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Research paper

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RECONSTRUCTION OF PARTICULARITIES OF ANCIENT HUMAN ACTIVITY BASED ON GEOCHEMICAL AND SOIL MICROBIOLOGICAL INVESTIGATION OF SOTK-2 SITE (REPUBLIC OF ARMENIA)

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АРХЕОЛОГИЯ

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Исследовательская статья

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РЕКОНСТРУКЦИЯ ОСОБЕННОСТЕЙ ХОЗЯЙСТВЕННОЙ ДЕЯТЕЛЬНОСТИ ДРЕВНЕГО ЧЕЛОВЕКА НА ОСНОВЕ ГЕОХИМИЧЕСКОГО И ПОЧВЕННО-МИКРОБИОЛОГИЧЕСКОГО ИССЛЕДОВАНИЯ ПАМЯТНИКА СОТК-2 (РЕСПУБЛИКА АРМЕНИЯ)

Для цитирования: Чернышева Е.В., Амирян М.А., Ельцов М.В., Петросян А.А., Потапова А.В. Реконструкция особенностей хозяйственной деятельности древнего человека на основе геохимического и почвенно-микробиологического исследования памятника Сотк-2 (Республика Армения) // История, археология и этнография Кавказа. 2022. Т. 18. № 4. С. 993-1013. doi: 10.32653/CH184993-1013

Abstract. The article presents the results of the first joint soil-archaeological investigations on the territory of the Republic of Armenia. The cultural layers of the Sotk-2 site, located on the southeastern coast of Lake Sevan, were chosen as the object of study. The Sotk-2 played a special role in the settlement system in the region, as it is located on the way to the Bronze Age gold mine. A multi-layered settlement has been recorded here, which settled from the early Bronze Age until the early Iron Age (with certain interruptions). However, only the Bronze Age layer was characterized by the presence of anthropogenic deposits, while only scattered artifacts identified other periods of occupation. As part of joint research, samples were taken from the previous excavated trenches at the archaeological site in August 2021 for laboratory analysis. Analysis of the chemical and microbiological properties of cultural layers made it possible, for the first time on the archaeological monuments of this type, to identify periods with the lowest and highest intensity of human activity, as well as to establish the infrastructural features of the settlement. The strongest anthropogenic impact took place during the formation of the Middle – Late Bronze Age layer. Places for cooking and household pits were localized, where an increased concentration of organic phosphorus, copper, manganese, lanthanum was observed, as well as high microbial biomass and lipase activity. In another site of the settlement in the layer of the Middle – Late Bronze Age, an increased concentration of calcium, strontium and magnesium was revealed, which indicates the possibility of butchering fish in this place. The lowest residential load on the Sotk-2 site, according to soil analysis, took place in the early Bronze Age.

Keywords: soil biological memory; archaeological microbiology; phosphorus; cultural layers.

Аннотация. В статье представлены результаты первых совместных почвенно-археологических исследований на территории Республики Армения. В качестве объекта исследования были выбраны культурные слои поселения Сотк-2, расположенного на юго-восточном побережье оз. Севан. Поселение играло особую роль в системе расселения в регионе, поскольку оно расположено на пути по направлению к золотым приискам, которые активно разрабатывались в бронзовом веке. Поселение Сотк-2 представляет собой многослойный памятник, который функционировал с раннего бронзового века вплоть до раннего железного века (с определенными перерывами). Однако только для бронзового века было характерно наличие культурных отложений, тогда как другие периоды заселения выявлены только по рассеянным артефактам. В рамках совместных исследований из археологических раскопов на поселении в августе 2021 г. были отобраны образцы для лабораторных анализов. Анализ химических и микробиологических свойств культурных отложений позволил впервые на пятниках такого типа выявить периоды с наименьшей и наибольшей интенсивностью хозяйственной деятельности, а также установить инфраструктурные особенности поселения. Наиболее сильное антропогенное воздействие имело место при формировании слоя среднего – позднего бронзового века. Были локализованы места приготовления пищи и хозяйственные ямы, где наблюдалась повышенная концентрация органического фосфора, меди, марганца, лантана, а также высокая микробная биомасса и липазная активность. На другом участке поселения, в слое среднего – позднего бронзового века, выявлена повышенная концентрация кальция, стронция и магния, что указывает на возможность разделки рыбы в этом месте. Наименьшая селитебная нагрузка на поселение Сотк-2, по данным почвенного анализа, имела место в раннем бронзовом веке.

Ключевые слова: биологическая память почв; археологическая микробиология; фосфор; микроэлементы; культурные слои.

The concept of “soil memory” originated in the 70-80’s of the 20th century, and represents the futher development of V.V. Dokuchaev’s idea – “soil is a mirror of the landscape” [1]. Soil memory is considered as the ability of the soil in its physico-chemical and biological properties to store information about various events that occurred in its layers or on its surface. At various levels of the genesis of the Earth’s pedosphere, the carriers of soil memory are very diverse. The hierarchy of soil memory carriers includes all levels of formation of the solid phase of the soil system, starting with the molecular-crystalline one, then aggregate and horizontal levels and ending with the level of the soil body and topsoil. At different levels of the formation of the soil’s solid phase, information about various events in the past are recorded as different layers of memory, varying in content and volume, in recording speed and resistance to erasure. Science distinguishes granulometric, geochemical, mineralogical, humus, pedno-aggregate, cutaneous and other types of soil memory [1].

One of the aspects of soil memory is its biological component [2]. The concept of biological memory of soils was originally developed in the works of O.E. Marfenina and A.E. Ivanova in the study of the community of soil microscopic fungi in the cultural layers of medieval sites [3]. In some sense, the soil or ground of an archaeological site can be considered as a specific ecotope, in which microbial communities become so-called ecofacts [4], which, like archaeological artifacts, carry information about the past. Therefore, archaeological contexts can be considered as a kind of ecological niches with specific microbial communities to varying degrees, having their own biodiversity and a pool of enzymes. Even in the case of the death of microbial communities, traces of their activity remain in the form of enzymes fixed in the soil, as well as the residual diversity of microbial communities [5]. The peculiarities of changes in the soil microbial community persist for a long time due to the ability of microorganisms to transition into dormant forms and return to the active state when favorable conditions occur [6]. As for enzymes, they can persist in the soil indefinitely, becoming a part of organomineral complexes with soil particles and humic substances [7]. Information about the ingress of organic substrates associated with human activity is stored in biological soil memory in the form of an increase in the number of microorganisms specializing in the decomposition of this substrate (microbial memory), as well as in an increase in the activity of enzymes involved in the mineralization process (enzymatic memory of soils). Soil biological characteristics are utilized to study the boundaries of sites and their infrastructure, to determine the places where livestock was kept [8], as well as to identify the introduction of organic fertilizers into the soils of ancient fields [9]. The possibility of using microbial and enzymatic memory for the reconstruction of the funeral rite [10] and the original contents of the ritual vessels [11] is shown. Currently, the use of microbiology methods in archaeological research is described in detail in the papers «Microbiology Meets Archaeology» [4] and “Archaeological Microbiology: Theoretical foundations, methods and results” [12], which show the possibility of preserving information about anthropogenic impact in antiquity in the soil microbial community.

The chemical component of soil memory is no less significant. Determination of the bulk content of chemical elements is one of the classical approaches to the study of the cultural layers of archaeological sites. In the 20s of the last century, O. Arrhenius began studies of the accumulation of various chemical elements with the determination of the phosphate content [13]. Phosphorus, entering the soil together with food remains, garbage and ash can remain stable for a very long time, which allows to conclude about the nature of the economic use of a certain territory in ancient times [14]. Later it was shown that in places of long-term human habitation, in soils and cultural layers, the content of a whole spectrum of chemical elements can increase [15]. At the same time, the composition and variation of macro- and microelements in different sections of the site may carry information about the nature of introduced substrates, the existence of various functional zones within the archaeological site: production, residential, etc. [16-18].

The present paper provides the results of soil and archaeological investigations of the archaeological site Sotk-2, located on the outskirts of the village of Sotk, Republic of Armenia, on the southeastern shore of Lake Sevan. Sotk is a unique microdistrict located near the largest gold mines in the Near East. The uniqueness of the site is also due to its central position, connecting the southern and eastern Caucasus. The archaeological investigations initiated by the Armenian-German expedition in 2011 uncovered several settlements and burial grounds of the Early, Middle and Late Bronze Age, as well as the Early Iron Age. A total of 41 sites were explored. Most were classified as fortified settlements of cyclopean masonry [19].

For the first time, the potential of natural sciences to comprehend cultural, historical and economic phenomena in the region under study has been applied. Traditional historical and archaeological methods and a new soil-archaeological microbiological approach have been coordinated, the essence of which is to jointly use the potential of biological and geochemical memory of soils to reveal the features of the economic models of the ancient population of Armenia.

Description of the key section

The Sotk-2 site is located within the Masrik plain, on the southeastern coast of Lake Sevan. The boundaries of the studied territory include: from the north – Sevan, from the east – East Sevan, from the south – Vardenis Range, from the west – Lake Sevan. The average annual temperature in the region is +4 °C, the average annual precipitation is 430-440 mm [20]. The Sotk-2 site is located at an absolute altitude of 2100 meters, on the top of an oval hill with an area of 6500 m^2, on the northeastern outskirts of the village of Sotk (Geharkunik region, Republic of Armenia, N 40°20’35”, E 45°88’59”).

The site played a special role in the settlement system in the region, as it is located on the path towards the gold mines. The excavations have shown that the territory was inhabited during the Early Bronze Age (Kura-Araxes culture), the Middle Bronze Age (Sevan-Artsakh culture), the Late Bronze Age and Early Iron Age (Lchashen-Metsamor culture), as well as the Middle Iron Age and the Middle Ages. However, the presence of cultural deposits is characteristic only of the Bronze Age, while other periods of settlement have been identified only by scattered artifacts. In the Middle and Late Bronze Ages, the settlement occupied a central position inside the fortification walls [19].

The cultural deposits of the investigated section of the Sotk-2 site include layers of the Early Bronze Age (29-27 centuries BC, Cultural Layer 3), the Middle – Late Bronze Age (18-16 centuries BC, Cultural Layer 2) and the Early Iron Age (11/10-9 centuries BC, Cultural Layer 1). The Early Bronze Age is represented by the remains of adobe buildings, homogeneous typical pottery, typical stone and obsidian tools, arsenical bronze.

The Middle and Late Bronze Age is characterized by stone buildings with numerous pits and a very diverse ceramic material. At the middle stage of the Late Bronze Age, the settlement did not function for some time and was repopulated in the early Iron Age. Despite certain interruptions, hiatus has not been recorded in the stratigraphic column of the site. At the Sotk-2 site, the buried (fossil) soil has not been preserved, and the cultural layers are underlain by bedrock [21].

Samples from several sections of the cultural layers of Trench E (Soil Pits 1, 2) and K (Soil Pit 3) were selected from archaeological excavations at the Sotk-2 site in August 2021 (Fig. 1, 2).

Trench E is located in the western part of the flat top of the hill. In the trench, two stratigraphic levels of the cultural layer were revealed.

Layer 1, lying directly under the sod, is represented by clusters of irregularly shaped stones and diachronic ceramics.

Layer 2, lying below, is more homogeneous, with a smaller proportion of stones. Ceramics appear to be a transitional period from the Middle to the Late Bronze Age and are typical of the Sevan-Artsakh culture. Four rock pits and a stone foundation built on the rock are assosiated with this layer. The bottom and walls of the pits are adobe. Numerous animal bones and ceramics were found within these objects. One of the pits is divided into two parts, which differ in shape. The pits likely had an economic function.

Layer 3, corresponding to the early Bronze Age, has not been preserved in this part of the site and is identified only in Layer 1 by fragments of ceramics.

Two stratigraphic sections were investigated within Trench E.

Soil Pit 1. Sampling was carried out on the northern wall of the trench in layers every 10 cm. In this section, the profile of cultural deposits has the following structure. From the surface to a depth of 10 cm, the humus layer is dark-gray in color, lumpy-nutty structure (Cultural Layer 0). The 10-50 cm layer is less humusized, has a coarse-grained structure (Cultural Layer 1, Early Iron Age). Below (up to a depth of 110 cm) is Cultural Layer 2, slightly affected by soil formation (Middle Bronze – Late Bronze Age), ash-gray in color, powder-like structure), underlain by bedrock. Artifacts (animal bones, fragments of ceramics, stones) were found in large numbers in all layers. The soil pit was dug on the edge of the household pit. Cultural Layer 1 is represented by clusters of irregularly shaped stones. Cultural Layer 2 contains fragments of ceramics, animal bones and cereal seeds [22].

Soil Pit 2. The pit was dug on the southern wall of the trench, five meters from Soil Pit 1. It is also located near a large household pit. The soil profile is divided into the following horizons. Humus layer with a large number of roots, of dark-gray color, lumpy-nutty structure (0-10 cm, Culture Layer 0). The 10-20 cm layer is a cluster of 1-5 cm stones (Cultural Layer 1, Early Iron Age, presence of diachronic ceramics). Below, to a depth of 70 cm, lies a slightly transformed by topsoil formation cultural layer of pale gray, powder-like structure (Cultural Layer 2, Middle Bronze – Late Bronze Age). The profile's bottom ends in bedrock. Numerous artifacts are found in all layers of the profile.

Trench K adjoins the western slope of the hill. In this section, Cultural Layer 2 preserved poorly, has been largely redeposited, and includes later artifacts. Layer 3 is relatively undamaged; its better preservation was recorded in the northern part of the trench. Here, the burial of a child has been recorded.

Soil Pit 3. The soil pit was dug on the northern wall of the trench, 12 m from Soil Pit 1. The profile has the following structure. The upper 10-15 cm are humusized, dark-gray in color, lumpy-nutty structure, roots of herbaceous vegetation are observed in large quantities (Cultural Layer 0). Below (up to a depth of 30 cm) lies Cultural Layer 3 of the Early Bronze Age (whitish-gray, powdery structure). It is underlain by a gray-brown layer, with a lumpy-powdery structure (adobe floor, Cultural Layer 3a). At a depth of 60 cm lies bedrock. In all layers (except 3a), artifacts (animal bones, fragments of ceramics, stones) are found in large quantites. The artifacts mostly date back to the Early Bronze Age. The soil pit was dug near the child's burial.

Methods

For the analysis of soils and cultural layers of archaeological sites in order to reconstruct changes in the natural environment in the past, the following methods have been applied: the potentiometric method for determination of the pH of the water extract, the Tyurin method to assess the content of organic carbon, the acidimetric method to measure the content of carbonates [23]. The content of bulk, mineral and organic phosphorus was determined by the Sanders-Williams method [24]; the bulk content of chemical elements – using the X-ray fluorescence method on the MAX-GV spectrometer (Russia). The determination of chemical elements was carried out at the Center for Collective Use of the Institute of Physical, Chemical and Biological Problems of Soil Science, RAS. Microbial biomass was determined by the content of phospholipids [25], urease activity by a modified indophenol method [26]. Moreover, the enzymatic activity (acid and alkaline phosphatase, butyrate esterase and palmitate lipase, leucine aminopeptidase and glycine aminopeptidase) was determined by a microplate method using chromogenically labeled substrates based on p-nitrophenol and the heteromolecular exchange procedure [27-28].

Results and discussion
Chemical properties of the cultural layer

In the cultural layers of the Sotk-2 site, a significant accumulation of some chemical elements has been observed (Fig. 3): magnesium (Mg), manganese (Mn), potassium (K), phosphorus (P), barium (Ba), copper (Cu), lanthanum (La), tin (Sn) and zinc (Zn), elements that are traditionally associated with the anthropogenic activity of ancient humans [29-31]. In the studied cultural deposits, the maximum concentration of chemical elements is characteristic of the Middle–Late Bronze layer (Cultural Layer 2), especially for Soil Pit 1, dug on the northern wall of Trench E. This soil pit was dug on the edge of the household pit, therefore, a significant increase in lanthanum, manganese, calcium, phosphorus directly indicates a considerable ingress of food remains into the cultural layer [30]. Unlike other elements, manganese has several peaks of increase, which may indicate a different volume of plant materials entering the cultural layer at the time of its formation [15-16]. The maximum concentration of manganese was detected in the layer of the Early Iron Age. We can conclude that the formation of the cultural layer of the Early Iron Age is associated with the ingress of plant remains and ash, whereas during the formation of the Middle – Late Bronze layer – the ingress of food waste of animal origin. The maximum concentration of macro- and microelements has also been observed in the cultural deposits of Soil Pit 2, in the Middle – Late Bronze layer, as a whole. However, the content of anthropogenic elements recorded at this section is lower than in the cultural layers of Soil Pit 1. This section of the trench was likely a residential area of the settlement or had other economic significance. Soil Pit 3, dug on the northern wall of Trench K, distinguishes by only the oldest layer belonging to the period of the Early Bronze Age with the lowest concentration of chemical elements. Apparently, at this stage of development of the territory, the population was not so high, and the anthropogenic load did not result in a significant change in the soil. At the initial stage of the development of the territory of the site, the main human activity might have been associated with fishing, as indicated by the increased concentration of calcium, strontium and magnesium [31].

The content of organic carbon in the studied sections of the trench decreased evenly with depth (Fig. 4). However, in Cultural Layers 1 and 2 of Soil Pit 1, dug on the northern wall of Trench E, next to the household pit, these values are higher than in similar layers of Soil Pits 2 and 3. This also indicates that during the formation of cultural deposits at this section, more organic waste entered the layer, since the ingress of organic materials usually results in an increase in the content of organic carbon in soils [32].

In order to ascertain the origin of phosphates in the culture layer, a separate determination of mineral and organic phosphates was carried out, and the proportion of organic phosphorus from the bulk one was calculated (Fig. 5). In the cultural deposits of section 1, the maximum proportion of organic phosphates reaches 62% in the Middle – Late Bronze Age layer. The high proportion of organic phosphates in this layer also confirms the previously stated assumption that a significant amount of food residues and other organic waste entered in it at the time of its formation. At the sections of Soil Pits 2 and 3, the proportion of organic phosphorus do not exceed 25%, the only exception is a layer of topsoil (0-10 cm) of Soil Pit 3, which is due to natural causes.

Biological properties of the cultural layer

The highest biological activity has been observed in the layer of topsoil at all sites of the trench, which is associated with the natural biogenicity of the soil (Fig. 4, 6). Microbial biomass, as a rule, decreased evenly with depth. The exception is anthropogenic deposits in Soil Pit 1, dug on the northern wall of Trench E, on the border of the household pit, while in the Middle – Late Bronze Age layer, at a depth of 70-80 cm and 100-110 cm, microbial biomass is significantly higher than in the topsoil, due to the significant ingress of organic materials into the depth of the cultural layer at the time of the functioning of the site. This site was likely a place for cooking. The ingress of food remains is also indicated by an increase in the content of organic phosphorus and some chemical elements (La, Mn, Ca) in the depth of the Middle – Late Bronze Age.

The most informative enzymes for archaeological reconstructions are enzymes of the phosphatase, lipase, protease and urease class [11; 33]. Phosphatases are involved in the decomposition of organophosphorus compounds, and posses no strict specificity. Depending on the reaction of the soil environment, microorganisms will mainly release either acidic or alkaline phosphatase. Lipase is involved in the decomposition of fatty substrates of animal and vegetable origin. Proteases are involved in the decomposition of protein molecules that enter the soil from all dead organisms, both animals and plants. Many bacteria and fungi are producers of proteases in the soil. They have no strict specificity, but can decompose any protein-containing organic components. Urease is involved in the decomposition of urea, which enters the soil as part of plant remains and manure [34].

The enzymatic activity (Fig. 6), as a rule, decreased uniformly with depth in all studied sections, its values were quite close in all examined soils. The even distribution of enzymatic activity was characteristic of phosphatase and urease. The profile dynamics of urease activity and the decrease in this indicator with depth does not give grounds to speak of any livestock living in the settlement at all stages of its existence. For enzymes involved in the decomposition of fats and proteins (lipases and proteases, respectively), several peaks of increased activity have been observed. A significant increase in the activity of lipases and peptidases in the Middle – Late Bronze Age layer in Soil Pit 1, located on the border of the household pit, has been revealed, which, together with other soil characteristics, confirms the probabilty of using this site as a place for cooking. A slight increase in the activity of lipases and proteases has also been observed in the Middle – Late Bronze Age layer in Soil Pit 2, dug on the southern wall of Trench E. In the Early Bronze Age layer, in Soil Pit 3, there was only a slight increase in the enzyme activity of glycine-aminopeptidase. This indicates a minimal anthropogenic load at the initial stages of the development of the territory of the site.

The determination of phosphatase activity together with the separate determination of mineral and organic phosphorus can shed light on the nature of the origin of phosphorus in the culture layer. Phosphatases are direct participants of the phosphorus cycle in the soil, responsible for the contribution of organic phosphorus to the phosphate pool of the culture layer. The degree of phosphatase activity reflects the intensity of phosphorus-containing organic compounds entering the soil [35]. Correlation analysis has shown that Soil Pits 1 and 2 are characterized by an inverse relationship between the content of mineral phosphorus and phosphatase activity (correlation coefficient of -0.71 and -0.79, respectively), whereas Soil Pit 3, on the contrary, has revealed a positive correlation with both mineral and organic phosphorus (correlation coefficient of 0.83). Taking into account the low content of both mineral and organic phosphates with high phosphatase activity, we assume that this site experienced the least anthropogenic load. On the contrary, at the sites where Soil Pits 1 and 2 were dug, a significant ingress of anthropogenic materials stimulated microbiological activity, which led to their increased mineralization and accumulation of the mineral form of phosphorus, and as the substrate was exhausted, phosphatase activity decreased. On the other hand, a high content of mineral phosphates with reduced phosphatase activity may indicate the mineral nature of phosphorus in the culture layer.

Statistical data processing

The principal component analysis, performed with microbiological and chemical data, has shown that 70.5% of the total variation is explained by the first two factors, and the samples of anthropogenic sediments are quite clearly grouped by the periods of development of the territory of the site (Fig. 7). Axis 1 accounts for 51.1% of the total variation and the following parameters are associated with it: chemical – organic carbon (C_{org}), strontium (Sr), iron (Fe), chromium (Cr), barium (Ba), calcium (Ca), copper (Cu), magnesium (Mg), gross phosphorus (P_{bulk}), manganese (Mn), as well as microbiological – the activity of phosphatase (PhA), urease (UA), lipase (LA), peptidase (PA) and microbial biomass (MB). Axis 2 accounts for 19.4% of the total variation, and parameters such as potassium (K), mineral (P_{min}) and organic phosphorus (P_{org}) are associated with it. The topsoil layers of the studied soil profiles (TS 1-3) are associated with increased values of all parameters of biological activity and organic carbon. The Early Iron Age layer (OL1-1, Soil Pit 1) is distinguished by elevated concentrations of magnesium, barium, chromium, copper and lanthanum. As mentioned above, the formation of this layer is associated with the ingress of ash. No accumulation of these elements in the Early Iron Age layer of section 2 (OL1-2) has been recorded, which indicates a different nature of the use of the settlement territory during this period, for example, as a residential zone or a production zone associated with a slight ingress of organic matter. The Middle–Late Bronze layer on the northern wall of Trench E (OL2-1, section 1) is characterized by a high concentration of elements such as calcium, phosphorus (all forms) and lanthanum, which indicates the ingress of organic residues associated with cooking into the cultural layer [30]. An increase in the concentration of elements such as magnesium, strontium, calcium and sulfur has been observed on the southern wall of Trench E (OL2-2, section 2). An increased content of calcium and strontium, as well as sulfur, is also characteristic for the Early Bronze Age layer (OL-3, section 3). An increase in the concentration of elements such as calcium, magnesium and strontium is associated with the fish butchering [31]. Therefore, we assume that in the early Bronze Age, the main human activity could be associated with fishing, and the site on the southern wall of Trench E in the Middle – Late Bronze Age could be a fish butchering zone.

Conclusion

Morphological, chemical and microbiological features of the cultural layer at various sections of the Sotk-2 site allow us to identify differences in household and production activities on the territory of the site in the early Bronze Age and in the transition period from the Middle – Late Bronze Age to the early Iron Age, as well as reconstruct the infrastructural features of the site.

Taking into account the obtained results of the soil examination of cultural layers, we conclude that the formation of the Early Iron Age layer is conditioned by the ingress of plant residues in the form of ash, whereas the Middle – Late Bronze Age layer on the northern wall of Trench E was formed with a significant ingress of organic (food) waste into the soil, and this area could likely be a cooking zone. This is consistent with the archaeological data, since the maximum concentration of archaeological material (bones, ceramics, stones) has been revealed at this section of the trench. The opposite section of the trench (on its southern wall, 5m away) during this period might have been a production area, for example, for butchering fish. This type of economic activity is not associated with significant ingress of organic matter into the soil, therefore, there is no significant increase in biological activity; but an increase in the concentration of elements such as calcium, magnesium and strontium, that is, chemical elements, the accumulation of which is associated with the butchering fish, has been observed. The layer of the Early Bronze Age, identified only in the investigated site of the Trench K, is associated with the initial stage of development of the territory and minimal anthropogenic load, which did not result in a significant change in the soil and its properties.

Thus, the combined application of geochemical analysis and methods of soil microbiology increases the reliability of archaeological reconstructions of the features of the economic activity of ancient humans. Traditional geochemical analysis cannot determine with great accuracy whether organic or inorganic matter entered the cultural layer at the time of its formation. But whether a significant increase in the concentration of certain chemical elements (for example, phosphorus, manganese, sulfur, zinc, strontium, lanthanum), an increase in biological activity is also observed, then we can speak of the ingress of organic matter into the culture layer. In this regard, in order to increase the reliability of soil reconstructions, we recommend the joint use of geochemical analysis and methods of soil microbiology to study anthropogenic deposits of archaeological sites of different ages.

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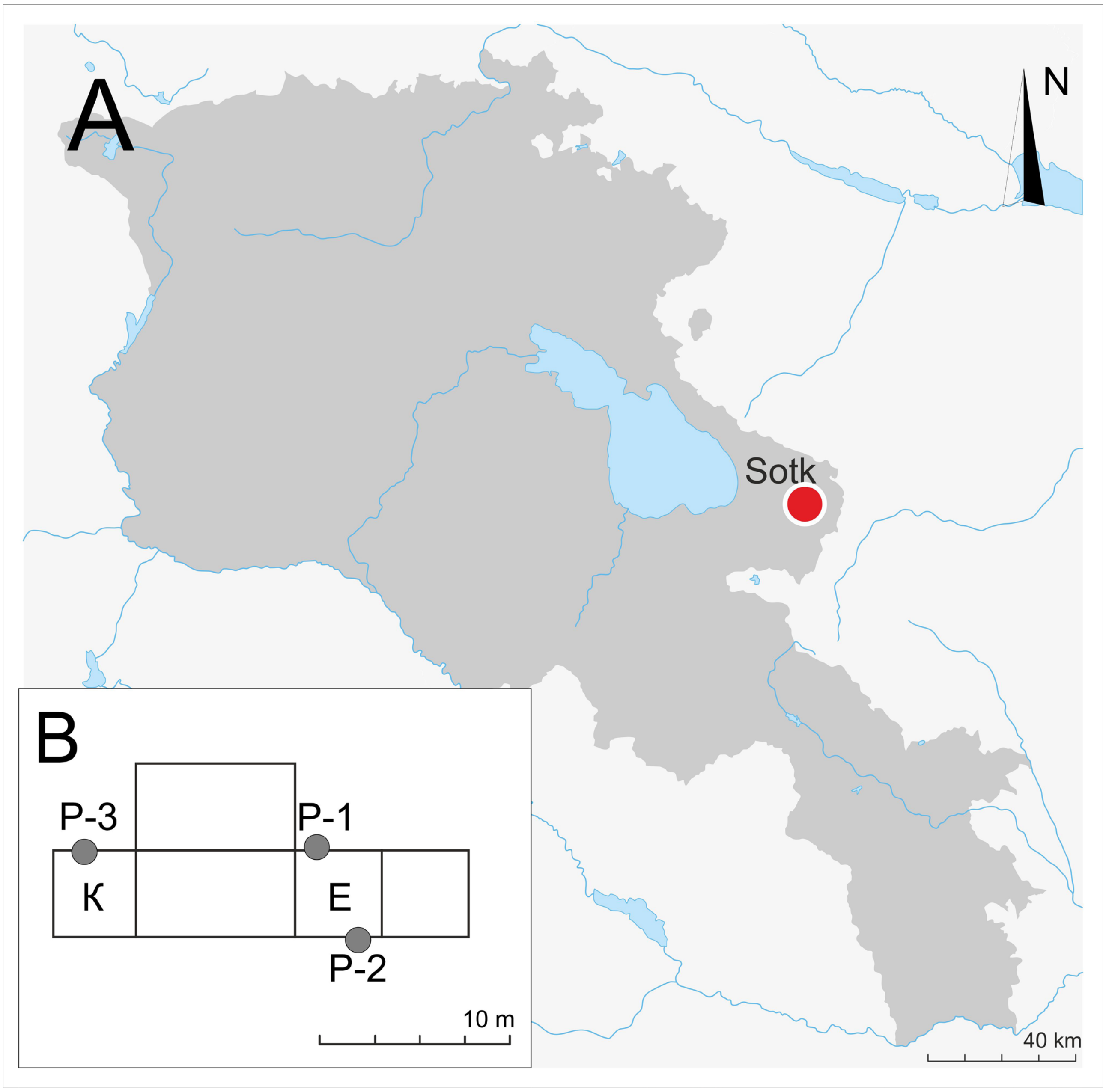

Fig. 1. Study area.
A – Location of the Sotk-2 site,
B – location of soil pits (P-1 – soil pit, E – trench)

Рис. 1. Регион исследования.
A – Расположение поселение Сотк-2,
Б – схема расположения почвенных разрезов (P-1 – разрез, E – раскоп)

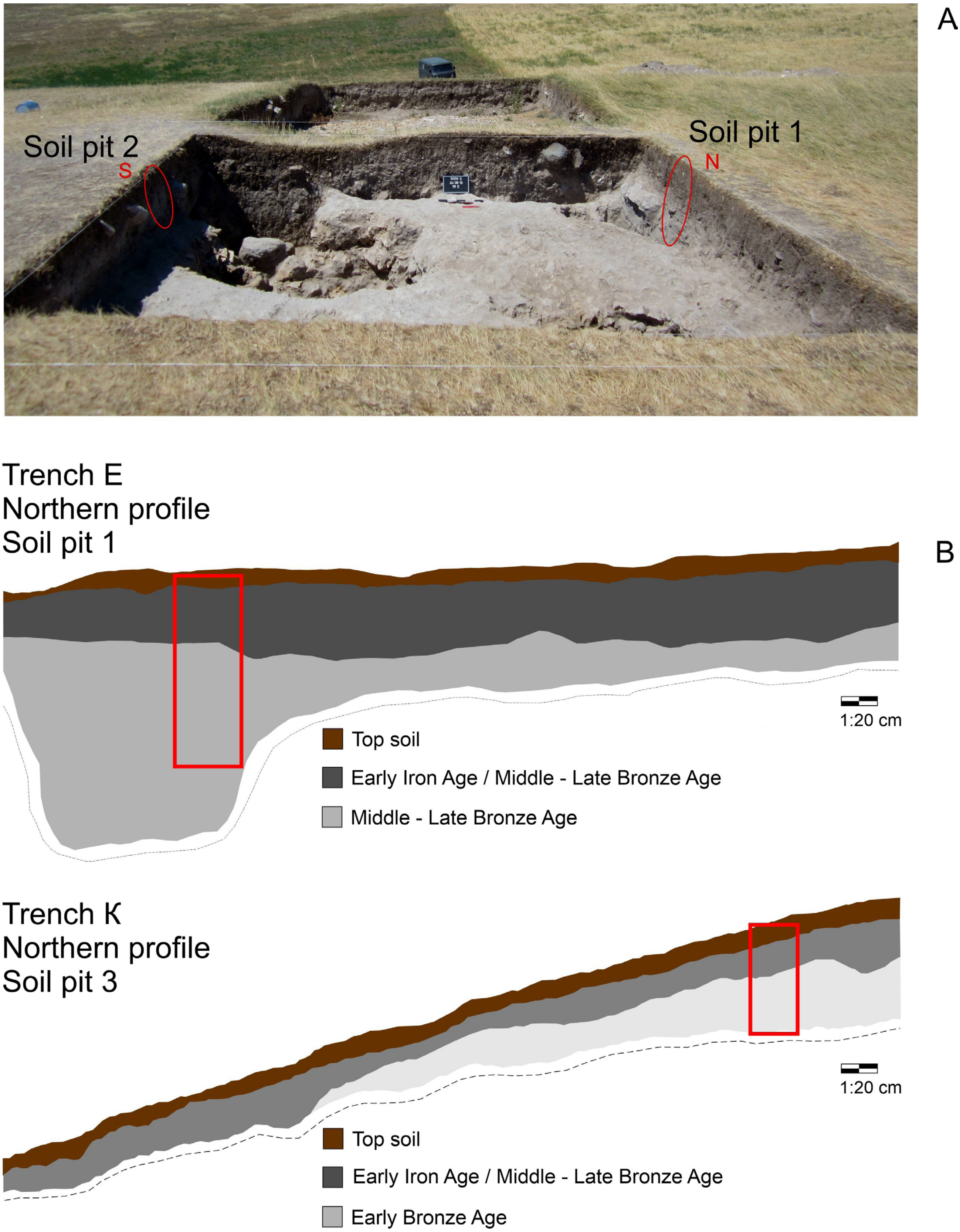

Fig. 2. General view on Trench E of the Sotk-2 site (A)
and profile diagram at the locations of Soil Pits 1 and 3 (B)

Рис. 2. Общий вид на раскоп Е поселения Сотк-2 (А)
и схема профиля в местах заложения разреза 1 и 3 (Б)

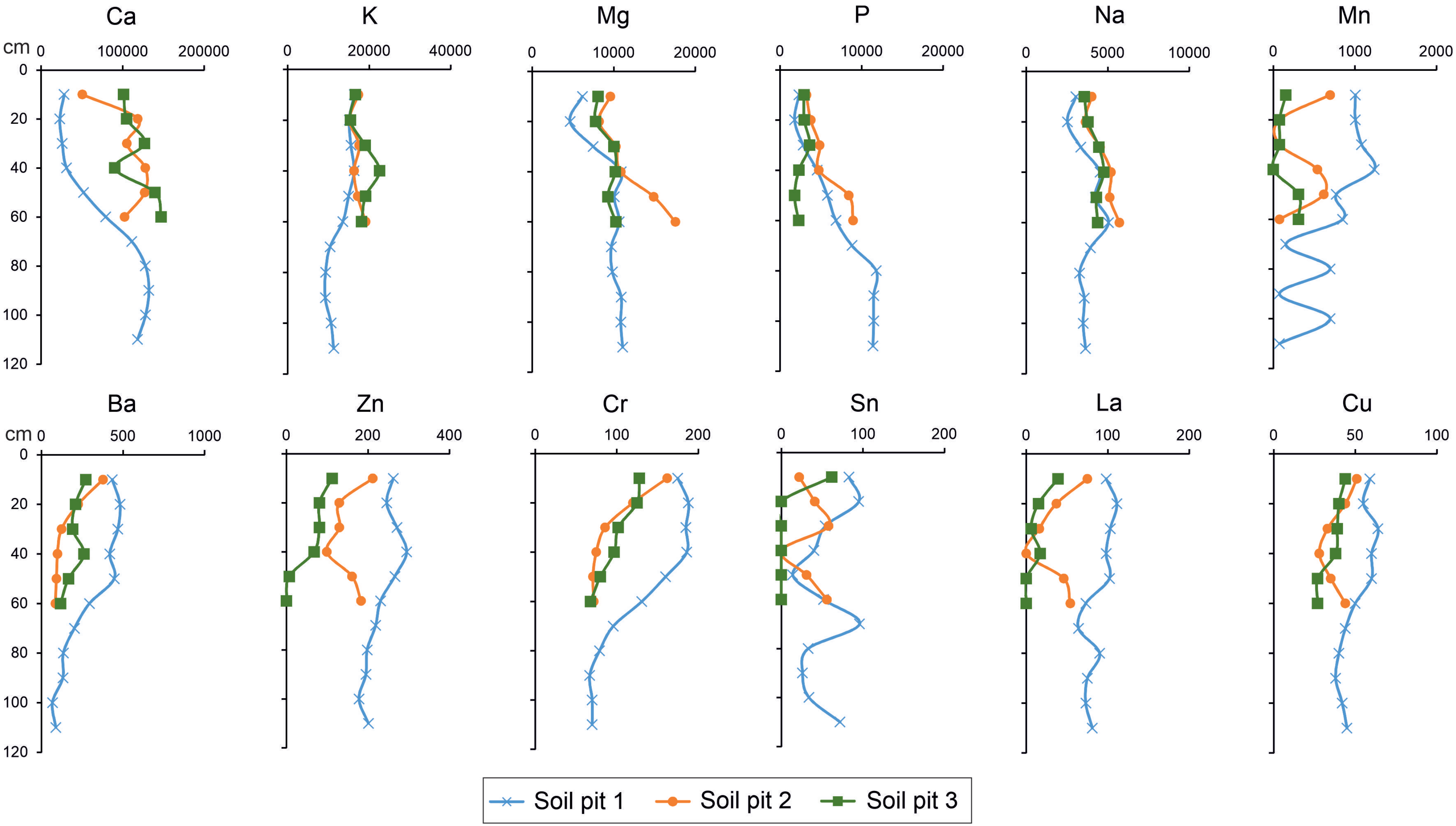

Fig. 3. The content of some chemical elements (mg g–1 soil) in the occupation layers of the Sotk-2 site

Рис. 3. Содержание некоторых химических элементов в культурных слоях поселения Сотк-2

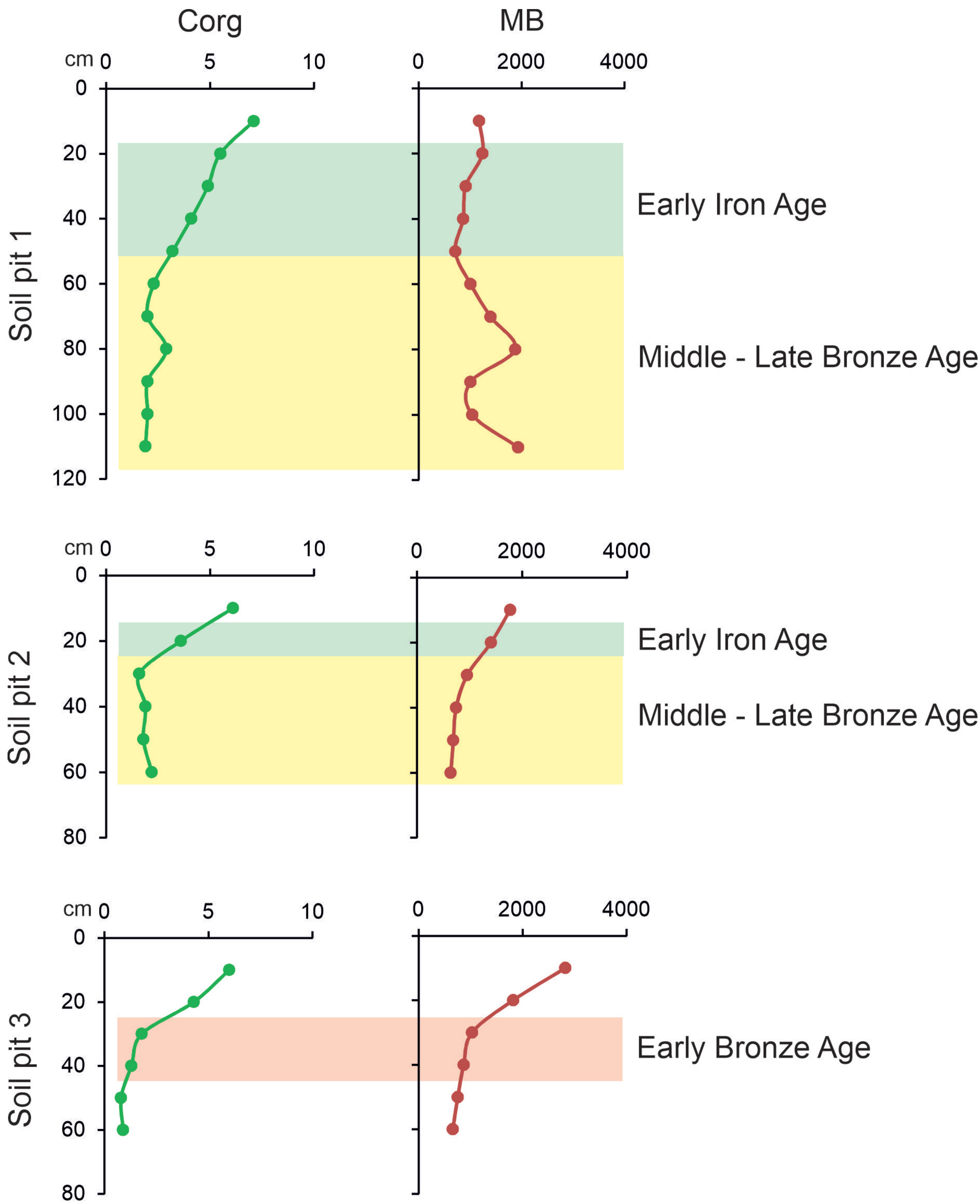

Fig. 4. The content of organic carbon (Corg, %) and microbial biomass (MB, μg g–1 soil) in the cultural layers of the Sotk-2 site

Рис. 4. Содержание органического углерода (Сорг, %) и микробная биомасса (МБ, мкг С/г почвы) в культурных слоях поселения Сотк-2

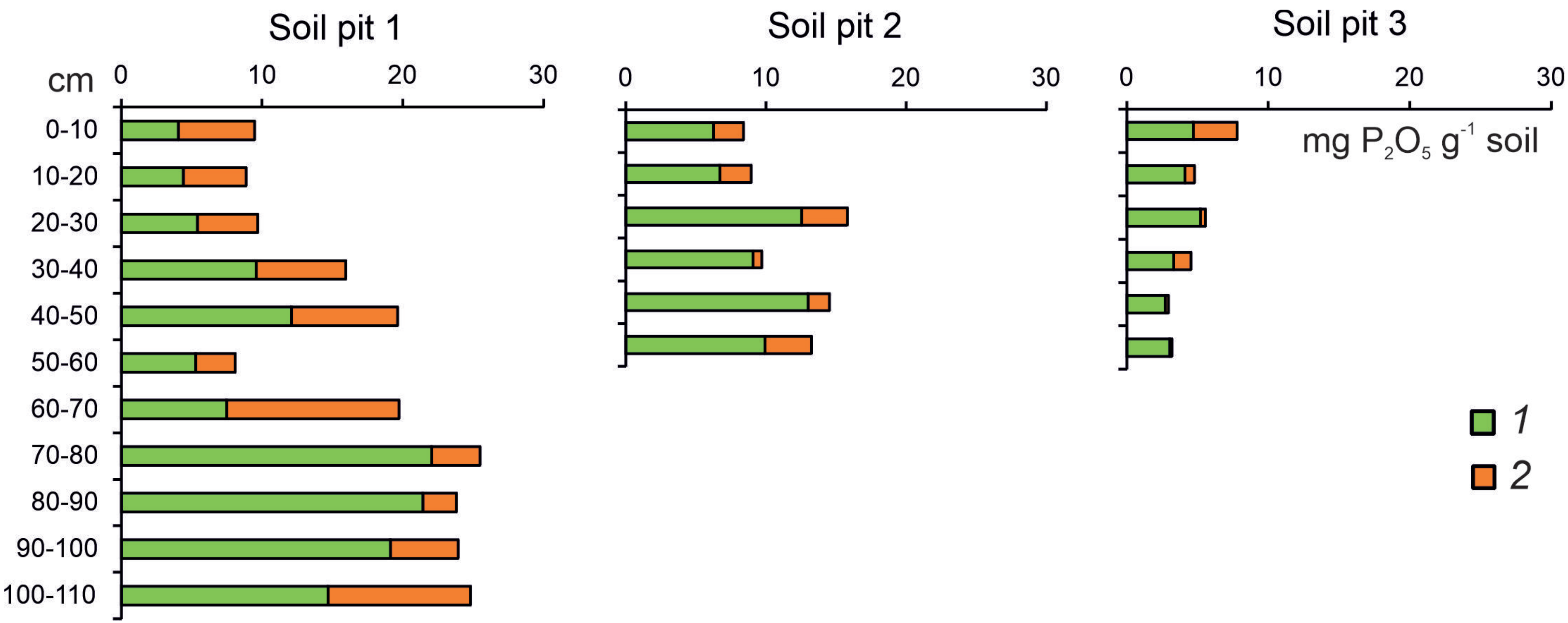

Fig. 5 The content of phosphates in cultural layers of the Sotk-2 site.
1 – mineral phosphorus; 2 – organic phosphorus

Рис. 5. Содержание фосфатов в толще культурных отложений поселения Сотк-2.
1 – минеральный фосфор; 2 – органический фосфор

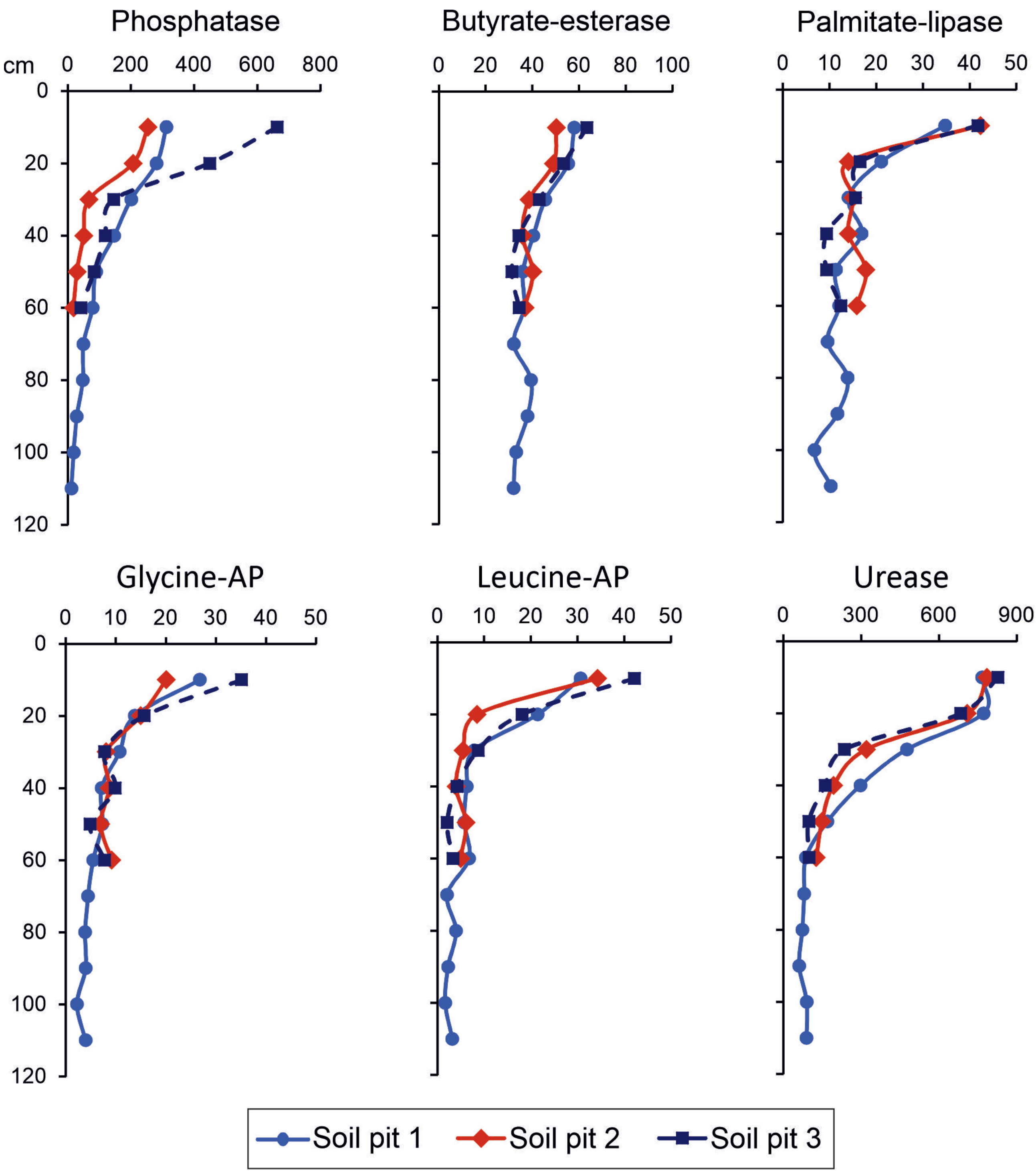

Fig. 6. Enzymatic activity in the cultural layers of the Sotk-2 site (phosphatase, butyrate-esterase, palmitate-lipase; glycine-aminopeptidase, leucine-aminopeptidase – nmol pNP g–1 soil hour–1, urease – µg NH4+ g–1 soil hour–1)

Рис. 6. Ферментативная активность в толще культурных отложений поселения Сотк-2 (фосфатаза, бутират-эстераза, пальмитат-липаза, глицин-аминопептидаза и лейцин-аминопептидаза – нмоль пНФ/г почвы в час, уреаза – мкг NH4+/г почвы в час)

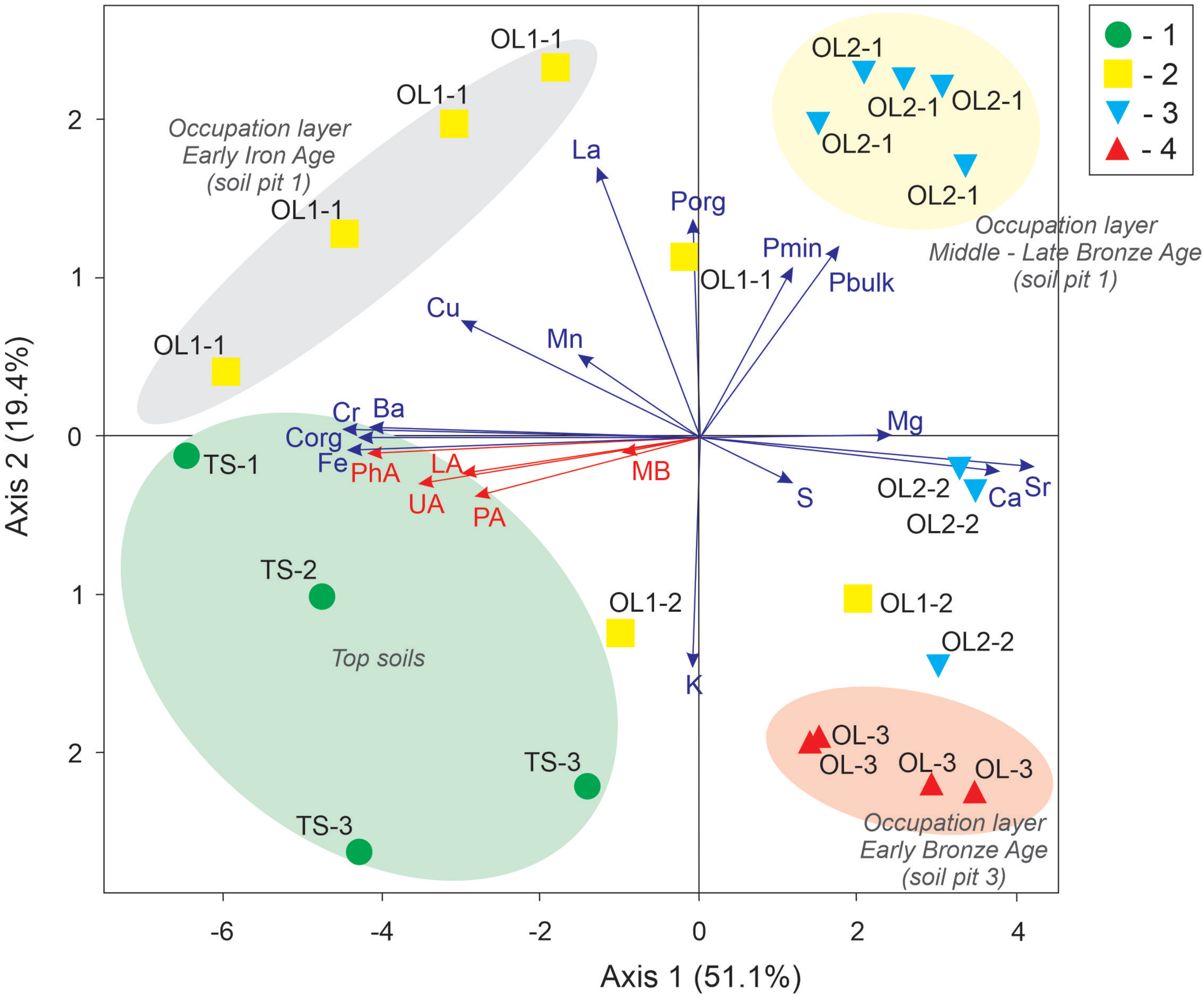

Fig. 7. Principal component analysis for chemical and microbiological parameters.
1 – topsoil (TS), 2 – occupation layer of early Iron Age (OL1),
3 – occupation layer of Middle – Late Bronze Age (OL2), 4 – occupation layer of early Bronze Age (OL3).
Corg. – organic carbon; Pbulk – total phosphorus, Pmin. – mineral phosphorus,
Porg. – organic phosphorus, MB – microbial biomass; PhA – phosphatase activity,
UA – urease activity, LA – lipase activity, PA – protease activity

Рис. 7. Метод главных компонент для химических и микробиологических параметров.
1 – верхние горизонты (TS), 2 – культурный слой раннего железного века (OL1),
3 – культурный слой среднего – позднего бронзового века (OL2), 4 – культурный слой раннего бронзового века (OL3). Corg. – органический углерод, Pbulk – валовый фосфор; Pmin. – минеральный фосфор,
Popг. – органический фосфор, MB – микробная биомасса, PhA – фосфатазная активность,
UA – уреазная активность, LA – липазная активность, PA – протеазная активность

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