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GENESIS AND GEOGRAPHY OF SOILS

# Anthropogenic Sediments and Soils of Tells of the Balkans and Anatolia: Composition, Genesis, and Relationships with the History of Landscape and Human Occupation

**S. N. Sedov[a, b, c], A. L. Aleksandrovskii[d, *], M. Benz[e], V. I. Balabina[f], T. N. Mishina[f], V. A. Shishkov[d], F. Şahin[g], and V. Özkaya[g]**

[a] *Institute of Geology, National Autonomous University of Mexico, Ciudad Universitaria, C.P. 04510, DF, Mexico*
[b] *Tyumen Industrial University, ul. Volodarskogo 38, Tyumen, 625000 Russia*
[c] *Tyumen State University, ul Volodarskogo 6, Tyumen, 625003 Russia*
[d] *Institute of Geography, Russian Academy of Sciences, per. Staromonetnyi 29, Moscow, 119017 Russia*
[e] *Department of Near Eastern Archaeology, Albert Ludwig University, 79085 Freiburg, Germany*
[f] *Institute of Archaeology, Russian Academy of Sciences, ul. Dm. Ul'yanova 19, Moscow, 117036 Russia*
[g] *Dicle University, 21280 Diyarbakır, Turkey*
**e-mail: alexandrovskiy@mail.ru*

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**Abstract**—Soils and sediments composing Tell Körtik Tepe (Epipaleolithic, Turkey) and Tell Yunatsite (Chalcolithic (Eneolithic), Bulgaria) have been studied with the aim to gain a better insight into their microfabrics, determine the composition of anthropogenic artifacts, and, on this basis, to analyze similarities and distinctions between these objects and the modern soils of urban areas. The methods of micromorphology, scanning electron microscopy with an energy dispersive X-ray microanalyzer, X-ray fluorometry, and other techniques to determine the chemical and physical properties of the soils and sediments have been applied. Two paleosols have been identified in Tell Yunatsite with a total thickness of 9 m: the paleosol buried under the tell and the paleosol in its middle part. Sediments of Tell Körtik Tepe have a total thickness of up to 5 m; their accumulation began at the end of Pleistocene over the surface of buried paleosol. The cultural layer of the tells consists of construction debris mainly represented by a mixture of clay and sand and of domestic wastes with the high content of phosphorus. The major source of phosphorus is calcium phosphate (apatite) of bone tissues. The abundance of various anthropogenic materials in the sediments is clearly seen in thin sections. Even in the paleosols developed within the cultural layer (the mid-profile paleosol in Tell Yunatsite), the amount of microinclusions of bone fragments, charcoal, and burnt clay (ceramics) is very high. Micromorphological data indicate that up to 50% of the layered material filling an Epipaleolithic construction in Tell Körtik Tepe consists of the anthropogenic inclusions: bone fragments, charcoal, etc. The features of pedogenic transformation are present in the sediments. Such sediments can be classified as synlithogenic soils similar to the modern Urbic Technosols [22]. It is shown that the formation of paleosols and sediments of Tell Körtik Tepe took place under extreme environmental conditions—arid climate of the latest Pleistocene climate cooling phase (the Younger Dryas, Tell Körtik Tepe)—and intensive anthropogenic loads (tells Körtik Tepe and Yunatsite).

*Keywords:* urban sediments, urban soils, urbanozems, Urbic Technosols, soils of extreme anthropogenic sites, buried soils, pedolithogenesis

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## INTRODUCTION

The development of urban soils strongly transformed by anthropogenic processes in the settlements attracts keen interest of soil scientists. A larger part of the results obtained in this field concerns the mechanisms of formation, spatial diversity, and classification of urban soils of the modern urban territories, including megalopolises [9]. However, the development of urban soils is not limited to modern urban environments. Soils with an urbic horizon have been forming within the entire history of sedentary population and long-existing settlements. The assessment of spatial distribution of such soils in the past is of great significance for solving a large range of scientific problems, including the problems of pedodiversity, soil pollution, soil degradation, archaeological research, etc.

At present, considerable materials are available on urban soils and pedosediments (cultural layers, occupation deposits) in the antique and medieval settlements [2, 10] and on their dependence on the environmental conditions [15]. The high resilience of the major anthropogenic soil features even after restoration of the natural ecosystems in place of the former settlements has been demonstrated [2, 30]. It can be supposed that the history of urban pedogenesis is several millennia older than it is usually considered. Its beginning should be searched in the pre-agricultural and early agricultural societies and the related to them large permanent settlements that appeared simultaneously with the Neolithic Agricultural Revolution [29].

A series of such early settlements—tells (archaeological mounds; in Arabian, tell means "a hill")—has been discovered in the southeastern Turkey. These settlements date back to the beginning of the Prepottery Neolithic and attest to the early transition of people in Upper Mesopotamia to sedentary life at the beginning of the Holocene [23, 26–28]. Among these tells, Tell Körtik Tepe is the oldest settlement formed in the period of transition from the Epipaleolithic to the Prepottery Neolithic A (PPNA) at the end of Pleistocene–the beginning of Holocene. As follows from the radiocarbon dating, the development of this tell began at the end of the Younger Dryas cooling phase, in the Epepaleolithic (10400–10200 cal. BP) [17, 18] and ended in the Early Holocene (the PPNA layer).

Tells are a characteristic feature of Mesopotamian landscapes; their origin is related to the early settlements constructed of clay (turluk, mudbrick). There are small tells and large tells; Tell Brak and Tell Beydar are among the latter [13, 25]. Together with Uruk, Babylon, Nineveh, and many others ancient cities, they represent the earliest urban centers.

Tells constructed by the early agricultural societies were widespread in the Neolithic, Latest Neolithic (Chalcolithic), and Bronze ages within Mesopotamia, Asia Minor, Egypt, Balkans, Central Asia, Caucasus, and some other regions; they formed a specific "tell zone" typical of the steppe and desert environments of the Old World.

In this paper, we argue that the material composing relatively small early tells (Tell Körtik Tepe) and tells that appeared later (Tell Yunatsite) consists of analogous components, i.e., predominantly household and construction wastes. Being on the surface in the past and representing synlithogenic soils at present, the layers of tell sediments are an important element of ancient soil covers that allow us to perform paleosol reconstructions of the Holocene environments. We also argue that the properties of these soils meet the criteria of Urbic Technosols; the studied soils represent one of the earliest objects of that kind. As their properties were formed under the impact of ancient anthropogenic processes and do not correspond to the modern factors of soil formation, we consider these Technosols as paleosols. Sediments of tells, or cultural layers, preserve diverse features of pedogenesis that can be used for paleoreconstruction purposes. The works containing both pedological and sedimentological characteristics of the material of tells are few in number [12]. There is certain experience in the micromorphological analysis of the composition and structure of these materials [24, 33]. However, in most of the geoarchaeological investigations, micromorphology is mainly applied to characterize specific anthropogenic components with the aim to reconstruct the particular living activities of ancient humans [32].

Not only cultural layers that can be perceived as synlithogenic soils but also normal postlithogenic soils buried under them are of great interest for researchers [16]. Special studies of the latter soils are also few in number. It should be noted that such soils have been discovered under all the previously studied tells: Tell Arakhlo in Georgia, Tell Gindarkh in Azerbaijan, and Tell Yunatsite in Bulgaria. A well-developed full-profile soil has been identified in the middle part of Tell Yunatsite [1]. In this study, we analyze the first results of micromorphological investigations and data on the chemical properties of buried soils and cultural layers of two tells: Tell Yunatsite (Bulgaria) and Tell Körtik Tepe (Turkey).

## OBJECTS AND METHODS

**Tell Körtik Tepe** is a small (1.5 ha) low (5-m-high) mound at the confluence of the Batman Çayı and Tigris rivers (37°48′52″ N, 40°59′02″ E) (Fig. 1) in the southeastern Anatolia. It is elevated at about 520 m a.s.l. The study area has a Mediterranean climate; the mean annual temperature is 16.7°C, and the mean annual precipitation is about 500 mm. Summer is hot (about 35°C) and dry, and winter is cool, cloudy, and rainy. Gray cinnamonic soils typical of the subtropical regions with seasonally wet climate [6], or Calcisols [31] predominate in the soil cover. Considerable areas are used in the irrigation farming. It should be noted that the climatic and landscape conditions at the very beginning of the formation of this tell were colder and somewhat drier than those at present; at the beginning of the Holocene, they were warmer and wetter [18].

The parent materials are represented by the loamy sediments on river terraces and by the layered alluvium on floodplains. The upper part of loamy material on the terraces has a loesslike morphology. Tell Körtik Tepe is found in the marginal part of the low terrace (terrace T4 according to [20]) covered by the loesslike loam from the surface. In recent years, it has been subjected to plowing.

Soils and sediments of this tell were studied in archaeological trenches of rectangular (4 × 3.5 m) shape and down to 5.6 m in depth. In trench 104, the full sediment column was examined; in trench 21, the lower (Epipaleolithic) part of the sediments was studied in detail; and in trenches 116, 121, and 132, the soil buried under the tell sediments was studied. Samples

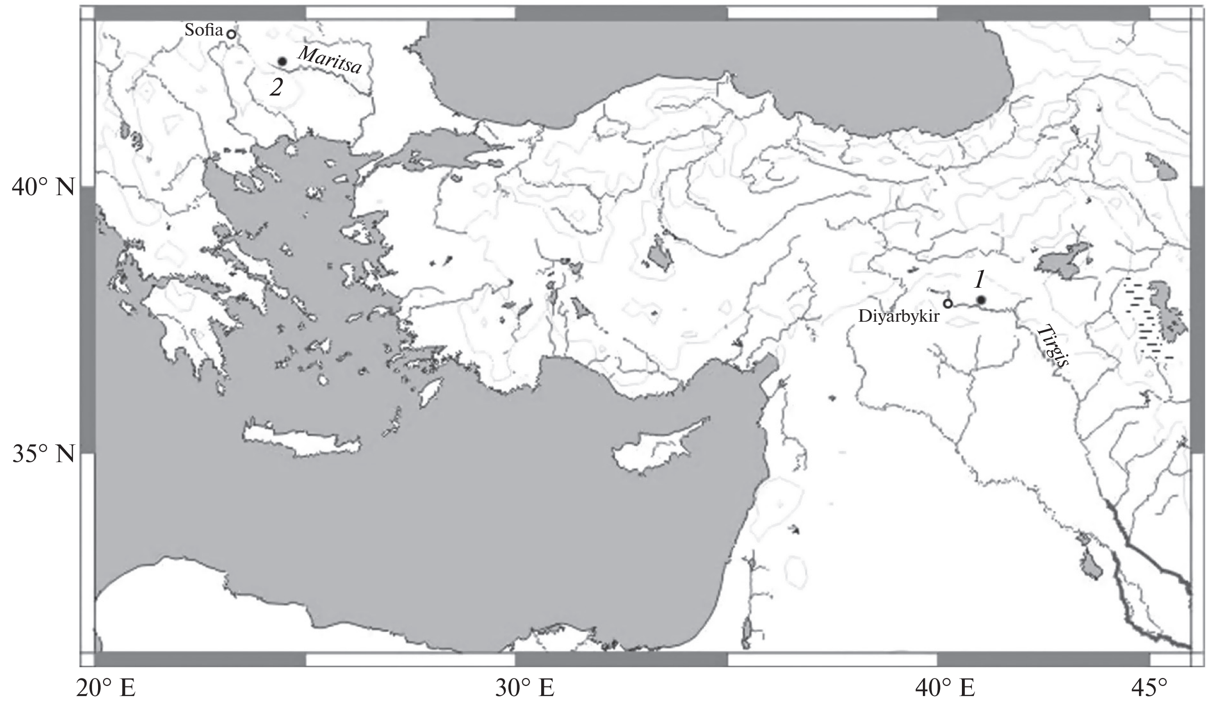


**Fig. 1.** Location of studied objects: (*1*) Tell Körtik Tepe and (*2*) Tell Yunatsite.

from the cultural layer and the soils were taken from each of the horizons separated according to their morphology and the presence of artifacts.

**Tell Yunatsite** occupies approximately the same area (about 1 ha), but it is less destroyed, because it is considerably younger and has never been plowed. It is found in the Upper Thrace (Bulgaria) on the bottom of a wide Thrace valley between the Rhodope and Sredna Gora Mountains, on the right bank of the western distributary of the Topolnitsa River not far from its confluence with the Maritsa River (42°13′56″ N, 24°15′46″ E). It's absolute height is 225 m a.s.l. Low terraces of the Topolnitsa River are composed of the loamy alluvium. The tell is allocated to a lower half of a gentle slope of the terrace. Chernozems and vertic chernozems are developed around the tell; cinnamonic and gray soils are also present in this area at the transition between steppe and forest-steppe landscapes with a moderately continental climate transitional to the Mediterranean climate. The mean July temperature is 23°C, and the mean January temperature is about 0°C. The mean annual temperature is 11.3°C, and the mean annual precipitation is 550 mm [5].

Sediments of the tell are represented by thick (9.2 m) calcareous loams. They are derived from the remains of constructions built of clay (turluk, mudbrick) and transformed by pedogenesis and diagenesis. In the sediment column within the main part of the tell, the deposits of the Early Bronze Age and Latest Neolithic lie at the depths from 2.5 to 10 m and are separated by a soil profile in the middle; the soil buried under the tell could also be studied in this section. Sediment layers and buried soils contain valuable information on the environment in the Middle Holocene. With the aim to reconstruct the paleoenvironmental conditions, special carpological, palynological, and phytolith studies were performed [4, 7].

The physical and chemical analyses included the determination of $C_{org}$ by the wet combustion method (according to Tyurin); $P_2O_5$, by Ginzburg's method; $CaCO_3$, by the acidimetric method (according to Kozlovskii); and trace elements, by the X-ray fluorometry.

Micromorphological studies were applied to study modern urban soils [8] and ancient cultural layers [30]. They ensured reliable identification of the inclusions of anthropogenic materials (microartifacts) and the features of weakly pronounced pedogenetic processes. Undisturbed samples from the lower parts of the cultural layer of both tells and from the buried paleosols were used to prepare thin sections; the latter were described in agreement with terminology suggested in [19].

The materials from the lower horizons of Tell Körtik Tepe were examined under a scanning electron microscope JEOL 6610 LV equipped with an energy dispersive X-ray spectrometric analyzer INCAXact (Oxford Instruments). Before the microscopy, the specimens were coated with platinum in an auto fine coater JEOL JFC1600.

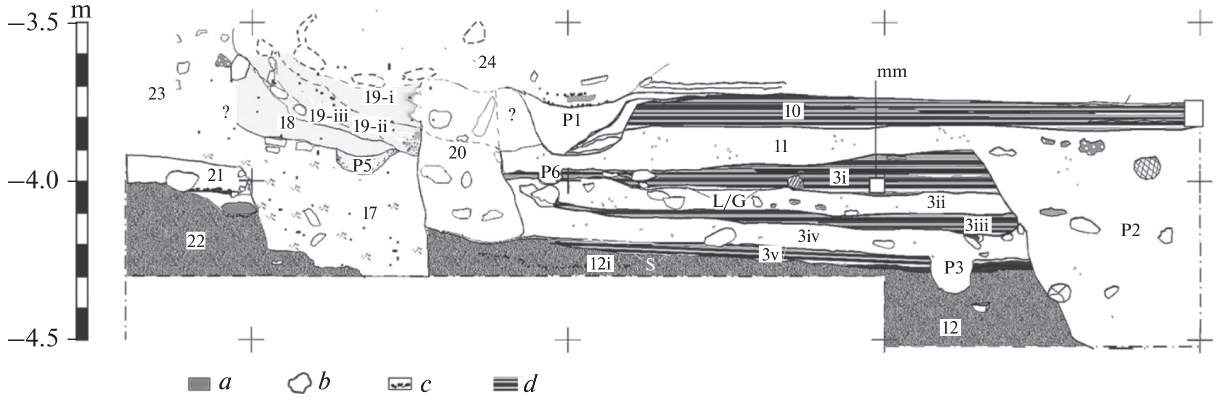


**Fig. 2.** Tell Körtik Tepe, Epipaleolithic layer in the eastern section of trench 21: thin-layered sediments of dwelling floors (3i, 3iii, 3v, and 10) alternating with the layers of leveled surface (3iv, 3ii, and11); S—sand; P—pit; mm—loci of sampling for the micromorphological study; (*a*) clay; (b) stones; (c) charcoal; and (d) thin-layered sediments.

## RESULTS

### *Morphology and Age of Sediments and Soils*

**Tell Körtik Tepe.** According to the results of radiocarbon dating, the beginning of sediment accumulation in this tell dates back to the end of the Younger Dryas stage, 10 400–10 200 cal BC [17, 18], which coincided with the appearance of the river terrace (terrace T4), on which the tell is found [20]. The accumulation of the lowermost Epipaleolithic layer and the overlying Prepottery Neolithic A layer (PPNA) with a total thickness of 5 m continued for about 700 years.

The total thickness of sediment columns studied in archaeological trench 104 is 5 m. The upper 100–150 cm contain the material accumulated in the medieval period; the modern soil profile is developed from it. Below, the PPNA layers are distinguished, and the lowermost meter of the section belongs to the Epipaleolithic. The morphology of this layer (trench 21) is shown in Fig. 2.

All the layers mainly have a loamy sandy texture; their color varies from brownish light gray (10YR 6/2) to gray or dark gray (10YR 5/1-4/1). Some interlayers are enriched is sand. Bones of fish and wild mammals are often present. There are laminae of ash material. Fragments of pottery are absent. All the layers contain the remains of rounded constructions with a gravelly base. The periphery of oval-shaped dwellings are outlined by river pebbles covered with clay that formed the walls. The continuity of the layers is disturbed by numerous pits, some of which are deep enough to reach the base of the tell and penetrate the buried natural soil.

The layers with thin lamination are often seen in the sections, especially in their lower parts. Such laminated sediments were studied in detail by archaeologists and soil scientists in the Epipaleolithic dwelling described in trench 21 and several other trenches. They were identified as the floors of the dwellings [18]. They are characterized by the high content of charcoal, including fine charred particles that ensure dark color of the sediments.

The soil buried under the lowermost Epipaleolithic layer has a relatively thin profile and consists of three horizons with distinct effervescence: the weakly developed layered humus horizon (A, 5–10 cm; 10YR 6/3-6/4 (light brown to light yellowish brown)), light-colored and poorly structured B horizon (B1, 5–10 cm, 10YR 6/4 (light yellowish brown)), and the well-structured clayey horizon with carbonate concretions (BCA, 10YR 5/4 (yellowish brown)) of more than 40 cm in thickness. It is underlain by the parent material (Cca, 10YR 5/4 (yellowish brown)). The genesis and classification position of this soil are open to argument. It is probable that, as well as modern soils of the region [31], it should be attributed to Calcisols.

**Tell Yunatsite.** The chronology of sediments composing this tell is based on the results of radiocarbon dating. Within the thickness belonging to the Early Bronze Age, the dates for the lower layers (VII–XV) are within the interval from 4280 ± 60 to 3830 ± 60 yrs. (Bln-3685 and Bln-3668, respectively; Bln is the index of the Radiocarbon Laboratory in Berlin). For the upper horizons (I–VI), they are within the interval from 3780 ± 50 to 3700 ± 50 yrs. (Bln-3658 and Bln-3659) [21]. Close results for the lower horizons were later obtained in the Radiocarbon Laboratory of the Institute of Geography of the Russian Academy of Sciences in Moscow [11].

The morphology of sediments in the central part of Tell Yunatsite (section D) is characterized by the layered character; dark laminae enriched in charcoal and charred particles are clearly seen. These sediments mainly have a loamy texture. The remains of pits are seen in the sections. The sediments contain inclusions of the fragments of large ceramic vessels for grain storage (pithoses) and interlayers enriched in ash and charcoal particles and, in some places, with burnt grains of cereals, bones of domestic and wild animals, and pottery fragments.

In contrast to the only one weakly developed profile of the natural soil buried under Tell Körtik Tepe, Tell Yunatsite contains two profiles of well-developed buried soils. The upper profile is found at the depth of about 5 m in the middle of the deposit. The lower profile (9.2 m) is buried under the tell. The soil in the middle part of the deposit is clearly distinguished against the background of the cultural layers by its color and morphology. The cultural layer is of the light grayish yellow color with darker mottles and interlayers. The soil is much darker, and its dark gray-brown color pattern is more homogeneous. The crumb–granular structure of the soil material is very distinct, especially in the upper dark-humus (AU) horizon. The transitional AB horizon is somewhat lighter in color and has the crumb structure. In general, the soil profile in the middle part of the anthropogenic deposit consists of the system of humus horizons AU–AB with a gradual attenuation of the gray humus color in the lower part. Below, the carbonate-accumulative BCA and the carbonate-bearing Cca horizons are distinguished. The effervescence is observed in the entire profile. The BT horizon typical of the forest soils in the region is absent. At the same time, there are numerous rounded tunnels of earth-burrowing animals of 5–10 cm in diameter (the tunnels of such shape and sizes are usually left by mole-rats, susliks, marmots, etc.). This soil can be classified as a Chernozem. However, it inherits from the parent material (cultural layer) numerous pottery fragments, animal bones, charcoals, and other anthropogenic inclusions.

The lower buried soil (920–1000 cm) overlain by the Chalcolithic layer of the tell has a thicker profile, but less distinct coloring with humus. The soil material has a crumb structure. The entire profile contains carbonate pedofeatures in the form of disperse calcite and calcitic veins. In the upper part of the soil profile, numerous inclusions of the Chalcolithic pottery are found.

The cultural layer of the tells also contains various pedogenetic features: secondary calcite, aggregation, porosity related to the paths of roots and animals, etc. (see below). It represents a synlithogenic formation and can be attributed to Urbic Technosols.

### *The Results of Micromorphological Study*

**Tell Körtik Tepe.** In thin sections from the lower (Epipaleolithic) part of the cultural layer, specific interlayering of thin lenses composed of different anthropogenic materials is clearly seen. Some of the lenses are composed of bone fragments and charcoal particles retaining their cellular structure; they alternate with the microlayers composed of coarse sand particles (Fig. 3a). Phytoliths often form oriented accumulations inheriting the structure of plant tissues. Such accumulations of the phytoliths could be formed from the heaps of herb or straw litter; it cannot be excluded that they were initially present in the excrements of domestic animals (Fig. 3b). The carbonates are represented by the loose concentrations of small calcite crystals (microsparite and sparite) of the biogenic and pyrogenic origins (Fig. 3c). Similar components were identified in thin sections from the cultural layer of the tells by other researchers, though their presence in such high concentrations was not recorded [24, 33]. Thin sections from the natural soil buried under the cultural layer attest to the abundance of micrite in the soil mass. The indications of pedogenesis are seen in the granular coprogenous microstructure in the A horizon, and diagenetic features are represented by iron concretions (Fig. 3d). In the B horizon, there are angular blocky peds; some of them are wedge-shaped, which is indicative of the vertic properties (Fig. 3e). Few coarse charcoal particles in the A horizon (Fig. 3f) may be related to the anthropogenic activity.

**Tell Yunatsite.** Indications of the presence of anthropogenic materials are abundant not only in the cultural layer proper but also in the paleosols. Thus, in the mid-profile paleosol developed from the Chalcolithic cultural layer, there are abundant charcoals and bone fragments inherited from the parent material. The coprogenous granular structure of the AU and AB horizons represents the feature formed during the pedogenesis in the cultural layer. It is characterized by the presence of loosely packed microaggregates forming a specific spongy microfabric with the high porosity (Fig. 4a).

In the AB and BCA horizons, there are accumulations of the newly formed microcrystalline calcite (micrite) that forms continuous films on some pore walls. At the same time, primary carbonates, including large fragments of mollusk shells (Fig. 4b), are present in the soil mass within the entire profile. Microscopic particles of the materials derived from the human activity are also present in the profile. They include bone fragments, burnt bone fragments (Fig. 4c), small blocks of burnt clay, pottery fragments (Fig. 4d), small charcoal particles derived from herbs, and coarse charcoal particles derived from arboreal vegetation. The latter can be seen not only in the upper horizons but also in the middle BCA (carbonate-accumulative) horizon. In general, taking into account that a considerable part of sand and clay fractions consists of the remains of dwelling constructions, the portion of the added anthropogenic material in this soil may exceed 50%.

In the paleosol buried under the tell, the composition of soil mass is different from that in the mid-profile paleosol: sand particles, including coarse sand, are more abundant, and the portion of clay and silt fractions is smaller. This difference in the textures of the

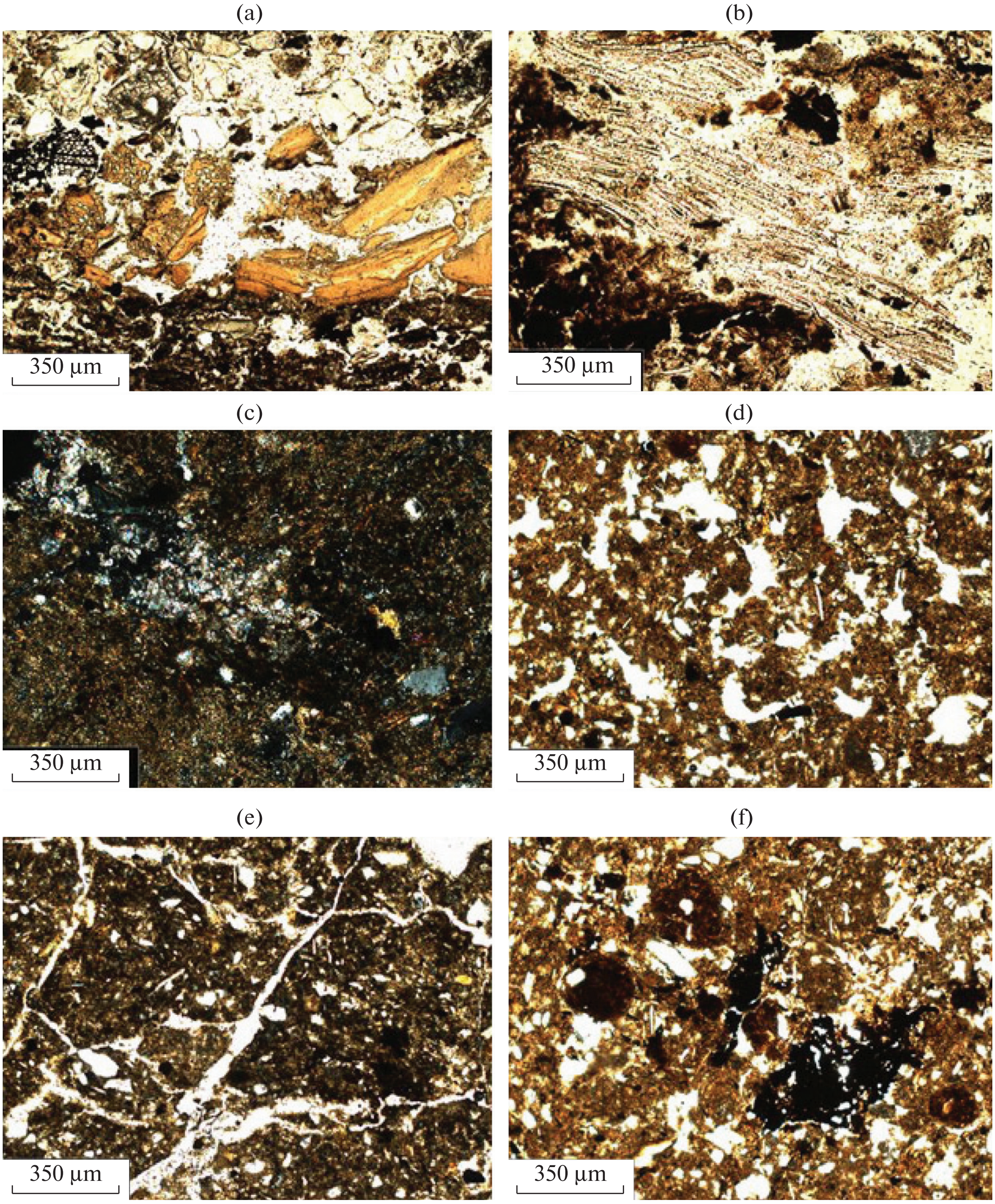


**Fig. 3.** Micromorphology of paleosols and cultural layers of Tell Körtik Tepe: (a) microlamination of the material of the cultural layer—a lens composed of bone fragments (center) and charcoal (left side) covered by the accumulation of sand particles (upper part of the visual field); Epipaleolithic layer (without analyzer); (b) accumulation of elongated phytoliths with subparallel orientation, Epipaleolithic layer (without analyzer); (c) loose cluster of calcite grains, Epipaleolithic layer (N ×); (d) granular microstructure and spongy fabric of the A horizon of the paleosol under the tell (without analyzer); (e) angular blocky to wedge-shaped structure of the B horizon of the paleosol under the tell (without analyzer); and (f) charcoal particles in the A horizon of the paleosol under the tell (without analyzer).

two soils points to the fact that a large part of the raw "construction material" of the tell was taken from some remote places of different composition in comparison with the underlying soils and sediments. Analogous observations were made in the tell in Mesopotamia: the mineral mass of its material corresponded to that in the surrounding sedimentary rocks, though it differed from the local deposits in its structure and had a mixed character attesting to the transfer of the material by humans [33]. The coprogenous structure of the

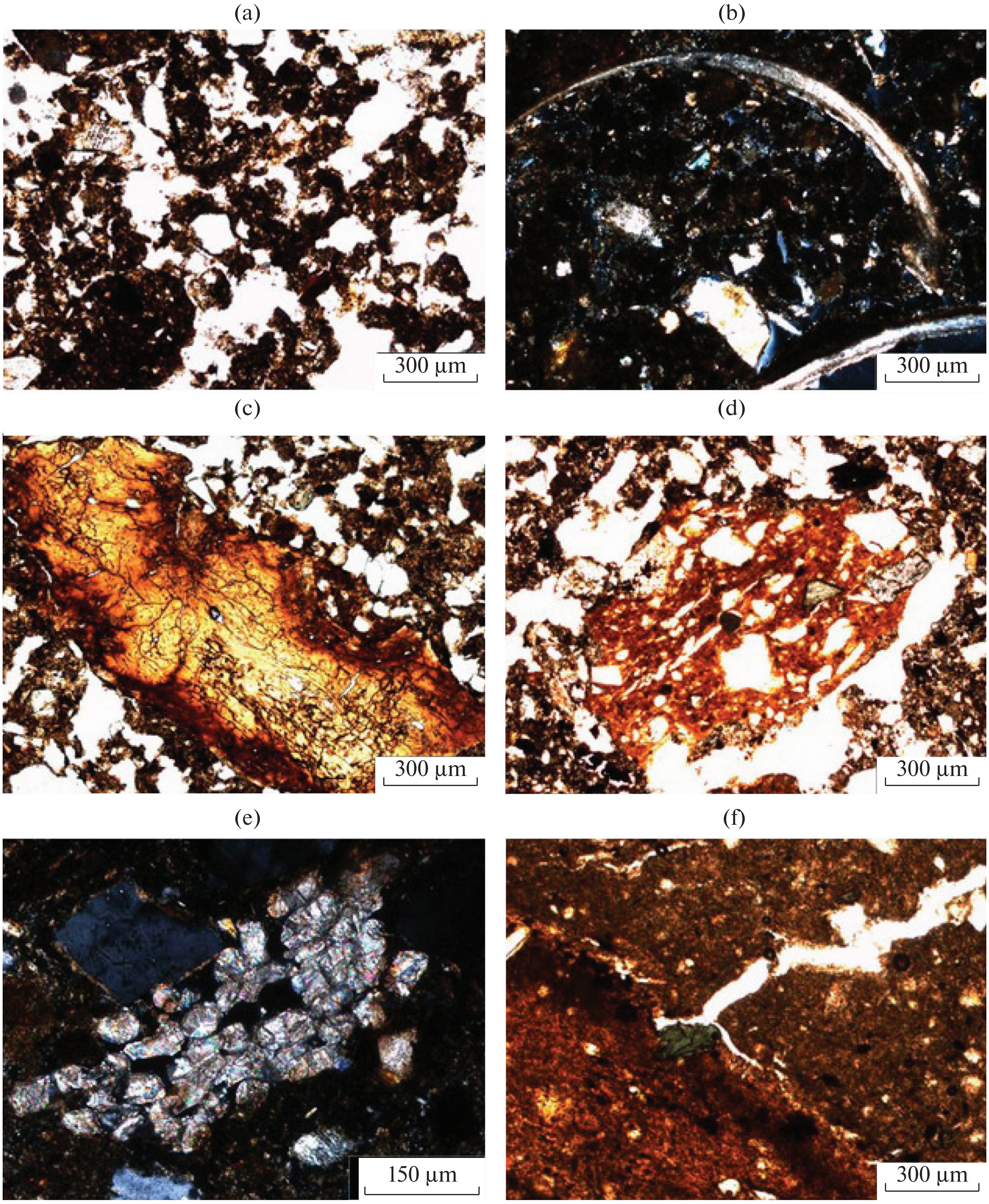


**Fig. 4.** Micromorphology of paleosols and cultural layers of Tell Yunatsite: (a) spongy fabric and high microporosity, AU horizon of the mid-profile paleosol (without analyzer); (b) fragment of a mollusk shell, AU horizon of the mid-profile paleosol (N ×); (c) charred bone fragment, AU horizon of the mid-profile paleosol (without analyzer); (d) pottery fragment, AU horizon of the mid-profile paleosol (without analyzer); (e) compact concentration of newly formed calcite grains (pseudomorphic substitution of root tissues), BCA horizon of the paleosol buried under the tell (N ×); and (f) highly compacted microfabric with single fissures, cultural layer immediately above the buried natural soil (without analyzer).

upper horizon of the paleosol buried under Tell Yunatsite is less pronounced than that in the mid-profile paleosol, and the primary carbonates in the form of sand-size debris of calcareous rocks are more abundant. Secondary carbonates are represented by micrite and by coarser crystals forming pseudomorphic substitutions of root cells (Fig. 4e).

The microfabric of the cultural layer immediately above the lower buried paleosol has a number of specific features. It consists of the compact material

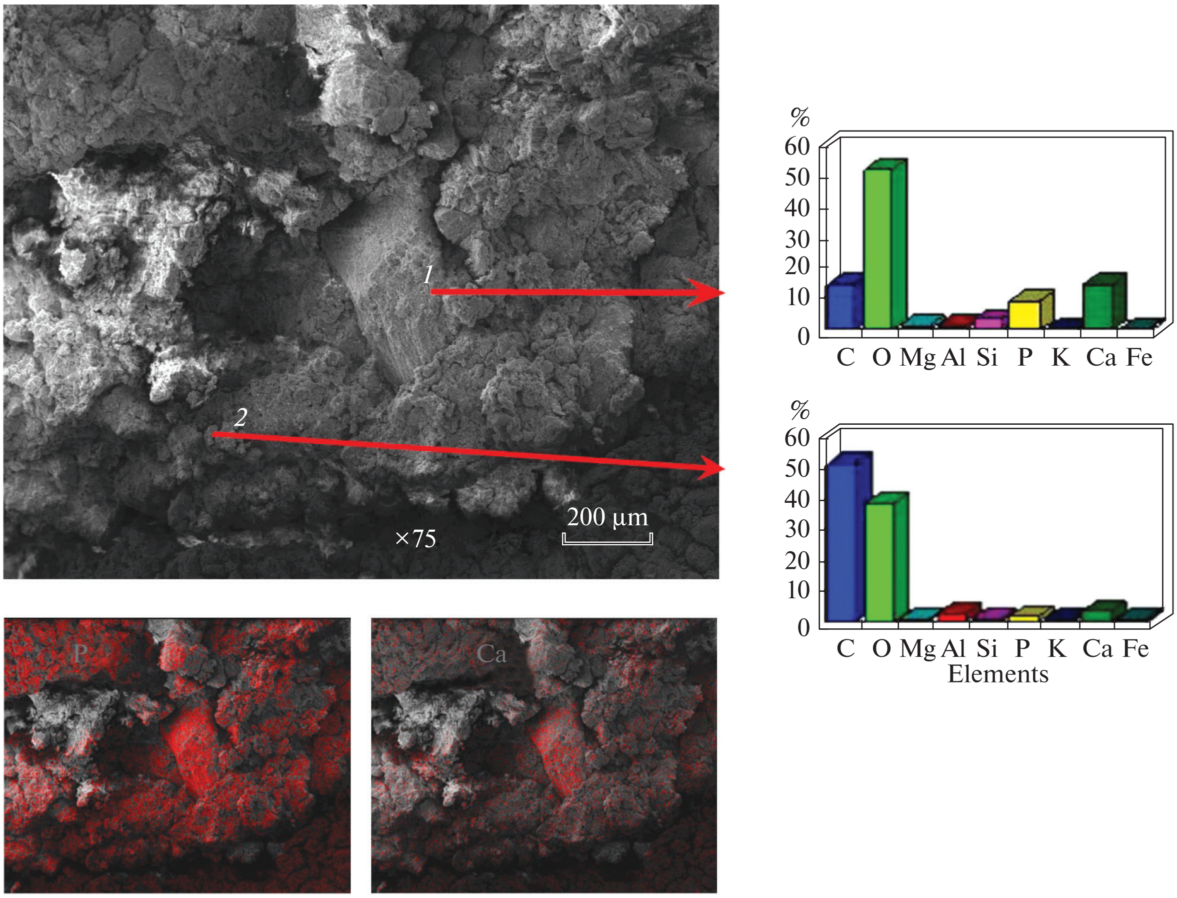


**Fig. 5.** Results of scanning electron microscopy obtained for (*1*) bone fragment and (*2*) charcoal. Element concentrations are given in wt. %. Under the image, the maps of P and Ca distribution are given.

enriched in clay (sandy and silty particles are present in small numbers) impregnated by iron hydroxides and humic substances. Visible pores are represented by single discontinuous fissures that do not separate the soil mass into well-shaped aggregates (Fig. 4f). It is probable that this soil mass is derived from some fragments of former constructions made of turluk, mudbricks, or clayey plaster.

Thus, the results of micromorphological studies lead us to a conclusion that more than a half of the material of the tells has an anthropogenic origin. This is particularly true for Tell Körtik Tepe, where the main mass drastically differs in its composition from natural soils and is composed of the components generated by the living activities if humans. For Tell Yunatsite, this conclusion is less evident, because the composition of its mineral base is close to that of natural soils and sediments in the region. However, it has been shown that this material was transported and redeposited by humans. We argue that the sediments composing both tells can be considered synlithogenic Urbic Technosols; they meet the diagnostic criteria of this group of soils. Normally developed lower and upper postlithogenic soils in the Yunatsite section differ from one another. The lower soil was developed from the natural sediments, whereas the upper (middle-profile) soil was formed from the human-derived cultural layer.

### *The Results of Chemical Analyses*

**Tell Körtik Tepe.** Detailed information about the distribution and composition of bone fragments and organic matter in the sediments was obtained with the use of scanning electron microscopy and X-ray dispersive element analysis (Fig. 5). The cultural layer contains microfragments of bones preserving their structure and clearly diagnosed from the dominance of Ca, P, and O in their composition. An analogous composition is typical for a larger past of the surface of the cultural layer, but the presence of bone fragments in it can only be judged from analytical data. These fragments cannot be visually detected, because they are mixed with other components of the cultural layer, including silicates (with a predominance of Si and O in their elemental composition) and charcoal particles (with a predominance of C and O).

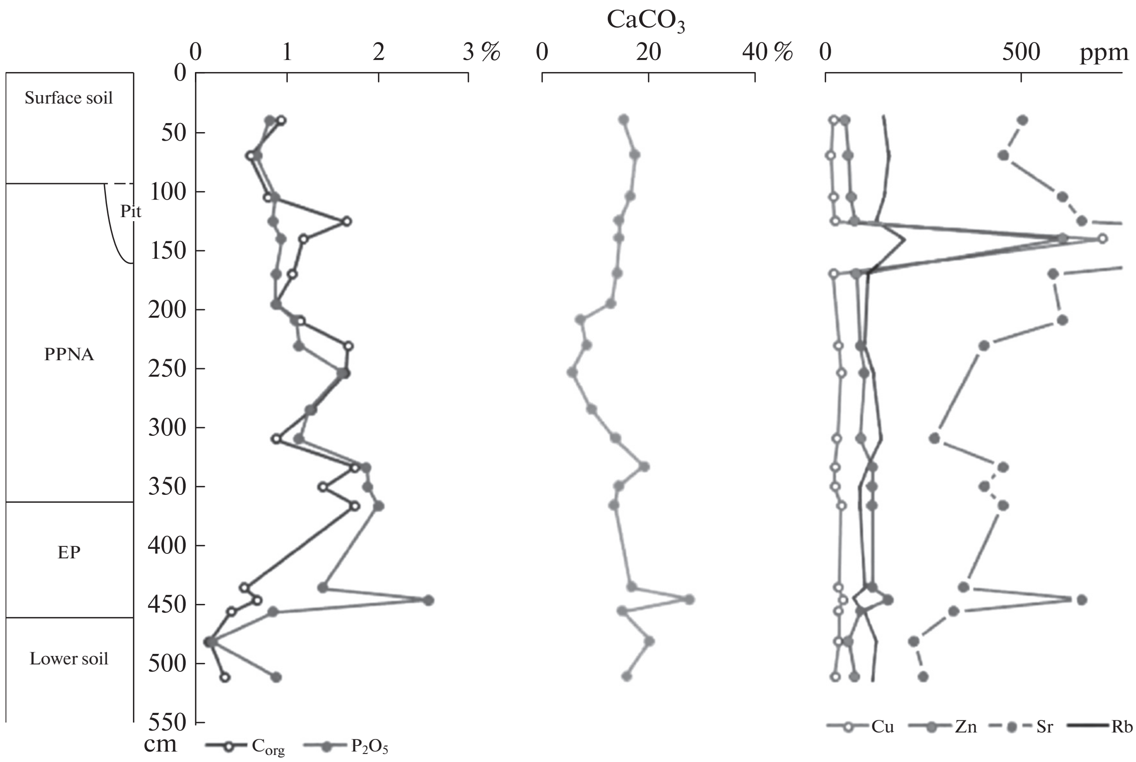


**Fig. 6.** Some results of the analyses of soils and sediments of Tell Körtik Tepe (trench 104); EP—Epipaleolithic layer and PPNA— Prepottery Neolithic A (PPNA) layer.

The distribution of elements in the profile of Tell Körtik Tepe is characterized by considerable heterogeneity. The accumulation of phosphorus related to the presence of animal bones is clearly seen in the lower layers (Fig. 6).

The contents of phosphorus, organic matter, and pedogenic carbonates were determined in the Epipaleolithic layer of trench 21 at the level of the dwelling floor, at the depths of –4.00 to –4.25 м. Inside the dwelling, the phosphorus content reaches 1.37–1.79%; outside it, it is even higher (1.75—2.14%, table). At the level of –4.50 m, under the dwelling and outside it, the phosphorus content decreases to 1.05–1.48%. Analogous differences between dwelling loci and the surrounding mass are seen in the distribution of organic matter mainly represented by the products of charcoal decomposition. The sandy layer under the layered floor of the dwelling (Location 2, –4.31 m; Fig. 2) is characterized by the considerably lower contents of organic matter, phosphorus, and $CaCO_3$: 0.28, 0.34, and 2.1%, respectively. This attests to the allochthonous genesis of sand. It could be taken from the river channel and used as a filling for the floor. This sand consists of large rounded grains of quartz and silicate mineral and was obviously transferred by ancient humans from the outside. It has been clearly seen in thin sections from the cultural layer. Later, this sandy layer was enriched in the organic matter, phosphorus, and carbonates leached off from the cultural layer into this soil.

In the lowermost horizons of the cultural layer, only Zn displays a significant accumulation among trace elements. The high content of Zn, as well as several other elements (Cu, Pb, As), was only found in the upper horizons of the cultural layer.

In the Epipaleolithic and PPNA layers, the contents of clay and carbonates are lower than those in the underlying buried paleosol and in the overlying carbonate-accumulative (BCA) horizon of the modern soil. The $C_{org}$ content in the modern surface soil is relatively low, which corresponds to the dry climatic conditions and the dehumification effect of the soil plowing.

**Tell Yunatsite.** The phosphorus content in the cultural layer of this tell is approximately the same as that in Tell Körtik Tepe; the organic matter content is somewhat higher, whereas the content of carbonates is lower. The results of chemical analyses of 70 samples taken from column D attest to sharp fluctuations in the contents of phosphorus, $C_{org}$, and carbonates (Fig. 7). Numerous peaks are related to the heterogeneity of the cultural layer and are specified by the particular kinds of human activity. Thus, the phosphorus content reflects the intensity of the input of the remains of animals (bones and other tissues) and their excrements.

The content of carbonates in the cultural layer is controlled by the anthropogenic and natural factors.

Results of chemical and physical analyses of the soils of Tell Körtik Tepe

| Horizon, sample | Depth, cm | $pH_{H_2O}$ | $C_{org}$ | $P_2O_5$ | $CaCO_3$ | Clay | Notes |
|---|---|---|---|---|---|---|---|
| | | | % | | | | |
| Buried soil from trench 21, southern wall | | | | | | | |
| CL | 0–10 | 8.50 | 1.20 | 1.61 | 10.4 | 12.9 | None |
| CL/A | 10–15 | 8.45 | 0.49 | 0.70 | 11.8 | 16.7 | " |
| A | 15–22 | 8.45 | 0.31 | – | 12.0 | 20.8 | " |
| B1 | 22–32 | 8.50 | 0.16 | – | 13.1 | 28.0 | " |
| BCA1 | 32–45 | 8.65 | – | 0.31 | 13.8 | 32.0 | " |
| BCA2 | 45–55 | 8.90 | – | | 20.4 | 44.2 | " |
| Cultural layer, trench 21 | | | | | | | |
| $D3_{north}$ | 422 | 8.95 | 1.61 | 1.37 | 11.0 | – | Inside the dwelling walls |
| $D3_{north}$ | 431 | – | 0.28 | 0.34 | 4.7 | – | Sand interlayer |
| $D3_{south}$ | 423 | – | 1.31 | 1.79 | 12.0 | – | Inside the dwelling |
| $D3_{north}$ | 450 | – | 1.45 | 1.48 | 13.8 | – | Under the dwelling |
| $C4_{west}$ | 425 | – | 1.61 | 1.60 | 11.2 | – | Inside the walls |
| $E2_{south}$ | 400 | – | 2.06 | 2.00 | 12.7 | – | Outside the dwelling |
| $E1_{east}$ | 420 | – | 2.21 | 2.14 | 12.9 | – | Pit (?) |
| $A1_{west}$ | 420 | 8.70 | 1.59 | 1.96 | 12.9 | – | Beyond the dwelling |
| $A1_{west}$ | 450 | 8.75 | 0.66 | 1.05 | 12.4 | – | Under the dwelling |
| $C1_{west}$ | 420 | – | 1.43 | 1.75 | 12.1 | – | Beyond the dwelling |

CL is the cultural layer; $D3_{north}$ is the designation of the square and wall, from the which the sample was taken. Dashes stand for "Not determined."

Anthropogenic processes specify numerous sharp peaks in the $CaCO_3$ content. However, the smoothed curve of the content of calcium carbonates reveals changes that might be related to the intensity of leaching processes and, hence, to changes in the atmospheric precipitation.

## DISCUSSION

**Tell Körtik Tepe.** The soil profile buried under the tell is relatively thin, though it has a rather complex morphology. Thus, two separate layers enriched in carbonate concretions can be specified in the carbonate-accumulative horizon of this soil. The complexity of the soil morphology allows us to suppose that this paleosol had been developing for a long time and had passed through several pedogenetic stages before being buried under the tell. Its lower clayey horizon has a distinct vertic microstructure. It is probable that it was formed during the early stage of pedogenesis. This is confirmed by the radiocarbon date of carbonate coatings on the lower sides of pebbles found in the BCA horizon [18]. The genetic nature of this soil has yet to be explained.

The properties of the humus (A) horizon of the buried paleosol give us some information about the paleoenvironmental conditions immediately before the appearance of the Epipaleolithic settlement. This horizon is thin (<10 cm) and has a distinct biogenic microstructure, though a low humus content. The layered morphology of this horizon could be due to eolian processes before the appearance of the settlement, or due to some anthropogenic impacts during the initial period of human occupation. The presence of charcoal particles in thin sections can be indicative of the influence of humans on the soil development.

The chemical analysis of the sediments in trenches A21 and A104 shows that they are enriched in phosphorus. Organic remains of the animal origin and grain could be the major source of phosphorus in the cultural layer [18]. Plant residues are the main source of organic matter in the sediments of the cultural layer. It mainly consists of fine charcoal particles (Fig. 6). In the buried soil, the $C_{org}$ content is considerably lower, though some accumulation of both the organic matter and phosphorus is seen in the topmost part of this soil. This may be related to the anthropogenic impact on the paleosol before it was buried and/or to some illuviation of phosphorus into this soil from the overlying cultural layer after the soil was buried.

The phosphorus content in the lower part of the cultural layer is somewhat higher than in the middle and upper parts, because there are many dwellings and their surroundings in the lower part of the cultural layer in the examined tranches. In the layered deposits of the floors of Epipaleolithic dwellings, the concentration of phosphorus ($P_2O_5$) is high (1.37–1.79%); it is even higher near the walls outside the dwellings, where kitchen and other domestic wastes could accumulate. In the upper horizons, the participation of the material of ancient constructions made of mudbrick in the composition of the cultural layer is more significant. The accumulation of organic carbon in the lower part of the cultural layer can be related to the high concentration of charcoal remains in this part of the sections.

The chemical composition of the multilayered floors of the dwellings is similar to that of the nonlayered material lying between the thin-layered units. Thus, we can suppose that all these sediments originated from the similar source materials, and the hypotheses about their alluvial or some other natural origin do not have sufficient grounds.

The properties of the investigated layers of the tell dating back to the Epipaleolithic and the PPNA are largely similar to the properties of the cultural layers of modern cities. The latter layers also consist of construction debris and contain domestic wastes. Cultural layers of Tell Körtik Tepe, as well as Urbic Technosols and sediments of modern cities, are enriched in phosphorus getting into the soil with animal bones, which is confirmed by the microscopic study of thin sections and by the results of scanning electron microscopy. The organic matter content in them is low, which is typical of the cultural layers forming under conditions of a droughty climate [2]. Some increase in the $C_{org}$ content is observed in the Epipaleolithic layer in the lower part of the cultural layer, which might be explained by the presence of charred particles seen in thin sections. However, it rarely exceeds 2%.

In contrast to phosphorus, concentrations of many other "anthropogenic" elements (in particular, Cu and Zn) in the studied Epipaleolithic layer is considerably lower than that in the modern Urbic Technosols. The contamination of the cultural layer with most of the pollutants began later, in the Bronze and Iron ages, when copper, lead, tin, and other elements found their application in industry and in household activities [14]. Extremely high concentrations of a number of elements (Cu, Zn, As) appeared in the cultural layer of Tell Körtik Tepe only in its medieval part [18], for which, as well as for the whole recent millennium, the contamination with these elements was typical.

**Tell Yunatsite.** Paleoreconstructions obtained from the study of the buried paleosols and the cultural layer of this tell are somewhat different. The study of the profile of postlithogenic paleosols allows us to make more definite conclusions based on a large set of morphological and analytical data. At the same time, these data reflect the "averaged" history of the environment for a long period of the soil formation under conditions of a stable surface. They mainly characterize the latest stages of the soil development. In the paleosol buried under the tell, the content of carbonates is high. In the mid-profile paleosol, carbonates were partly leached off from the humus horizon and accumulated in the BCA horizon. It can be supposed that the latest stages of the formation of the lower paleosol took place under conditions of a drier climate than that during the formation of the mid-profile paleosol and modern surface soil.

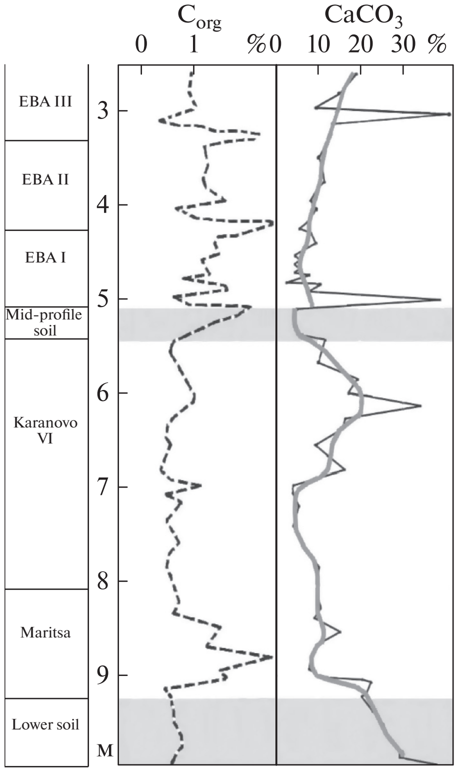


**Fig. 7.** The contents of Corg and calcium carbonates in the paleosols and cultural layers of Tell Yunatsite.

The environmental record in the cultural layer is of the soil–sedimentary type. It is characterized by a greater degree of detail in comparison with the normal soil record. Under conditions of a high rate of accumulation of sediments of the cultural layer, we can use data on the contents of pedogenic carbonates for the paleoenvironmental reconstructions. This characteristic is more dynamic than humus accumulation and is sensitive to centennial changes in the environment [3]. On the smoothed curve of the $CaCO_3$ content, we can distinguish between the layers with an increased and decreased content of carbonates and relate them to changes in the climatic humidity. Thus, the parts of the curve corresponding to the depths of 7–7.5 and about 4.5 m are characterized by the minimum content of carbonates. Carbonates were leached off from these layers, and this could take place under conditions of a more humid climate. This conclusion is confirmed by the paleobotanical data [3].

Micromorphological features of pedogenesis also carry paleoenvironmental information. The fact that both paleosols contain primary carbonates without definite features of their dissolution attests to the arid conditions of the soil formation. The well-developed biogenic structure and high porosity in the mid-profile paleosol might be indicative of some humidization of the climate. It is also important that this soil was developed from the human-transformed sediments of the cultural layer, which is proved by the abundance of microartifacts in all the horizons.

The curve of changes in the degree of climatic moistening was built on the basis of data on the $CaCO_3$ content and the composition of charcoals [3]. The periods of leaching of the carbonates and, hence, higher humidity of the climate were observed 4950–4529 cal BC and about 2500 cal BC [1]. Similar results were obtained from the palynological and phytolith studies [4, 7].

Sediments of the cultural layer of both tells generally have the high contents of phosphorus and carbonates. This is typical of thick urbosediments and deposits of ancient settlements in arid and semiarid regions [15]. The phosphorus concentration in the studied tells is considerably higher than that in the rural settlements and within the main part of recent cities.

The anthropogenic effects can be seen not only in the composition of the cultural layers but also in their structural features. Thus, the lowermost layer immediately above the buried soil is characterized by the high compaction and the predominance of clayey material. It can be supposed that we deal with the remains of a clayey floor of the dwelling.

Thus, both tells have normal postlithogenic soils and sediments (cultural layer) containing the features of synlithogenic pedogenesis. The pedogenic features in the cultural layer are revealed from the morphological, micromorphological, and analytical data. The presence of more than 50% of the anthropogenic materials (construction and household wastes, burnt layers, charcoal, bones, plant remains, ceramics, etc.) in these sediments that can also be referred to as synlithogenic soils or pedolithosediments allows us to classify them as Urbic Technosols [22]. Paleosols of Tell Yunatsite were developed under steppe vegetation and belong to Chernozems. The modern conditions in this area correspond to the steppe–forest-steppe transition [3]. The mid-profile paleosol in this tell was formed from the already deposited cultural layer (Urbic Technosol). The high content of anthropogenic materials in the BCA and Cca horizons of this soil allows us to identify it as a Chernozem developed from the Urbic Technosol (or as a chernozem developed from the technogenic substrate). The paleosol buried under Tell Körtik Tepe was formed under colder and drier climatic conditions in comparison with those at present [18]. The properties of this paleosol considerably differ from the properties of surface soils in the studied region that are classified as gray cinnamonic soils according to [6] and as Calcisols according to [31].

## CONCLUSIONS

The mid-profile and lower soils of Tell Yunatsite are represented by the dark humus and carbonate-accumulative horizons and belong to chernozems, which allows us to suppose that these soils were formed under steppe and forest-steppe landscapes. The features of anthropogenic impacts are not vividly expressed in the profiles of these soils. Pottery fragments are found in the mid-profile soil and in the upper part of the soil buried under the tell. Indications of the anthropogenic features are better pronounced in thin sections. Their micromorphological analysis allows us to identify artifacts that could not be observed by naked eye. It is important that this method makes it possible to show the allochthonous nature of the mineral material in the cultural layer, because it differs from that in the surrounding local soils and natural sediments.

Morphological and microscopic studies of the cultural layer of Tell Körtik Tepe indicate that the anthropogenic materials related to the early occupation of this site compose the major part of the Epipaleolithic layer. Their abundance results in considerable differences in the chemical composition and texture of this layer in comparison with the underlying natural paleosols. Thus, this layer formed on the buried paleosol surface and containing more than 50% of the anthropogenic material (artifacts) meets the diagnostic criteria of Urbic Technosols.

According to our data on Tell Körtik Tepe, the environmental conditions during the development of the buried natural soil and the formation of the Epipaleolithic cultural layer were rather harsh: the climate was drier and colder, because the latest phase of the Pleistocene cold period (the Younger Dryas) still continued. The occupation of this territory by ancient humans was accompanied by considerable anthropogenic loads. According to paleobotanical data. the vegetation of the Younger Dryas corresponded to that of a relatively dry open land with participation of riverine flora [18]. However, the ancient Körtik Tepe settlement appeared in the upper Tigris reaches in that period despite its climatic extremes. It is probable that this settlement was not the only one human settlement in the region. The appearance of such settlements was an important prerequisite for the further Neolithic Revolution in the studied region. The soils developing on Tell Körtik Tepe were greatly affected by the harsh climatic conditions; this was manifested by the degradation of their humus horizon. As for the cultural layers, they were mainly formed under the impact of human activities. The impact of humans caused certain changes in the character and intensity of pedogenesis: instead of the natural gray cinnamonic soils typical of seasonally humid subtropical regions [6], or Calcisols (according to [31]), specific pedolithosediments were formed. Such pedolithosediments composing the cultural layer can be classified as Urbic Technosols.

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