollen data.

Key words: non-pollen palynomorphs, lake sediments, Black Sea, Holocene.

Непилкові паліноморфи як індикатори палеогеографічних змін на прикладі озера Чокрак (Кримський півострів)

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Анотація. У статті вперше представлено дослідження непилкових паліноморф у верхньоголоценових відкладах гіперсолоного озера Чокрак. Як було показано раніше, соляні озера Криму мають низький рівень різноманіття та концентрації непилкових паліноморф (Mudie et al., 2011). Досліджені зразки відкладів мають високу концентрацію пилку, та відносно різноманітний спектр НПП, включаючи акрітархи, цисти динофлагелят, оболонки мікрофорамініфер, спори грибів, яйця *Artemia salina*, щелепи остракодів та частини скелету Cladocera. Акрітархи представлено переважно *Sigmopollis* sp., які переважають в усіх досліджених зразках, та поодинокими спорами *Micrhystridium* sp. та *Pseudoschizaea circula*. Серед спор грибів було виявлено спори *Podospora*, *Delitschia* та *Sporormiella*, які є інікаторами давнього поселення. Ідентифіковано три види цист динофлагелят – *Lingulodinium machaerophorum*, *Impagidinium caspiense* і *Spiniferites* cf. *crusiformis*. Ці види надають перевагу солонуватим та морським водам і не переносять надто високу солоність води. Вони могли бути принесеними в озеро морськими водами, які переливалися через пересип між озером та Азовським морем. Таким чином, наявність цих паліноморф є індикатором, як імовірних змін рівня моря, так і збільшення припливних хвиль. У проаналізованих відкладах, потужністю 2 м, виявлено п’ять інтервалів, у яких присутні цисти динофлагелят та оболонки мікрофорамініфер, які представляють збільшення впливу моря на узбережжя, які чергуються з чотирма інтервалами, у яких не виявлено видів, які проживають у солонуватих водах. Цисти *Impagidinium caspiense* переважають у всіх зразках, окрім поверхневого, у якому *L. machaerophorum* представлено у більших кількостях. Це може вказувати на підвищення солоності та збільшення надходження поживних речовин у Азовське море протягом XX ст. Алохтонне походження диноцист та інших НПП у відкладах озера Чокрак може відігравати важливу роль як у реконструкції змін рівня Азовського моря та басейну осадконакопичення озера, так і доповнювати спорово-пилкові дані.

Ключові слова: непилкові паліноморфи, озерні відклади, Чорне море, голоцен.

Introduction. Environmental changes that have been occurring in the Black Sea region through the Holocene are associated with climatic changes and fluctuations of the Black Sea basin. These short-term changes can be reconstructed using continuous sedimentary archives, like the saline lakes in the Crimean Peninsula. Many of these lakes have annually laminated sediments, the fact that enables high-resolution palaeoenvironmental reconstructions of the lake and its surroundings. Palynological content of these lacustrine sediments is of particular use for reconstructions of past vegetation cover and land-use practices, and modelling of climate changes. Pollen and spore content of various sediment types have long been studied by Quaternary researches, but there have been comparatively few studies of non-pollen palynomorphs in the marine and lacustrine sediments in the Black Sea and the adjacent area. Non-pollen palynomorphs (NPPs) are other microfossils than pollen and spores from vascular plants observed in palynological samples. Their usage as palaeoecological indicators is rapidly growing because of their potential to reconstruct palaeohydrological regime and to complement reconstructions of past vegetation cover based on pollen analysis.

The history of non-pollen palynomorphs studies in the Black Sea region starts with works by Wall *et al.* (1973) and Wall and Dale (1974), who first described new types of dinoflagellates in the brackish waters of the Black Sea and outlined their affinities to water salinity. Traverse (1974) described two dinocyst species and three acritarchs in the south-eastern part of the Black Sea. Later, Traverse (1978) presented and illustrated some NPPs in the Black Sea cores, including fungal spores, several types of dinocysts, *Botryococcus*, *Pediastrum*, and several types of acritarchs (*Cymatiospherae*, *Tasmanites*, *Pseudoschizaea*). Mudie *et al*. (2002) described the abundance of dinocysts species, acritarchs, fungal spores and microforaminiferal linings in the Marmara and Black Seas in the Upper Pleistocene-Holocene sediments and the influence of salinity on their distribution patterns. Marret *et al.* (2009) proposed a two-step transformation of the Black Sea basin in the early Holocene using brackish and euryhaline assemblages of dinocysts. More recently, Mudie *et al.* (2011) illustrated different types of NPPs in the Caspian-Black Sea-Mediterranean corridor, their frequencies in marine, estuarine and lacustrine sediments, and their value as indicators of salinity and nutrient level of waters and human activity in the region. Shumilovskikh *et al.* (2013) reconstructed sea-surface salinities and temperatures of the south-eastern part of the Black Sea during the Holocene and Eemian using freshwater/brackish and marine assemblages of dinocysts. Zonneveld *et al.* (2013) mapped and described present-day environmental conditions and geographic distribution of dinocysts in sediments based on 2405 data points, including several points in the Black Sea. To summarise research results over the past decades, Mudie *et al.* (2017) presented atlas of modern dinocysts distribution in the Black Sea corridor (based on 185 surface samples), in which relationships between the distribution of individual dinocyst species are described, as well as such water parameters as salinity, temperature, nutrient content and bottom water oxygen. The first standardised taxonomy of the dinoflagellate cysts found in the Black Sea corridor was provided. As can be seen, the NPP studies in the Black Sea have been rapidly developing, producing new important data on geographic distribution and ecological affinities of individual species of NPPs.

In this paper, we analysed NPP content from the upper Holocene sediments of hypersaline Lake Chokrak, in the north-east of the Crimean Peninsula. The specific objectives are 1) characterisation of diversity and concentration of NPP in the sediment samples, 2) investigation of mechanisms of their distribution in the lake, and 3) outlining indicative environmental value of individual species.

Materials and methods. Lake Chokrak is a hypersaline coastal lake in the north-east of the Crimean Peninsula (Fig. 1). The lake is a former marine lagoon, which evolved around 5,000 years BP due to postglacial transgression of the Black Sea (Kurnakov *et al.*, 1932). Marine conditions terminated around 4,000-3,000 BP, when a sand barrier started to form and separated the lake from the Sea of Azov (Kelterbaum *et al.*, 2012). At present, the lake is separated by a sand barrier up to 350 m in width. The area of the lake is 8.5 km^2 and the maximum depth is 1.3 m. The sediments of the lake show annual lamination: it is suggested that dark spring layers of washed off soil are coupled with light summer evaporite layers. The climate of the study area is arid and continental. The present mean annual temperature is 11°C, with mean July temperatures of 24°C, and mean January temperatures of –1°C. Annual amount of precipitation does not exceed 350 mm. At present, Lake Chokrak dries up completely during summer (July–August). The sa-

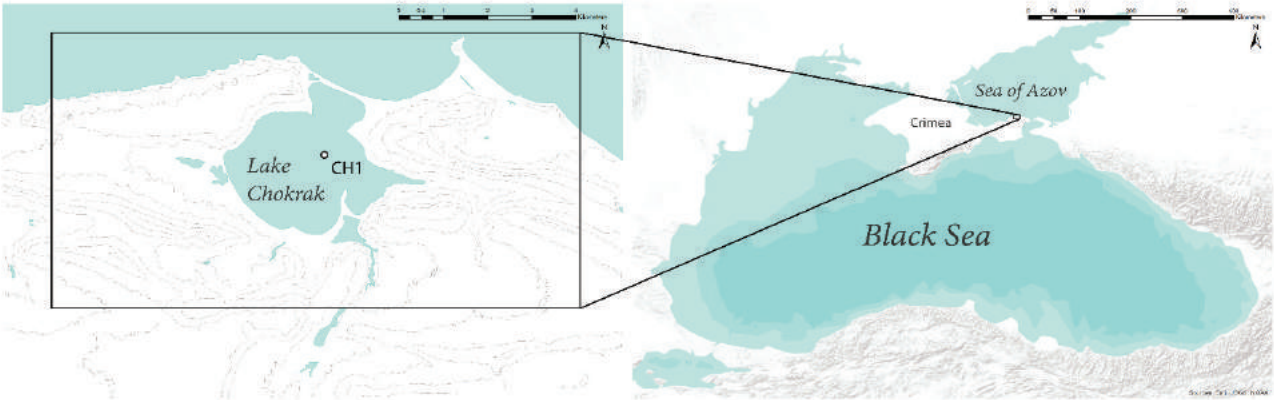

Fig. 1. Left: a map of the study area around Lake Chokrak showing the location of core CH1. Right: a map of the Black Sea region showing the location of Lake Chokrak.

linity of the lake ranges from 80 to 180‰, whereas the Sea of Azov near the study site has the salinity of 11.5‰. The bedrock consists of Neogene clays, limestones and marls, which are frequently exposed around the lake. The soil cover is composed of chernozems on heavy clays. The vegetation cover of the study area is represented by grassland with admixture of *Artemisia* and Chenopodiaceae, and the lake itself is surrounded by halophytic vegetation.

The 11-metre core CH-1 was collected from the western part of Lake Chokrak (45°27'37'' N, 36°18'10'' E) within the framework of USA-Ukrainian-Russian project "High resolution Holocene proxy precipitation record in varved lake beds of Eastern Europe" (1995-1999). The core was subsampled at 5-cm interval with the aim to reveal sort-term palaeoenvironmental changes of the lake and its vicinities. The laboratory processing of the subsamples involved treatment with 10% HCl in a hot water bath, hot treatment with 10% NaOH, cold treatment with 40% HF and secondary treatment with 10% HCl to remove the secondary formed salts and calcium. The residues were mounted in glycerol and analysed under a light microscope. Mudie et al. (2011) notes that the use of acetolysis or hot 10% KOH may decrease the number of recovered palynomorphs as some dinoflagellate cysts are extremely sensitive to oxidation. The identification of dinoflagellate cysts was preformed using

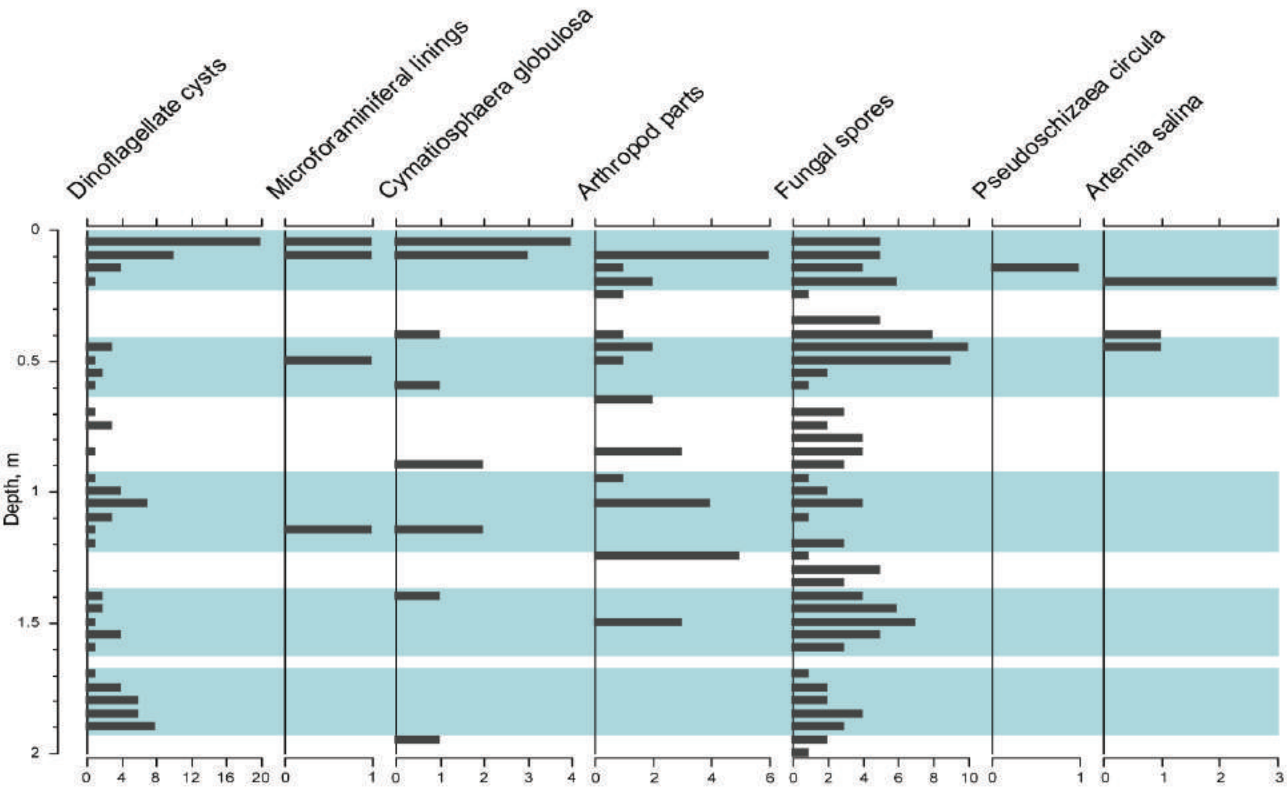

Fig. 2. Diagram of main NPP groups in the Lake Chokrak samples. The taxa are shown in numbers of specimens. Blue zones indicate intervals of increased marine influence on the lake basin.

modern atlases and keys (e.g. van Geel, 2001; Mudie *et al.*, 2011, 2017; Zonneveld, Pospelova, 2015).

Results. The upper sediment samples from Lake Chokrak have yielded high pollen frequencies, as well as a relatively diverse assemblage of NPPs, including dinoflagellate cysts, prasinophytes and acritarchs, fungal spores, foraminiferal linings and other animal remains (Fig. 2, 3). No specimens of Chlorococcales, like *Pediastrum* or *Botryococcus*, Zygnematales or cyanobacteria have been recorded in the samples.

Dinoflagellate cysts. Dinocyst content in the Lake Chokrak samples is not abundant. Their values range from being virtually absent to about 3% of the total pollen sum. The highest number of dinocysts (20 specimens) is recorded in the topmost sample, and in the lower samples, 10 or fewer specimens were observed. Dinocyst occurrence in the Lake Chokrak samples follows a certain pattern, being absent or present across several samples in line. The following species have been identified: *Lingulodinium machaerophorum*, *Gonyaulax baltica* (the motile stage of *Impagidinium caspiense*), *Impagidinium caspiense*, *Spiniferites* cf. *cruciformis*. *Lingulodinium machaerophorum* and *Impagidinium caspiense* are most abundant in the samples, and the others are rarely observed.

Prasinophytes and acritarchs. Prasinophytes are represented by *Cymatiosphaera globulosa*, which appears sporadically in the samples and does not exceed 0.8% of the total pollen sum. Most specimens are recorded in the upper part of the sequence. Acritarchs are most abundant palynomorphs in all studied samples, especially *Sigmopollis*-type, and occasionally *Micrhystridium* and *Pseudoschizaea circula* were observed.

Fungal spores. Fungal spores are encountered in almost all samples, but they are more diverse in the top part of the sequence (0.0-1.0 m). Their content ranges between 1.0% and 2.5% of the pollen sum. From the total fungal spore assemblage, we have been able to identify *Glomus*-type, *Podospora* spp., *Delitschia* sp. and *Sporormiella* sp.

Animal remains. In the samples, several specimens of trochospiral organic linings of microforaminifera were recorded. Ostracod mandibles are occasionally observed in the upper part of the sequence (0.0-1.75 m), along with exoskeletal parts of juvenile Cladocera and eggs of *Artemia salina*.

Interpretation. Dinoflagellates are the organic-walled encysted stages of the life cycle of this group of one-celled organisms. Most dinoflagellates are of marine origin, although freshwater specimens are known. Due to high salinity of Lake Chokrak, dinocysts do not make up a large part of the fossil assemblage as they would do in marine sediments. Nonetheless, they are common in the upper part of the sequence to represent marine influence on the lake. Mudie *et al.* (2011) reported that organic-walled dinocysts had not been found in the saline Crimean lakes Saki and Dzharylgach, probably because of alkaline environment of the lakes or laboratory treatment with KOH. *Lingulodinium machaerophorum* is the most widespread and often the most abundant species of the Black Sea corridor (Mudie *et al.*, 2010). The species is present in many types of waters, although not found in low salinity basins. The specimens are generally found in coastal areas and regions in the vicinity of continental margins, where sea-surface temperate is above 10°C and salinity ranges between 8.5 and 39.4‰ (Mudie *et al.*, 2017). High relative abundances of *Lingulodinium machaerophorum* occur both in high and low sea surface salinities (the latter is as a result of river discharge). They are abundant in regions with strong (seasonal) variability in the trophic state of the upper waters (Zonneveld *et al.*, 2013). In the Lake Chokrak sediments, *Lingulodinium machaerophorum* is most abundant in the top sample (0.05 m), and being an euryhaline species, it is more indicative of nutrient loading to the Sea of Azov than of changes in the sea-surface salinity.

Impagidinium caspiense is most dominant in the Caspian and Aral Seas (Marret *et al.*, 2004), although rare cysts of *I. caspiense* have been reported along the Black Sea coast and in the Marmara Sea (Mudie *et al.*, 2017). *Impagidinium* cysts are usually found in open oceanic sediments from polar to equatorial latitudes covering a wide range of temperatures (Zonneveld *et al.*, 2013). The modern sea-surface salinity range for *I. caspiense* is 11.7-17.5‰ (Mudie *et al.*, 2017). The increase of relative abundance of *I. caspiense* at 0.10 m and lower, may indicate decrease in salinity or insufficient nutrient content of waters for *Lingulodinium machaerophorum* to exceed in numbers.

Cysts of *Spiniferites cruciformis* are only found in the Black Sea corridor and observed in coastal areas (Mudie *et al.*, 2010). They are found mostly in brackish waters with high river discharge (Zonneveld *et al.*, 2013). These dinocysts are found in a broad range of sea-surface temperatures, but they are more abundant in the warmest areas (Mudie *et al.*, 2017). Most dinoflagellates are intolerable to the salinities higher than 35‰, and their presence in the Lake Chokrak sediments is therefore associated with surface waters from the Sea of Azov. There are five intervals in the sequence where the dinocysts are present in relatively moderate numbers (Fig. 2). Thus, these intervals are related to periods when waters rise upwards, which led to increased availability of nutrients in the sea sur-

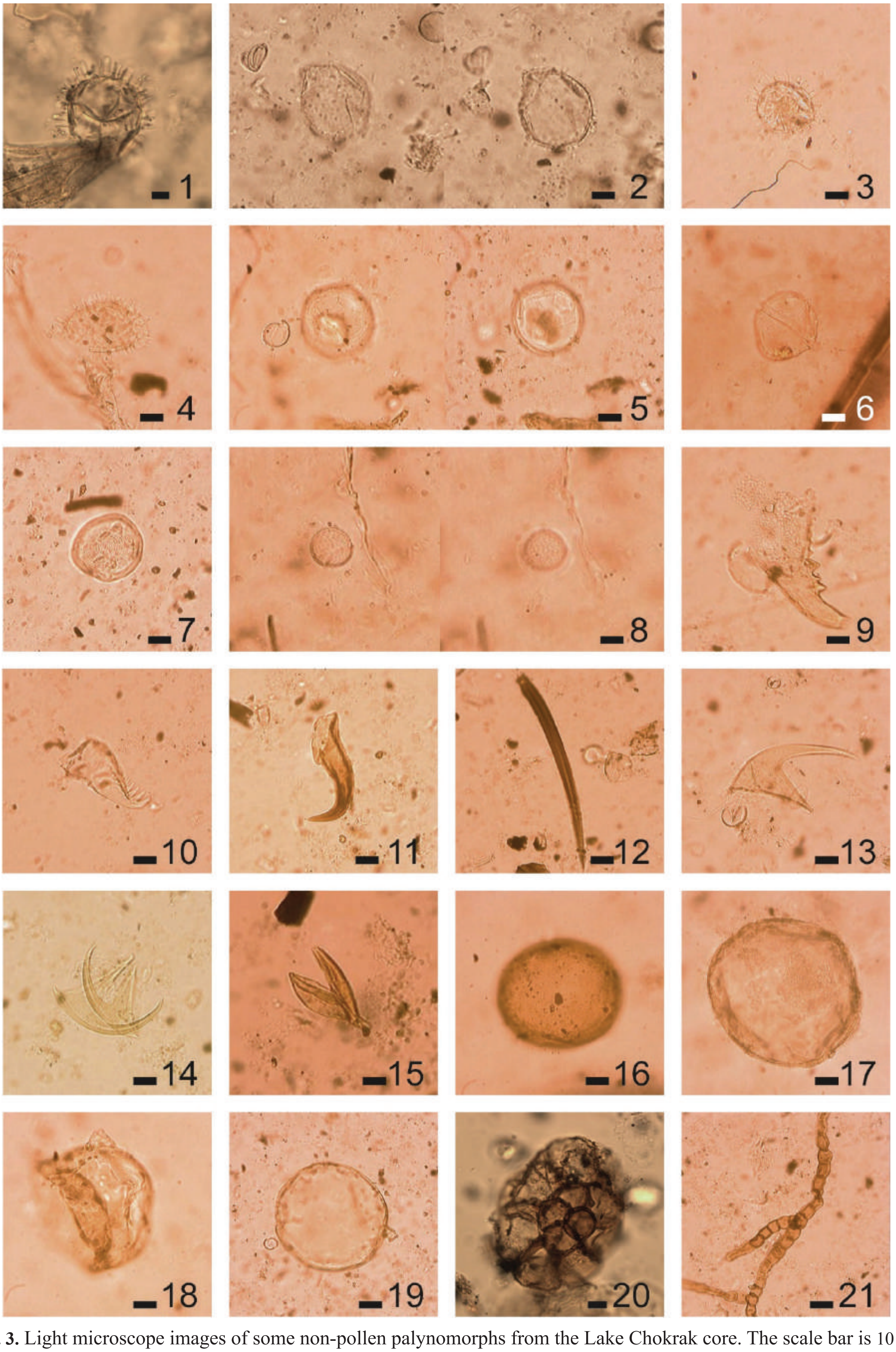

Fig. 3. Light microscope images of some non-pollen palynomorphs from the Lake Chokrak core. The scale bar is 10 μm. 1-4 – *Lingulodinium machaerophorum*; 5 – *Gonyaulax baltica*; 6 – *Impagidinium caspiense*; 7 – *Pseudoschizaea circula*; 8 – *Sigmopollis* sp.; 9-11 – mouth parts of small ostracods; 12-15 – exoskeletal parts of Arthropods; 16, 17 – crustacean eggs; 18 – an egg of *Artemia salina*; 19 – a spore of *Glomus*; 20 – a foraminiferal lining; 21 – a spore of *Sporormiella* sp.

face waters and transport of dinocysts to the shore of the lake.

Acritarchs are palynomorphs with uncertain biological affinity, although it is assumed that they are a part of the life cycle of marine algae (Traverse, 1974). Batten (1996) states, that abundance of small, round acritarchs indicates nearshore, fine-grained marine sediments of variable salinity. Acritarch *Cymatiosphaera globulosa* belongs to the indicators of marine conditions, which was first shown by Pals *et al.* (1980) in the studies of peat and lake sediments in the Netherlands. *Micrhystridium* sp. is usually found in marine waters and is common in the Black Sea (Mudie *et al.*, 2010). Wall (1965) reported that *Micrhystridium* favours nearshore environments that supports the idea that these specimens can be found at the sandbar between Lake Chokrak and Sea of Azov. *Micrhystridium* specimens have also been reported to be observed in saline Lakes Saki and Dzharylgach (Mudie *et al.*, 2011). Acritarch *Sigmopollis* is considered to be a freshwater species and mostly found in mesotrophic water streams or calm water environments (van Geel et al., 1989), which suggests that its presence in Lake Chokrak is linked to transport from freshwater bodies.

From the various studies of fossil fungal spores, it is evident that the recorded spores in the majority of cases are of local occurrence. They were fossilised at, or near, the place where they had been produced, or the spores were deposited at only a short distance from the place where sporulation took place (van Geel., 2001). Spores of mycorrhizal fungus *Glomus* in the studied samples indicate soil erosion in the area around the lake or other soil disturbance (van Geel, 1989). Fungal spores, including *Glomus*-type, are common in the saline Lake Saki, whereas in Lake Dzharylgach fungal spores are rare (Mudie *et al.*, 2011). Spores of coprophilous fungi *Delitschia*, *Podospora* and *Sporormiella* are regularly reported in palynological samples from archaeological sites (Cugny *et al.*, 2010) and indicate presence of human settlements or domestic livestock. In our case, they might indicate very recent agricultural usage of the lands around the lake.

Microforaminiferal linings indicate marine depositional environments, although they can be abundant in estuaries and lagoons of variable salinity. They have been widely used as marine indicators, whether occurring in abundance or as isolated specimens, and are common in clastic shelf sediments deposited in warm, shallow waters that are not greatly affected by terrestrial input (Batten, 1996). Therefore, microforaminiferal linings, which are present in the upper part of the sequence, are indicators of sea water incursions or sea-level changes in the Late Holocene. Ostracod mandibles and exoskeletal parts of Cladocera are also indicators of marine environments, especially shallow coastal basins. Linings of microforaminifera and ostracods are also reported in Lake Dzharylgach (Mudie *et al.*, 2011). Crustacean *Artemia salina* is native to saline lakes, therefore its eggs are indicators of their autochthonous origin in the lake.

The sediments from both saline lakes Saki and Dzharylgach contain spores of colonial algae, *Pediastrum* in particular, indicating freshwater input into the lakes, whereas in Lake Chokrak there is no evidence to support that.

Conclusion. The palynological study of the Lake Chokrak sediments revealed that sediment samples contain a relatively diverse assemblage of non-pollen palynomorphs, including dinoflagellate cysts, acritarchs, fungal spores, microforaminiferal linings and ostracod mandibles. The frequencies of dinocysts, algal and fungal spores are low, which can be explained by NaOH laboratory treatment of the samples, or by alkaline depositional environment of Lake Chokrak. The obtained data were interpreted in the light of known ecological affinities of individual species and their modern distribution. The majority of identified NPPs are indicators of marine conditions and are typically found in brackish/marine waters, therefore their presence in the studied samples indicates periods of increased wave activity and/or sea-level oscillations. We have been able to recognise five intervals when sea waters entered the lake basin. Human impact on the environment in the recent time has been traced by the presence of coprophilous fungal spores.

NPPs are useful for palaeoenvironmental reconstructions of coastal systems influenced by sea-level oscillations and climate changes. Ecological affinities of the studied palynomorphs can lead to general and detailed palynological conclusions about past depositional environments. Further study of NPPs can significantly contribute for interpretations based on pollen data and elaborate the Mid- and Late Holocene history of Lake Chokrak.

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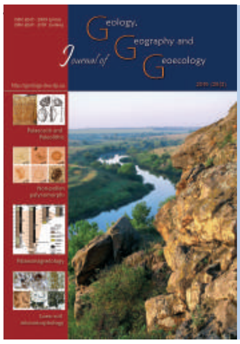

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Changes in Pleistocene vegetation and climate of Ukraine in the range of 1.8-0.4 million years

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Abstract. On the basis of the analysis of the results of detailed palynological studies of Pleistocene deposits in Ukraine, the correlation between climatic changes and vegetation dynamics was retraced in the range of 1.8-0.43 million years. The curve of paleoclimate changes was constructed and analyzed. It was shown that certain climatic characteristics were inherent for each stage of the nature development, which was reflected in the composition of vegetation. It was found that temperature and humidity fluctuations also occurred during each stage. The evidence of this is the reconstructed micro-rhythm in the development of vegetation of each stage. The main features of vegetation composition were determined for four warm and five cold stages of nature development, and a pattern of vegetation changes was retraced during each stage. The dynamics of vegetation cover of the Prydonetska Plain, different parts of the Prydniprovska Lowland, the Prydniprovska Upland, the Near Black Sea Lowland, and the Podil'ska Upland vegetation during the specified geological time was reconstructed. General and regional distinctions of the composition of vegetation cover were revealed, and the influence of the main climatic factors such as temperature and humidity on the character of its changes was retraced. The stages characterized by the warmest and wet climatic conditions and the most cold and dry ones were established. It was substantiated that the climatic conditions of the Sula period were less severe than in the subsequent stages of the fall of temperature. The existence of refugiums of thermophilic flora in the Sula period within separate regions of Ukraine was established. The existence of vegetation zonality was substantiated not only in warm stages, but also in cold periods of the Early Neopleistocene.

Key words: vegetation cover, climate, Pleistocene, Ukraine

Зміни плейстоценової рослинності та клімату України в інтервалі 1,8-0,4 млн. років

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Анотація. На основі аналізу результатів детальних палінологічних досліджень плейстоценових відкладів України простежено взаємозв'язок кліматичних змін та динаміки рослинності в інтервалі 1,8-0,43 млн. р. Побудовано та проаналізовано криву змін палеокліматів. Показано, що для кожного етапу розвитку природи властиві певні кліматичні характеристики, що знайшло відображення у складі рослинності. Встановлено, що коливання температури та вологості відбувались також і в межах кожного етапу. Свідченням цього є реконструйована мікроритмічність у розвитку рослинності кожного етапу. Визначено основні риси складу рослинності для чотирьох теплих та п'яти холодних етапів розвитку природи та простежено характер змін рослинного покриву протягом кожного з етапів. Реконструйовано динаміку рослинного покриву Придонецької рівнини, різних частин Придніпровської низовини, Придніпровської височини, Причорноморської низовини, Подільської височини протягом зазначеного геологічного часу. Виявлено загальні та регіональні відміни складу рослинного покриву та простежено вплив основних кліматичних чинників – температури та вологості на характер його змін. Встановлено етапи, що характеризувались найбільш теплими та вологими кліматичними умовами, та найбільш холодними і посушливими. Обгрунтовано, що кліматичні умови сульського часу були менш суворими, ніж у наступні етапи похолодань. Встановлено існування рефугіумів термофільної флори в сульський час у межах окремих регіонів України. Обгрунтовано існування рослинної зональності не лише у теплі етапи, а і у холодні періоди нижнього неоплейстоцену.

Ключові слова: рослинний покрив, клімат, плейстоцен, Україна

Introduction. The dynamics of the Pleistocene vegetation in time is inextricably linked with the rhythmic changes in the climate primarily due to the interchanges of glacial and interglacial periods. Vegetation reacts sensitively even to minor climate change. In the interval considered within the plain part of Ukraine, five cold (Berezan, Illichivsk, Priazovya, Sula, Tiligul) and four warm (Kryzhanivka, Shyrokyne, Martonosha, Lubny) stages of nature development occurred.

During the warm stages, the pedo-complexes consisting of soils of early and late optimum and the final stage of pedogenesis were formed. In the most complete sections, soils of optimums were separated by thin loessial layers, which is the evidence of inter-staging falls of temperature. During the cold stages in the non-glacial zone, loess and loessial loams were accumulated, in the strata of which immature embryonic soils formed during short-term inter-stage warming were retraced. Each of these stages differs in terms of temperature as well as the degree of irrigation and humidification of the climate, which was reflected in the composition of vegetation.

According to the International Stratigraphic Scale 2018 (ISS), the stages of nature development in the range of 1.8-0.8 million years are dated to Calabriane, and in the range of 0.8-0.43 million years – Middle Pleistocene. According to the stratigraphic scheme of the Quaternary deposits of Ukraine (Stratygrafichnyj kodeks Ukrai'ny Redaktor P.F. Gozhyk, 2012), the paleogeographical stages of the first interval are dated to Eopleistocene, and the second interval – Early Neopleistocene. The purpose of this research is to establish the patterns of vegetation dynamics within the plain part of Ukraine related to changes in climatic parameters during the specified geological period, not only at the level of separate stages of nature development, but also within each stage; determination of general and regional differences of vegetation cover within individual regions of Ukraine; construction of paleoclimate curve according to palynological data.

Materials and methods. The main method of the research was a spore-pollen analysis. The material for the performed reconstructions was the analysis of the results of detailed palynological studies of the Pleistocene deposits in 16 sections located within the Donets folded structure, the Dnieper-Donets and the Black Sea depressions (Sirenko, 1994, 2017a, b), the central, northern and southern parts of the Ukrainian shield (US) (Sirenko, 2002, 2009a, 2017b), as well as the Volyn- Podil'ska Plate (Sinenko, 2009b), and, correspondingly, within three modern vegetation zones: steppe, forest-steppe and mixed forests (Fig. 1). In the process of the research, not only spore-pollen charts but also the cyclograms of the ecological structure of the complexes constructed for each section were analyzed, which allowed not only to reconstruct a type of vegetation, but also gave an opportunity to draw conclusions about the nature of climate change in certain periods.

In addition, the data of palynological studies of Pleistocene deposits by S.I. Turlo (Sirenko, Turlo, 1986) and N.P. Gerasimenko (Gerasimenko, 2004, Matviishyna, Gerasimenko, Perederii, Brahin, Ivchenko, Karmazynenko, Nahirnyi, Parkhomenko, 2010) were analyzed.

Main results. The features of the vegetation composition of Ukraine in the range of 1.8-0.8 million years, which corresponds to Calabriane according to the International Stratigraphic Scale (IIS), are closely linked to global trends in climate change. According to A.A. Velichko with co-authors (Velichko A.A., Pisareva V.V. Faustova M.A., 2011), the tendency to falling of temperature intensified in the range of 1.8-0.8 million years. At that time, in Western Europe glaciation spread to Scandinavia and Northern England. Significant aridization of climate occurred about 1.8 million years resulted in the depletion of vegetation. In particular, the role of mesophyllous plants decreased in the composition of vegetation in the territory of the European part of Russia and Ukraine, including the changed composition of herbaceous cenoses from miscellaneous herbs to more xerophilous miscellaneous herbs–orach and mugwort–orach. The role and taxonomic diversity of thermophilic and broad-leaved species of moderately warm zone in forest groups also decreased.

During the Berezan period (1.8 million years) the forest-steppe type of vegetation predominated within Ukraine, while in the southern and southeastern regions (Sirenko, Turlo, 1986, Gerasymenko, 2004) the area occupied by herbaceous cenoses increased. In the Prydonetska Plain and area near the Azov Sea (Sirenko, Turlo, 1986), their main components were representatives of Chenopodiaceae and Asteraceae families, in the central part of the Prydniprovska Upland – Poaceae. The last region and the western part of the Prydniprovska Lowland were characterized by meadow-steppe cenoses and locations with a few aquatic and coastal aquatic plants: Sparganium sp. and Typha sp. The herbaceous groups of the southern part of Ukraine included xerophytes and halophytes of Frankeniaceae family (Sirenko, Turlo, 1986), which may indicate the existence of saline vegetation.

The main component of thinned forests was

Pinus spp. subg *Diploxylon* with a small impurity of *Betula* spp., and in humid places – *Alnus* spp. Broad-leaved forests were mainly represented by *Quercus robur*, and the forest groups of the north-western part of the Prydniprovska Lowland included *Tilia cordata*, *Corylus avellana* and very rare – single *Juglans regia*.

According to N.P. Gerasimenko (Matviishyna, Gerasimenko, Perederii, Brahin, Ivchenko, Karmazynenko, Nahirnyi, Parkhomenko, 2010), the most humid conditions, and, correspondingly, the greater representation of deciduous plants in cover of the southern and south-eastern regions (domination of xerophilic herbaceous groups) and the central, northeastern and western regions (prevalence of broad-leaved –coniferous, oak–pine and mixed forests). Within the area near the Azov Sea, the Donets Basin and the area near the Black Sea, forest groups were confined to the river terraces.

The vegetation cover of the Early Kryzhanivka period was characterized by insignificant taxonomic diversity of deciduous plants (*Alnus* spp., *Betula* spp., *Quercus* spp., *Tilia* spp.) and a fairly significant

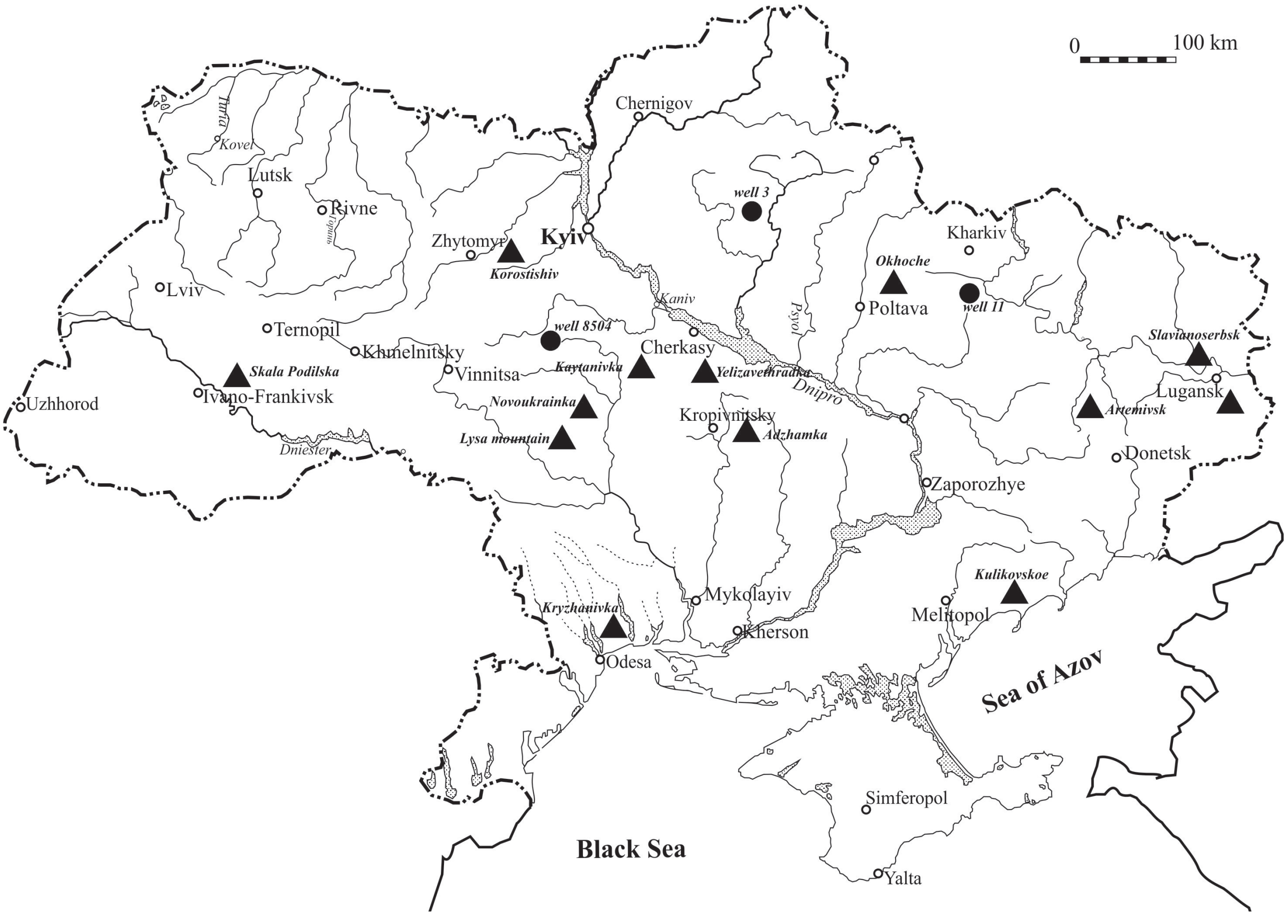

Fig. 1. The scheme of location of Pleistocene deposit sections in Ukraine, studied by the method of spore-pollen analysis (according to O.A. Sirenko).

forest groups, as well as miscellaneous herbs in the composition of herbaceous cenoses existed in the Middle Berezan, and the most arid and cold – in the Late Berezan.

The general tendencies of aridization and fall of temperature that occurred at the beginning of Calabriane influenced the vegetation composition of both cold and warm stages.

The characteristic features of Kryzhanivka vegetation might include the presence of dark conifers (mainly *Picea* spp. sect *Eupicea*) in the forests of almost the whole territory of the platform Ukraine, as well as the bright differentiation of vegetation representation (depending on the relief) of conifers and herbs. Thermophilic plants in forests were represented by few *Juglans* spp.

In the Middle Kryzhanivka period, humidity of climate and heat supply probably increased, which resulted in the expansion of the representation of deciduous plants, especially broad-leaved species: such as *Fagus sylvatica, Fagus* sp., *Tilia platyphyllos*, *T. rubra*, *Carpinus betulus*, *C. orientalis*, *Ulmus laevis*, *Ulmus* sp. and shrubs: *Corylus* spp., *Elaeagnus* sp., *Rhamnus* sp., *Euonymus* sp. in forests. Birch forests and thickets (*Salix* spp. and *Alnus* spp.) grew on various forms of relief.

In the central part of the Prydniprovska Upland, there were probably freshwater basins where *Typha* spp. and *Sparganium* spp. grew. The thermophilic elements in forests existed in small quantities and were predominantly represented by *Juglans cinerea*, and only single *Pterocarya stenoptera* and *Juglans nigra* grew in the valleys near the Azov Sea and the Black Sea regions, and *Myrica* sp. – along liman shores.

Forests predominated in the vegetation cover of the Prydniprovska Upland and the Prydniprovska Lowland, while herbaceous cenoses, the main component of which were various Asteraceae and miscellaneous herbs – on the Prydonetska Plain. The dominant part of the deciduous forests was *Quercus* spp. in most regions of Ukraine and *Tilia cordata* – only within the northwestern part of Prydniprovska Lowland and the central part of the Prydniprovska Upland.

A certain fall of temperature and climate irrigation occurred in the Late Kryzhanivka period, which caused a reduction of broad-leaved and thermophilic species in the forest groups. Significant areas were occupied by pine forests with a small impurity of *Quercus* spp. and *Tilia cordata* as well as birch light forests within the Prydniprovska Upland and the Prydniprovska Lowland. *Picea* was not already met in woods. Within the southern regions and the Prydonetska Plain the area occupied by herbaceous cenoses, in whose composition the role of *Chenopodiaceae* significantly increased, expanded even more as compared to the Middle Kryzhanivka period.

In the Illichivsk period further fall of temperature (Fig. 2) and aridization of climate occurred, which resulted in the fact that the vegetation was notable for impoverished composition not only compared with Kryzhanivka, but also to Berezan. In the structure of vegetation cover of the whole territory of plain Ukraine, the role of herbaceous cenoses, which consisted mainly of the representatives of Poaceae, Chenopodiaceae and Asteraseae families, increased. The composition of arboreal groups also grew poorer due to mainly broad-leaved and thermophilic plants.

Birch-pine light forests and grass-orach-mugwort cenoses occupied approximately equal proportions in the vegetation cover of the Prydniprovska Lowland. In the northwestern part of the Prydniprovska Lowland, the area of forest groups slightly

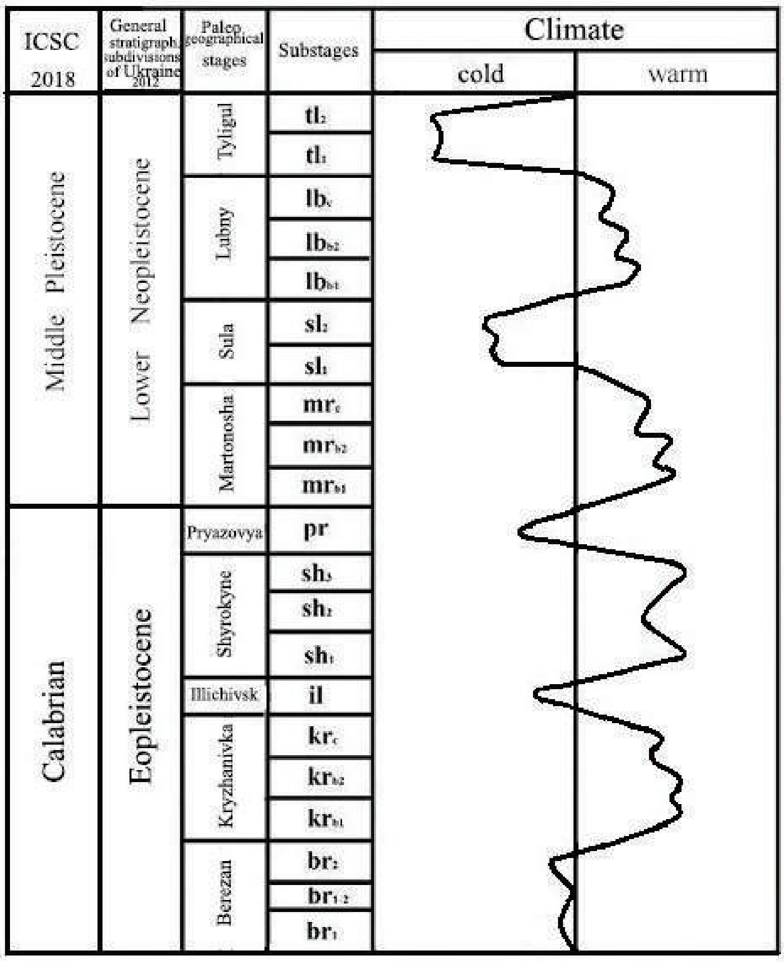

Fig. 2. The curve of changes in heat supply during the stages of nature development in Ukraine in the range of 1.8-0.4 million years.

expanded, and single *Tilia cordata* occurred in their composition. In the forest groups of the coastal areas of the Eastern Azov Sea, the role of *Quercus robur* slightly increased in comparison with the central regions.

In the structure of vegetation cover of the northwestern part of the Prydniprovska Upland, pine forests and herbaceous groups, the main component of which was Asteraceae, occupied approximately equal areas.

Within the Prydonetska Plain mugwort-orach cenoses dominated, and valley forests sometimes included *Tilia cordata* and *Ulmus*, and very rarely single *Juglans* (Sirenko, Turlo, 1986). Pine forests with single *Quercus robur* grew on river terraces.

In the Early Shyrokyne period significant warming occurred (Figure 2) and climate humidity slightly increased in comparison not only with the Illichivsky period but also with the Kryzhanivka period. The above-mentioned climate changes caused increase in a number, generic and specific diversity of thermophilic species and heat-loving pine species of *Haploxylon* subgenus in the forests of the Shyrokyne period, as compared with Illichivsk and Kryzhanivka vegetation. At the same time, the structure of Shirokinsky vegetation still included a large part of herbaceous cenoses, which was typical for the previous stages of nature development.

In the Early Shyrokyne period coniferous-deciduous forests with a significant share of *Tilia* spp. and thermophilic plants dominated within the Prydniprovska Lowland, the northern part of the Prydniprovska Upland and the Podil'ska Upland. Forests also dominated in vegetation cover of the central part of the Prydniprovska Upland but their area declined as compared with the Kryzhanivka period.

In pine–broad-leaved and mixed forests *Tilia cordata*, *Quercus robur* and *Q. pubescens* were sub-dominant, and also *Tilia platyphyllos*, *Fagus sylvatica*, *Carpinus betulus*, *Juglans cinerea* and *Juglans regia* grew. The undergrowth consisted of *Corylus* spp. and *Thelycrania* sp. The grass cover of forests consisted of ferns and floating plants at humid sites. It is also possible to assume the existence of lime groups at isolated sites. Herbaceous cenoses occupied small areas and mainly consisted of Asteraceae and Chenopodiaceae, and meadow grasses on relief depressions. Compared to the Kryzhanivka period, the role of Potamogetonaceae and Sparganiaceae water and coastal water plants decreased in the composition of plant groups.

Within the Prydniprovska Lowland broad-leaved and coniferous forests also included *Ulmus laevis*, and *Pterocarya* sp. from the thermophilic plants. Compared to one-year-old forest groups of adjacent regions, the role of *Carpinus betulus* increased.

Within the territory near the Azov Sea broad-leaved groups with a significant participation and specific diversity of walnut tree: *Juglans sieboldiana*, *J. cinerea*, *J. mollis* existed in river valleys. Single *Rhus* sp. grew at more arid sites. The composition of dominants among deciduous plants of a moderately warm zone did not change as compared with the forests of the central regions.

Despite the fact that a forest-steppe type of vegetation predominated in the southern regions of Ukraine and Donets Basin (Sirenko, Turlo, 1986) in the Early Shyrokyne period, the representation of forests in the structure of vegetation cover was higher than in the subsequent Late Shyrokyne period.

Insignificant fall of temperature and climate aridization that occurred in the Middle Shyrokyne period led to a reduction in the vegetation cover of broad-leaved and thermophilic plants and the expansion of areas occupied by herbaceous groups. Particularly, herbaceous cenoses including multiple Asteraceae prevailed in the structure of vegetation cover of the Prydonetska Plain and the central part of the Prydniprovska Lowland. Thermophilic species consisted of oak-pine light forests occurred very rarely and in small quantities.

A forest type of vegetation was only typical for the north-western part of the Prydniprovska Lowland. Within this region vast areas were occupied by mixed forests. In their composition *Betula* spp. dominated deciduous species, and also *Carpinus betulus*, *Tilia cordata*, *Ulmus laevis* and *Juglans regia* occurred in small quantities, which was no longer typical for the forest groups of the Late Shyrokyne period.

In the Late Shyrokyne period the temperature regime of climate increased again but in comparison with the Early Shyrokyne period, the degree of humidity decreased. In connection with this, forest groups were characterized by a significant number of broad-leaved and thermophilic plants but in comparison with the Early Shyrokyne period, they differed in smaller taxonomic varieties. In the structure of vegetation cover in practically all regions of Ukraine a part of herbaceous groups increased including miscellaneous herbs in their composition: Apiaceae, Ranunculaceae, Lamiaceae, Fabaceae, Plantaginaceae, Polygonaceae, and Rosaceae. In the central and northeastern regions of Ukraine arboreal and herbaceous cenoses occupied almost equal areas, and in the southern regions (Sirenko, Turlo, 1986) herbaceous groups prevailed.

The Priazovya stage was characterized by significant aridization and fall of temperature (Figure

2), which resulted in the impoverishment of both arboreal and herbaceous groups. In the southeastern and southern regions of Ukraine (Sirenko, Turlo, 1986), the steppe type of vegetation predominated. Significant areas were covered with grass-mugwort-orach cenoses, and grass-miscellaneous herbs within the Prydonetska Plain. In the vegetation cover of the Middle and Lower Prydniprovia herbaceous cenoses also dominated, and a few arboreal groups existed only along the valleys and river terraces and mainly consisted of pine, oak, ulmus and hazel (Sirenko, Turlo, 1986). Within the southwestern part of the Prydniprovska Upland, a significant part of vegetation cover belonged to pine and birch-pine light forests with a small impurity of oak. In the territory of the Prydniprovia near Kyiv both pine light forests (Sirenko, Turlo, 1986) and different miscellaneous herb-mugwort groups (Gerasymenko, 2004) existed in various durations of the Priazovya period.

The Martonosha period was characterized by the dampest climate for the investigated geological time, which was very clearly appeared in the vegetation cover of the entire territory of Ukraine. In the central, northeastern and western parts of the region, a forest type of vegetation dominated. And only within the southern regions of Ukraine and Donets Basin, the wooded steppe prevailed. The forests of the Martonosha period were characterized by the considerable participation of coniferous species including thermophilic pine species of *Haploxylon* subgenus, a large variety of broad-leaved species in the moderately warm zone and thermophilic elements. In contrast to the forest groups of the Shyrokyne period, the role of small-leaved species of a temperate zone increased in Martonosha forests, which together with the growth of the participation of conifers might indicate a slight fall of temperature during the Martonosha period.

The Martonosha period is characterized by the long-winded climatic optimum and, correspondingly, the weak differentiation of vegetation cover in the periods of formation of early and late optimal Martonosha soils. This feature is characteristic mainly for the vegetation cover of the central and northwestern parts of the Prydniprovska Lowland as well as the northern part of the Prydniprovska Upland, and it is associated with high humidity, under which Martonosha soils were formed in these regions. And only in the regions with more arid conditions of the formation of Martonosha soils (the southern and central parts of the Prydniprovska Upland, the Prydonetska Lowland) the differences in the conditions of the formation of early and late optimum soils, as well as the final stage of Martonosha soil formation more distinctly appeared.

Within the Prydonetska Plain in the Early Martonosha y period the forest-steppe type of vegetation predominated. Large areas were occupied by herbaceous groups with the participation of Chenopodiaceae and Asteraceae. Hygrophytes and herbaceous groups as well as sphagnum mosses grew along river valleys and shore.

The composition of mixed and pine-deciduous forests was quite variegated: *Pinus* spp. sect *Eupitys* (dominated), *P.* spp. sect *Cembrae*, *Picea* sect. *Eupicea*, *Carpinus betulus*, *Quercus robur*, *Quercus* sp., *Tilia cordata*, *T. platyphyllos*, *Corylus avellana*. Thermophilic plants were represented by *Juglans cinerea* and *Juglans* sp. Deciduous species of the temperate zone *Alnus glutinosa*, *A. incana*, *Betula* sp. sect *Albae* in forests occupied a smaller area compared to broad-leaved plants of moderately warm zone. Ferns Polypodiaceae participated in the grass cover of forests.

During the first inter-stage fall of temperature, a forest-steppe type of vegetation also predominated, but the role of *Betula* spp. significantly increased in the composition of arboreal formations, while the role of ferns decreased in the grass cover of forests.

In the Middle Martonosha period the temperature again increased but in comparison with the Early Martonosha period, the humidity slightly reduced. The role of herbaceous groups consisted mainly of Chenopodiaceae and Asteraceae increased in the composition of vegetation cover. Compared to the Early Martonosha period, a number of thermophilic plants increased in the forests but their specific composition as well as the composition of broad-leaved species practically did not change. The undergrowth consisted of *Corylus avellana*. The role of deciduous plants of the temperate zone *Betula* and *Alnus* diminished in the composition of forest groups, while *Ulmus* spp. quite often occurred.

The second inter-stage fall of temperature was characterized by compared with the first one greater lowering of temperature regime and humidity of climate, which caused impoverishment of both arboreal and herbaceous groups that already occupied much larger areas. A few arboreal groups mainly consisted of *Pinus* sect *Eupitys* with a small impurity of *Tilia cordata*, *Quercus robur*, *Corylus avellana*, and thermophilic plants were not found there. The composition of herbaceous cenoses became poorer due to herbs and hygrophytes.

In the Late Martonosha period a slight increase in the temperature occurred as compared with the period of formation of a loess-type layer. The main components of a few arboreal groups located on lowered relief elements were mostly *Pinus* sect. *Eupitys* and *Betula* with a small participation of *Quercus robur*. Within the region of research large areas were occupied by herbaceous cenoses. In their composition as compared with the Middle Martonosha period, the share of miscellaneous herbs reduced.

The conditions of high humidity that existed during the formation of Martonosha soils in the Prydniprovska Lowland leveled differences in the structure of vegetation cover during the periods of soil formation of the early and late optimum of Martonosha pedogenesis. Within the specified region, the forest type of vegetation dominated during the Martonosha period. In the central part of the Prydniprovska Lowland, pine and oak-pine forests occupied mostly watershed areas, while broad-leaved–coniferous forests grew on lowered relief elements. In addition to *Pinus* spp., *Picea* spp. sect *Eupicea* played a significant role in their composition. Few *Carpinus betulus* were found in forests of the Early Martonosha period but *Tilia platyphyllos* and *Ulmus laevis*, which were typical the Prydonetska Plain, were absent. In general, except for the indicated differences, a deciduous component of forests was similar to the forest groups of the Prydonetska Plain. Thermophilic plants in forests were represented by *Juglans cinerea* and *Juglans* sp.

Herbaceous groups occupied insignificant areas and grew predominantly in forest glades; dominants in their composition were various Asteraceae with a small impurity of miscellaneous herbs. Mosses and ferns occurred in the grass cover of forests.

The forests of the northwestern part of the Prydniprovska Lowland were distinguished by a more diverse composition of broad-leaved trees of a moderately warm zone. In particular, in addition to the taxonomy already mentioned, various forest elements included *Carpinus betulus*, *Quercus pubescens, Tilia dasystyla*, *T. platyphyllos*, *Ulmus*. *laevis, U. camprestris*, and *Juglans nigra.* As opposed to the forests of the Prydonetska Plain and the central part of the Prydniprovska Lowland, *Tilia cordata* was sub-dominant in the forests but not *Quercus*. A significant role in forest groups also belonged to *Betula* sp. sect. *Albae*. The grass cover of the forests consisted of *Lycopodium* sp and Polypodiaceae. Few herbaceous groups grew in forest glades.

A slight fall of temperature occurred during the formation of loess-type loam that separates the soils of the early and late optimum Martonosha pedogenesis. This led to an increase in the number of *Betula* in forests and a reduction in the taxonomic diversity of broad-leaved trees.

During the Late Martonosha period, the area occupied by herbaceous vegetation increased. In the forests, the share of broad-leaved trees decreased and thermophilic plants disappeared, while a number of plants increased in the temperate zone.

There were no sharp changes in the composition of vegetation in the central part of the Prydniprovska Upland during the Early and Middle Martonosha periods. The main differences consisted in the fact that the most generic and specific diversity of broad-leaved species of temperate-warm zone and thermophilic elements were typical for the middle Martonosha forests: *Carpinus betulus*, *C. orientalis*, *Tilia cordata*. (dominated), *Tilia platyphyllos*, *Tilia dasystyla*, *Tilia* sp., *Quercus robur* L., *Q. pubescens*, *Fagus sylvatica*. The elevated elements of relief were occupied by pine-oak and mixed forests with *Pinus* sp. sect *Eupitys*, *P*. sp. sect. *Cembrae* and *P*. sp. sect. *Strobus*, *Betula pendula*, and *Betula* sp. Pine-deciduous forests including *Ulmus camprestris*, *Juglans cinerea*, *J. regia*, *Juglans* sp. grew near ponds and in the lowered elements of relief. The undergrowth consisted of *Corylus* sp., *Thelycrania* sp., Caprifoliaceae, Grossulariaceae, *Vitis* sp., Moraceae. Lime groups probably existed. *Betula pubescens*, *Alnus glutinosa*, and *A. incana* grew along the banks of ponds and in wetlands. The grass cover of forests consisted of ferns and mosses. The specific composition of pines did not change in comparison with Martonosha forests in adjacent regions. As opposed to the forest groups of the Prydniprovska Lowland, *Picea* spp. sect *Eupicea* did not grow in the forests of the central part of the Prydniprovska Upland. Herbaceous groups occupied insignificant areas, and dominants in their composition (the representatives of Asteraceae family) did not change as compared to the Prydniprovska Lowland, whereas the proportion and diversity of mesophilous herbs and Poaceae increased.

In the Late Martonosha period the share of forests decreased in vegetation cover and the composition of forests changed. Pine–broad-leaved forests and lime groups interchanged with oak-pine forests including *Fagus* and oak forests, the edificator of which was *Quercus robur*. Mixed forests with various *Betula* spp. and a small impurity of *Carpinus betulus*, *Tilia cordata*; *Tilia dasystyla*, and *Quercus pubescens* grew only on lowered relief elements. Thermophilic plants did not grow in forests.

As a result of the growing fall of temperature, on the second half of the Late Martonosha period the forests became poorer due to *Carpinus betulus* and *Tilia dasystyla*, and predominantly consisted of *Betula* spp. and *Pinus* spp. with a small impurity of *Quercus robur* and *Tilia cordata*.

During the Martonosha period within the northern part of the Prydniprovska Upland almost all the area was occupied by pine, birch-pine and mixed forests. In contrast to one-age forest groups of the central part of the Prydniprovska Upland, a part of *Betula* increased in their composition, a number of thermophilic elements decreased, and the taxonomic diversity of broad-leaved species of moderately warm zone decreased. Among deciduous forests, *Tilia cordata* was subdominant, and a small part of the forests included *Tilia platyphyllos, Carpinus betulus, Fagus* sp*., Quercus robur, Quercus* sp*., Ulmus* sp*., Corylus* sp. A quite significant part in the composition of vegetation cover belonged to *Sphagnum* sp. and Polypodiaceae. Small herbaceous groups were presented by the plants of Chenopodiaceae, Poaceae, Asteraceae families and miscellaneous herbs as well as *Artemisia* spp. genus.

Martonosha forests of the Podil'ska Upland were similar in composition to the forest groups of adjacent regions. The most distinctive features were the most specific variety of pines *Pinus* sp. sect *Eupitys*, *P*. sp. subg *Diploxylon* (dominated), *P*. sp. sect *Banksia*, a significant part of the heat-loving species of *Pinus* sp. sect *Cembrae*, P. sp. sect *Strobus*, which was probably due to the influence of the Carpathian Mountains, as well as the most specific variety of thermophilic species of Juglandaceae family: *Pterocarya stenoptera*, *Juglans cinerea*; *J. regia*, *J. nigra*, *Juglans* sp.

In the Early Martonosha period mixed and pine-broad-leaved forests occupied large areas. A characteristic feature of the forests was the wide representation of deciduous plants of the temperate-warm zone in their composition, notably *Quercus* spp., *Carpinus betulus*, *C. orientalis*, *Ulmus laevis*, *Rhamnus* sp., *Corylus* sp. Representatives of the Tiliaceae family such as *Tilia dasystyla*, *T. cordata*., *Tilia* sp. were dominant in a deciduous component of the forests. Probably, separate lime groups could also exist within the region of the research. The forests also included *Pinus* spp., *Betula* spp., *Alnus* spp., *Salix* spp. The composition of vegetation cover consisted of Polypodiaceae, *Sphagnum* sp., *Bryales* sp. Herbaceous cenoses occupied small areas and consisted of miscellaneous herbs, Poaceae, Asteraceae and Cyperaceae.

In the Midddle Martonosha period, forest groups also dominated in the structure of vegetation cover of the investigated region but their area reduced in comparison with the Early Martonosha period. Probably, under the influence of climate humidity decrease, hydrophilous plants such as *Salix* spp., *Pterocarya stenoptera*, *Juglans nigra* disappeared from the forests; dominants of the deciduous component of the forests also changed, notably, the leading positions already belonged to *Quercus* spp. By the number of broad-leaved and thermophilic species these forests predominated over the Early Martonosha forests. The herbaceous cover of the forests also included few Polypodiaceae and *Lycopodium* sp. On the contrary, in the structure of vegetation cover the areas occupied by herbaceous groups expanded, and a part of plants of Chenopodiaceae and Asteraceae families increased in their composition.

In the Sula period aridization and fall of temperature intensified but according to palynological (Sirenko 2017b) and malacofaunistic (Kunitsa, 2007) data, climatic conditions of the Sula period were less severe than in the subsequent stages of the fall of temperature. The composition of forest groups became poorer due to heat-loving pine species, broad-leaved species of moderately warm zone and thermophilic elements. Asteraceae were dominant in herbaceous cenoses, and Chenopodiaceae had a subordinate value.

A steppe type of vegetation existed within the Prydonetska Plain. Among the herbaceous groups, Chenopodiaceae and Asteraceae were dominant. Meadow-steppe cenoses and a few forest groups consisted of *Pinus* sect. *Eupitys*., *Alnus* sp., *Betula* spp., *Ulmus* sp. spread on the wettest areas.

The central part of the Prydniprovska Plain is characterized by a forest-steppe type of vegetation. Watersheds were covered with pine forests including *Quercus robur*, and *Tilia cordata* within the northwestern part of the region. Significant participation in the structure of vegetation cover belonged to herbaceous cenoses consisting of Poaceae, Asteraceae, Chenopodiaceae. Birch-pine and coniferous forests as well as meadow–miscellaneous herb groups grew on lowered relief elements. Within the northwestern part of the Prydniprovska Lowland refugiums with single Juglans sp. existed.

The distinctive features of vegetation cover of the central part of the Prydniprovska Upland might consist in participation in arboreal formations *Tilia cordata*, *Alnaster*, cf. *manshuricus*, miscellaneous herbs, aquatic and coastal aquatic plants. Within the specified region there were certain distinctions in the structure of vegetation cover in the Early and Late Sula periods.

In the structure of vegetation cover of the Early Sula period arboreal groups were dominants including, in addition to usual pine, isolated thermophilic pine species. The deciduous component of forests was mainly represented by *Betula verrucosa* with a small impurity of *Quercus robur* and *Tilia cordata*. Miscellaneous herb groups and *Alnus* spp. as well as helophyte cenoses including *Sparganium* spp., *Typha* spp., and *Sphagnum* spp. distributed in humid places on lowered relief elements.

In the Late Sula period the proportion of herbaceous cenoses, the main component of which was Chenopodiaceae with miscellaneous herbs, increased in the structure of vegetation cover. As opposed to the Early Sula period, a number of hydro- and hygrophytes significantly decreased while a part of the representatives of Betulaceae family increased in forest groups, and *Alnaster* and *Corylus* appeared. *Tilia cordata* singly occurred in forests, and *Juglans* in river valleys.

Forest type of vegetation predominated in the territory of the northern part of the Prydniprovska Upland. Pine and birch-pine forests no longer included heat-loving pine species. Besides *Pinus* spp. and *Betula* spp. the forests occasionally included *Alnus* sp. and *Tilia cordata*, and *Juglans* sp. sometimes occurred in refugiums.

In the Sula period pine and mixed forests dominated in the central part of the Podil'ska Upland, and included, as compared to forest groups in other regions of Ukraine, the largest part of broad-leaved species. On lowered relief elements deciduous groups including various Betulaceae, *Quercus robur* and *Tilia cordata* as well as individual *Tilia platyphyllos* grew. Single *Juglans* survived in isolated refugiums. Compared to the Martonosha peiod, the representation of gramineous-herb and mugwort groups expanded in the structure of vegetation cover.

Thus, the palynological data indicate that in the Sula period within the platform Ukraine there was a clearly defined plant zoning. Within the Prydonetska Plain and the southern regions of Ukraine, the steppe type of vegetation predominated. The southern and northern boundaries of the forest-steppe zone were within the limits of the modern forest-steppe zone, while the western part was shorter. In the northern part of the Prydniprovska Upland and probably the central part of the Podil'ska Upland a forest zone existed.

In the western, northwestern and partly central regions of Ukraine there were refugiums near ponds where broad-leaved and thermophilic species grew. Higher humidity could level to some extent global climate fluctuations and influence the composition of vegetation cover.

In Lubny period, warmth and humidity increased again but, compared to the Martonosha period, the intensity of increase was lower. In contrast to the Martonosha period, the role of conifers reduced in the composition of vegetation, the participation of deciduous species increased in temperate and temperate warm zones (mainly due to *Quercus robur* and *Tilia cordata*), a number of thermophilic elements significantly decreased, and the role of herbaceous groups including miscellaneous herbs in their composition expanded.

Temperature and humidity fluctuations occurred within the territory of platform Ukraine during the Lubny period, which affected the nature of vegetation cover in the Early, Middle and Late Lubny periods.

In the Early Lubny period herbaceous groups with the participation of Chenopodiaceae, Asteraceae, Rosaceae, miscellaneous herbs, aquatic and coastal aquatic plants predominated within the Prydonetska Plain. Arboreal groups had a subordinate value but as against before Sula period, they occupied larger areas. Depending on the relief, birch-pine light forests with a small amount of *Picea* sect. *Eupicea* and oak-lime-hardbeam groups including *Carpinus betulus*, *Fraxinus sp.*, *Quercus robur*, *Quercus sp.*, *Tilia cordata*, *T. platyphyllos*, and *Corylus avellana* occurred. Single *Juglans* sp. grew in valley forests, and *Typha angustifolia* and *Alnus glutinosa* – along the banks of ponds.

Inter-stage fall of temperature that occurred during the formation of a thin loess-type layer caused impoverishment of forest groups due to disappearance of thermophilic and hydrophilic plants (*Juglans, Tilia, Carpinus*). This period was also characterized by an increase in irrigation that resulted in the expansion of areas occupied by herbaceous cenoses, in the composition of which a share of miscellaneous herbs reduced, while *Artemisia* spp. played a significant role.

In the Middle Lubny period a degree of humidity decreased. As a result, the role of *Quercus* increased in the composition of few arboreal groups. Certain changes occurred in the structure of forest groups as compared with the Early Lubny period. In oak-pine and pine-deciduous forests with *Corylus. avellan*a and *Elaeagnus* sp. hygrophilous plants such as *Carpinus betulus*, *Fraxinus* sp., *Picea* sect. *Eupicea* no longer occurred in undergrowth. Herbaceous cenoses, dominants in which were Chenopodiaceae family, prevailed in the composition of vegetation cover.

The second inter-stage fall of temperature was more intensive compared to the first one. The edificators of small forest groups were *Pinus sylvestris* and *Betula pendula*. Thermophilic and broad-leaved species no longer entered into the composition of forests. Herbaceous cenoses, which occupied a significant part of the region of the research, also became poorer mainly due to miscellaneous herbs and hygrophilic plants.

In the Late Lubny period there was a slight increase in the humidity of climate, which led to a wider participation of birch-pine forests with a small impurity of *Quercus robur* as a part of vegetation cover and an increase in the role of miscellaneous herbs in the composition of herbaceous cenoses.

Climatic fluctuations retraced during the Lubny period also influenced the structure of vegetation cover of the Prydniprovska Lowland. In the Early Lubny period large areas were covered with mixed forests including *Pinus* spp. sect. *Eupitys*, *Betula pendula*, *Picea* spp. sect. *Eupicea*, *Quercus robur*, *Corylus avellana* within the central part of the region. Thermophilic species did not enter into the composition of forests. Herbaceous groups occupied small areas and mainly consisted of Asteraceae, Chenopodiaceae and miscellaneous herbs. Polypodiaceae were present in the grass cover of forests.

Under the influence of inter-stage fall of temperature, the proportion of herbaceous cenoses including Poaceae, Polygonaceae, and Cyperaceae increased in the structure of vegetation cover. Compared to the Early Lubny period, the composition of few arboreal groups did almost not change.

In the Middle Lubny period, a forest-steppe type of vegetation predominated. In comparison with the Early Lubny period, the areas of forests decreased, and a number of *Pinus* and *Picea* diminished.

In the Late Lubny period the area of birch-pine forests increased in the composition of vegetation cover but the deciduous species of the temperate-warm zone (*Quercus* and *Corylus*) were already absent. Herbaceous groups occupied small areas and consisted predominantly of Poaceae, Asteraceae and miscellaneous herbs. Similar patterns of vegetation changes during the Lubny period were also retraced within the northwestern part of the Prydniprovska Lowland. The differences consisted in the presence of *Carpinus betulus* and *Juglans regia* in the composition of forests in the Early Lubny period, pronounced representation of deciduous plants of the temperate-warm zone in the forests of the Middle Lubny period, especially *Tilia cordata*, as well as the appearance of *Ulmus camprestris* and *Ulmus laevis*.

In the Early Lubny period a forest-steppe type of vegetation predominated within the Prydniprovska Upland. Birch-pine and mixed forests occupied larger areas compared to herbaceous groups. Besides the representatives of Pinaceae and Betulaceae families, numerous broad-leaved species such as *Quercus robur, Q. pubescens, Tilia cordata*, and *T. platyphyllos* grew in forests. Sometimes *Carpinus betulus, Fagus sylvatica*, and *Juglans cinerea* occurred in the composition of forest groups. The undergrowth consisted of *Corylus avellana* and *Rhamnus* sp. Meadow-steppe groups mainly consisted of miscellaneous herbs. Cyperaceae, *Typha* sp., and *Sparganium* sp. grew in ponds and along their banks.

Climate aridization, which occurred in the Middle Lubny period, led to the reduction in the area occupied by forests. Instead, a large part of the investigated territory was occupied by steppe cenoses mainly consisting of Asteraceae, Poaceae and Chenopodiaceae. Miscellaneous herbs only extended at wet sites. As compared with the Early Lubny period, a number of *Quercus robur* increased in forests but *Juglans cinerea* no longer occurred.

In the Late Lubny period within the region of the research there was a significant number of freshwater reservoirs with Potamogetonaceae, near which numerous Cyperaceae, *Typha* sp., and *Sparganium* sp. grew. The herbaceous groups of flat interfluves consisted of the representatives of Poaceae and Chenopodiaceae families. In the composition of mixed forests the main role belonged to *Pinus* spp. and *Betula* spp. Single *Juglans regia* only grew in valley forests.

In the Early Lubny period, a forest type of vegetation prevailed within the northern part of the Prydniprovska Upland. In the mixed and birch-pine forests, broad-leaved species were represented by *Tilia cordata* and *Quercus robur*, and the undergrowth consisted of *Corylus* sp. and *Elaeagnus* sp. On lowered relief elements arboreal groups consisted of individual *Juglans cinerea* and *J. nigra*. The grass cover of forests included Polypodiaceae and *Bryales*. A few grassy groups consisted of Chenopodiaceae, *Artemisia* spp., miscellaneous herbs and coastal aquatic plants.

In the middle Lubny period, the role of *Alnus* spp. and *Betula* spp. decreased in the composition of forests, whereas a number of *Tilia cordata* increased, and *Juglans nigra* was absent. In the composition of herbaceous groups, a number of miscellaneous herbs and coastal aquatic plants appreciably decreased due to the increased part of Asteraceae and *Artemisia* sp.

A forest type of vegetation was also typical for the territory of the Podil'ska Upland in the Early Lubny period. In the composition of forests, besides various *Pinus* species (with the participation of heat-loving *Haploxylon* species), *Picea* sp. sect *Eupicea*, *Tilia* *cordata*, *T. platyphyllos*, *Tilia* sp., *Quercus robur*, *Q. pubescens*, *Quercus* sp., and *Carpinus betulus* were presented. *Juglans regia* and *J. cinerea* thermophilic species also entered into the composition of forests, but in smaller quantities in comparison with the Martonosha period as well as *Tilia dasystyla*. A few herbaceous groups mainly consisted of miscellaneous herbs with a small part of Poaceae and Asteraceae.

In the Middle Lubny period the areas occupied by herbaceous groups with various Asteraceae increased. *Tilia* spp dominates in the deciduous component of coniferous–broad-leaved and mixed forests, whereas a number of plants of the temperate zone decreased. The forests included a small amount of *Picea* sp. sect. *Omorica*, *Carpinus orientalis*, *Fagus* sp., *Rhamnus* sp., *Corylus* sp. The thermophilic species were presented by *Juglans regia* and *J. cinerea*.

In the Late Lubny period the areas occupied by mixed forests increased. In comparison with the Middle Lubny period, a number of *Pinus* sp. subg *Diploxylon* increased in their composition but Tiliaceae family representatives decreased. Herbaceous groups grew mainly in forest glades.

Thus, in spite of the regional distinctions of the composition of Lubny vegetation, general tendencies of its changes associated with climatic fluctuations was clearly observed during the Lubny period. The most significant part of arboreal groups including coniferous (including dark coniferous) species as well as hygrophilous plants (*Carpinus betulus*) and an insignificant number of thermophilic elements was typical for the composition of Eearly Lubny vegetation in most regions of the platform Ukraine. In the Middle Lubny period the area occupied by herbaceous cenoses expanded in the structure of vegetation of all regions of Ukraine. The dominant components of deciduous forest were *Quercus* spp. and *Tilia* spp. In the Late Lubny period, the areas occupied by the forests expanded again in the structure of vegetation cover, but a significant part of them belonged to *Pinus* sp. subg. *Diploxylon* and *Betula* spp.

The Tiligul period was characterized by considerable aridization and a decrease in the temperature regime of climate (Figure 2), which resulted in impoverishment of both arboreal and herbaceous groups.

Within the Prydonetska Plain a steppe type of vegetation predominated. Significant areas were occupied by mugwort-orach coenoses with a small part of miscellaneous herbs and Poaceae. Few birch-pine forests including single *Quercus robur* and *Corylus* sp. occupied lowered relief elements.

A forest-steppe type of vegetation was inherent in the Prydniprovska Lowland. The composition of arboreal groups was close to the forests of the Prydonetska Plain. Herbaceous cenoses were mainly represented by plants of Asteraceae family, whereas Chenopodiaceae have a subordinate value.

In the Tiligul period, as compared with the Lubny period, in the central part of the Prydniprovska Upland the area occupied by forests decreased, and broad-leaved and thermophilic species almost completely disappeared from their composition.

In the Early Tiligul period gramineous-herb, mugwort and orach cenoses dominated. Pine and birch-pine forests had a subordinate value, but in comparison with the Late Tiligul period they occupied larger areas. Within the region of the research there were a large number of freshwater reservoirs, around which *Typh*a sp., *Potamogeton* sp., *Sparganium* sp., *Betula humilis*, and *Alnus* sp. grew.

During inter-stage warming the area of forests increased, and a few *Tilia cordata*, *Quercus robur*, and *Corylus avellana* appeared in their composition again. A part of meadow grasses increased in herbaceous cenoses.

In the Late Tiligul period aridization significantly increased, which led to domination of herbaceous cenoses consisting of Chenopodiaceae and Asteraceae in the composition of vegetation cover. Compared to the Early Tiligul period, a part of helophyte cenoses decreased. Few arboreal groups with *Pinus sylvestris* and *Betula pendula* sometimes included single *Quercus robur*.

Conclusions The analysis of the results of the palynological studies showed that regardless of the established regional differences, the general features of vegetation development due to changes in climatic conditions associated with global climate changes were retraced in the territory of plain Ukraine in the range of 1.8-0.43 million years.

The climatic conditions of each stage of nature development of the Pleistocene of Ukraine differed by the temperature regime and the degree of aridization or climate humidization, which affected the composition of vegetation cover. Temperature and humidity fluctuations occurred during each stage, which indicates the existence of not only macro- but also micro-rhythmicity in the development of Pleistocene vegetation in Ukraine.

During the formation of sediments that correspond to Calabrian according to ISS, the warmest climatic conditions were typical for the Early and Late Shyrokyne periods, and the dampest climatic conditions were in the Middle Kryzhanivka and Early Shyrokyne periods.

Among more recent Pleistocene stages of nature development in Ukraine (in the range of 0.8-0.43 million years), the warmest and dampest conditions existed in the Early and Middle Martonosha periods, while the coldest ones were in the Tiligul period (Figure 2).

Climatic conditions of the Sula period were less severe than in the subsequent stages of fall of temperature. The existence of refugiums (mainly near ponds) with thermophilic and broad-leaved species was established within the western, northwestern and partly central regions of Ukraine in the Sula period. It was determined that the vegetative cover of the cold stages of the Early Neopleistocene (especially the Sula period) was characterized by the differentiation of vegetation cover in different regions of Ukraine. In the Sula period steppes dominated within the Near Black Sea Lowland (Sirenko, Turlo, 1986) and the Prydonetska Plain, forest-steppes in the Prydniprovska Lowland and the Prydniprovska Upland, and forests in the northern part of the Prydniprovska Upland and the Podil’ska Upland.

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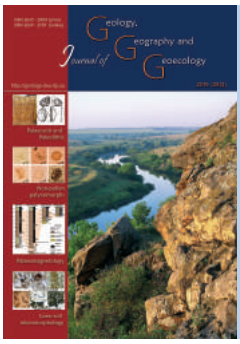

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Map of Quaternary formations of Ukraine in scale 1:2,500,000

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Abstract. The article announces a new map of Quaternary formations on the territory of Ukraine on the scale 1:2,500,000. It considers the prerequisites for the preparation of this map and summarises more than a century of historical research and mapping of the Quaternary formations on the territory of Ukraine. Due to the continuity of scientific research, an extremely developed theoretical and methodological basis of both research and mapping of Quaternary formations has been formed in the country. This is also due to the extraordinary diversity of the geological structure of the Quaternary cover, due to the presence of two mountain systems, lowland areas (including within them several deflections and two crystalline foundations), as well as due to the presence of two seas (including the continental shelf, slope and deep-water zone). A very wide spectrum of facies and formations is also listed (including a thick loess-soil cover, facies of two glaciers of different ages, alluvia, estuary, marine shelf, deep-water and etc.). Attention is focused on two important problems of mapping Quaternary cover. The first is related to new views on the origin of the subaerial cover. The significance of the new (geo-eolian) factor is disclosed, which determined both the thickness and lithological properties of the strata of each paleogeographic stage (of climatoliths) of each separate section, and the stratigraphic structure of the loess-soil cover. Spatial patterns of the structure of the subaerial cover are briefly described, in particular, the mosaic division into areas with a homogeneous stratigraphic structure (type-sections), due to the corresponding geo-eolian mode (sequence). The second problem concerns the ways of visualization of the geological structure of Quaternary sediments on the map. Two principles of reflection of the Quaternary cover are considered, and the disadvantages and advantages of each of them are indicated. Promising ways to map the Quaternary subaerial cover on the basis of ideas about its mosaic structure are proposed. A solution to the problem of various principles of visualization of the Quaternary cover is recommended involving compilation of «multi-visual» maps based on their interactive re-issuing (re-design) with modern geographic information systems in accordance with various principles of visualization of the structure of the Quaternary. It has been proposed to use the above scientific approaches in the mapping of the Quaternary deposits of Europe and the World, and also to take into account the geo-eolian factor in the studies of the subaerial cover.

Key words: mapping, map of Quaternary formations of Ukraine, subaerial sedimentogenesis.

Карта четвертинних відкладів України масштабу 1:2 500 000

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Анотація. У статті анонсована нова карта четвертинних відкладів території України масштабу 1:2 500 000. Акцентована увага на двох важливих проблемах картування четвертинного покриву. Перша пов'язана з новими поглядами на походження субаерального покриву. Розкрита сутність нового (гео-еолового) чинника, який визначив як потужності й літологічні властивості стратонів кожного палеогеографічного етапу (кліматолітів) на кожній окремій ділянці, так і стратиграфічну будову лесово-ґрунтового покриву загалом. Коротко описані просторові закономірності будови субаерального покриву, зокрема мозаїчний його поділ на ділянки з однорідною стратиграфічною будовою (типо-розрізи), що зумовлено відповідним гео-еоловим режимом. Друга проблема стосується шляхів візуалізації геологічної будови четвертинних відкладів на карті. Розглянуто два принципи відображення четвертинного покриву, а також вказані недоліки й переваги кожного з них. Запропоновані перспективні шляхи картування четвертинного субаерального покриву на основі уявлень про мозаїчну його будову. Рекомендовано вирішення проблеми різних принципів візуалізації четвертинного покриву шляхом складання «полівізуальних» карт на основі інтерактивного їх переоформлення сучасними засобами геоінформаційних систем відповідно до різних принципів візуалізації будови четвертинного покриву. Запропоновано використовувати наведені наукові підходи при складанні карт четвертинних відкладів Європи та Світу, а також враховувати при дослідженнях субаеральних покривів гео-еоловий чинник.

Ключові слова: картування, карта четвертинних відкладів України, субаеральний седиментогенез.

Introduction. In Ukraine, the mapping of Quaternary formations on a 1:2,500,000 scale of a new generation is being completed (Fig. 1), the results of which will become part of a set of GIS maps of geological content (http://ukrdgri.gov.ua/uk/geo-map). A similar map on the same scale was published in the National Atlas of Ukraine (National Atlas of Ukraine, 2007), but the new map differs significantly in several parameters at once. In particular, it more fully takes into account the geological mapping data for the last 10-15 years, more fully reflects the structure of the bottom of water bodies, and it is based on other principles of research and mapping of subaerial facies, including of loess-soil cover (in the south of Ukraine) and sandy cover in Polissia (in its north).

Already at the beginning of compiling this map, several problems were discovered, each of which affects the content and images of the maps. Within the framework of this article, we will dwell only on two of them, which are important for the content and form of the display of the geological structure on the Quaternary formations map. The first problem concerns the methodology and techniques for the study of Quaternary deposits and is the choice of certain principles of the stratigraphic and facies or genetic classification of parts of the Quaternary cover.

The second problem concerns the principles of reflecting the geological structure of the Quaternary cover, two of which are mainly used at present: 1) «classical-geological» (mapping the first Pleistocene layer from the earth's surface), and 2) «glyptogenetic» (mapping the main geological order of the formation of the Quaternary cover in its manifestations in relief).

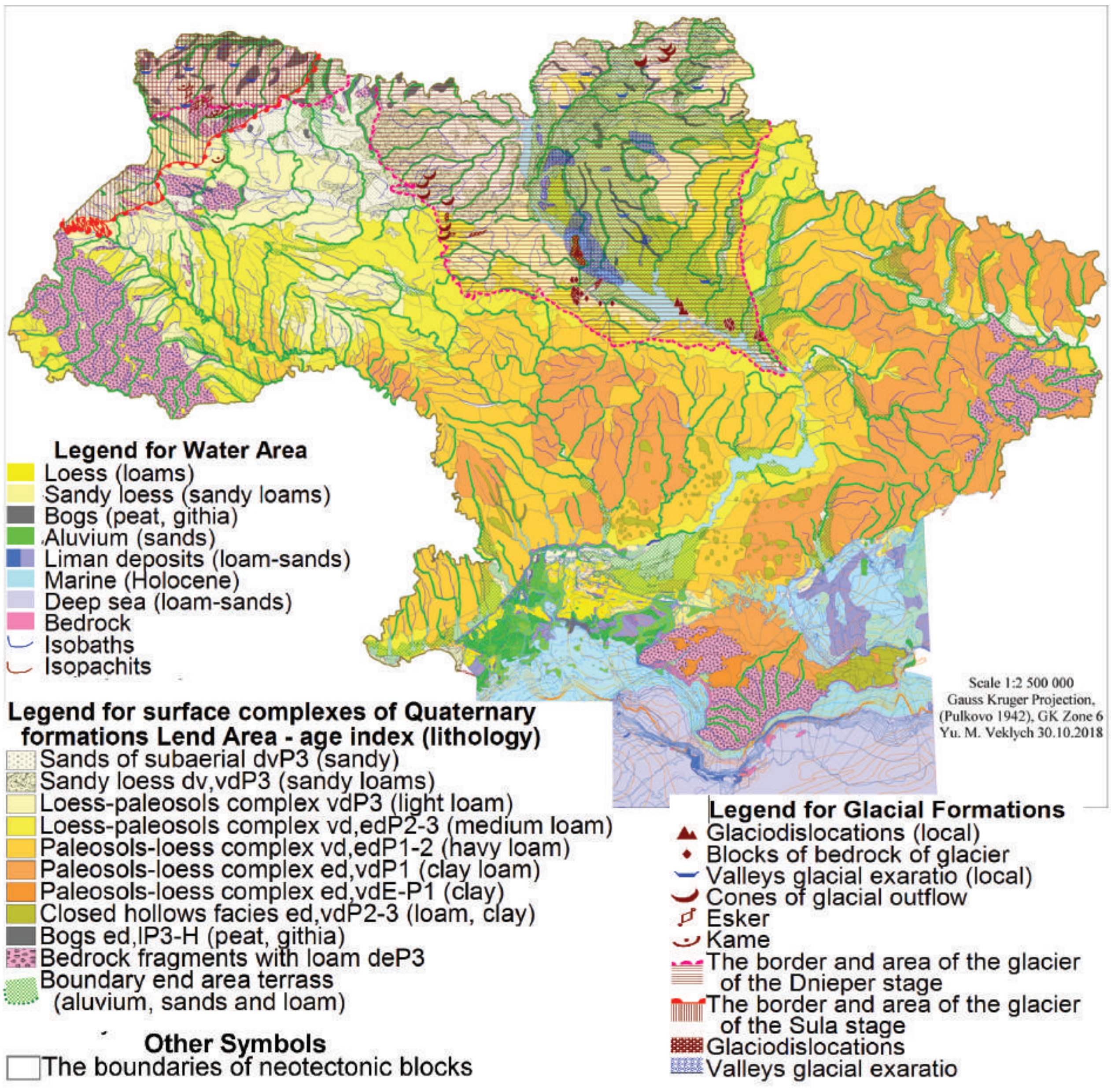

Fig. 1. The map of Quaternary formations of Ukraine, scale 1:2,500,000

First, it makes sense to dwell on the prerequisites that served as the basis for problems in the preparation of this map, as well as ways to solve them. Geological mapping of Quaternary formations in Ukraine has at least several features that are important for understanding the issues under consideration. 1. This territory is characterized by a long history of research and colossal amounts of accumulated factual and cartographic material. 2. The territory is diverse both in the spectrum of continental, marine and sub-marine facies. 3. About 2/3 of the territory of Ukraine is covered with a thick loess-soil cover. 4. Various aspects of the Quaternary cover and the history of its development have been studied by many prominent researchers. Thanks to the continuity of research, the modern Ukrainian scientific school has acquired an extremely high theoretical and methodological-technical level and depth of substantiation of the basic theoretical positions of periodization and paleogeographic development of different sides and components of the Quaternary.

The history of geological studies of Quaternary sediments in Ukraine extends back for more than a century, and the first Quaternary maps for the entire territory of Ukraine sediments at a scale 1:1,000,000 were compiled in the 1950s-1960s - «The geological map of the Quaternary sediments of the Ukrainian SSR on scale 1:1,000,000», 1954, 1961, 1962 (Sossa, 2002). The increase in the amount of factual material, which due to continuous large and medium scale geological research and mapping, as well as the emergence of new theoretical solutions for detailed dismemberment and age identification of Quaternary formations (loess-soil sequence, alluvial terraces, etc.) prompted the compilation of new versions of Quaternary maps. Such maps were compiled in 1977 (V. Cherednichenko et al., 1978) and in 2000 (B. Vozgrin et al., 2000). The author also took part in the preparation of the latest version.

It should also be added that maps on this scale were compiled based on the results of the state geological mapping on the scale of 1:200,000, which began on the territory of Ukraine in the late 1960s. And after 2000, the program of mapping the new generation of the State Geological Map-200 was launched. This is a set of 3-6 geological maps for several age sections, including with a Quaternary sediment map. Now, new generation maps of Quarternary formations are in the process of completion or have already been completed for more than 4/5 of territories (Fig. 2). Nine regional geological enterprises are engaged in mapping of each of them, the maps taking up more than 190 sheets, using large volumes of field research, drilling, and analytical data. More than six academic and industrial institutes are also involved in theoretical support of these works. In addition to geological mapping, other types of map were compiled within Ukraine (in particular, engineering-geological and hydrogeological mapping), within which the Quaternary cover was also studied in detail. Due to these circumstances, the territory of Ukraine has in the geological sense become one of the most studied regions of the World.

A variety of geological structure. The territory of Ukraine is extremely attractive to researchers of various scientific fields: geologists, geomorphologists, stratigraphers, paleopedologists, paleontologists, geotectonists, paleogeographers, etc. This is due to the extraordinary diversity of the geological structure and the presence of a wide range of genetic types and facies of Quaternary deposits. This peculiarity is also extremely favourable for solving theoretical problems: interfacial and stratigraphic correlations, paleoclimatic and geotectonic periodization, the establishment of spatial and temporal patterns of paleogeographic, biostratigraphic archaeological and other components, as well as the history of the formation of the geological structure of the Quaternary in general.

Within the lowland part, two mountain systems (the Carpathians and the Crimean mountains), and two seas (Black Sea and Azov), the following features are present: 1) loess-soil formation, which covers 2/3 of the territory of the country (which by stratigraphic completeness is similar to Chinese loess formations); 2) subaerial eolian deflationary and accumulative formations (dunes, sandy shafts, hills, ridge relief etc.) in Polissia, in the Oleshkovsky sands, in the valleys of individual rivers, and the like; 3) alluvial terraces, among which some are unique in area (up to 260 km in the Dnieper Valley), in morphology expressed in relief (east-sloping terraces of the Dniester), in location (on the shelf of the Black and Azov Seas), in the reorganizations of river networks (numerous «hanging», «dead», etc. valleys, interception of rivers by one another, etc.); 4) glacial formations of two different glacial ages - of Middle Quaternary and Early Quaternary (various types of moraines and morenoids, erratic block, glaciodislocation, valleys of plucking and erosion, kames, eskers, etc.); 5) mud volcanoes and their deposits are distributed both on the land territory (Kerch peninsula, Carpathians), and in the aquatoria (Black and Azov Seas); 6) marine and coastal (estuary) facies and terraces are common both on the coast and within the aquatoria of the above seas, there are also facies of the continental slope and

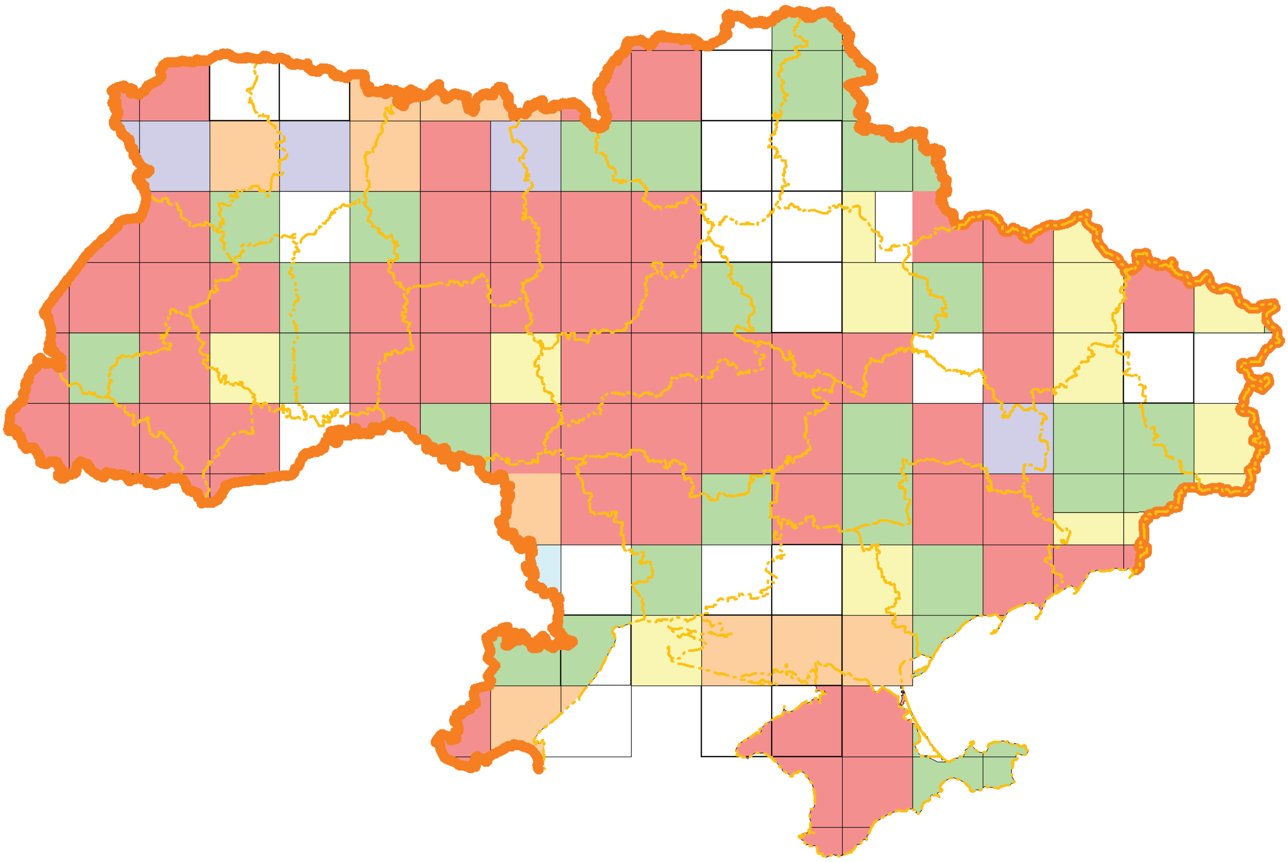

Fig. 2. Cartogram of the geological mapping of Ukraine by program State Geological Map-200 of new generation (2000-2018)

of the deep water part of the Black Sea; 7) the facies of lakes and marshes; 8) the facies of closed depressions (areas of salinization and subsidence loess); 9) cave facies associated with gypsum and carbonate karst; 10) chemogenic travertines; 11) various facies of mountain regions (the Crimean mountains and the Carpathians); 12) volcanic facies in the form of small interbeds of volcanic ash (volcanic activity on the territory of the Ukrainian Transcarpathia was completed approximately 7 million years ago); 13) places of natural seepage of liquid hydrocarbons onto the surface (the Carpathians, Kerch Peninsula); 14) and, finally, bedrock on the surface - the regions where the Quaternary cover is completely absent.

To this should be added a large saturation of sediments with paleontological remnants (especially of subaqual facies), as well as the uniquely detailed record of changes in the paleo-ecological settings of the Mediterranean-Black Sea-Azov-Caspian of sea system. All this over the past decades has turned the territory of Ukraine into a kind of Mecca for researchers of various aspects of the Quaternary.

Theoretical and methodological basis of research and of mapping of Quaternary sediments in Ukraine. Within the framework of this article, it makes sense to dwell only on the current Ukrainian scientific direction of Quaternary research, but it is worth noting the hundreds of prominent scientists whose research results form the foundation of the modern theoretical foundation.

The Ukrainian scientific direction of research on the Quaternary was founded by M. F. Veklych (since 1968) and supplemented by like-minded colleagues and followers. It is represented by an extensive system of theoretical, methodological, and technical principles and positions. This system (paleogeographic approach) includes several components in particular: the «Documentary approach», the «principle of Stages», «Neotectogenesis», «Geoeolian morpholithogenesis» and the «Scheme of periodization and detailed stratigraphy of late Cenozoic Ukraine». (Veklych, 2018). The latter is based on paleoclimatic principles and covers the age range from the present to 7 MA. The Paleogeographic approach has a lot of differences from the generally accepted principles and approaches of both periodization and the study of the Quaternary, and therefore it may be of interest to researchers both as an alternative point of view on the initial principles and as providing additional methods for research into the Quaternary. The theoretical foundations of the Ukrainian scientific field are described in detail in a series of monographs and articles (M. Veklych, 1982 and etc.; Zh. Matviinyna, 2013-2018; N. Gerasymenko, 2013-2018, Yu. Veklych, 2011\a, 2011\b, 2018 and etc.).

Only certain provisions of the paleogeographic approach concerning the problems of mapping Quaternary formations are considered below. In particular, the question of the genesis (the origin) of loess-soil covers and of sandy facies of the palaeo-deserts turned out to be important.

Quaternary cover mapping problems. There are two problems that significantly affect the result of the mapping of Quaternary formations, including the contours and the colouring of map objects. Both concern mainly the subaerial cover of both loamy (loess-soil) and coarse-grained (sandy, stony) composition.

Geo-eolian morpho-lithogenesis. The first problem is connected with a new point of view on the origin of the loess, as well as of loess-soil cover and of cover without loam. It significantly changes the view on the formation of the Quaternary cover, including the formation and structure of Quaternary covers, the origin of the subaerial facies of different lithological composition, as well as the spatial differentiation of the Quaternary cover by genetic, lithological and stratigraphic composition and the like. A detailed description and justification of this phenomenon are given in a separate monograph (Yu. Veklych, 2018), therefore, only its basic provisions are given here.

According to the results of years of research and multi-scale mapping of Quaternary formations of the territory of Ukraine, the author identified several phenomena that could not be explained within the framework of generally accepted ideas about geological (paleogeographic) processes and factors (including ideas about loess origin).

Using the example of one of the loess islands, it was established that the presence or absence of loamy (loess-soil) cover in certain areas cannot be explained by the prevailing wind flows, nor by any of the known geological factors. By all indications, the presence of such cover is determined by the properties of the earth's surface in these areas to attract (from the air) atmospheric dust. Similarly, the absence of loam cover at the regional level is due to the push away of small (dusty and clay) particles from such sites. In Fig. 3, using the example of the Ovruch loess island, the principle of the redistribution of tiny grain particles in the accumulation of loess strata (afflationary conditions) and deflationary landscapes (deflation) is shown.

Further studies have established that the earth's surface is divided into a continuous mosaic of areas that during the Quaternary had different geoeolian regimes (modes, sequences). The differences in the geoeolian regime of each such region were determined by the individual sequence of stages of accumulation of atmospheric dust or deflation processes. In the case of predominance of accumulation of atmospheric dust, loess-soil covers were formed, whereas in areas

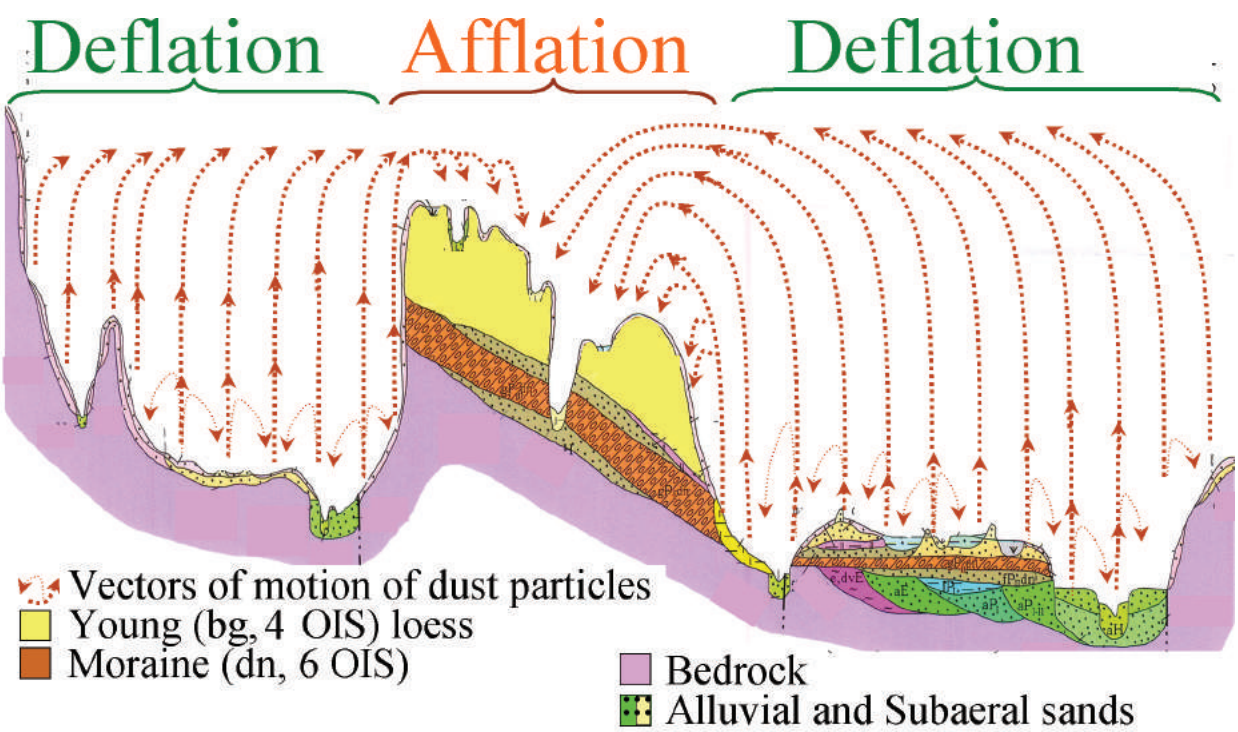

Fig. 3. The principle of geo-eolian redistribution of dust on the earth's surface (on the example, the accumulation of loam Ovrutsky loess Island and the formation of deflationary sand cover around it during the bedrock stage ,4 OIS)

with deflationary conditions (only for particles less than 0.25 mm), cover without loam (sandy, coarse grained, or no Quaternary cover at all) was formed.

Furthermore, the geological factor determines the thickness, the lithological composition, and the stratigraphic structure of each section. Thus, within the limits of the predominance of deflationary conditions, thin sand coverings were formed, while thick clay-loamy loess-soil covers formed on the dust deposition sites. Polissia (in Fig. 1 light coloured areas in the north of Ukraine) is a vivid example of the prevalence of deflationary conditions in the Quaternary, where landscapes with a thin sandy Quaternary base were formed. The loess regions of the central and southern areas (Fig. 1, yellow and brown coloured) reflect a mosaic of areas with a predominant accumulation of atmospheric dust.

Studies show that the geoeolian rhythm differs from the climate rhythm (which is the basis of the periodization and stratigraphy of the Quaternary). And if a deflationary mode was established on the territory for one or several climatic rhythms, then these rhythms «drop out» of the cut, because they lost the medium of their reflection. That is, a regional stratigraphic break has formed within such territories. The age range of such stratigraphic breaks generally matches the duration of the «non-accumulation» of atmospheric dust, and this provided a methodological basis for the study of the «temporal» aspects of geoeolian litho-morphogenesis.

An analysis of the spatial and temporal differences of the geoeolian factor in different territories confirmed the heterogeneity of the loess-soil cover. It was established that the seemingly homogeneous loess-soil cover on the territory of Ukraine is actually a mosaic of areas with a different climatic- stratigraphic structure. The loess-soil cover of each element of this mosaic is characterized by its own «type-section», which has a stratigraphically homogeneous area of loess-soil cover- with the same power ratio of climatoliths and the same stratigraphic interruptions, making it easy to recognize in each section.

There are also established general patterns of sequences of abrupt changes in direction or (deflationary or afflationary conditions) and the intensity each of these geoeolian regimes. In particular, the same age of the boundaries between sharp changes in geoeolian processes, that is, their belonging to certain palaeoclimatic stages, was traced. On the basis of the analysis of numerous factual materials, a geoeolian and phased scheme has been compiled, which reflects the temporal patterns of qualitative relative changes in all possible geoeolian regimes. This scheme makes it much easier to determine the geoeolian regime, by the stratigraphic structure of loess cover, as well as to clarify the boundary between regions with different geoeolian regime.

Without a doubt, all other geological factors and processes (fluvial, deluvial, gravity, etc.) are also acting, and all geological phenomena and objects that are characteristic of traditional Quaternary geological maps will also be present on the new map. However, it should be noted that the results of the action of most of these factors differ significantly for the accumulative (afflating) or deflationary regions. In deflationary sandy Polissia, deluvial, proluvial, alluvial, colluvial, and other facies have a sandy or coarse-grained composition, whereas in afflation-loess regions these facies are loamy or clayey (Yu. Veklych, 2018).

Of course, such significant differences in views on the formation of subaerial Quaternary cover significantly affect the principles of its mapping. This applies to both the zoning procedures and contours of the Quaternary cover, as well as their content and colouring.

On the principles of display on the map of the Quaternary formations. Modern GIS-technologies have almost unlimited possibilities for displaying and analyzing geospatial information, but, in one way or another, the final result is a map that displays (drawing) a system of elements arranged according to certain display rules. Even in the case of compiling a «poly-visual» set of maps of the same content, when maps of map objects can be interactively changed by automatic renewal using one or another display principle (for example, interactive replacement of symbol sets with GIS-tools), it is necessary to algorithmize each of these principles. Creating a single map of Europe or the World also requires some agreement between the authors of the principles of reflection of the final map (even if there are several such principles). All this forces us to examine in more detail the existing approaches of visualization of the geological structure on the maps.

The following is an analysis of the basic principles of the cartographic display of Quaternary deposits, which are most often used in mapping, as well as a new principle that allows one to a certain extent to combine their positive properties.

The analysis of the long-term experience of mapping of the Quaternary deposits of the territory of Ukraine revealed at least two quite distinct principles of displaying the Quaternary cover. Their difference relates to the main object of the mapping of the Quaternary cover. Consider the main differences between the previously mentioned glyptogenetic and classically-geological mapping principles of Quaternary cover.

In 1977 and 2000, maps of Quaternary deposits of Ukraine were compiled, illustrating both the above mapping principles. In Fig. 4 for comparison, two images: «a)» the 1977 map (V. Cherednichenko et al., 1978) illustrates the mapping result according to glyptogenetic mapping principle, and «b)» the 2000 map (B. Vozgrin et al., 2000) is an example of

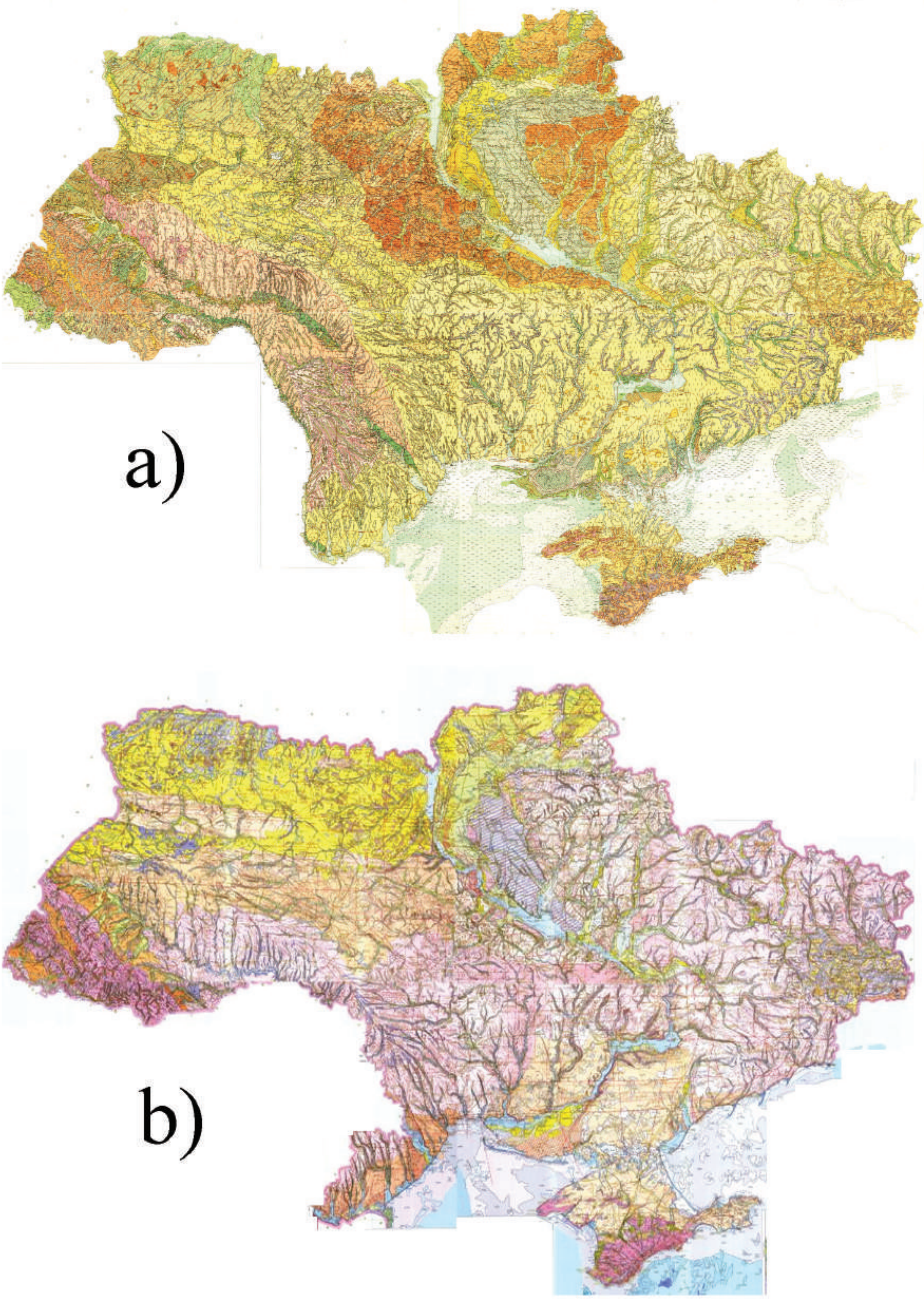

Fig. 4. Examples of two principles of visualization of the geological structure on the maps of the Quaternary formations of Ukraine: a) - glyptogenetic (1977) and b) - classic-geological (2000)

applying its classic-geological principle. As you can see, these maps are very different in terms of contours and fill. It should be noted, however, that the number of cartographic objects and in many respects the contours on both maps are generally the same, but the same objects (for example, deposits of glaciers, alluvial deposits) are in one case represented by colour, and in the other represented by contours.

On maps of 1:1,000,000 scale (a decade earlier and 1:200,000), the criterion for establishing the main mapped object was the determinative geological factor that conditioned the main features of the geological structure of a particular site. To this principle of mapping of the Quaternary sediments, we have the given code name «glyptogenetic» by E. F. Shantser, who coined this term in wide use. This approach is justified for small-scale and medium-scale mapping, as well as for areas with insufficient geological study. The geological content of areas of such a map are determined by individual sections (support, etc.), and their contours are predominantly geological (more precisely, glyptogenetic) principles. This allows one even in the conditions of a small number of sections studied to recreate the contours of the main geological factors - of the ancient glaciers, river terraces and the like.

A striking example of this approach is the reflection of glacial and alluvial sediments on the 1977 map. As can be seen (Fig. 4, «a)»), the loess cover is «removed», although it covers glacial (and sometimes alluvial) deposits, that is, reflected on the map only by contours. But the distribution areas of the buried moraine, as well as alluvial deposits of the terraces, are shown in colour. Most of the maps of the Quaternary formations of the first generation (« State Geological Map-200») are compiled precisely on this principle. A positive feature of this principle is that it focuses attention on the main morpho-lithogenetic features of the geological structure. Their disadvantage is that the information about the near-surface layer of the Quaternary cover (which is important for human activity) is reflected by specks, contours, or not drawn at all on the map.

Another feature is the fact that this map reflects the facies or genetic types of the beginning of the formation of the Quaternary cover and relief (fluvial terrace-formations - green colour, surface glaciers - brown colour, etc.). That is, such a map displays mainly the subface of the Quaternary cover, that is, so to say «bottom view». With this approach, compromises are often necessary, for example, in the case of several «floors», for example, when the moraine is located on alluvium and is overlapped by the loess. The loess-soil cover of the extra- glacial territories on such maps as an exception is depicted mainly «from above» (under the modern soil). Exceptions are also subaqual facies of the Holocene age, the age equivalents of which are «removed» in subaerial segments.

In Ukraine, from the 1970s-1980s, a new principle of Quaternary cover mapping was developed and introduced, which is called ***«classic-geological»***. This principle is the basis of the 2000 map (the image «b» in Fig. 4) is applied on all large-scale maps (including the new generation map «State Geological Map-200»). Its provisions are borrowed from the principles of classical geological mapping that is, mapping of outputs to sub-Quaternary or surface of pre-Quaternary sediments. But in our case, it consists in the reflection of the first pre-Holocene Quaternary strata from the surface or the strata complex. This approach focuses attention on the near-surface layer of the Quaternary cover, which is important for human activity. As can be seen from Fig. 4 (the image «b)»), on this map soil-loess (yellow colour) and loess-soil (pink colour) formations prevail. Buried deposits of other morpho-genetic factors (moraines, alluvium and marine sediments) are indicated by contours, or symbols.

The basis of the contours of the individual Quaternary areas of the new generation map is taken from the data of the lithological (granulometric) composition of the maps of modern soils. The sharp boundaries between the plots with different such composition simultaneously display the boundaries between the plots with different facies-stratigraphic structure of the Quaternary cover. This approach significantly increases the objectivity and reliability of the map, since lithological data are obtained on the basis of analytical studies. But the «filling» of the geological content of each site selected in this way is a real scientific study, which requires a high scientific potential, as well as a sufficient amount of field work with detailed stratigraphic and age identification of many geological sections.

Of course, such an approach requires a much denser network of geological observation points, each of them needing a detailed stratigraphic division. This was made possible thanks to the high level of the theoretical and methodological and technical base in Ukraine, as well as the introduction to the level of regional geological enterprises within the framework of the current program State Geological Map-200 of new methods for stratigraphic subdivision of loess-soil sections and the age identification of other phenomena of the Quaternary (terraces, facies etc.).

Maps compiled according to the classical-geological principle have their drawbacks. Thus, some of the most important facets of the Quaternary cover here are depicted by lines or symbols and look like minor ones. However, there is no doubt that new generation maps are more reliable and informative than previous ones.

And finally, a few words about the ***new principles of Quaternary sediment mapping***. New ideas about the spatial separation of the Quaternary cover, taking into account the geoeolian regime, suggest that it is necessary to introduce additional criteria for this mapping. And the fact that it is this factor that determines the basic characteristics of most other facies (namely, the lithological composition, thickness and stratigraphic completeness) gives it a special meaning. Of course, all the traditional components of Quaternary cover (alluvium, moraine, proluvium, deluvium, etc.) should be on the map. However, additional regionalization of the new principle significantly increases the value and reliability of such a map, expands and deepens the understanding of the essence of the paleogeographical formation of Quaternary cover and relief.

The introduction of the concept of a type-section also opens up new paths for the compilation of a legend. Now a two-level legend is being developed, in which each colour symbol of the map is accompanied by a quasi-stratigraphic column, in which the full structure of the Quaternary cover is revealed. This column reflects the genetic stratigraphic information for each climatic stage (genetic type or facies, as well as its frequency of presence in the sections of such an area. This principle of compiling a legend has excellent prospects, especially when applying modern GIS-technologies. In particular, such an approach makes it possible to map not only the stratigraphic-genetic complex, but also the stratographic-genetic features of the sediment of all climatic stages, and volumes of stratigraphic breaks. The combination of such detailed stratigraphic-genetic and spatial information with the capabilities of GIS-technology provides for the possibility of creating interactive maps in which you can achieve instantaneous renewal of maps according to the mentioned glyptogenetic and classical geological principles. Furthermore, the availability of information on each climatolith of each selected (mapped) area (type-section) turns such a GIS map into a visualization tool for each climate stage, as well as for individual genetic divisions and much more. At present, the question has been raised about the creation and use of such an information environment for automatic interactive translation of maps from one scale to another, taking into account stratigraphic and genetic detailing or generalization.

Conclusions. Mapping the Quaternary formations of Ukraine with a scale of 1:2,500,000 facilitated improvement of new approaches to the study of the geological structure and deep analysis of aspects of its cartographic visualization. New ideas about the formation of the subaerial Quaternary cover (taking into account geoeolian processes) and its spatial discretization into areas with a homogeneous stratigraphic structure (type-sections) reveal new approaches in its mapping. In conjunction with modern information technologies (including GIS) in the field of geological mapping , a qualitatively new basis for the implementation of these tasks is formed. Among other solutions the formation of maps with the possibility of interactive redrawing and visualization by several different principles is attractive.

After publication on the GEO-site, the announced map could supplement the general Quaternary map of Europe and the World. Despite the fact that the compilation of these (general) maps is at its peak, given the above, the prospects for improvement are far-reaching. In this regard, even before the completion of these projects, it would be advisable to intensify the public discussion with a view to sharing experience and agreeing on the principles of cartographic visualization of formations and deposits of the Quaternary.

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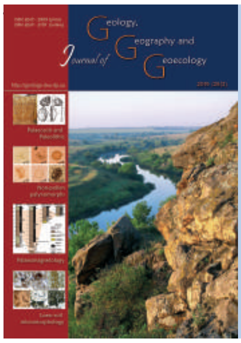

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