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CONTENTS

Статті

Articles

Публікації археологічних матеріалів

Publications of Archaeological Materials

Нові відкриття та знахідки

Discoveries and Recent Finds

Дискусії

Discussions

Історія науки

History of Science

Хроніка

News Review

Статті

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RESULTS OF PALAEO-SOIL STUDIES OF OLBIA IN THE CONTEXT OF EARLY URBANISATION PROCESSES IN THE NORTH-WESTERN BLACK SEA REGION

The article is focused on the results of geoarchaeological research of ancient Olbia[1]. On the basis of field and laboratory (micromorphological and physicochemical analyses) studies of modern and buried ancient soil, the natural factor in the formation of the classical settlement of Olbia within the Dnipro-Buh estuary is analysed. A brief historical and archaeological note on the urbanisation processes in Olbia Pontica is added.

Keywords: Olbia Pontica, palaeogeography, urbanisation, palaeo-soil studies.

Introduction

Reconstruction of the Holocene paleogeographical history and the causal relationships in the process of colonisation of the Northern Black Sea region during antiquity requires understanding both the general relationships between space and humanity and specific natural and social factors.

Olbia, one of the largest poleis founded on the northern shore of the Black Sea, in the delta of the Southern Buh River, emerged due to a number of political and socio-geographical processes at the turn of the 7th—6th centuries BC. According to the stages of natural development, this corresponds to the end of the Subboreal chronological interval of the Holocene, microstage hl_{b2}^{6} (Веклич 1987). In terms of relief, it is the territory of the Black Sea Lowland, and the city itself, along with the adjacent areas, is located on the shore of the Buh Estuary, which determined the specific lowering and dissection of the terrain. According to the climate zoning of Ukraine by B. P. Alisov (ред. Ліпінський, Дячук, Бабіченко 2003), the area belongs to the coastal regions, which, in turn, are part of the southern Atlantic-continental climatic zone, with the primary factor influencing the climate being the breeze circulation.

Palaeo-soil studies of archaeological sites dating to the Holocene provide an opportunity to understand how natural conditions changed during a certain time interval of the last warm stage of natural development. Soil, as the "memory of the landscape", is a highly representative component of the natural environment in palaeolandscape reconstructions. Additionally, the soil was a factor in the choice of settlement structures of various types and a determinant in the placement of structures within them (ritual, economic, etc.). In general, the interdisciplinary interaction between palaeogeography and archaeology aims to fill the gaps in reconstructing the natural conditions of a certain time interval and studying the living conditions of a particular cultural-historical community, and as a result, its way of life, economic practices, and etc.

The application of interdisciplinary methods today allows investigating several important as-

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pects. One of the relevant questions in the study of palaeogeographical and historical factors of settlement structure development during antiquity is the exploration of the process of mastering specific areas — residential quarters, public spaces, necropoleis, communication routes, etc. Each of these elements of the urbanisation process contains different information about the activities of the ancient society and provides a new perspective on the source base of interdisciplinary studies. For example, the development of local crafts, particularly pottery, can already be studied using various methods (Kotenko et al. 2021; Kotenko, Kushnir, Smyrnov 2023). Among the archaeological objects in Olbia suitable for such studies, the necropolis holds a priority place since the disturbed soil remained in place and was mainly used for covering burial structures, unlike earthworks in residential quarters and other objects within the settlement.

The integration of archaeological and palaeogeographical research is crucial for the advancement of both soil sciences and historical sciences, and the results of such efforts are mutually beneficial for these fields. Palaeogeography, particularly one of its branches — palaeo-soil studies — provides archaeology with information about the natural living conditions of a particular cultural-historical community, and consequently, its way of life, economic practices, etc. At the same time, research within archaeological sites gives palaeogeographers the opportunity to study soils "buried" beneath various dated archaeological objects, comparing them with background (modern) soils, which is essential for reconstructing natural conditions of a specific time interval in the general rhythm of Holocene nature development. Thus, it leads to the formation of a geoarchaeological approach in studying the nature and history of a particular territory.

The subject of study in the geoarchaeological approach, as has already been noted, includes buried soils of various ages "preserved" beneath dated historical-archaeological sites. In this context, the geoarchaeological approach is based on comparing the soil beneath the archaeological object with the background (modern) soil.

Description of the Site and Previous Research on Urban Development

In the last quarter of the 7th—early 6th centuries BC, Greek settlers from Miletus founded a new polis, Olbia, in the Lower Buh region, laying the foundation for Greek traditions in the area. The area of the Upper City, excluding the slopes, was about 28 ha; the necropolis and public buildings occupied approximately 3–4 ha of the total area, while the rest was a residential zone (Буйских 2021, с. 694).

Research on the urban planning of Olbia Pontica had begun in the first half of the 20th century, due to archaeological excavations of the ancient polis conducted by B. V. Farmakovskyi (Фармаковский 1929, с. 40). He proposed the idea of a regular city layout dated by the end of the 6th century BC (Буйских 2015, с. 18)[2]. Other scholars, including A. von Gerkan, E. Diehl, R. Wycherley, F. Castagnoli, and S. D. Kryzhytskyi, have contributed to the study of this issue (for a detailed discussion on Olbia's urban planning, see: Буйських 2021, с. 673-698). Researchers believed that the plan of early Olbia, which occupied an almost triangular area bounded by ravines and the Buh estuary, was similar to the plan of Miletus, although it had some differences (Русяева 2010, с. 90-91). However, this view is not entirely accurate (Буйских 2021, с. 674). Despite decades of research, a clear understanding of Olbia's urban planning remained elusive.

In 2021, due to many years of archaeological research, A. V. Buiskykh was finally able to shed light on this complex issue. The researcher noted that the earliest construction objects in the southern part of the Upper City are dated to the first quarter of the 6th century BC, with residential buildings appearing in the early second quarter of the same century (Буйских 2021, с. 680).The construction during the early period (lasting until the last quarter or the end of the 6th century BC) was characterised by single-chamber square, rectangular, or, less commonly, circular dwellings, somewhat embedded in the mainland surface (Буйских 2021, с. 681).

The next stage of Olbia's urbanisation is associated with the emergence of a street network, indicating an organised city layout on the upper plateau of the polis. A. V. Buiskykh, therefore, proposes abandoning the long-held thesis of spontaneous development of the city (Буйских 2021, с. 683). For instance, S. D. Kryzhytskyi claimed that the urban centres of the ancient period had a regular rectangular structure that formed spontaneously. According to him, in Olbia, socio-economic and production differentiation in construction was not evident in the Archaic period. The main streets could be up to 6 m wide, while secondary streets

[2] This point of view has been criticised by new archaeological evidence, which has confirmed the layout of the city with only some elements of regularity (Буйских 2015, с. 18).

were 1.5–3 m wide (Крыжицкий 1993, с. 36). Moreover, S. D. Kryzhytskyi believed that in the Classical period, there was still no evidence of a rectangular grid system in the city's urban plan. In Olbia, construction continued to be spontaneous during this period, as it had been in the Archaic era, though some quarters displayed a regular rectangular layout (Крыжицкий 1993, с. 6). It is characterised by the absence of an acropolis and is dominated by trade and administrative, cultural and religious centres — the temenos and the agora.

However, the Main Longitudinal Street became the basis for the planning of the ancient city: residential quarters were located to the east and west of it, with the city entrances located in the north (where natural topography created a narrow passage between two ravines) and the west[3].

The Upper City was situated on a higher elevation relative to the coastal part of the Lower City, where the port was located (Русяева 2010, с. 91). Based on this information, there is a solid foundation to assert that the Upper City of the ancient polis was planned regularly, with the Main and several arterial streets (Буйских 2021, с. 686).

At the beginning of the 5th century BC, Olbia faced a transition from dugouts to above-ground buildings made of clay bricks and stone. Categories and types of structures characteristic of Ionian cities in Asia Minor and Greece began to spread. By the end of this stage, construction reached a high level of development (Крыжицкий 1993, с. 58).

In the mid-5th century BC, Herodotus described Olbia as a city surrounded by **defensive walls and towers** (Herod., IV, 78, 79), which has been confirmed by archaeological excavations (Крыжицкий 1993, с. 15) and geophysical research (Patzelt et al. 2016; Fornasier et al. 2017; Patzelt, Waldhör 2021).

In the 5th—4th centuries BC, the Northern Black Sea centres were equipped with defensive lines, primarily consisting of walls and towers. In Olbia, remains of 5th—4th centuries BC defensive structures have been uncovered. The city's defensive walls were 4.0–4.5 m thick (Крыжицкий 1993, с. 64).

It was believed that the defensive structures of this period lacked ramparts and moats. However, modern research in the Olbian suburbs has refuted this thesis by discovering an early defensive moat in Olbia (Fornasier et al. 2017, S. 31), which has already been mentioned above. The area of the ancient polis' suburbs was investigated in a focused and interdisciplinary manner for the first time due to Ukrainian-German research in 2014 and 2017, which significantly expanded our understanding of the layout of the city and its nearest surroundings. In particular, the hypothesis that the suburbs of Olbia did not begin immediately outside the city wall, but at least 100–200 m from it, was confirmed. That is, the suburbs were located on both sides of the Western Road and could cover at least 6 ha (Patzelt et al. 2016, p. 4). However, continued geophysical research in the area of Olbia Pontica corrected the previous data, so that the total area of the suburbs was 26 ha (Patzelt 2019, S. 8). Thus, the territory of ancient polis covered a larger area than it was previously believed.

The Central quarter of the city to the west of the agora was formed during the Hellenistic period. Additionally, public buildings were constructed in the area of the gymnasium and the Eastern Temenos in the second half of the 4th century BC by narrowing the Main Street, and the agora was delineated (Буйских 2021, с. 686-687). Multi-chamber houses with inner courtyards and stone basements appeared in the third construction period, no earlier than the second half of the 4th century BC (Буйских 2021, с. 693).

In the 4th century BC, **terrace construction** became widespread in the Northern Black Sea region, leading to the use of retaining structures (Крыжицкий 1993, с. 80). In Olbia, this is confirmed by the results of research in the "T" sectors in the terraced part of the city.

Researchers were also interested in discovering road systems in the terraced part of the city, which connected the Lower and Upper cities, as well as slope reinforcement structures. To confirm survey data, archaeological excavation "T-4"[4] was conducted, and its results confirmed the slope reinforcement system detected in magnetic surveys (Буйських та ін. 2020, с. 130-133).

Special attention should be paid to the **sacred areas** of Olbia. They were located in the central part of the Upper City and were divided by the

[3] Namely in this place between the Pivnichna and Bezimenna ravines, no later than the turn of the 6th—5th centuries BC, the first defensive moat of Olbia was constructed, and in the second half of the 4th century BC — the Northern Gates (Буйских 2021, с. 686).

[4] Given the positive results of the geophysical work, confirmed by archaeological research in the suburban area, in 2017 the use of interdisciplinary methods was continued to identify the extent of the suburban area, as well as in the terraced part of Olbia, so another 14 ha of territory were investigated (Patzelt, Waldhör 2021, S. 142). The southern slope of the terrace of the central part of the ancient city was explored in order to find the remains of an ancient theatre.

Main Street. In the first construction period, this included the Western Temenos[5], which emerged no later than the border of the 7th—6th centuries BC, simultaneously with the founding of Olbia (Буйских 2015, с. 6; according to A. S. Rusiaieva, this temenos had begun functioning in the first quarter of the 6th century BC, see: Русяева 2006, с. 18). Additionally, an area was set for the Eastern (Central) Temenos and the agora, while the Southern Temenos, located in the south-eastern part of Olbia on the highest section of the settlement, appeared only in the next, second construction period, along with the city's layout (Буйских 2021, с. 687). The formation of the Eastern Temenos occurred in the third quarter of the 6th century BC (Буйских 2015, с. 6), and by the early Hellenistic period, its territory had been reduced due to the expansion of the agora and the construction of the Great Stoa (Буйских 2021, с. 688).

The city's **necropolis** was established at the beginning of the 6th century BC on the north-eastern part of the upper plateau (Буйских 2021, с. 685-686). The boundaries of Olbia's necropolis changed throughout its period of use (Папанова 2006, с. 67). The necropolis of the Olbian polis, from the city's founding, followed the widespread ancient Greek tradition of being located in the inter-road sectors. The residents of the rural surroundings and the city chose the necropolis area based on the natural relief, distance from buildings, roads, and sanctuaries, while also considering the potential for expansion (Снитко 2015, с. 72-75).

Necropolis of the Archaic period emerged simultaneously with the founding of Olbia and occupied two areas: 1) an area from the Zaiacha ravine to the west, within the bounds of the first and sixth western roads; 2) the north-eastern part of the Upper City plateau above the Buh estuary (site "И"[6]) (Папанова 2006, с. 68).

During the Classical period, the area of the necropolis doubled, although the main burial area remained the western sector, which expanded to the south, north, and west. Additionally, the "И" sector continued to serve as a burial site (Папанова 2006, с. 69, 72).

The necropolis of the Hellenistic period spanned approximately 500 ha and surrounded the city on three sides. Its boundaries were marked by the Zaiacha and Pivnichna ravines; to the south, it was delimited by the Shyroka ravine, and to the north by the Parutyne ravine (Паровић-Пешикан 1974, с. 6-8; Козуб 1984, с. 162). The city's residents continued to use the territories from earlier chronological periods in the Shyroka ravine area (along the fourth and southern roads) and in the western part of the necropolis. Furthermore, a new area appeared to the north of the Pivnichna ravine during this time (Папанова 2006, с. 72).

Public buildings in Olbia — such as the gymnasium, building "Б", and the three-chamber structure to the west of the dicastery — have an unclear architectural and functional nature. Technical and industrial buildings, such as the water supply system designed to deliver water from a cistern through a siphon from the Upper City to the Lower City, were also discovered in Olbia. The water channels were made from ceramic pipes, sometimes stone. Water supply was ensured through springs, wells, and water-storage cisterns (Крыжицкий 1993, с. 79).

To summarise the brief historical and archaeological description of the urbanisation processes of Olbia Pontica, it should be noted that the natural conditions, as well as the landscape with ravines and slopes on which this ancient polis was located, played an important role in the formation of its settlement structure. The cooler and more humid climate of this region, compared to the territory from which the inhabitants of Miletus came at the time of the polis' foundation, was decisive in the construction of the first buildings, including deepened and semi-deepened dugouts, which is confirmed by archaeological evidence. The successful use of the terrace is also evident, as due to the significant strengthening of the slopes with retaining stone structures, which were recorded by georadar survey and subsequently confirmed by archaeological research (site Т-4), soil erosion processes would not have damaged the structures of the Lower City. The influence of natural conditions and climate on the formation of the spatial structure of the ancient city will be analysed in more detail in the Discussion section below.

Materials and Methods of Palaeo-Soil Studies

Field Research.

The authors conducted palaeo-soil studies of Olbia in 2015 and 2021. When studying Holocene deposits, which include the soils formed within Olbia's territory, a key method is the spatial morphological study of archaeological site soils. This method in-

[5] Later, its territory was reduced due to the construction of the dicastery, a court building, in its south-eastern part (Буйских 2021, с. 688).

[6] During the Hellenistic period, this area was built up, as it became part of the city limits (Папанова 2006, с. 68).

volves identifying the stratigraphy, internal structural features, and the material composition of the soils (e.g., ancient humus layers, a mixture of palaeo-soil horizons, etc.), which in turn allows reconstructing the site's construction technology. It also helps to identify signs in the structure of the embankment related to ritual-mythological practices and the specifics of various ancient peoples' rituals. During field research, cartographic data is refined, and geospatial data obtained from remote sensing (RS) is verified.

The macromorphological description of soils is indispensable in palaeo-soil studies. It includes examining the soil's external appearance and physical properties at various depths (by genetic and/or stratigraphic horizons). First, the structure and texture, as well as soil colour and moisture content, are described (Веклич и др. 1979). General evolutionary changes in palaeo-soils in multi-age land cover are closely related to cardinal changes in climate and biodiversity, are irreversible, and consist in a gradual shift of pedogenesis conditions and changes in soil genetic properties.

One of the most important aspects of fieldwork is collecting soil samples for further laboratory analysis. Typically, soil and soil deposit samples are collected separately by genetic and/or stratigraphic horizons. Different sampling methods are used for each type of analysis. For instance, for micromorphological analysis, soil is collected in monoliths, while for physicochemical analyses, a small amount of loose soil is often gathered, etc.

Laboratory Research.

In this publication, we present new data on the results of granulometric analysis and their author's interpretation. The conclusions are based on our own results of micromorphological analysis and soil analysis for biogenic elements, and references to relevant publications are provided.

Interpretation

Granulometric Analysis.

To determine the content of particles of various sizes in the soil material across genetic horizons, namely sand, dust and silt fractions, corresponding samples were collected and sent to the landscape ecology laboratory at the Taras Shevchenko National University of Kyiv. The classification of soil material based on mechanical composition, determined by the ratio of physical sand and clay, was conducted following N. A. Kachynskyi's method. The soil was also characterised according to the classification by M. M. Godlin.

Research Results.

Field Research. A total of eight soil profile clearings were laid out and studied within Olbia, covering various hypsometric levels and different objects, such as the "Necropolis area" and "Excavation no. 25." To visualise the locations of research points and analyse the relief features of the area, a hypsometric map (fig. 1) with 5-meter contour intervals was created. This map was the first to be produced for this area in such detail (compiled by A. S. Kushnir and V. M. Shvaiko). The hypsometric map also helps to analyse the terrain as a factor in urbanisation processes within Olbia.

General characteristics of the soil profiles studied by the authors is the following:

Profile 1. Located on a high terrace to the west of the Dnipro-Buh estuary within the Necropolis. The structure according to the genetic horizons is as follows: H(e) — 0.0–0.12 m; Hpik — 0.12–0.32 m; Phk — 0.32–0.5 m; Pk — 0.5–0.7 m; bg — 0.7–1.0 m.

By the sum of its features, the soil is similar to chestnut soils on loess.

Profile 2. Located in unit no. 30, 30 m to the south of profile 1. The structure according to the genetic horizons is as follows: He — 0.0–0.12 m; Hpi — 0.12–0.32 m; Phik — 0.32–0.50 m; Pk — 0.5–0.7 m; bg — 0.7–1.8 m.

By the sum of its features, the soil is similar to solonetzic light loamy chestnut soils on loess.

Profile 3. Located on a cape, 30 m to the southeast of profile 2. The structure according to the genetic horizons is as follows: He_{ag} — 0.0–0.4 m; Hik — 0.5–0.6 m; Pik — 0.62–0.93 m; H of the modern soil horizon — 0.93–1.10 m.

By the sum of its features, the soil is also similar to solonetzic light loamy chestnut soils on loess.

Profile 4. Located in the southern wall of an excavation within the Necropolis. The structure according to the genetic horizons is as follows: Hk — 0.0–0.25 m; Phk — 0.25–0.40 m; buried layer (pit) — 0.4–0.8 m; Pk — 0.8–0.9 m.

In this profile, the upper part of the modern soil is truncated, and the ancient natural soil layer is visible, similar to the soil described in previous profiles.

Profile 5. Located within the "Orient" section of the Olbian Necropolis. The soil, by the sum of its features, resembles southern heavy loamy solonetzic chernozems formed on loess (described in detail below).

Profile 6. Located within "Excavation no. 25" on the Zavadivka-Dnipro terrace. The structure according to the genetic horizons is as follows: H(e)

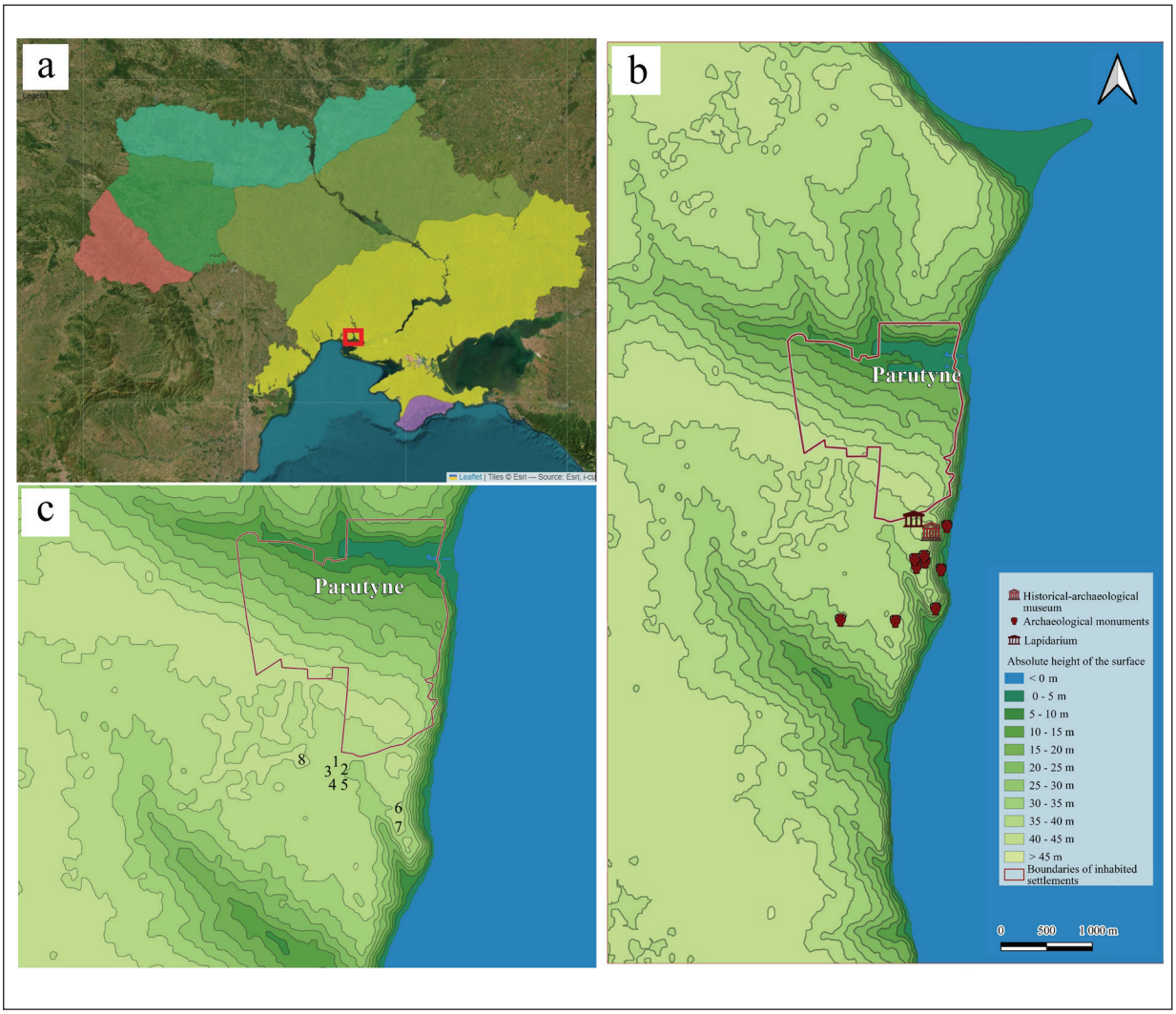

Fig. 1. Palaeo-Soil Research of Olbia. *a* — location of Olbia on the map of physical-geographical zoning; *b* — general relief situation within Olbia and the nearby chora; *c* — location of the studied profiles according to the numbering in the text

— 0.0–0.3 m; Hpik — 0.3–0.5 m; Phk — 0.5–0.7 m; Pk — 0.7–1.0 m.

By the sum of its features, the soil is similar to southern solonetzic chernozems formed on loess.

Profile 7. Located 20 m to the south of profile 6 in the wall of an archaeological trench. The structure according to the genetic horizons is as follows: Hp — 0.0–0.2 m; Hik — 0.2–0.4 m; Phk — 0.4–0.6 m; Pk — 0.6–0.8 m; bg — 0.8–1.2 m.

By the sum of its features, the soil is similar to solonetzic chestnut soils with a well-defined carbonate horizon, medium loamy.

Profile 8. Background soil. The structure according to the genetic horizons is as follows: $H_{techn.}$ — 0.0–0.1 m; Hk — 0.1–0.35 m; Hpk — 0.35–0.6 m; Phk — 0.6–0.8 m; P(h)k — 0.8–1.0 m; Pk — 1.0–1.2 m (visible).

By the sum of its features, the soil is similar to southern carbonate chernozems, light loamy on the surface, formed on loess.

The authors studied the largest number of soil profiles within the Necropolis, which occupies one of the highest terrace surfaces of the Dnipro and Buh rivers within Olbian Reserve. Across the vast area of the studied territory and in the excavations of large chamber burials, the ancient burial surface with well-defined light-brown or brown soil can be traced almost everywhere, overlain by a 1.5-meter layer of loess material. Below, the weakly developed brown soil is also underlain by loess. It is likely that this brown soil existed during the establishment of the necropolis and can be dated to the 4th—5th centuries BC.

Laboratory Research. Detailed results of micromorphological analysis and soil analysis for the content of biogenic elements in ancient and modern

soils of Olbian territory are presented in a number of previous publications by the authors (Матвіїшина, Пархоменко 2017; Кушнір, Котенко, Івченко 2022; Кушнір, Матвіїшина, Харитонова 2023), and thus will not be discussed in detail here.

The results of the granulometric analysis, however, provide new analytical data and offer insights into the conditions of sedimentogenesis, hypergenesis, and soil formation in this area. Granulometric indices, such as particle diameter, allow for a more precise characterisation of the relationship between these processes.

Granulometric analysis was conducted on soil samples from two profiles within the "Necropolis"

Table 1. **Detailed mechanical composition of the soil (in %) based on the results of granulometric analysis of profile 1 sediments**

Fractions (their size, mm)	Genetic horizons, their deposit depth and content in %				
	H(e) 0.0–0.12 m	Hpik 0.12–0.32 m	Phk 0.32–0.5 m	Pk 0.5–0.7 m	bg 0.7–1.0 m
Sand coarse (1.0–0.25)	3.14542525	2.93105525	2.73453978	1.0038405	1.3764808
Sand fine (0.25–0.05)	19.45111835	17.42409475	17.74163822	3.0804867	27.2443352
Dust coarse (0.05–0.01)	29.8633432	33.89585	33.0968596	47.36068	31.692028
Dust medium (0.01–0.005)	4.8663108	3.03607	5.1493232	1.7296944	5.233924
Dust fine (0.005–0.001)	16.5537752	17.01031	14.0775852	21.8682792	15.536924
Silt (<0.001)	26.1200272	25.70262	27.200054	24.9570192	18.916308
Physical clay (<0.01)	47.5401132	45.749	46.4269624	48.5549928	39.687156
	Conclusion according to the classification of N. A. Kachynskyi (M. M. Godlin)				
	Heavy loam (sandy-medium loam)	Heavy loam (sandy-medium loam)	Heavy loam (sandy-medium loam)	Heavy loamy (dusty-medium loamy)	Medium loamy (sandy-medium loamy)

Table 2. **Detailed mechanical composition of the soil (in %) according to the results of granulometric analysis of sediments of profile 5**

Fractions (their size, mm)	Genetic horizons, their deposit depth and content in %			
	Hk(e) 0.0–0.3 m	Hk(i) 0.3–0.6 m	Hpk 0.6–1.1 m	P(h)k 1.1–1.6 m
Sand coarse (1.0–0.25)	2.34901942	1.57081054	0.6841108	1.02400873
Sand fine (0.25–0.05)	17.77814138	19.04236506	23.5883372	18.57538607
Dust coarse (0.05–0.01)	38.309304	33.851896	29.513904	30.7716164
Dust medium (0.01–0.005)	5.2726784	8.1739944	6.903112	2.3006816
Dust fine (0.005–0.001)	22.1205336	17.2562104	20.006624	22.5138128
Silt (<0.001)	14.1703232	20.1047236	19.303912	24.8144944
Physical clay (<0.01)	41.5635352	45.5349	46.2137	49.629
	Conclusion according to the classification of N. A. Kachynskyi (M. M. Godlin)			
	Medium loamy (sandy-medium loamy)	Heavy loam (sandy-medium loam)	Heavy loam (sandy-medium loam)	Heavy loam (sandy-medium loam)

(profile 1 and profile 5), two profiles from "Excavation no. 25" (profile 6 and profile 7), as well as from the background soil (profile 8).

Below are the tables presenting the research results for each profile according to genetic horizons (tables 1–5).

Table 3. **Detailed mechanical composition of the soil (in %) according to the results of granulometric analysis of sediments of profile 6**

Fractions (their size, mm)	Genetic horizons, their deposit depth and content in %			
	Hk(e) 0.0–0.3 m	Hpik 0.3–0.5 m	Phk 0.5–0.7 m	Pk 0.7–1.0 m
Sand coarse (1.0–0.25)	2.75989404	2.5759708	3.01697488	2.36208882
Sand fine (0.25–0.05)	26.83568996	27.7645492	22.62733632	8.33321518
Dust coarse (0.05–0.01)	34.1379552	31.540832	39.9112072	54.3576072
Dust medium (0.01–0.005)	5.730592	7.272368	5.5900352	6.8099928
Dust fine (0.005–0.001)	9.8648048	14.953296	14.0572944	9.3382536
Silt (<0.001)	20.671064	15.892984	14.797152	18.7988424
Physical clay (<0.01)	36.2664608	38.118648	34.4444816	34.9470888
	Conclusion according to the classification of N. A. Kachynskyi (M. M. Godlin)			
	Medium loamy (sandy-medium loamy)	Medium loamy (sandy-medium loamy)	Medium loamy (sandy-medium loamy)	Medium loamy (dusty-light loamy)

Table 4. **Detailed mechanical composition of the soil (in %) according to the results of granulometric analysis of sediments of profile 7**

Fractions (their size, mm)	Genetic horizons, their deposit depth and content in %			
	Hik 0.2–0.4 m	Phk 0.4–0.6 m	Pk 0.6–0.8 m	bg 0.8–1.2 m
Sand coarse (1.0–0.25)	3.41173286	3.31626246	3.32539984	2.87404128
Sand fine (0.25–0.05)	14.22971434	4.95907234	32.54188896	31.29982912
Dust coarse (0.05–0.01)	52.9594688	57.1077192	29.9367892	33.7475952
Dust medium (0.01–0.005)	4.4818184	5.8992192	2.9076772	7.0833312
Dust fine (0.005–0.001)	12.6231032	9.9139656	15.6850756	12.3754752
Silt (<0.001)	12.2941624	18.8037612	15.6031692	12.619728
Physical clay (<0.01)	29.399084	34.616946	34.195922	32.0785344
	Conclusion according to the classification of N. A. Kachynskyi (M. M. Godlin)			
	Light loamy (dusty-light loamy)	Medium loamy (coarse-dusty-medium loamy)	Medium loamy (sandy-light loamy)	Medium loamy (sandy-light loamy)

Detailed information about the field and laboratory palaeo-soil research of Olbia and other key sites studying the Holocene, both in the Northern Black Sea region and throughout Ukraine, can be found in the operational GIS application "Palaeo-Soil Research of the Holocene within the Plains of Ukraine," available at the link: https://paleosoil-holocen.info (Кушнір, Лейберюк 2022).

Discussion of Research Results and Conclusions

In the chronology of natural development, the beginning of Olbia's existence, as mentioned earlier, falls at the end of the Sub-Boreal period, and further development occurs at the beginning of the Holocene Sub-Atlantic chronological interval, in which climatic conditions began to change.

The end of the Sub-Boreal — beginning of the Sub-Atlantic period is characterised by less pronounced landscape changes than during the entire Sub-Boreal period, along with a cooler climate than the previous Atlantic period. The start of the Sub-Atlantic period had a typical cooling and an increase in moisture of the climate, with regular flooding along rivers leading to the accumulation of fluvial alluvium. The Sub-Atlantic period of the Holocene is a time of relatively stable landscapes, with minor changes in the composition of plant groups, although in azonal conditions there is a variety of changes in palaeolandscape complexes at the beginning of the Sub-Atlantic (Герасименко 1993, с. 31; ред. Матвіїшина 2010, с. 163-164).

In terms of historical and social development, this was a period of the rise and fall of Scythian and Sarmatian tribes, the cities of the Northern Black Sea region, and others. These developments were gradual, but occasionally accelerated by significant advances in historical material culture. While socio-political factors greatly influenced changes in historical types of cultural communities, climate change and the rhythms of the natural environment were also important.

Based on our and previous palaeo-soil research, it can be stated that during the existence of the ancient city, from the end of the 7th century BC to the 4th century AD, the climate was different from today's — it was more arid. On the watersheds, full-profile chestnut soils, either saline or solonetzic, were formed. Closer to the Southern Buh River valley, under more humid conditions and with more intense accumulation processes, soils similar to dark chestnut solonetzic or southern solonetzic chernozems formed. Elevated areas were dominated by dry steppe vegetation, while lower areas had steppe vegetation growing on southern chernozems or dark chestnut soils.

The natural conditions of the second half of the Sub-Boreal period, when the ancient Greek polis of

Table 5. **Detailed mechanical composition of the soil (in %) based on the results of granulometric analysis of sediments of profile 8, background soil**

Fractions (their size, mm)	Genetic horizons, their deposit depth and content in %				
	Hk 0.1–0.35 m	Hpk 0.35–0.6 m	Phk 0.6–0.8 m	P(h)k 0.8–1.0 m	Pk 1.0–1.2 m
Sand coarse (1.0–0.25)	2.36484666	1.3666914	1.08754104	2.06654588	1.84708488
Sand fine (0.25–0.05)	14.46566694	24.2869606	1.36583896	15.97848572	20.98488952
Dust coarse (0.05–0.01)	42.6233232	35.030568	50.8902792	32.22481	30.5179584
Dust medium (0.01–0.005)	5.3590728	8.861652	9.8376804	7.068668	8.0244768
Dust fine (0.005–0.001)	14.955552	10.775436	14.1961464	19.75069	15.2174016
Silt (<0.001)	20.2315384	19.678692	22.622514	22.9108004	23.4081888
Physical clay (<0.01)	40.5461632	39.31578	46.6563408	49.7301584	46.6500672
	Conclusion according to the classification of N. A. Kachynskyi (M. M. Godlin)				
	Medium loamy (sandy-medium loamy)	Medium loamy (sandy-medium loamy)	Heavy loamy (coarse-dusty-medium loamy)	Heavy loam (sandy-medium loam)	Heavy loam (sandy-medium loam)

Olbia was founded, were one of the main factors influencing urbanisation processes, of which the formation of the necropolis was a part. At the beginning of the region's settlement during the ancient period, the climate was cooler and wetter, than the area from which the resettlement to this territory took place. Palaeogeographical and physicochemical studies indicate that the area was favourable for urbanisation during the formation and functioning of the ancient polis of Olbia, which is confirmed by the results of studies by other scholars of this area (Иевлев 2014, с. 144). This is especially evident in comparison with the western part of the Anatolian Peninsula, from where the colonisation impulse came in the 6th century BC (the end of the Sub-Boreal Holocene period), where conditions were even more arid and hot. The relief, climate, and soil types favoured colonisation and urbanisation, with the chestnut and southern chernozem soils allowing Olbia to engage in agriculture within its chora (Одрін 2014, с. 73), similar to the practices of the Greeks on the Mediterranean coast. They successfully adapted to this environment, partly by constructing terraces, which mitigated the challenges posed by steep slopes that are visible today and probably existed in ancient times. This, according to the authors, allowed them to control erosion processes, nutrient leaching and low moisture content. Overall, the climatic conditions were more arid compared to today, with predominantly dry steppe landscapes. Geo-spatial analysis of the relief suggests that the main buildings of the polis were located on a slightly elevated area, which probably was raised above the surrounding land even in ancient times. This protected the city from sudden rises in water levels in the estuary. The studied soil profiles by the authors within the necropolis (as well as the necropolis itself) are situated at higher hypsometric levels than the ancient city, meaning that the wind blew toward the estuary, effectively eroding the humus-eluviated horizon (looser deposits with a lighter mechanical composition), leaving behind thin solonetzic soil horizons with surface carbonates. Later, the soil became sandier, as confirmed by granulometric analysis. Thus, this may be evidence that this site was probably chosen for the necropolis, as soils just a few hundred meters to the north (within the chora of Olbia) had similar agronomic properties, but were less affected by wind erosion. It's also worth noting that the Neogene limestone bedrock, exposed by the estuary waters, could have served as the primary building material, as such processed rocks are found in different places of the chora (Katalyne et al.) and the main settlement.

Urbanisation processes in Olbia during antiquity were largely determined by the natural environment and climatic conditions (Иевлев 2014, с. 151-152, 154-157). The city's inhabitants interacted with the environment, adapting their established ways of living and worldviews to new conditions. The authors identify several thematic blocks to characterise Olbia's urbanisation processes based on palaeogeographical research results:

Natural conditions and agricultural aspects. The geographical location of Olbia, the favourable agronomic properties of the soils, and the inhabitants' adaptation to agriculture shaped the city's development. Agricultural practices, particularly terrace construction, demonstrate a deep understanding by the citizens of Olbia of the natural environment in the retrospective and their ability to make assumptions.

Engineering solutions and infrastructure development. The strategic placement of the city's main buildings on elevated ground and the use of erosion control and flood prevention measures illustrate the ability of Olbian people to plan construction with a view to mitigating natural risks.

Interaction with available natural resources. The use of natural resources, such as Neogene limestone for construction or Pliocene-Pleistocene deposits for pottery, was essential for urbanisation on this site and demonstrates an understanding of the properties of different materials.

The described blocks for the features of urbanisation processes within the Olbian polis are also confirmed by the results of research by other scholars, both archaeologists and geographers, who have worked within the area. To confirm or refute the conclusions presented, it is necessary to conduct more detailed palaeo-soil studies, which are currently impossible due to Russian aggression.

Summing up the characteristics of urbanisation as a historical process marked by the increasing importance of cities and urban lifestyles in the development of ancient society, we note J. Gibbs's (1963) approach to the historical periodisation of urbanisation. He proposed a cyclical approach, highlighting five stages of natural historical urban development (pre-urbanisation, initial urbanisation, agglomerative urbanisation, agglomerative suburbanisation, deconcentration, and gradual stabilisation). Ancient cities in the Northern Black Sea region went through various stages of urbanisation due

to a range of social and natural processes. Some (such as Olbia) stopped at the third stage, while others (such as Chersonesos) went through all five stages. Therefore, further research is needed to examine certain transitional periods, as some proto-urban centres managed to achieve city status, while others did not.

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РЕЗУЛЬТАТИ ПАЛЕОҐРУНТОЗНАВЧИХ ДОСЛІДЖЕНЬ ОЛЬВІЇ В КОНТЕКСТІ РАННІХ УРБАНІЗАЦІЙНИХ ПРОЦЕСІВ У ПІВНІЧНО-ЗАХІДНОМУ ПРИЧОРНОМОР'Ї

Урбанізаційні процеси в Ольвії Понтійській були пов'язані з природним середовищем та кліматичними змінами. Дослідження палеогеографічних та археологічних аспектів вказують на більш аридний клімат у часи функціонування міста. Рельєф, клімат та ґрунти впливали на сільське господарство, розміщення будівель та некрополя. У 2015 та 2021 роках проведено польові палеоґрунтознавчі дослідження, які включали закладення восьми профілів на різних гіпсометричних рівнях території міста. Це дозволило вивчити стратиграфію ґрунтів, їхню морфологію та генетичну будову, що раніше не здійснювалося для цієї території.

Мешканці Ольвії взаємодіяли з довкіллям, адаптуючи свої господарські практики до природних умов. Системи сільськогосподарських та інженерних рішень свідчать про розуміння та пристосування до природного середовища. Особливу увагу приділено гранулометричному аналізу, що дозволив визначити механічний склад ґрунту за генетичними горизонтами. Аналіз розташування будівель на підвищеній території є ознакою вміння мешканців планувати господарство для захисту від природних ризиків, таких як ерозія та підтоплення. Разом з цим використання природних ресурсів, таких як вапнякові породи, для будівництва демонструє розуміння і використання наявних ресурсів для розвитку урбанізації.

Польові дослідження також включали вивчення картографічних джерел та використання геопросторових даних дистанційного зондування Землі (ДЗЗ), що уточнили межі міських територій. Вивчені стратиграфічні особливості давніх ґрунтів дали можливість реконструювати не тільки природні процеси, а й ритуально-міфологічні практики мешканців. Загалом, урбанізація в Ольвії була результатом взаємодії мешканців із природним середовищем та природними ресурсами, їх здатності адаптувати свої господарські та будівельні практики до умов часу. Це підтверджується матеріалами багаторічних археологічних досліджень античного поліса.

К л ю ч о в і с л о в а: Ольвія Понтійська, палеогеографія, урбанізація, палеоґрунтознавчі дослідження.

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