Micromorphological features of medieval cultural layers formed in different environmental backgrounds

Rasgos micromorfológicos de los estratos culturales medievales formadas en diferentes entornos ambientales

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ABSTRACT

This research compares results of micromorphological case studies conducted on four early medieval archaeological sites with differentiated spatialization of human impacts and a varied craft production located in different background environments: humid climate, subzone of mixed forests, floodplain of the Dnieper River (Gnezdovo site); semi-humid climate, subzone of forest-steppe, Middle Volga region (Muromsky Gorodok and Malaya Ryazan' sites); arid climate, cold desert of the Aral region, ancient delta-alluvial plain of the Syr-Darya River (Dzhankent site). Micromorphological studies of habitation deposits revealed clear geographical and geochemical regularities in the occurrence of geogenic (soil, sedimentary and post-sedimentary) features. Intrasoil migration and accumulation of clay and coarser silicate material in textural pedofeatures were described in cultural layers of sites located in forest and the forest-steppe zones. An anthropogenic input of phosphates provokes simultaneous migration and illuvial accumulation of phosphates and clay. In the habitation deposits in steppe landscapes with calcareous lithology, the key background soil process is redistribution and intrasoil accumulation of calcium carbonates. In the alluvial desert landscape, major soil processes are accumulation of gypsum and readily soluble salts. All layers are or were affected by at least some seasonal over-moisturizing that resulted in a variety of redoximorphic features depending on their palaeo- and/or contemporary water regime. The high variety of anthropogenic processes and corresponding microfeatures was grouped as follows: (1) input, output, turbation, compaction; (2) neoformation and migration; (3) pyrogenic processes (products); technological processes (products). The set of anthropogenic features records past human impact in the locality. The higher the variety of anthropogenic features and their general abundance is, the more intensive and variable the human impact which had occurred in the past. At the same time, the occurrence of certain anthropogenic features may indicate not only human-related processes of their formation (or input), but also a contemporary soil environment. This environment can be favorable, or, in the opposite, deteriorative for earlier formed anthropogenic features.

Keywords: cultural layers, micromorphology, anthropogenic processes, geogenic processes, environmental conditions.

RESUMEN

Esta investigación compara los resultados de estudios de casos micromorfológicos, realizados en cuatro sitios arqueológicos del medieval temprano con una diferenciación espacial del impacto humano y de la producción artesanal, localizados en diferentes entornos ambientales: clima húmedo, subzona de bosques mixtos, planicie de inundación del Río Dnieper (sitio Gnezdovo); clima semi-húmedo, subzona de bosque-estepa, región del Volga Central (sitios Muromsky Gorodok y Ryazan); clima árido, desierto frío de la región de Aral, planicie antigua deltáica-aluvial del Río Syr-Darya (sitio Dzhankent). Los estudios micromorfológicos de los depósitos habitacionales revelaron claras regularidades geográficas y geoquímicas en las ocurrencias de las características geogénicas (pedológicas, sedimentarias y post-sedimentarias). La migración de intrasuelo y la acumulación de arcilla y material de silicato más grueso en pedocaracterísticas texturales se encontraron en capas culturales de sitios ubicados en el bosque y las zonas de bosque-estepario. El aporte antropogénico de fosfatos provoca la migración simultánea y la acumulación iluvial de fosfatos y arcilla. En los depósitos habitacionales en paisajes esteparios con litología calcárea, el proceso fundamental del suelo es la redistribución y acumulación intrasuelo de carbonatos de calcio. En el paisaje desértico aluvial, los principales procesos del suelo son la acumulación de yeso y sales fácilmente solubles. Todas las capas están o fueron afectadas por al menos un exceso de humedad estacional que resultó en una variedad de características redoximórficas dependiendo de su régimen hídrico paleo y/o contemporáneo. La gran variedad de procesos antropogénicos y microcaracterísticas correspondientes se agrupó de la siguiente manera: (1) entrada, salida, turbación, compactación; (2) neoformación y migración; (3) procesos pirogénicos (productos); procesos tecnológicos (productos).El conjunto de características antropogénicas registra el pasado del impacto humano en la localidad. Cuanto mayor sea la variedad de características antropogénicas y su abundancia general, más intenso y variable será el impacto humano que ha ocurrido en el pasado. Al mismo tiempo, la aparición de ciertas características antropogénicas puede indicar no solo procesos de formación (o entrada) relacionados con el hombre, sino también un entorno de suelo contemporáneo. Este entorno puede ser favorable o, por el contrario, desfavorable para las características antropogénicas formadas anteriormente.

Palabras clave: estratos culturales, micromorfología, procesos antropogénicos, procesos geogénicos, condiciones ambientales.

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1. Introduction

Human activity is acknowledged as the sixth factor of soil-formation, or at least as a force capable of modifying other factors (Bidwell and Hole, 1965; Amundson and Jenny, 1991; Richter and Yaalon, 2012). Human societies and soils are in a constant interaction and co-influence within the inhabited areas. Human impact progressively increases during the Anthropocene. As Richter and Yaalon (2012, p. 775) observed: "Changes in soil directly influence the evolution of human societies and cultures. This is a mutual co-genesis, with soil and humanity developing jointly and interactively".

Within the last update of WRB, soils in archaeological contexts of former settlements are distinguished as Technosols, with a supplementary qualifier Archaic, if there is more than 20% of technic material which is represented mostly by artefacts produced by pre-industrial processes (IUSS Working Group, 2015), or as natural reference soil groups if they contain ≥ 10% artefacts. In the case of soils of long and intensive agricultural use in the past, soils in archaeological contexts can be classified as Anthrosols. Soils of ancient urban or proto-urban areas are very close to (Palaeo)Urban soils (Alexandrovskiy *et al.*, 2015), and a lot of contemporary urban areas are located over thick ancient cultural layers, included in present-day urban pedo- and sedimentogenesis (Stroganova *et al.*, 1998; Alexandrovskaya and Alexandrovskiy, 2000; Prokof'eva *et al.*, 2001; Alexandrovskiy *et al.*, 2012; Mazurek *et al.*, 2016; Devos *et al.*, 2017).

Micromorphological studies of cultural layers and habitation floors were introduced in archaeology in the end of the 1950s (Dalrymple, 1958); and exponential development of this research area began at the end of 1980th. Since then, micromorphology is widely applied for understanding archaeological deposits, their facies, and microstratigraphy; as well as the anthropogenic alterations, sedimentary, soil and diagenic processes of site formation and post-anthropogenic transformation (Courty *et al.*, 1987; Courty *et al.*, 1989). This knowledge is important both for practical geoarchaeology and for the fundamental concept of archaeological deposits as a product of human-environmental interaction. There are hundreds of published case studies containing local-scale information on micromorphology of archaeological sediments all over the world. Such publications have exponentially increased in numbers within the last decades. Studied archaeological sites vary widely in their age, ethno-cultural and environmental contexts, level and type of economy: among others, cave occupation sites of archaic hominins (Morley *et al.*, 2019); Palaeolithic open-air sites (Holliday *et al.*, 2007), Neolithic temporary dwellings of shepherds (Díaz *et al.*, 2014) and medieval urban layers within contemporary cities of Europe (Mazurek *et al.*, 2016; Devos, 2017); rock shelters (Villagran *et al.*, 2016), and urban environments (Sulas *et al.*, 2017) in tropics, the North European and Canadian Arctic (Macphail *et al.*, 2013; Todisco, Bhiry, 2008), and so forth. Thus, a huge amount of evidence has been accumulated on the micromorphology of archeological deposits. A majority of knowledge on archaeological micromorphology is accumulated in practically oriented case studies. It is concerned with the reconstruction of specific site formation processes, local environments, and human activities. At the same time, basic concepts of the formation of cultural layers[1] have not been comprehensively developed. In particular, there are no data on the variety and systematization of processes which participate in formation and further transformation of cultural layers, and no understanding how these processes are recorded in their micromorphology. Several approaches to comprehend the formation of cultural layers are contained in key monographs and key manuals on soil, and in micromorphological and geoarchaeological studies of archaeological sites and cultural layers (Courty *et al.*, 1989; Goldberg and Macphail, 2006; Nicosia and Stoops, 2017; Macphail and

[1] The following terms are also applied along with "cultural layer": archaeological, habitation or occupation deposits (sediments), archaeological soils.

Goldberg, 2018; Karkanas and Goldberg, 2019), but there is still no agreement on these questions.

Some conclusions were drawn concerning the relations between the intensity of human impact and the level of an original soil transformation along with the accumulation of archaeological sediments (Alexandrovskij, 1989; Alexandrovskij, 2019; Stroganova *et al.*, 1998 for soils of contemporary urban areas including archaeological sediments). A number of generalizations were suggested for a variety of anthropogenic microfeatures and their occurrence in different archaeological backgrounds and in different functional zones of a settlement (Macphail and Goldberg, 2010; Macphail *et al.*, 2017; Nicosia and Stoops, 2017; Karkanas and Goldberg, 2019). Meanwhile there have been only isolated attempts to compare features of cultural layers (including those located within contemporary urban areas) from a geographical perspective. Divergence of local natural soils and soils of palaeo- and contemporary residential areas was suggested together with convergence of soils of urban/palaeo(proto)urban areas in different environmental contexts (Stroganova *et al.*, 1998; Zazovskaya, 2013). According to this suggestion, features of urban (palaeo-urban) soils located in different climatic conditions are similar, but considerably different from those of zonal background soils. At the same time, it is declared that the composition and morphology of habitation deposits directly depend on the natural conditions of the territory (Stroganova *et al.*, 1998; Alexandrovskiy *et al.* 2012); and these deposits are being gradually transformed by pedogenetic processes in correspondence to their natural environmental conditions into zonal soils both in humid and arid temperate regions (Alexandrovskiy *et al.*, 2012; Golyeva *et al.*, 2016).

There are nearly no studies regarding the variability of micromorphological features of cultural layers in different climatic conditions and local environments. Some very general geographical regularities of the formation of cultural layers were recently discussed in Aleksandrovskij (2019). A few studies mention that a set of micromorphological features and corresponding soil formation processes in urban archaeological sediments is dissimilar to those of original zonal Retisols (Prokopf'eva *et al.*, 2001). Some other works discuss the influence of post-depositional processes, including soil-forming ones, on the preservation of archaeological records, microartefacts and micromorphological features within cultural layers after their deposition, but mostly at a theoretical level (Courty *et al.*, 1989; Campbell *et al.*, 2011; Nicosia, Stoops, 2017; Karkanas, Goldberg, 2019).

This paper offers a comparative study of micromorphological features on four early medieval archaeological sites located in different background environments: humid temperate mixed-forest zone, temperate continental semi-humid forest-steppe zone, and arid desert landscapes of delta areas.

The key aims of this study are: 1. to describe a set of micromorphological anthropogenic and geogenic features and supposed processes responsible for cultural layers formation on studied sites; 2. to estimate the proportional contribution of different environmental conditions and variability of medieval human impact on the described diversity of micromorphological features.

2. Materials and Methods

This study is a first-level generalization based on the evidence obtained by the authors within the last decade from four early medieval archaeological sites of different ethno-cultural background, but to a certain extent similar in general patterns and levels of economic development. The settlements under investigation were significant trading and multi-craft centres with land-use zoning: residential, craft, rural areas etc. All four sites are located in temperate continental climate, but differ in climatic humidity/aridity, landscape conditions, and geological background: (1) humid climate, subzone of mixed forests: floodplain of the Dnieper River (Gnezdovo site); (2) semi-humid climate, subzone of forest-steppe: watershed positions in the Middle Volga region (Muromsky Gorodok, and Malaya Ryazan' sites); (3) arid climate, cold desert of the

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Aral region: ancient delta-alluvial plain of the Syr-Darya River (Dzhankent site) (Figure 1 and Table 1). More details on the background of the studied archaeological sites will be given under.

3. Regional setting: archaeological and landscape background

Sampling of archaeological deposits/cultural layers was done within ongoing archaeological excavations in stratigraphic sequences of cultural layers, on habitation floors, and within individual archaeological structures and features (household pits, fireplaces, etc.). Sampling was carried out according to the general principles for micromorphological studies in geoarchaeology (Goldberg and Macphail, 2003; Karkanas and Goldberg, 2019), in archaeological contexts which have been described in detail. Thin sections from different archaeological contexts were studied as follows: 84 in the floodplain area of the Gnezdovo site, 52 for the Dzhankent site, and 27 from five different sections of Muromskij Gorodok and Malaya Ryazan' (Middle Volga region). Each of the studied thin sections corresponds to a certain stratigraphic or planigraphic unit and records specific environmental conditions including a certain type of local human impact.

Undisturbed samples were impregnated with polymeric epoxy resin and processed according to standard procedure for producing thin sections.

Figure 1 Location and landscapes of archaeological sites discussed in the text.

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Table 1. Regional settings: climate and geomorphology.

Environment	Gnyezdovo[2], 54°46'N 31°52'E	Muromskij Gorodok[3], 53°21´N 49°22' E	M. Ryazan'[3] 53°14' E 50°18'	Dzhankent[4], 45°36' N 61°55W
Köppen-Geiger clasif.[1]	Dfb	Dfb	Dfb	Bwk
MAT, °C	+4,3	+4,2	+4,2	+8,0
MAP, mm	691	483	483	100-120
mean Jul., °C	+17.1	+20.4	+20.4	+26,0
mean Jan., °C	-9.4	-13.5	-13.5	-11,3
geomorphology	Floodplain, 1st terrace	watershed	High riverbank, limestone outcrops	flat alluvial plain, former delta
landscape	Mixed boreal forests,	forest-steppe/steppe transition	steppe	desert
soils in surroundings	Retisols, Fluvisols	forested area: Cambisols, Phaeozems, steppe: Luvic Chernozems.	Leptic Skeletic soils and Leptosols	Solonchaks

[1] Köppen-Geiger climate classification (Kottek et al., 2006).
[2] Smolensk meteorological station (Nauchno-prikladnoye spravochnik po climatu SSSR, 1988).
[3] Samara meteorological station (Nauchno-prikladnoye spravochnik po climatu SSSR, 1988).
[4] Kazalinsk meteorological station (Nauchno-prikladnoye spravochnik po climatu SSSR, 1989).

The size of thin sections varies between 25 x 30 mm and 35 x 45 mm.Thin sections were studied under a polarizing microscope Nikon E200 Pol, at magnifications of 40x, 100x, and 400x. Micromorphological features were described with special attention to those related to human impact as specifying an original anthropogenic nature of cultural layers and geogenic features related to natural sedimentation and pedogenic processes. Micromorphological descriptions were done according to G. Stoops (2003), diagnostics and interpretation of anthropogenic and geogenic features according to Stoops *et al*. 2018; Macphail and Goldberg, 2010; Nicosia and Stoops, 2017.

3.1. RUSSIA, UPPER DNIEPER REGION: GNEZDOVO

The Gnezdovo archaeological site (including settlement and burial ground) is located in the central western part of the Russian Plain, within the Upper Dnieper river valley, 15-20 km downstream from contemporary Smolensk (Figures 1 and 2a). The Gnezdovo archaeological site is a unique cultural landscape dating to the time of the formation of the Ancient Rus' (last quarter of 8th century to beginning of 11th century AD). The site includes a settlement with a total area of more than 30 ha (Figure 2a). The settlement had wooden buildings which have not survived until today. Archaeological investigations over more than 140 years have revealed a spatial arrangement within the settlement: there are residential and craft areas, zones related to shipyard and river harbour activities, locations related to agriculture and to storage and processing of agricultural products. Archaeological material testifies to on intensive and varied human impact including agriculture and husbandry [various crops: wheat, rye, oat, barley, millet, buckwheat, (Kiryanova, 2007; Bronnikova, 2003); animal husbandry: cattle, pigs, sheep and goats, (Kirillova, 2007)], fishing, various types of craft production such as iron and non-ferrous metal working, and bone carving (pre-urban to early-urban centre).

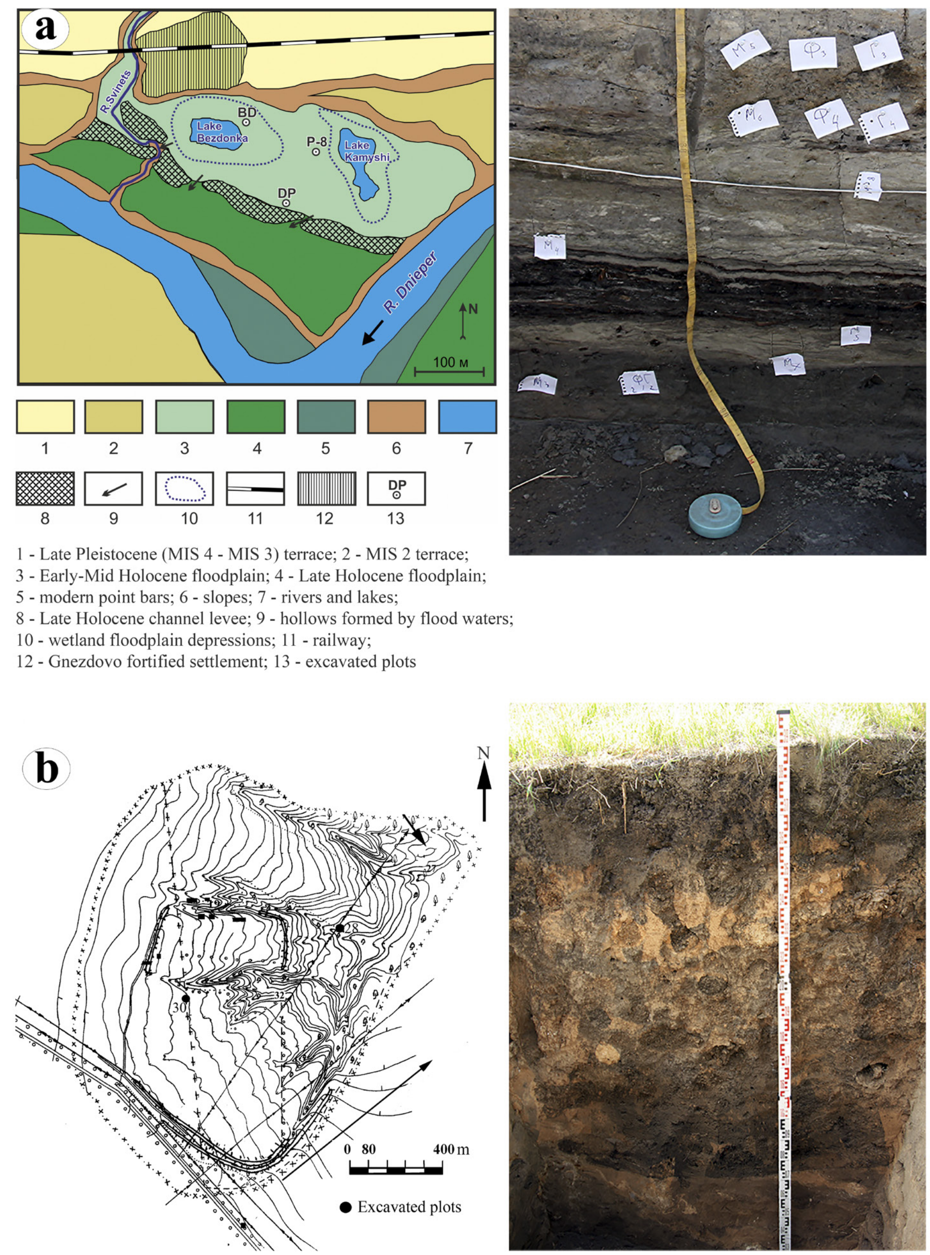

Figure 2 Local topography and key stratigraphic sequences of the sites; a. Gnezdovo (Modified from Panin et al., 2014); b. Muromskij Gorodok.

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The climate of the area is moderately continental, temperate humid with moderately warm, rainy summers and cold snowy winters (for key climatic characteristics, see Table 1). Zonal vegetation of the region is mixed forests; zonal soils are mostly Retisols. Sandy river terraces are covered by pine forests over Albic Arenosols Protospodic; the floodplain is today covered with meadows and bogs on a variety of Fluvisols. Natural vegetation and soils of the area are considerably transformed due to contemporary human impact.

The site is situated mostly on the first terrace above the floodplain, but part of the open settlement is on the floodplain buried under a layer of

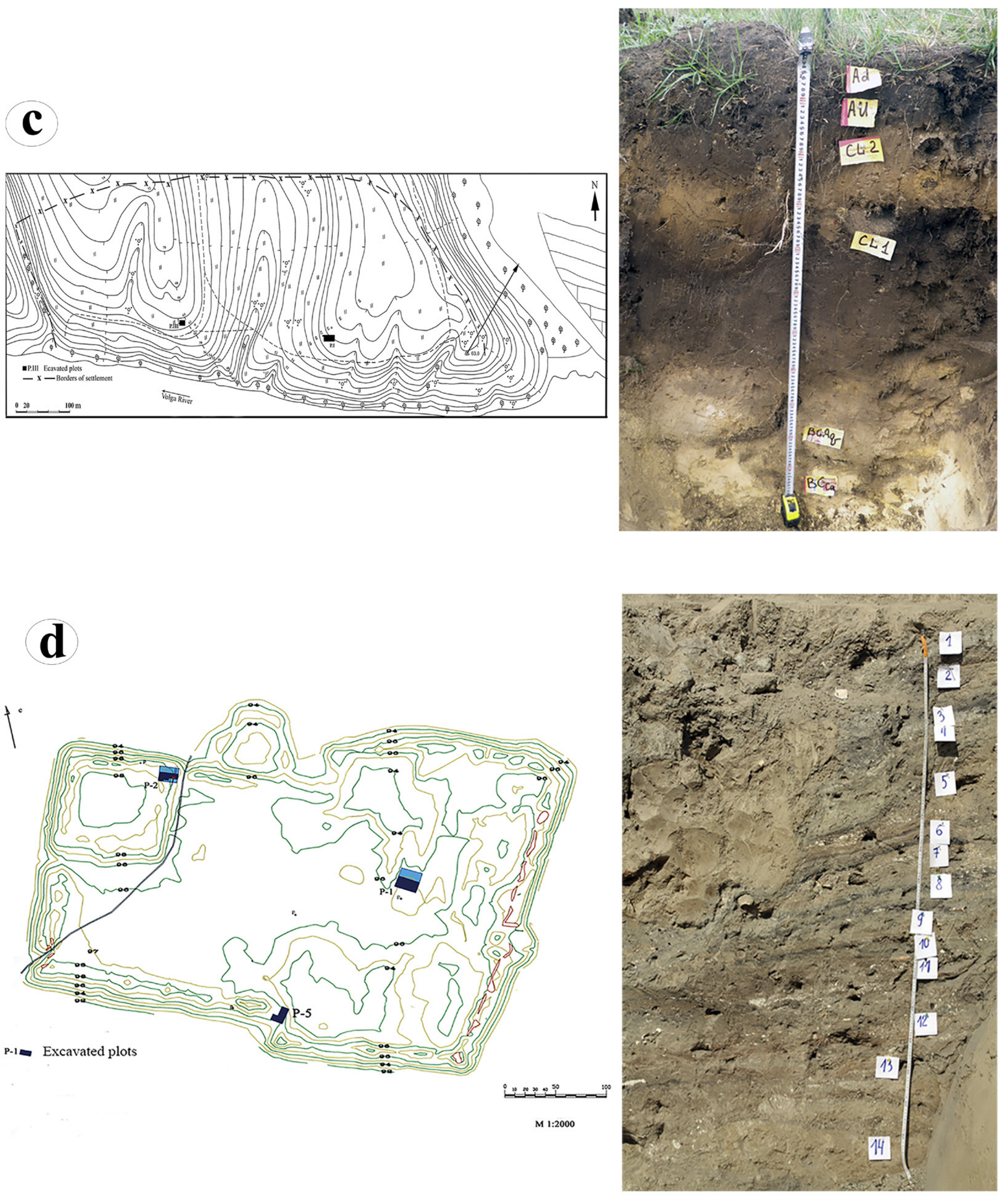

Figure 2 (Continuation) Local topography and key stratigraphic sequences of the sites; c. Malaya Ryazan'; d. Dzhankent.

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contemporary alluvium of 0.7 – 3.0 m thickness. Micromorphological studies were conducted in the floodplain soil-sedimentary sequences with buried cultural layers. This buried part of the cultural layer is of a key importance for archaeology because of its excellent preservation. The layer was not disturbed by contemporary ploughing comparatively to the one located on the first terrace. The wetland floodplain depressions (Figure 2a-10) are contemporary waterlogged providing conditions for conservation of organic materials. Nowadays, the floodplain is regularly flooded seasonally during spring snowmelt.

Surface Fluvisols are formed over stratified silt, loamy sand and sand fluvic material. Buried Retisols were studied in the escarpment of the high riverbank beyond the area of the medieval settlement in particular in the section 07-01, and the rests of the same Retisols were described under the cultural layers in the excavation plots P8 and DP, in particular (Figure 2a). The buried Retisols indicate that about 1.5 kyr cessation of floodplain sedimentation preceded the accumulation of early medieval cultural layers (Bronnikova *et al.*, 2003). The episode of decreased floodplain sedimentation was dated at Gnezdovo to 2,300 (2,000)–900 cal BP (Panin *et al.*, 2014). This episode is known for many rivers of the East European Plain (Sycheva, 2006).

The cultural layer and buried Retisols vary in texture from loamy sand and silt to sandy loam. The pH values of cultural layers are close to neutral (6.5 -7.2) in comparison with slightly acid (5.5 – 6.5) surface Fluvisols and rests of Retisols under the cultural layers (Bronnikova *et al.*, 2003).

3.2. RUSSIA, MIDDLE VOLGA REGION: MUROMSKIJ GORODOK AND MALAYA RYAZAN’

The archaeological sites of “Muromskij Gorodok” (conventional name) and Malaya Ryazan’ are located in the east of the Russian Plain, in the Middle Volga region, within the Samara Bend in its western central and south-western part, respectively (Figures 1, 2b and 2c).

“Muromskij Gorodok” is one of the largest (about 400 ha) and most important fortified administrative centres and towns of Volga Bulgaria dated between the 11th and 13th centuries. It has been studied by archaeologists intermittently since the 1920s. The site includes an internal fortified part and an open settlement (Figure 2c). Remains of wooden and mud-brick constructions have been found within the settlement during excavations. Residential and craft zones, communal buildings, and market places have been identified. The town was one of the most important craft production and trade centres in the south of Volga Bulgaria. The archaeological finds document a range of highly specialized crafts: smithing, iron and non-ferrous metal working, jewellery, woodworking, bone carving etc. There are also numerous finds of agricultural tools and other data testifying to crop production (millet, wheat, rye, oat, barley, buckwheat etc.) and livestock. A second site of interest in the middle Volga region is the Russian settlement of Malaya Ryazan’ of the Golden Horde period (second half of 13th to first half of 14th centuries). This settlement is somewhat later compared to the others discussed here, and more modest in both, actual size (approximately 3 ha) and extent of fieldwork. Archaeological finds testify to its character as a trade and craft centre. There is evidence of fishing, animal husbandry, craft production and trade.

The climate of the area is temperate, continental, and semi-humid (Table 1). The origin of the Samara Bend is related to the tectonic uplift of the Zhiguli Hills. This is the only young mountain range of tectonic origin within the Russian Plain (Obedientova, 1953). This area was not glaciated in the Pleistocene so that the landscape has some relic features. The western part of the Samara Bend where both sites are located is a dissected plateau (up to 200 m above sea level) dominated by Permian and Carboniferous limestone and marlstone. The bedrocks are often covered with loess-like loams in the western part of the plateau. Thus, Muromskij Gorodok is situated in the watershed area covered of loess-like loam while the M. Ryazan’ site is related to outcrops of limestone on the high cut bank of the Volga river. Both sites have no connection with ground water. The cultural layer of Muromskij Gorodok is well-drained silt loam and silt clay loam. Short-term water stagnation is possible within the lower part of the cultural layer of Malaya Ryazan' due to the low permeability of the overlying consolidated rock; this layer includes sandy loam and silt loam units. The area under investigation is located in the transition zone between forest-steppe and steppe. Zonal vegetation is broadleaved forests and steppes; zonal soils are Cambisols and Phaeozems in forested areas, and Luvic Chernozems under steppe vegetation. Leptic Skeletic soils and Leptosols occur over outcrops of limestone. The pH values are moderately alkaline in the cultural layers of Muromskij Gorodok, and strongly to very strongly alkaline in the cultural layers of Malaya Ryazan'. Both layers (as well as surrounding soils) are calcareous.

3.3. KAZAKHSTAN, ARAL SEA REGION: DZHANKENT

The site of Dzhankent is a fortified early medieval settlement located in the eastern part of the Aral Sea region (Republic of Kazakhstan) (Figures 1 and 2d). It is one of three known so-called 'marsh towns' of the Early Middle Ages in the ancient Syr-Darya River delta. This site is mentioned as an "Oghuz town" and as the seat of the Oghuz *yabgu* (lower-rank khan) in various medieval documentary sources. The location suggests that Dzhankent may have been a trading port on the lower Syr-Darya close to the Aral Sea, on the intersection of several land and water transport routes. In Kazakhstan, the 'marsh towns' play a key role in research and debate on the origins of the Oghuz state in the $9^{th}/10^{th}$ centuries AD and the emergence of a distinct Kazakh ethnos. Today, Dzhankent has well-preserved fortifications, with up to 8 m high earthen ramparts enclosing an area of 15 ha. Mud-brick and adobe were mostly used as building materials, fired brick is uncommon. Excavations have produced evidence of intensive urban occupation, with cultural layers from 2 to 8 meters thick. Part of the interior of the town has a regular lay-out, including several residential areas. There is archaeological evidence of local production (metal-working, pottery, animal husbandry), including a metal workshop located within a residential zone.

The study area is in the desert zone with ultra-continental, temperate arid (evaporation 10 times exceeding precipitation) climate, cold winters and hot summers (Table 1). Dzhankent is situated in a flat alluvial plain which was the delta of the Syr-Darya River in times of high sea-levels. Today the shoreline of the residual Aral Sea is approximately 90 km from the site. The area has a complicated hydrological net composed of active and dry river channels, lakes, and modern irrigation systems. The groundwater level within the site varies between 8 and 9 m.

The vegetation on the site and in its surroundings is rather sparse, represented by halophytic plant associations: tamarisk (*Tamarix* spp.) and wormwood-saltwort (*Artemisea* spp. – *Salsola* spp.); the surrounding soils are strongly salinized, mostly Solonchaks. Both surrounding soils and the cultural layers are fine-textured (silt clay loams to clays), slightly to moderately alkaline to strongly alkaline: pH values vary from 7.4 to 8.7 in the cultural layers and between 8.8 – 9.3 in soils beyond the settlement. Soils and cultural layers contain carbonates, gypsum, and readily soluble salts.

4. Results

4.1. GROUPING MICROMORPHOLOGICAL FEATURES AND RELATED PROCESSES

The general idea of this study was describing and classifying micromorphological anthropogenic and geogenic features in cultural layers formed in different environmental backgrounds, with regard to their formation processes and the estimated stability of the described micromorphological features in the contemporary environment.

There were a number of attempts to systematize micromorphological features and related site-formation processes (Schiffer, 1987; Courtly *et. al*., 1989; Nicosia, Stoops, 2017; Karkanas, Goldberg, 2019), but there is no a unified system. We applied an approach based on composition and

Table 2. (Micro)morphological features in cultural layers of medieval settlements located in different environmental conditions.

Features	Gnezdovo	Muromskiy Gorodokh	Malaya Ryazan'	Dzhankent
1. Soil features related to human impact				
1.1. Input, output, turbation, compaction				
1.1.1. Disturbed original soil and sedimentary horizonation, lamination, and structures, anthropogenic sedimentary horizonation, lamination, lateral heterogenity, trampling patterns	+[1]	+	+	+
1.1.2. Fragments of rocks and sediments uncommon for the area – Figure 3b	+	+	+	+
1.1.3. Wood and other plant residues	+	+	-	+
1.1.4. Accumulations of phytoliths, pollen and other biomorphs	+	+	+	+
1.1.5. Phytoliths of cereals – Figure 3d	-	+	-	+
1.1.6. Herbivore excrements – Figure 3g	+	-	+	+
1.1.7. Calcitic faecal spherulites – Figure 3e, 3f	-	+	+	+
1.1.8. Bones – Figure 4a	+	+	+	+
1.1.9. Mollusc shells	-	-	+	-
1.1.10. Eggshells – Figure 3h	-	-	+	-
1.2. Neoformation and migration				
1.2.1. Phosphate features with admixtures of clay, Fe-oxides, organic matter: coatings, intercolations etc.– Figure 3k, 3l	+	+	+	+
1.3. Pyrogenic products				
1.3.1. Charcoal	+	+	+	+
1.3.2. Burned fragments of mineral soil and rocks	+	+	+	+
1.3.3. Vitrified vesicular silica (melted phytoliths) – Figure 3i,	-	-	+	+
1.3.4. Calcitic ash – Figure 3j	+	+	+	+
1.4. Technological products				
1.4.1. Ceramic fragments	+	-	+	+
1.4.2. Fragments of earth building materials (rammed earth, daub, mudbricks, wall and floor plasters etc.) – Figure 3a	+	+	+	+
1.4.4. Iron oxides infillings, intercalations and coatings; metal droplets – Figure 3c	+	-	+	-
2. Geogenic features (soil, sedimentary, diagenic)				
2.1. Features related to fauna activities: pores, structures, faecal pellets etc. – Figure 3h, 3l, 4a	+	+	+	+
2.2. Textural pedofeatures – Figure 4b, 4c, 4d	+	+	-	-
2.3 Carbonates – Figure 4a, 4e, 4f	-	+	+	+
2.4. Gypsum – Figure 4g, 4h	-	-	-	+
2.5. Readily soluble salts	-	-	-	+
2.6. Redoximorphic features – Figure 4i	+	+	+	+
2.7. Sedimentary patterns: alluvial, lacustrine etc. – Figure 4j, 4k, 4l	+	-	-	-

[1] Qualitative estimate: + feature was detected; - feature was not detected.

origination of the described features. Concerning the anthropogenic features, we do not intend to go into the details about how these features were related to certain types of human activities since the reconstruction of various processes of human impact was beyond the scope of this research. Frontiers in understanding the relations between specific types of anthropogenic features and types of activities were quite comprehensively discussed in Karkanas and Goldberg, (2019). Thus, here and in the discussion we will skip the problem of how anthropogenic features appeared, and concentrate on the facts of their presence / absence and possible processes of their post-depositional conservation or degradation related to environmental conditions. The term 'anthropogenic features' is applied here to features related to any kind of human impact including residential, building, craft and rural activities. ‘Anthropogenic’ in this understanding does not mean something directly produced by humans: an anthropogenic feature can be the direct or indirect result of human actions.

All types of anthropogenic features were subdivided into four groups based on their genesis and formation processes: 1.1. features related to input, output, turbation or rearrangement (compaction, deformation) of materials; 1.2. neoformation and migration features; 1.3. pyrogenic (fire-related) features; 1.4 technological products (Table 2).

The first group of features (1.1.) appear due to mechanical processes: long-distance or short-distance input of extraneous material into a site area, and local relocation: digging, shifting, discard, dumping and filling, mixing, compressing, compaction and deformation (trampling, for example) etc. These processes are typical for all kinds of cultural layers. Residential activities disturb original (lithological and pedological) patterns and replace them with newly formed anthropogenic horizons, lamination, and heterogeneity. These processes may strongly change geochemistry and physical characteristics of the cultural layer depending on origins of newly introduced material, and the type and level of physical impact.

Group 1.1. includes disturbed original soil and sedimentary horizonation, lamination, and structures; anthropogenic sedimentary horizonation, lamination, lateral heterogeneity, and trampling patterns. All these features are related to anthropogenic disturbance: turbation, disposal or other rearrangements (compaction for example) of original soil or sedimentary material, or on the contrary, sedimentation. These processes are most often related to all sorts of construction and maintenance activities (surface levelling, building, construction of different householding elements: earthen moats, embankments, living floors, disposal and dumping processes) and trampling.

Features related to input of materials were grouped in those introducing a variety of mineral matter, and organic or biogenic materials. Input of mineral material (group 1.1.2) is recorded in inclusions of loose sediment aggregates and rock fragments, specifically extraneous ones which do not occur naturally within the study area. These materials are also mostly related to some construction or other technological activities. So fragments of rocks are most often used for stone building, or as hearthstones. Gravelly material could be used as a temper in pottery production. Organic and organogenic materials are represented by different plant and animal residues and faecal products. Most of these materials cannot always be regarded as certain evidence of human impact. Any of these residues occur in soils and sediments not subjected to human impact. However, considerable quantities of organic and organogenic materials within an archaeological context, unevenly distributed within the stratigraphic units and sectors of the cultural layer, testify that these features are related to anthropogenic input. These are plant residues: wood and plant tissues of grasses (1.1.3.), phytoliths, pollen and other biomorphs (1.1.4.), phytoliths of cereals (stand-alone group 1.1.5. due to its great importance for archaeological interpretations), herbivore excrements (1.1.6.), calcitic faecal spherulites (1.1.7), bones (1.1.8.), mollusc shells (1.1.9.), and eggshells (1.1.10). Features resulting from the input of all kinds of plant materials into cultural layers relate to their use as building materials, for covering living floors, as stabling mats, fodder, and food supplies. Finds of bones, shells and eggshells are usually related to fireplaces and kitchen middens. Herbivore excrements and calcitic faecal spherulites are related to livestock activities.

Group 1.2. comprises features related to neoformation and migration resulting from processes of physicochemical transformations and biodegradation of anthropogenic materials, leading to accumulation of newly formed substances in anthropogenic pedofeatures. In the studied archaeological contexts, these are different kinds of entirely or mainly phosphatic features. These appear due to chemical transformation of phosphorus-containing materials: bones, organic waste mostly of animal origin, particularly all kinds of faecal remains, followed by redistribution and short-distance migration of the newly formed phosphate products. These micromorphological features are well known from archaeological soils and sediments, and they can occasionally appear in other specific conditions, for example in ornithogenic phosphate deposits and soils (Stoops *et al*., 2018).

The next group (1.3) is one of the most widespread of all types of archaeological sites of any date. It includes a variety of fire-related organic or mineral features – products of burning or heating. Most of these features are related to local fireplaces: hearth, home or yard ovens, and heating systems; extensive layers of pyrogenic materials may indicate fire events. In the last group (1.4), we separate out residues related to past technological processes. Fragments of ceramics are the most widespread example of such microfeatures.

All in all, 18 groups of anthropogenic microfeatures have been described for the studied cultural layers in different environmental contexts.

Under 'geogenic microfeatures' we understand pedofeatures and sedimentary features related to natural processes. Diagenic features and processes are not discussed in this study for cultural layers which are shallow-buried (as at Gnezdovo) and exposed (Lower Volga Region). We can expect diagenesis in the lower strata of the several meters thick cultural layers of Dzhankent. But there, diagenic features are closely combined with the results of soil processes and features related to groundwater and their long-term fluctuations.

4.2. SOIL-SEDIMENTARY SEQUENCES AND MICROMORPHOLOGICAL FEATURES

4.2.1. Russia, Upper Dnieper Region: Gnezdovo

Soil-sedimentary sequences including buried cultural layers on the floodplain area of Gnezdovo archaeological complex are classified as a variety of Fluvisols over Urbic Technosols (Archaic, (Fluvic), Gleyic, (Histic), (Lignic), (Pretic)). In some sections Albic Retisols (Cutanic, Siltic) or their Bt horizons were recorded under the Technosols. These remnants of buried Retisols are related to earlier studied 1.5 kyr cessation of floodplain sedimentation preceded the accumulation of early medieval cultural layers (Bronnikova *et al*., 2003). Floodplain sandy-silty sediments overlaying the cultural layers are 50-100 cm thick.

A wide variety of anthropogenic microfeatures is identified in the Gnezdovo cultural layers, except for features composed of the most soluble forms of carbonates (calcitic spherulites and eggshells) (Table 2). The most widespread group of anthropogenic features are all kinds of pyrogenic features: charcoals of different sizes and state of preservation, including charcoal dust (particularly incorporated in clay coatings), burnt fragments of clay, and charred stones. Lamination patterns related to sedimentation of anthropogenic material (particularly habitation floors, damping and filling features), trampling features, and microheterogeneity occur widely.

Coarse angular rock fragments (mostly granites) which are never found in local floodplain sediments, are common in the cultural layers, and there is a single occurrence of a limestone fragment (Figure 3b). Carbonate-containing features in general are very rare in the Gnezdovo cultural layers although there were several calcareous finds. One is micritic ash within a charcoal-rich spot on the habitation floor, another was the micritic - microsparitic, partly recrystallized filling of a small barrel within the crafts quarter.

Partly decomposed plants, especially wood residues, bone fragments and accumulations of phytoliths are also rather common in the Gnezdovo cultural layers. Phosphate accumulations with admixtures of organic matter, iron and clay occur in form of impregnations, intercalations, and nodules. Some of these features are probably developed because of leakage of faecal or midden sludge (Figure 3k).

A variety of redoximorphic features (nodules, intercalations, interlayers within clay coatings) and textural pedofeatures (layered clay, humus-clay, Fe-clay coatings, and silty infillings) are the most widespread pedofeatures within the cultural layers and below (Figure 4c, 4d). Some of these features

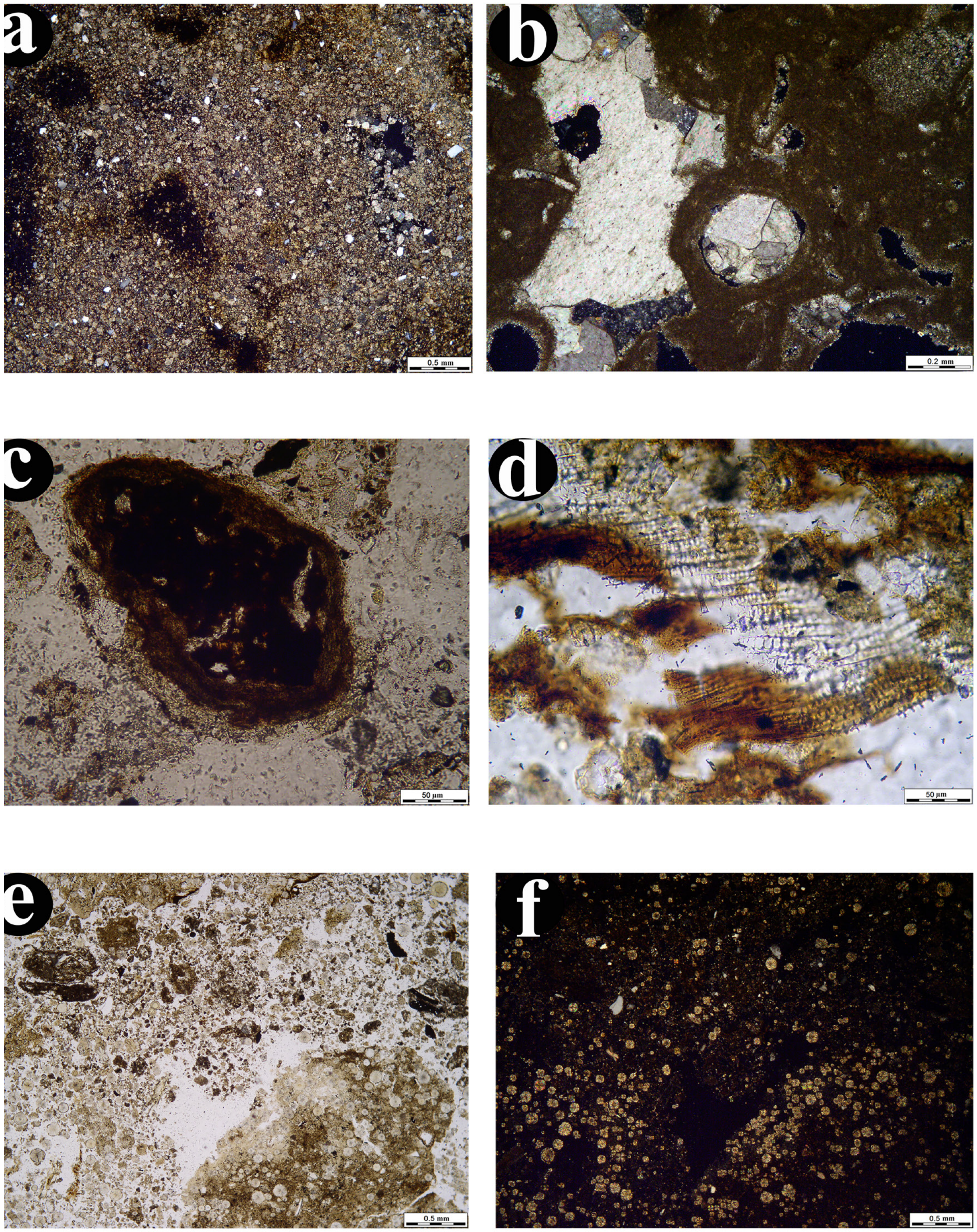

Figure 3 Anthropogenic microfeatures; a. Calcareous silt with irregular linear distribution of silicate sandy particles, Gnezdovo, XPL (crossed polarized light); b. Limestone fragment, Gnezdovo, XPL; c. Corroded iron droplet, Muromskij Gorodok, PPL (plane polarized light); d. Articulated cereal phytoliths, Dzhankent, PPL; e. Burnt dung with numerous calcitic faecal spherulites, M. Ryazan', PPL; f. Burnt dung with numerous calcitic faecal spherulites, M. Ryazan', XPL.

are anthropogenic (anthropogenically induced), particularly those enriched in dark organic matter and fine charcoal dust (Figure 4c and 4d).

Interlayers with banded distribution pattern, typical for alluvial deposits, occur in the Gnezdovo cultural layers (Figure 4k, 4l). Diatoms are found within interlayers with fine alluvial lamination (Figure 4j). These features indicate episodes of floodplain sedimentation before and within the period of the cultural layer accumulation.

4.2.2. Russia, Middle Volga Region: Muromskij Gorodok and Malaya Ryazan'

Both settlements are located in watershed steppe landscapes. Soils in the studied sections of the cultural layers of Muromskij Gorodok are classified as Luvic Chernozems (Loamic, Stagnic, Technich, Turbic) on loess-like loams. The M. Ryazan settlement is located on outcrops of limestone along the Volga River high bank. The thickness of the studied sections is 90 to 100 cm. Two studied sections were classified as Stagnic Chernic Rendzic Phaeozems (Loamic Technic, Turbic).

All varieties of anthropogenic microfeatures besides plant residues occur in these cultural layers. Phytoliths, particularly articulated (chained as they were inside plants), including phytoliths of vegetative parts of cereals, bones, faecal pellets of herbivores (Figure 3g), easily dissolved calcareous features such as calcitic faecal spherulites (Figures 3e, 3f), calcareous ash, fragments of eggshell (Figure 3h), and fragments of mollusk shells were recorded in these layers.

Phosphatic coatings and infillings are particularly frequent in the cultural layers of Muromskij Gorodok. Fen-like patterns are specific to these features (Figure 3l).

Fragments of rammed-earth materials occur in both sites. The rare find of a metal droplet was recorded in the cultural layer within a craft context of Muromskij Gorodok (Figure 3c).Pedogenic features related to biogenic activities are most frequent: zoogenic pores, structure and excrements of mezofauna (Figures 3h, 3l, 4a and 4e). Carbonate pedofeatures are also very common, variable and well-shaped in the cultural layers of the forest-steppe zone where soils originally have carbonaceous geochemistry and accumulate secondary carbonates. There are impregnations, coatings on pore walls, incrustations and pseudomorphs of plant residues and nodules (Figure 4e).

Textural pedofeatures are also rather typical for the cultural layers of forest-steppe zones formed at the base of Luvic Chernozems.

Redoximorphic features occur in lower horizons of the cultural layers and underneath them as the cultural layers at both sites are quite heavily textured. These features are more common for Malaya Ryazan' where the cultural layer is underlain by massive limestones.

4.2.3. Kazakhstan, Aral Sea Region: Dzhankent

The Dzhankent cultural layers are classified as Urbic Technosols (Archaic, Aridic, Calcaric, Loamic/ Clayic, Salic).

The cultural layers of this site are extremely rich and variable in anthropogenic microfeatures (Table 2). Various remains of earthen architecture (mud-bricks, adobe, daub, wall plaster) are the most common macro- and microartefacts here. There are abundant pyrogenic features, both in local hearths and fireplaces and within several stratigraphic layers related to fire events. Those are charcoals, in particular grass charcoals (Figure 3i, 3j), micritic ashes (Figure 3b), vitrified silica of melted phytoliths (Figure 3i), burnt bones, dung, and mineral material.

Thick layers stuffed with plant remains and phytoliths are common at Dzhankent. Phytoliths of *Phragmites* are among the most abundant. There are frequent accumulations of articulated phytoliths, which means in-situ decomposition of big amounts of plant materials. In particular, phytoliths of vegetative parts of cereals are quite frequent (Figure 3d).

Trampling features are very common, both in mineral layers and in interlayers rich in plant residues.

Bone fragments are widespread while phosphate pedofeatures are not so common.

Pure gypsum, in plates of several square centimeters as well as soft powdery pebbles, is found in the cultural layers. These materials were imported

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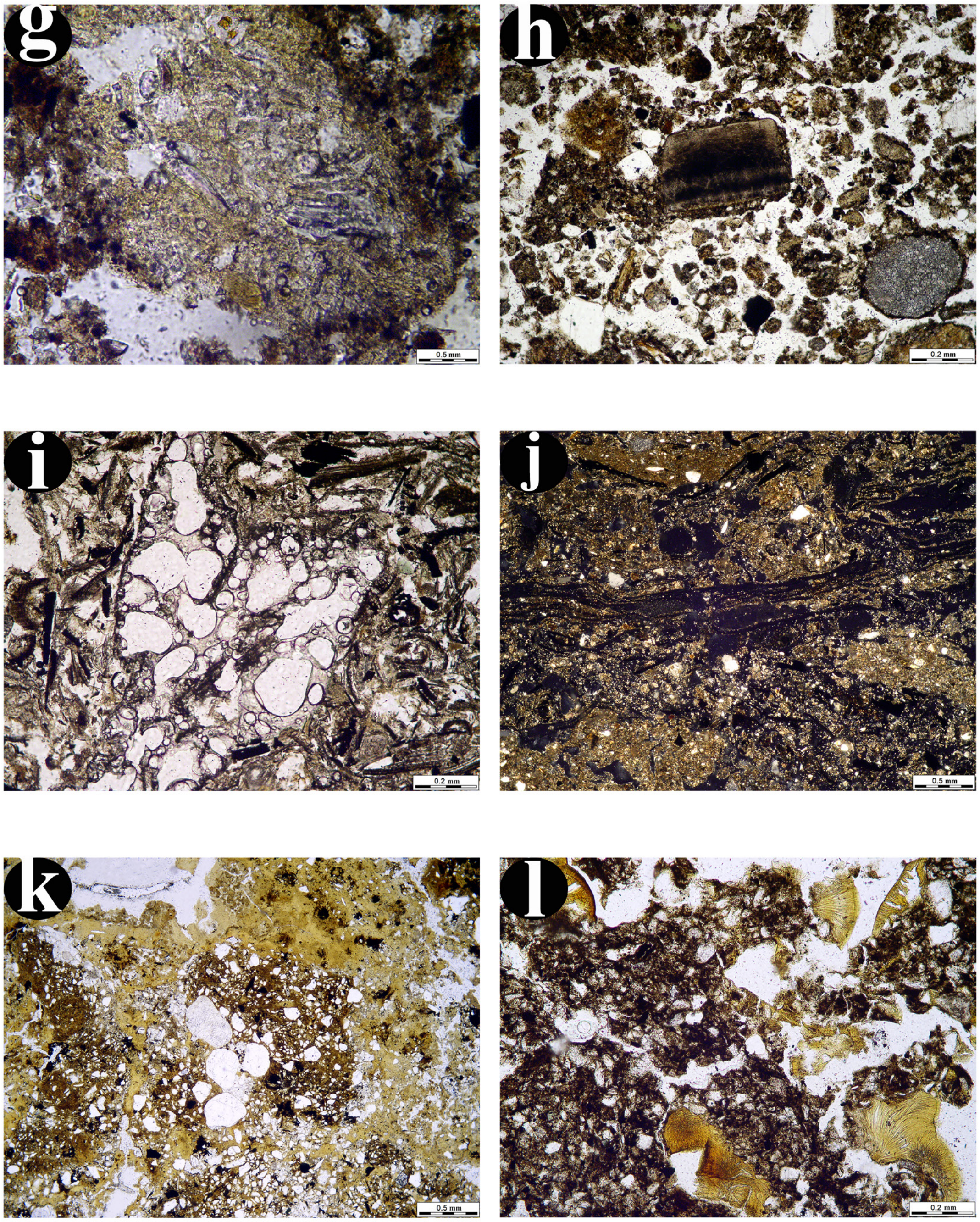

Figure 3 (Continuation) Anthropogenic microfeatures; g. Herbivore excrement: possible sheep/goat pellet, M. Ryazan', PPL; h. Burnt eggshell, biogenic crumb microstructure of the surrounding material, M. Ryazan', PPL; i. Vitrified vesicular silica (melted phytoliths), grass charcoals, Dzhankent, PPL; j. Micritic ash with grass charcoals, Dzhankent, XPL; k. phosphatized clay and silty groundmass, rich in organic matter, probably developed because of liquid faecal waste intrusion, Gnezdovo, PPL; l. Fen-like, probably phosphatic (iron-phosphatic) coatings and infillings, surrounding crumb biogenic microstructure, Muromskij Gorodok, PPL.

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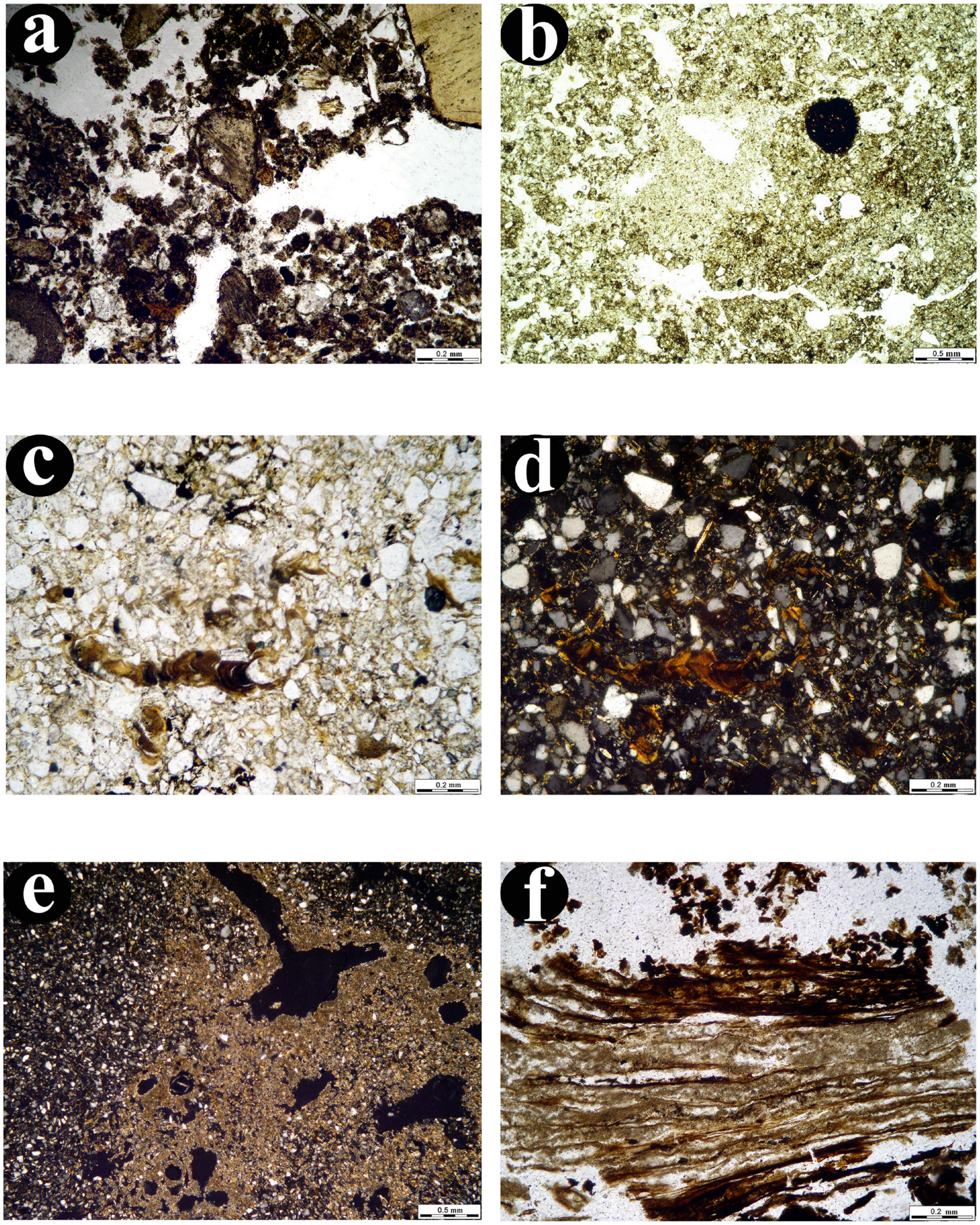

Figure 4 Geogenic microfeatures; a. Biogenic crumb microstructure, excrements of mesofauna, micritic grain coating, bone fragments, M. Ryazan', PPL (plane polarized light); b. Well-sorted bleached silt infilling, Fe-nodule, crumb microstructure, Gnezdovo, PPL; c. Crescent clay coating enriched with dark organic matter, fine charcoal dust and Fe-oxides, Gnezdovo, PPL; d. Crescent clay coating enriched with dark organic matter, fine charcoal dust and Fe-oxides, Gnezdovo, XPL (crossed polarized light); e. Micritic nodule with biogenic pores, Muromskij Gorodok, XPL; f. Fragment of plant tissue with micritic incrustations, excrements of mesofauna, Dzankent, PPL.

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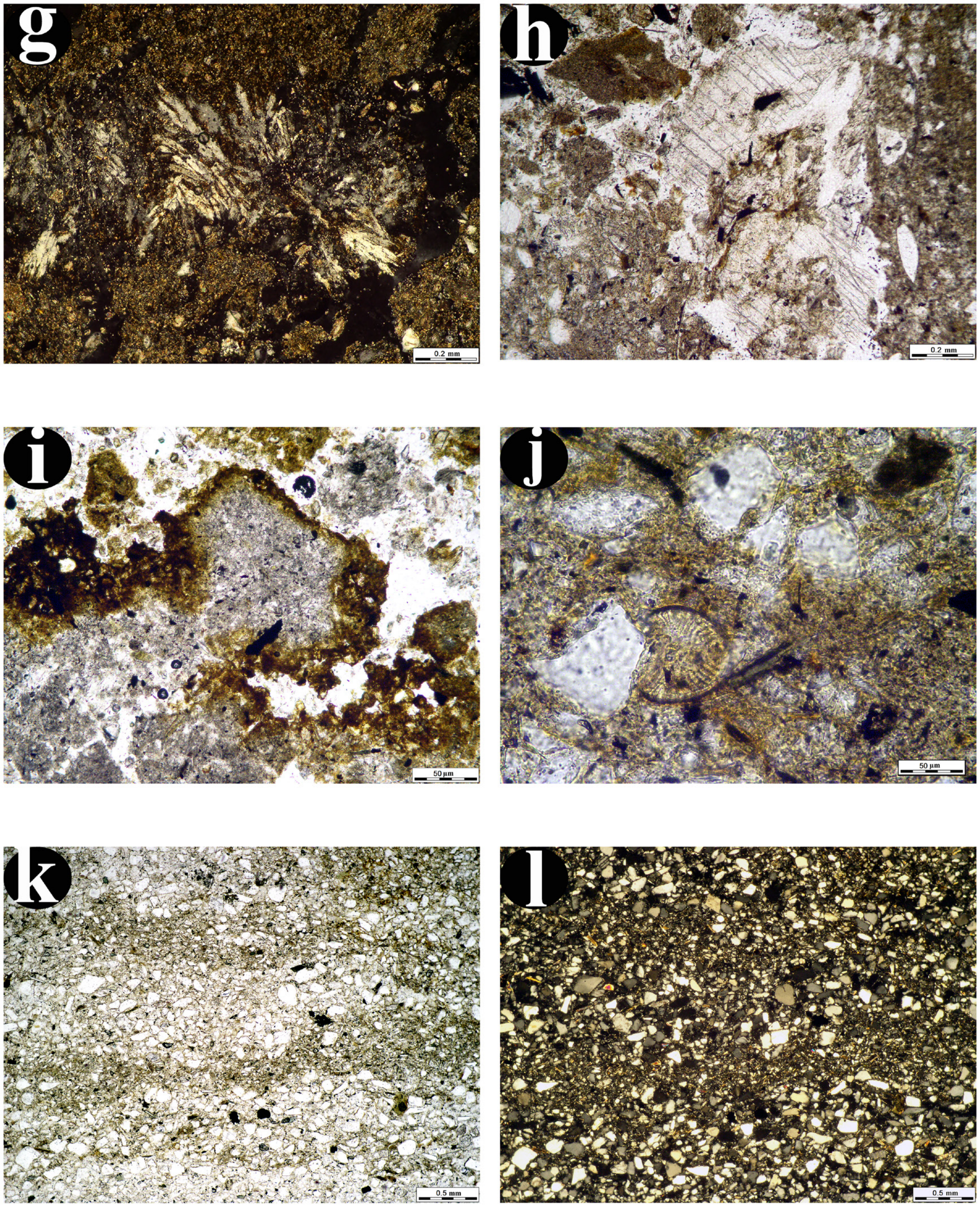

Figure 4 (Continuation) Geogenic microfeatures; g. Gypsum nodules (roses) in highly calcitic crystallitic b-fabric, Dzhankent, XPL; h. Probable hydrogenic aggregate composed of large gypsum crystals, Dzhankent, PPL; i. Fe-oxide hypocoating, Dzankent, deeper horizons, PPL; j. Diatom testifying to alluvial origination of sterile interlayer within the cultural layer, Gnezdovo, PPL; k. Banded distribution pattern of the sterile interlayer within the cultural layer, Gnezdovo, PPL; l. Banded distribution pattern of the sterile interlayer within the cultural layer, Gnezdovo, XPL.

from the surroundings beyond the settlement boundaries.

A set of geogenic microfeatures is typical for the desert soils and sediments. Carbonates are present everywhere, mostly in form of micritic impregnation: calcitic crystallitic b-fabric (Figure 4g). Micritic incrustations along plant tissues occur in the deeper horizons (Figure 4f). These features may have originated from precipitation of calcite in a capillary-moisture zone.

Highly variable forms of gypsum are found in the cultural layer of Dzhankent. We suppose that most gypsum features are pedogenic but related to different stages and conditions of soil formation. Thus, densely packed microcrystalline gypsum infillings were presumably formed by crystallization from solutions saturated in Ca^{2+} and SO_4^{2-}. Aggregates of lens-like crystals with radial growth (druses, or gypsum 'roses') often reveal partial gypsum substitution for carbonates which corresponds to somewhat decreased aridity (Figure 4g). Large idiomorphic crystals and their aggregates most probably were accumulated due to slow crystallization from dilute solutions within a water-saturated zone (Figure 4h).

There are not so many data on the variety of readily soluble salt accumulations because they are strongly disturbed during impregnation procedure. Nevertheless, infillings of pores with fine crystals of soluble salts (mostly NaCl as based on the data of bulk chemical composition and XRD-analysis in the electron microscope) were recorded in the cultural layers of Dzhankent.

Biogenic features are rare in the desert cultural layers of Dzhankent. Fine aggregation is mostly related to a high content of readily soluble salts. Nevertheless, excrements of mesofauna (Figure 4f), elements of zoogenic structure, fungal mycelium and fruits, eggs of mesofauna, and other biogenic features do occur here.

5. Discussion

Studying the cultural layers (archaeological sediments, anthropogenic soils) of archaeological sites and the regularities of their formation, we deal with the historical legacies of soil-human interrelations and local human impacts in the past. Cultural layers are multi-component objects, a product of complex multifactor and multiphase interactions. These interactions include geogenic (geomorphic, erosion-related and sedimentary, syn-sedimentary pedogenic and post-sedimentary pedo- and diagenic) processes as well as a variety of anthropogenic processes: input, translocation, turbation, processing and transformation of natural materials, and production of anthropogenic materials: ceramics, glass, mortars, alloys etc. (Butzer, 1982; Sycheva, 1995; Alexandrovskaya, Alexandrovskiy, 2000; Alexandrovskiy *et al.*, 2012; Alexandrovskiy *et al.*, 2015; Karkanas, Goldberg, 2019).

The present study was conducted on archaeological sites of the same respective period and with a more or less similar intensity of human impact. All settlements concerned (except for Malaya Ryazan') were large pre-urban or urban, densely populated centres with well-developed infrastructure, and evidence of various householding and economic activities. It is obvious already from classification issues and approximate thickness of cultural layers that not only the intensity and duration of human impact, as suggested earlier (Alexandrovskij, 1989; Stroganova *et al.*, 1998), define the depth, extent and direction of an original soil transformation and formation of cultural layers. The present thickness of cultural layers and their artefact contents are also a result of the quality of accumulated substrates and sediments, the conditions for their further preservation in a post-sedimentary period, and the transformation by post-sedimentary geogenic (natural erosion-sedimentation, soil and diagenic) processes.

In the specific case of Gnezdovo, the cultural layers in the floodplain in the humid temperate climate of the boreal mixed forest subzone are about 1 – 1.5 m thick and rich in artefacts (particularly due to the good preservation of wooden materials in a waterlogged environment), so that these soils meet diagnostic criteria of Technosol. (Palaeo)Technosols were overlain by floodplain sediments soon after the end of the settlement, and in some cases underlain by remains of Retisols which predate the early medieval settlement. Therefore, cultural layers here were classified as buried Technosols over buried Retisol.

Cultural layers on the watershed sites of the forest-steppe zone in subboreal semiarid climate have a similar thickness, but they are exposed to contemporary soil formation with high bioclimatic potential. These cultural layers are well aerated, balanced in water supply and biologically active. The settlement has a huge area and contains very little anthropogenic organic matter, so the cultural layers are not very thick, and poor in artefacts. The lack of organic materials, in this case, is explained, first of all, by good conditions for its mineralization.

The Dzhankent cultural layers were classified as the surface Technosols. These were accumulated in the delta-alluvial plain in arid desert landscapes. The contemporary capillary fringe is close to the lower boundary of the layers and possibly it was even closer to the surface in early medieval times. These layers are about 5-8 meters thick due to a large component of earthen building materials, big quantities of weakly decomposed plant materials in the lower part of the layer, and a low bioclimatic potential resulting from high aridity and high level of salinization.

The sets of geogenic micromorphological features are different and strongly environmentally dependent for every studied cultural layer. Clear zonal regularities are evident in the distribution of pedogenic features and their abundance. Thus, textural pedofeatures are typical of cultural layers in a humid boreal climate. The cultural layer of Gnezdovo settlement was studied in the floodplain part of the settlement, but as it was shown earlier, the settlement area was not affected by seasonal floods which were low and irregular (Bronnikova *et al.*, 2003; Panin *et al.*, 2014). Zonal soil formation proceeded in the floodplain at that time, and textural pedofeatures within the cultural layer and beneath are the relicts of this phase (Bronnikova *et al.*, 2003).

Biogenic features, accumulations of different forms of secondary carbonates, and clay coatings are the most common pedogenic features for cultural layers on the watersheds of the forest-steppe zone. All these features are typical for natural Chernozems and Phaeozems IUSS (Working Group WRB, 2015; Stoops *et al.*, 2018).

A variety of carbonate, gypsum, and soluble salts microfeatures are characteristic of the cultural layers of the desert zone. Despite the location on the delta-alluvial plain and the influence of ground waters, these features could be regarded as zonal because the geochemistry of the groundwaters and their fluctuations are also climatically dependent.

Along with zonal regularities, the sets of geogenic features are controlled by local geological backgrounds (geomorphology, hydrology and parent materials). Floodplains and delta alluvial areas in any climatic zone form in response to geomorphic and hydrological factors which define additional water supply related to seasonal inundation and ground waters. This results in permanent or semi-permanent waterlogging (Cook *et al.*, 2009). Gnezdovo cultural layers are located now in the seasonally inundated floodplain. Besides that, cultural layers of the wetland depression are located in the zone of groundwater discharge; these positions are constantly waterlogged. This explains that redoximorphic features are most common in the Gnezdovo cultural layers, especially within wetland depressions. Within these layers and underneath them, floodplain and lacustrine facies of fluvial materials were described.

Redoximorphic features are also common in the lower horizons of Dzankent cultural layers. These layers are not directly related to ground waters today but lay within the capillary fringe or close to it. Fluvial sedimentary patterns do not occur within the layer of Dzhankent but are always found underneath.

The cultural layers of the forest-steppe zone are located in watersheds having no connection with groundwaters. Some special aspects related to soil-forming substrates are observed here. Loamy texture and especially limestone bedding underlying the cultural layer of Malaya Ryazan' result in seasonal water stagnation and development of

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redoximorphic features in lower parts of these cultural layers. Carbonate features are more abundant and variable due to the highly calcareous parent material. A high diversity of anthropogenic features was observed in all the studied cultural layers located in different environmental backgrounds. Nearly all groups of anthropogenic microfeatures mentioned in manuals of archaeological micromorphology were present in medieval cultural layers (Macphail and Goldberg, 2010; Karkanas¿ and Goldberg, 2019). These are features related to input, output, turbation and compaction: features disturbing the original horizonation and lamination, creating new sedimentary patterns and lateral macro- and microheterogeneity; features related to input and processing of mineral and organic materials: extraneous fragments of rocks and sediments, plant residues, biomorphs, livestock excrements, faecal spherulites, bones, mollusc shells and eggshells; and neoformed phosphatic features, or ones composed of organophosphates with iron hydroxides, and clay admixture; various pyrogenic and technogenic products.

The sets of anthropogenic micromorphological features have much in common though they are not the same for all studied archaeological sites. Thus, features of the cultural layers located in different climatic conditions are similar in being considerably different from those of zonal background soils. This result confirms the convergence of features for thick and intense (proto)urban cultural layers in different environmental backgrounds, as suggested earlier (Stroganova *et al.*, 1998; Zazovskaya, 2013). In summary, the most obvious conclusion is that some described anthropogenic features are common for all studied objects. And regarding all accumulated knowledge on the occurrence of anthropogenic features in habitation deposits, we consider these features to be universal for cultural layers in general. Such features are related to (a) turbations: disturbance of original soil and sedimentary patterns of arrangement at all morphological levels, and replacement by newly formed anthropogenic horizonation, layering and other types of heterogeneity; to (b) anthropogenic sedimentation: accumulation of different mineral and organic materials, of earthen building materials or destroyed constructions; and to (c) pyrogenic processes. Most of these 'universal' features occur in archaeological deposits of any age, irrespective of cultural or environmental contexts (Macphail and Goldberg, 2010; Karkanas and Goldberg, 2019). The universal occurrence of these anthropogenic features in cultural layers is explained, first of all, by some universal anthropogenic processes related to life-supporting practices. As an example, the inevitable significance of fire in human history has resulted in the widest distribution of various pyrogenic features in soils and sediments of archaeological contexts. A high level of anthropogenic production of features is related to fire and to phosphor-containing materials. Since most ancient times, there have been two cornerstones of human existence: the human use of fire; and the human use, transformation, emittance, and accumulation of organic matter of animal origin. The second reason for the wide distribution of the above-mentioned features is the high resistibility of most of them in most environments. Carbonate ashes are an exception because they are theoretically unstable in acid or even in close to neutral intra-soil environment. They are widespread possibly due to the sheer quantities in which they are produced during residential, craft and other human-related activities, and because of local soil alkalinization in the burning process.

There are two inferences from the above-mentioned facts. As universal anthropogenic features occur in every cultural layer, they do not contribute much to a closer specification of human activities. On the other hand, the exact level of abundance of these features reflects the intensity of anthropogenic pressure.

Meanwhile, some deeper studies of these universal features also can give very important information on the local environment, some aspects of human impact and the important events in the settlement history. As an example, pyrogenic materials were studied in detail in the Dzhankent cultural layers. Stratigraphic, micromorphological and microstratigraphic investigations combined with anthracological studies and dating allowed us to identify three fire events recorded in the cultural layers, and to define the difference between the patterns related to fires (conflagrations) and local fireplaces.

In addition to the universal features, there are features of rare occurrence found only in some of the studied objects, and in certain stratigraphic layers or sectors of a site. The occurrence of such rare features is determined not only by the occurrence of related specific human activities, but also by the local intrasoil environment. For example, no faecal spherulites and metal droplets were found in the Gnezdovo cultural layers although there is evidence at the site for animal husbandry, and some of the studied objects were located directly within metal-working zones. The humid climate and the floodplain water regime of the location, leading to high groundwater levels, and slightly acidic pH values do not favour the preservation of unstable biogenic calcite nor of small metal artefacts. It is known that faecal spherulites are generally more soluble than geogenic calcite (Canti, 1999; Karkanas and Goldberg, 2018). Nevertheless, some calcareous material has been found there, in the form of carbonate ashes and limestone fragments. The reason for this is location conditions: alkalinization during burning, and the presence of large quantities of limestone.

Generally, the more intensive and variable the human impact has been, the more abundant and varied the anthropogenic features are. In the cultural layers of investigated pre-urban and urban medieval settlements with clear zoning and high intensities of human impact, anthropogenesis has changed (or even destroyed) the original soil profile, suppressed in some respects certain soil-forming processes (mostly due to changed geochemistry), and introduced a wide variety of anthropogenic processes and features. This is well known for urban and pre-urban archaeological sediments (Stroganova *et al*., 1998; Prokof'eva *et al*., 2001; Mazurek *et al*., 2016; Howard, 2017; Devos *et al*., 2017)

In medieval towns, the human impact considerably changed the geochemistry of local soil/sediments within habitation areas (primarily due to an input of phosphorus, organic matter, carbonate, sulphur, and nitrogen-containing materials). These changes are generally more advanced in humid/semi-humid conditions than in arid regions.

Despite intensive residential and craft-related human impact in the medieval past which formed the cultural layers in pre-urban or urban local environments, zonal regularities and the impact of geological background are of great importance for the occurrence and distribution of micromorphological features. Geogenic features in the studied cultural layers vary depending on the background landscape and climatic conditions. In addition to the described set of variable anthropogenic features, the studied cultural layers were characterized by a set of pedofeatures typical of zonal soils and some other geogenic features related to the geological setting.

6. Conclusions

The set of anthropogenic features reflects the past human impact in the locality: the more varied and frequent anthropogenic features are, the more intensive and variable has been the human impact which occurred in the past. At the same time, the occurrence of certain anthropogenic features may indicate not only human-related processes during their formation, but also a current soil environment which may be favourable or destructive for these features. For instance, calcareous features, especially delicate ones such as faecal spherulites or egg shells, are not normally preserved in conditions of humid climate and active leaching processes; metal droplets certainly would be easily dissolved even in a seasonally waterlogged environment. On the other hand, as a practical guide on environmental archaeology realistically commented: "Predicting the survival of environmental remains in archaeological deposits is not an exact science" (Campbell *et al*., 2011). For example, micritic and microsparitic ash accumulations and large quantities of softened and partly re-crystallized, but not considerably dissolved limestone was

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recorded in the Gnezdovo cultural layers, on a site which is located in a humid climate in a seasonally flooded location.

The set of anthropogenic features found in a certain stratigraphic unit or sector of settlement deposits is conditioned both, by the type and intensity of local human impact and by the current local soil environment. Thus, intensive and variable human impact in a medieval settlement would have strongly changed the geochemistry of local soil/sediments, transformed or (more often) destroyed the original soil profile, changed input and output of compounds and materials, widened the set of soil and sedimentary processes, and suppressed some of the original soil processes. Nevertheless, cultural layers contain data of the climatic and landscape conditions of their formation and transformation, in a set of features which is related to the local background environment.

Authors' contributions

Bronnikova, M.A. – general design of overall study and methodological approaches, pedological fieldwork, micromorphological studies on all sites, interpretation, and drafting most of the typescript. *Karpova, J.O.* – fieldwork at Dzhankent, micromorphological studies of the cultural layers in Muromskij Gorogok, Malaya Ryszan' and Dzhankent, preparation and configuration of figures, final formatting of the typescript. *Murasheva, V.V., Kochkina, A.F., Stashenkov, D.A., Arzhantseva, I.A.* – archaeological fieldwork, descriptions of the archaeological backgrounds and contexts. *Haerke, H.* – archaeological fieldwork, final edit of typescript.

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Conflict of interest

The authors declare no conflict of interests between authors, institutions or other third parties in respect to the entire content of the article or its parts.

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