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RAKUSHECHNY YAR SITE: LACUSTRINE AND FLUVIAL DEPOSITS, BURIED SOILS AND SHELL PLATFORMS FROM 6TH MILL. BC

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Abstract. The Rakushechny Yar site is a floodplain multi-layer archaeological site encompassing strata dated from the Early Neolithic to the Bronze Age. It is characterised by a complex stratigraphy, with the presence of different deposits, buried soils and archaeological layers. Fluvial deposits interlay different settlement strata, which provides an opportunity to elaborate a precise chronological scheme and to study the successive changes in hydrological regime, climate and vegetation, along with the phases of human occupation. A study of the pastes used in ceramic manufacture was conducted to investigate changes in the procuring of raw materials, whose procurement would have depended heavily on their availability and sedimentation process. The fluvial deposits, which have safely preserved the Neolithic–Bronze Age archaeological layers, reach thicknesses of more than 6 m, which makes this site interesting both for the reconstruction of the human–environmental interaction and for the palaeoenvironmental history of the region.

Key words: Neolithic, flood-plain multi-layer site, sedimentology, buried soils, shell platforms

Introduction

The Rakushechny Yar site, situated in the NW part of Porechny Island in the lower Don River valley (Rostov region, Russia) (Fig. 1), occupies a particular place in the Early Neolithic of Eastern Europe. It is one of the oldest Early Neolithic sites in this region, dated to the 6th millennium BC. Recent investigations have shown the area's particular importance in the study on the neolithisation of Eastern Europe (Mazurkevich, Dolbunova 2012, 2015; Gorelik *et al.* 2014, 2016).

The site was excavated in 1959–66, 1968, 1971, 1976–77 and 1979 by the Leningrad State University, under the direction of T.D. Belanovskaya (1995) (Fig 2). Excavations were renewed in 2008 by P.M. Dolukhanov (Aleksandrovsky *et al.* 2009), and further new research was done by the Don Archaeological Society and Lower Don Expedition of The State Hermitage Museum (Tsybryi *et al.* 2014, 2018).

In order to refine the site chronology, which at that time covered a wide period from the 7th to the 6th millennium BC (Belanovskaya, Timofeev 2003; Tsybriy *et al.* 2017) and included datings of the most ancient appearance of both pottery and cattle-breeding in SE Europe, new archaeological works were needed. The first excavations on the site and comparison with the data documented by T.D. Belanovskaya showed that the NW part of

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the island, where the archaeological site was located, has been eroded rapidly and is continuing to be eroded by the Don River channel. This near-bank area close to excavations II–III of 1968, which captured the modern channel and the remains of the eroded excavation pits, was chosen for a new archaeological campaign (Fig 3). The new investigations focused on the most ancient Early Neolithic layers, which were largely inaccessible in the 1960–70s due to the high water level on the Don River.

The Rakushechny Yar site has a complex stratigraphy, with the presence of different deposits, buried soils and archaeological layers (Telegin 1981; Belanovskaya 1995). Such floodplain multi-layer settlements with series of buried soils are very important for the study of human–environmental relationships. Fluvial deposits interlay different settlement strata, and provide an opportunity to elaborate a precise chronological system and to study the successive changes in hydrological regime, climate and vegetation, and the phases of human occupation. The fluvial deposits, which have safely preserved the Neolithic-Eneolithic archaeological layers, reach more than 6 m thick, which makes this site interesting both for the reconstruction of historical processes and for the study of the palaeoenvironmental history of the area.

T.D. Belanovskaya distinguished 23 strata (Fig. 4 f), which were formed under different conditions. The particularity of the formation of the layers and the presence of micro-layers allow for the creation of a microchronology for this site, where individual layers were formed during very short episodes. Local environmental changes were accompanied by diversified type and rate of deposit accumulation. This also had a direct impact in changing the raw material sources used for pottery production. This research combined different proxies for time modelling, namely: radiocarbon dating of samples originating from micro-layers, relative chronology induced in stratigraphical observation, and reconstruction of changes in environmental conditions.

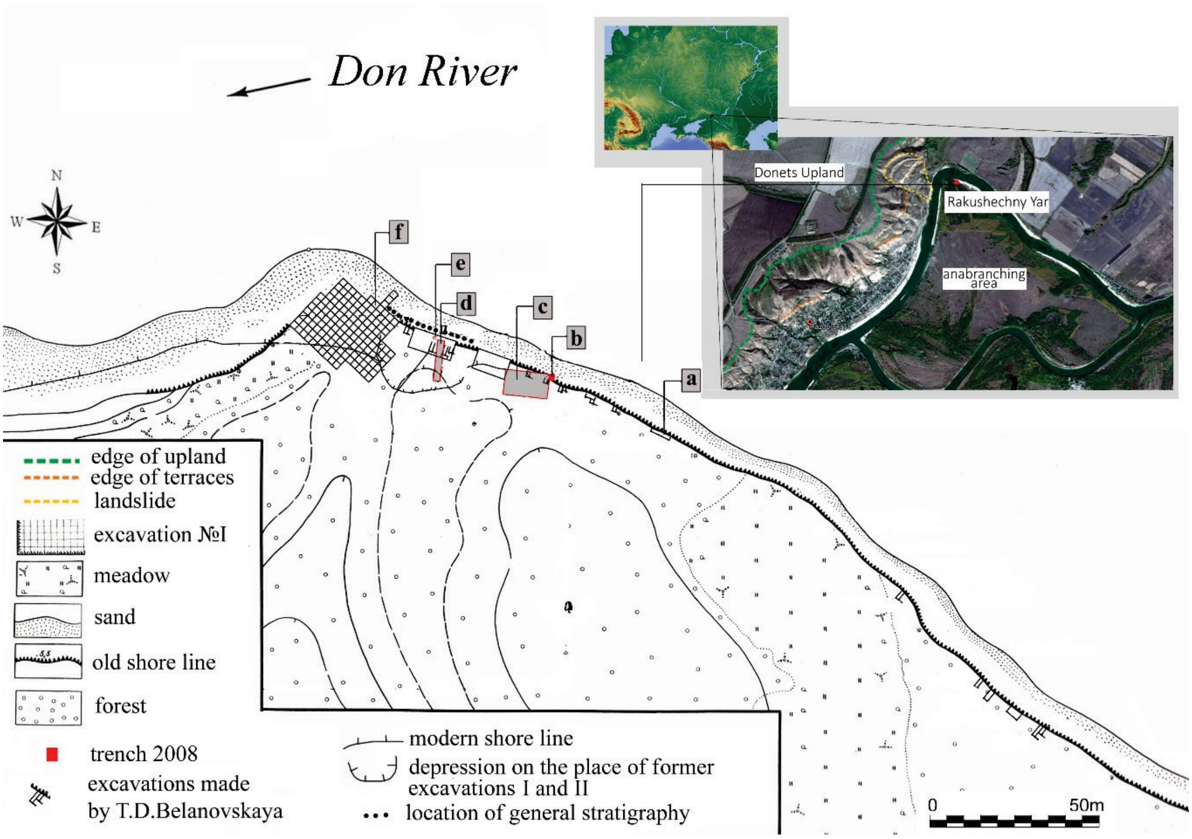

Fig. 1. Rakushechny Yar site. Location of excavations of the 1960s–70s, recent excavations and described profiles

a – stratigraphic profile of Telegin (1981); b – stratigraphic profile studied by P.M. Dolukhanov in 2008 (Aleksandrovsky *et al.* 2009) (location of profile RAY4); c, d – new excavations; e – generalised stratigraphy (location of profile RAY1); f – excavation I by T.D. Belanovskaya (after Tsybrij *et al.* 2017, modified)

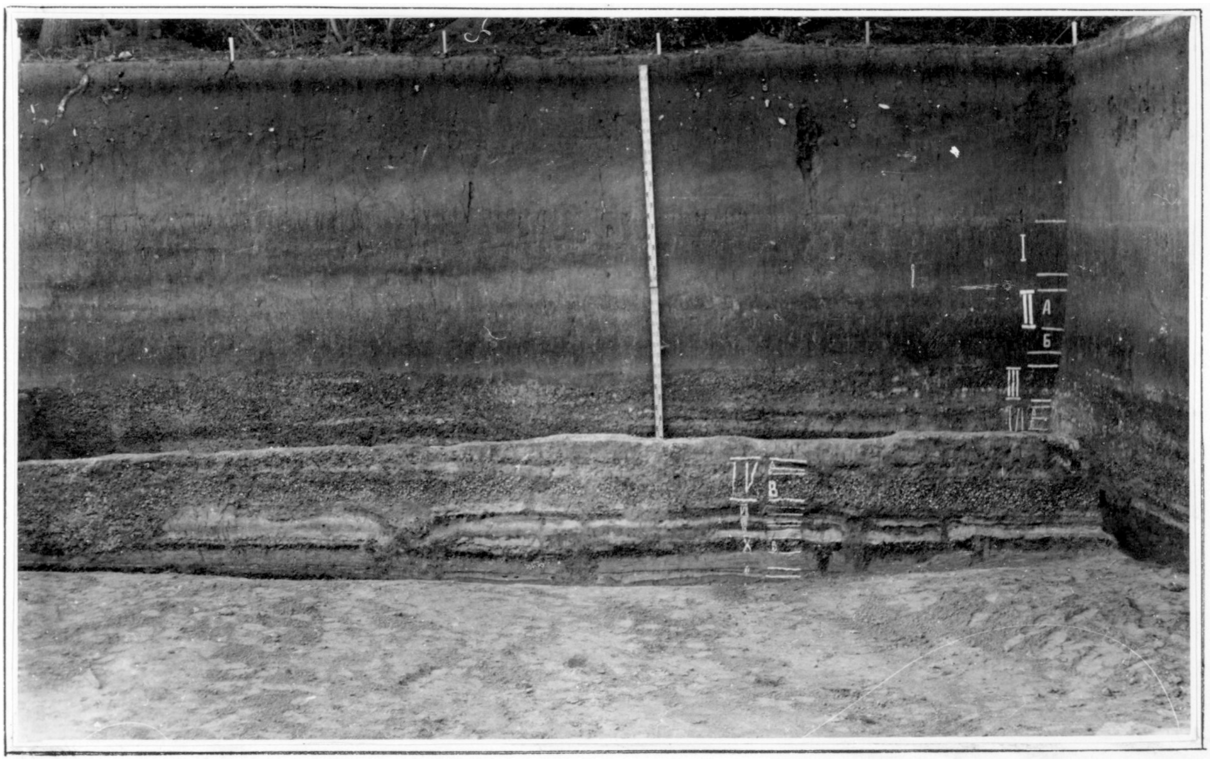

Fig. 2. Stratigraphy of excavation I of T.D. Belanovskaya with indication of archaeological layers (Belanovskaya 1962)

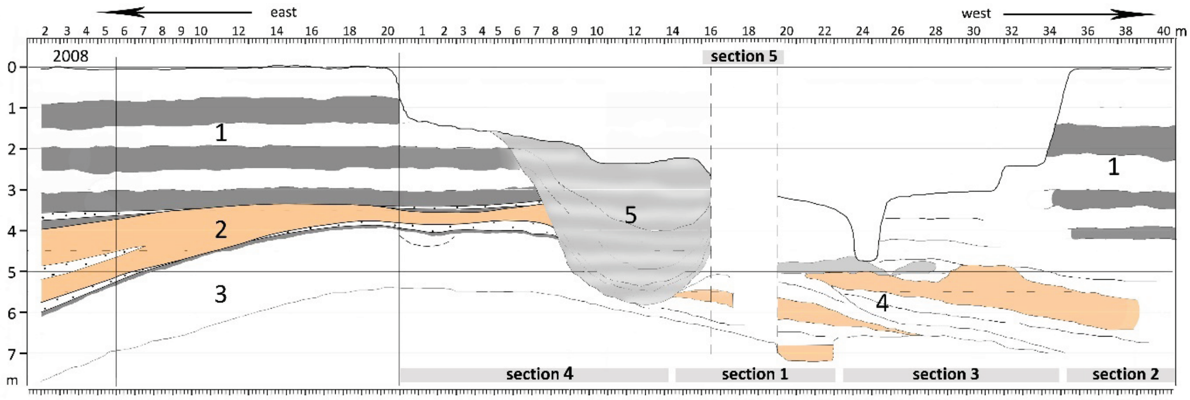

Fig. 3. Scheme of major stratigraphic units and sections of the site

1 – loamy flood plain alluvium with buried soils No. I–IX; 2 – shell strata with sandy interlayers, deposited in the buried soil X; 3 – sandy-loamy sediments (alluvium) with archaeological layers; 4 – shell, sandy and loam layers with Early Neolithic remains; 5 – modern laminated fill at the location of former excavations of T.D. Belanovskaya

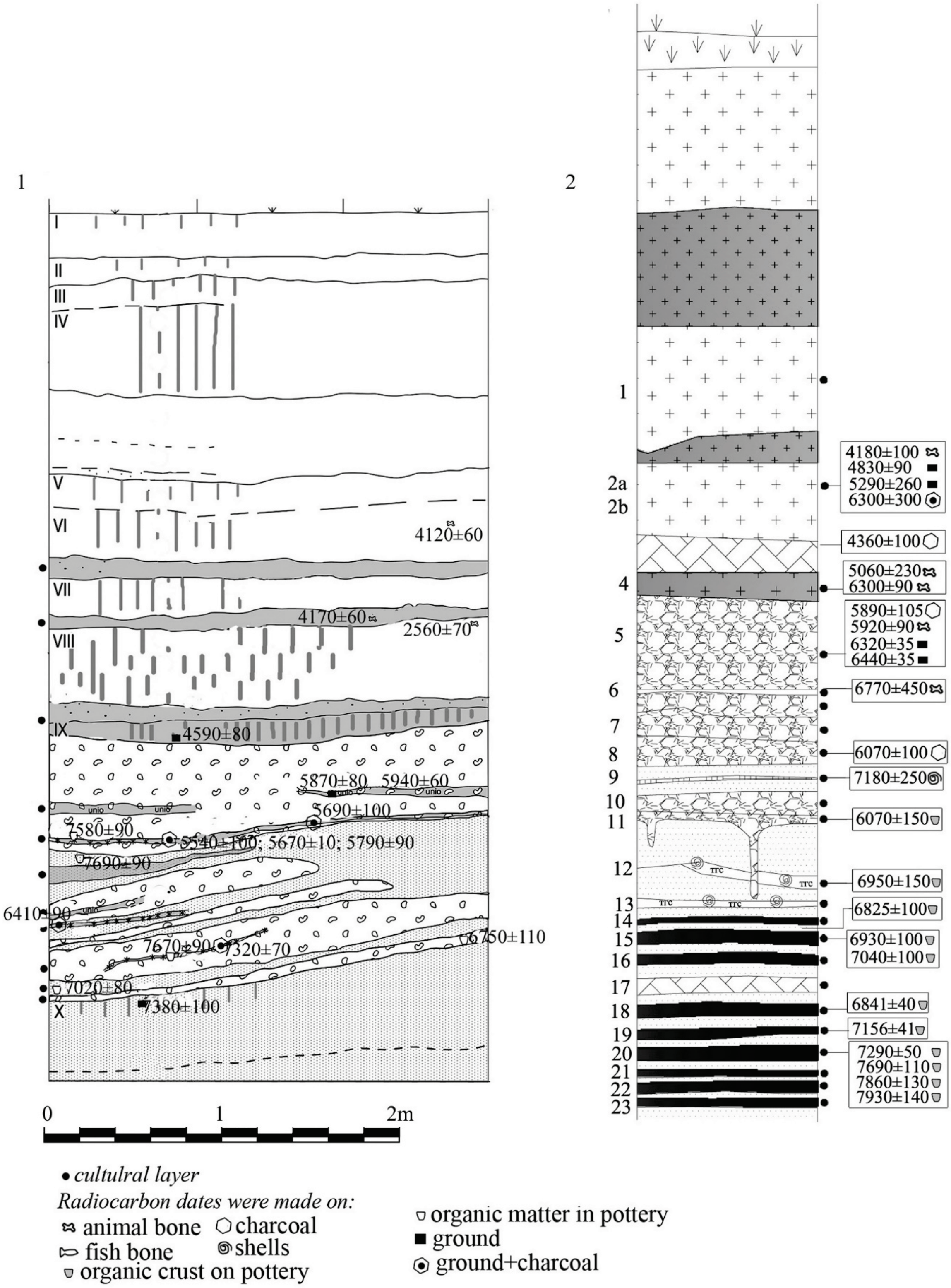

Fig. 4. Stratigraphy of the trench

b – made in 2008 (after Aleksandrovsky *et al*. 2009); f – stratigraphy of T.D. Belanovskaya excavation (after Tsybrij *et al*. 2017); radiocarbon dates are uncal. BP; for references and lab-indices see Tsybrij *et al*. (2017); upper strata consists of loamy sediments, middle strata – *Viviparus* layers, lower strata – shell *Unio* layers interlaminated with alluvial sands

Research methods

Archaeological and geological investigations were conducted in order to reconstruct the conditions in which archaeological layers were formed. Three-dimensional recording of all artefacts and ecofacts was conducted during excavations, which allowed for a better reconstruction of microlayers and ancient platforms. In order to refine the stratigraphy and trace it within a larger area, a generalised stratigraphy was made within 39 m along the shore line (Fig. 1).

Geomorphological investigations were applied based on sedimentological analysis of profiles of deposits at the site and in the surrounding localities. Two profiles were elaborated in detail: RAY1, situated in section 1 (Fig. 1, point e), and RAY4 at the location of the 2008 trench to the east of section 1 (Fig. 1, point b) (Aleksandrovsky *et al.* 2009). The basic method of sedimentological research comprised identification of the lithofacial features, the texture (grain-size composition) and the structure of deposits. The methods of lithofacial analysis of sediments were undertaken according to Miall (1977) as well as Zieliński and Pisarska-Jamroży (2012). The grain-size composition of selected sediment samples was also determined using a Mastersizer 3000 laser particle-size analyser with a Hydro MU dispersion unit (Malvern). The textural features were evaluated using Folk and Ward (1957).

The geological conditions of the region and the availability of suitable raw materials (i.e. that meet the cultural choice of the local ancient population) constitute one of the main factors in selecting raw materials for pottery production. In order to compare the types of raw materials used for pottery production in different periods, X-ray fluorescence analysis was carried out to establish the chemical composition of the vessel fragments originating from layers 23–11 of the T.D. Belanovskaya excavation and various sections of the new excavation. Data on the chemical composition of all samples were processed by the principal components of factor analysis and correspondence analysis (Statistica 8.0). Micro-morphological analysis of pottery fragments was carried out in thin sections using MBS-1 binoculars at 16×, 24× and 72× magnification. Petrographic study of the ceramics was carried out under a POLAM-11 polarisation microscope at 65.7× magnification.

Soil analyses were performed in the laboratory of the Institute of Geography of the Russian Academy of Sciences by routine methods: TOC content by Tyurin's method; P_2O_5 content by Ginzburg's method; pH of soil water suspension by potentiometry; and $CaCO_3$ content by the acidometric method (Vorobieva 1998). The structure of soil horizons, their colour and grain-size composition, and the nature of inclusions and carbonate nodules were all evaluated in order to analyse the degree of development of the soil profile. Publicly available data on the degree of soil development were used to estimate the duration of the formation of the soil profile. On the basis of morphogenetic analysis, the types of soils and their derivation from the steppe or forest type of soil formation were established. The nature of accumulation of carbonates was taken as evidence of climate aridity, and phosphorus content as an indicator of human activity.

The charcoal samples were analysed with the use of a Nicon Eclipse ME600P metallurgical microscope. The determinations were verified with the help of the wood reference collection of the W. Szafer Institute of Botany, Polish Academy of Sciences.

Radiocarbon dates were determined based on different materials – wood charcoal, bones, food crust, pottery and ground. Radiocarbon dates were calibrated based on data (Reimer *et al.* 2009) using OxCal v4.3.2 (Bronk Ramsey 2017).

Geological situation

Porechny Island is part of the anastomosing fluvial system of the Lower Don River and has a heterogeneous geological and geomorphological structure (Velichko *et al.* 2011). The island is an inter-channel area situated between the present-day main Don River channel (E, N and W of the island) and a secondary channel (S of the island). It might be suggested that this small island was formed during the formation of a new river bed (Velichko *et al.* 2011). The Don River valley is adjacent to the Donets Upland to the west. The northern channel of the Don River, which is located on Porechny Island, undercuts the base of the Donetsk Upland. The upland is built of Palaeozoic and Mesozoic solid sedimentary rocks covered with a several-metre-thick series of loess. Such a geological structure and the river channel's erosion of the upland's slope favours the formation of landslides. One is located about 100 m downstream of the Rakushechny Yar site. The valley slope and edge are diversified with numerous ravines and gullies, landslides and terraces.

The floodplain of the inter-channel area has a varied morphology, with numerous distributary channels separated by islands (inter-channel areas) that are flooded seasonally. Two terraced levels have been distinguished in the relief of the flood plain of the islands based on the topographical and geological situation. The higher level is developed in the eastern part of the island, with a homogeneous geological structure: a lower sandy unit of channel deposits and an upper unit of fine-clastic overbank deposits. The lower, western level, which is cut by the numerous distributary channels, has a more complicated structure than the higher one. In its bottom, there are mostly lacustrine massive silts and clays with layers of mollusc shells. The thickness of lacustrine deposits reaches up to 2 m. These deposits cover channel deposits. However, in the roof of the lacustrine deposits level, there are several sets of layers of sands and silts called "flood rhythmites". The series of flood rhythmites is covered by massive flood diamictons. The total thickness of overbank deposits reaches 4 m (Dolbunova *et al.* 2020).

Nowadays, the Rakushechny Yar site is situated in the northern part of an anabranching (interchannel) area of an anastomosed part of the lower Don River stream (Fig. 1). The inter-channel area is *ca* 4.5 km long (along the north main river channel) and *ca* 2.5 km wide. The site is located at the distributary channels flowing across Porechny Island. The distributary channel is an extension of the side valley drained by the Sukhoy Donets River, which flows to the Don River from the north. At the site area, lacustrine deposits were documented in archaeological outcrops under overbank alluvium (Dolbunova *et al.* 2020).

Soil stratigraphy and genesis

From the palaeopedological point of view, the lithological sequence at the area of recent excavations can be divided into five stratigraphical units (Fig. 3). The upper 3.5–4 m sediments of loamy flood plain alluvium include a total of nine buried soil horizons (unit 1), which are fully developed in the eastern part of the site (Fig. 4). Shell horizons and sandy layers with Neolithic remains lie beneath them in this part of the site. Shell layers (unit 2) and sandy layers (unit 3) were recorded in the eastern part of the site; they are inclined eastwards and differ from the upper strata and from each other. The thickness of shell strata deposited between buried soils IX and X increases in the eastern part on the slope, and they are laminated into several layers divided by sandy layers. A dome-like distribution of lower units 2, 3 and 4 is recorded; its highest part is located in the central part of this stratigraphy between the 2008 trench and section 4/1.

In the western part of the site, inclined shell-sandy strata (unit 4) with Early Neolithic artefacts were recorded adjoined to buried soil X. Soil X was noted in the trench made in 2008 and nearby (Aleksandrovsky *et al.* 2009). It is a humic horizon of 5–10 cm thick lying between the shell strata and sandy layers. It becomes thinner to the west because it was formed on the elevation of a palaeorelief form (Fig. 4). Archive photos may show a soil similar to the buried soil X nearby that might correspond to archaeological layer 10/11 of T.D. Belanovskaya (Fig. 2). The discrepancy in radiocarbon dates from this layer and the upper layers does not allow their precise correlation (Fig. 4). However, this soil horizon cannot be traced on field photos of T.D. Belanovskaya taken at the location of excavations II and III. Soil X is carbonated, relatively poorly coloured by pedologic organic matter, with pockets and wedges filled with humic material. A blurry low border typical of soils can be traced. On the slope of the elevation (the location of the trench made in 2008) the humus horizon displays lamination and was not totally degraded by pedogenesis. All this testifies to soil formation and the stabilisation of land relief lasting for a short period of about 100–200 years.

Within the upper strata of the floodplain alluvium, loamy sediments and soils dominate. By contrast, below, starting from soil V, deposits and soils are carbonate and only thin loamy sandy and sandy interlayers were recorded. Loamy soils are characterised by a well-expressed block structure, carbonate nodules and all soil mass impregnated with fine crystalline calcite. The carbonate content is 5–7%, excluding sandy interlayers. Despite the dark colour of the soil, the organic carbon content is relatively low (0.5–0.8%) (Alexandrovsky *et al.* 2009, Table 1). Phosphorus content in loamy strata, including soils I–VIII and archaeological layers 1–3, is low – it is higher only in the lower soil (IX) of these strata that corresponds to the upper Neolithic layer.

Soil IX is situated at the transition from floodplain alluvium to shell strata (Fig. 4). Its upper part is represented by humic loam with carbonates represented by impregnation forms and nodules. Below, in a shell stratum with a thickness up to 1 m, traces of soil formation processes are distinctly expressed – in particular, a high content of fine soil with a well-defined structure. The content of carbonates reaches 25%, and the organic carbon content of the upper part of the shell stratum processed by soil formation is equal to the soils of the overlying strata (Alexandrovsky *et al.* 2009) (Table 1). The upper part of the shell strata should be included into soil IX. The content of phosphorus in the fine soil from the shell strata is increased (Alexandrovsky *et al.* 2009, Table 1), which indicates more active human activity in the Early Neolithic.

Soils (VI–IX) in the loamy strata can be attributed to chernozems and kastanozems. They were formed in the conditions of a semiarid climate in the Middle Holocene under steppe vegetation (Kremenetsky *et al.* 1998; Alexandrovskiy 2000; Dyuzhova 2013). Similar conditions of soil formation also held during the accumulation of shell layers. Upper soils with a more coarse (sandy) grain-size composition were leached from carbonates, and their pH values are more acidic. They were formed under forest vegetation in a more humid climate and can be classified as dark grey forest soil or phaeozem (leached chernozem).

Sedimentology of deposits

The geological structure of the flat floodplain is mostly homogeneous. This structure consists of layers of massive diamictons (DFm) and massive silts (Fm) of the overbank alluvia deposited on the series of laminated sands (Sh, Sr) or massive sands (Sm) and massive silts (Fm) of the channel alluvia.

From the sedimentological point of view, the studied lithological profile RAY1 has been divided into two main units: (1) the lower – lacustrine deposits, and (2) the upper – overbank alluvium (Fig. 5).

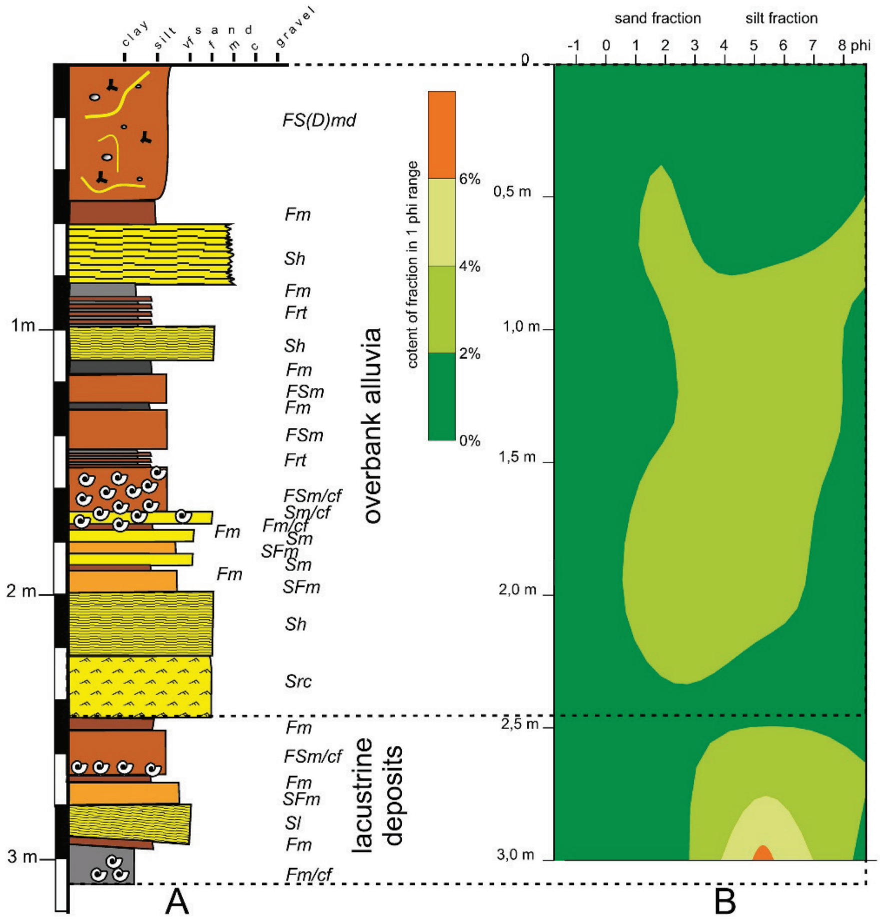

Fig. 5. Sedimentological traits of deposits of RAY1 profile

The lower unit is formed below a depth 2.45 m by massive silts (Fm), massive silts with remains of freshwater molluscs (Fm/cf), sandy silts with remains of freshwater molluscs (FSm/cf), silty sands (SFm) and low-angle laminated sands (Sl) (Fig. 5A). Spectral diagram analysis (Fig. 5B) demonstrates a predomination of coarse silt (4–5 phi) in the lower part, while the sorting of deposits decreases in the upper part of the unit and, at a depth of 2.9–2.5 m b.g.l., equal participation of fractions from 3 to 8 phi is observed. Such traits of deposits in the lower unit show their accumulation in a stagnant water body with only a low-energetic flow regime. These processes took place within the reconstructed dam-lake. The results of current geoarchaeological research indicate that the landslide developed *ca* 8.5 millennia BP. As a result, the northern channel of the Don River was dammed and a lake was created.

The upper unit is more lithologically diversified than the lower one. In the lower part of the upper unit, two horizons of sand occur: climbing ripple-laminated sands (Src) and horizontally laminated sands (Sh). These sediments were deposited most probably as a result of flow that drained the dammed lake and caused its disappearance. Starting from 2 m b.g.l. up to the surface level, vari-grained horizontally bedded deposits occur in the studied lithological profile and have been classified as overbank alluvium. It is demonstrated mostly by two series of rhythmites (Frt) at depths of 1.43–1.50 and 0.85–1 m b.g.l. The analysis of the spectral diagram indicates fining upward of the upper unit deposits. The sediments are poorly sorted with tendency to deterioration in the profile's upper part. The sequence of overbank alluvia is closed in the roof by sandy silts with gravels that form a diamicton layer FS(D)md.

In the lithological profile RAY4, too, two main sedimentological units were distinguished: (1) the lower – lacustrine deposits, and (2) the upper – overbank deposits (Fig. 6).

The lower unit is formed by fine deposits, massive silts (Fm), massive silts with remains of freshwater molluscs (Fm/cf) and massive silts with charcoal (Fm/C) of lacustrine origin. Within these deposits, ripple laminated sands (Src) and rhythmites of silty sands and sandy silts (SF/FSrt) occur that may be evidence of flood episodes. Simultaneously, high energy flows are evidenced by climbing ripple-laminated sand, while flows of changeable energy are evidenced by flood rhythmites (Szmańda 2018). However, the lacustrine origin of the discussed sedimentological unit is proven by the occurrence of Cladoceran remains.

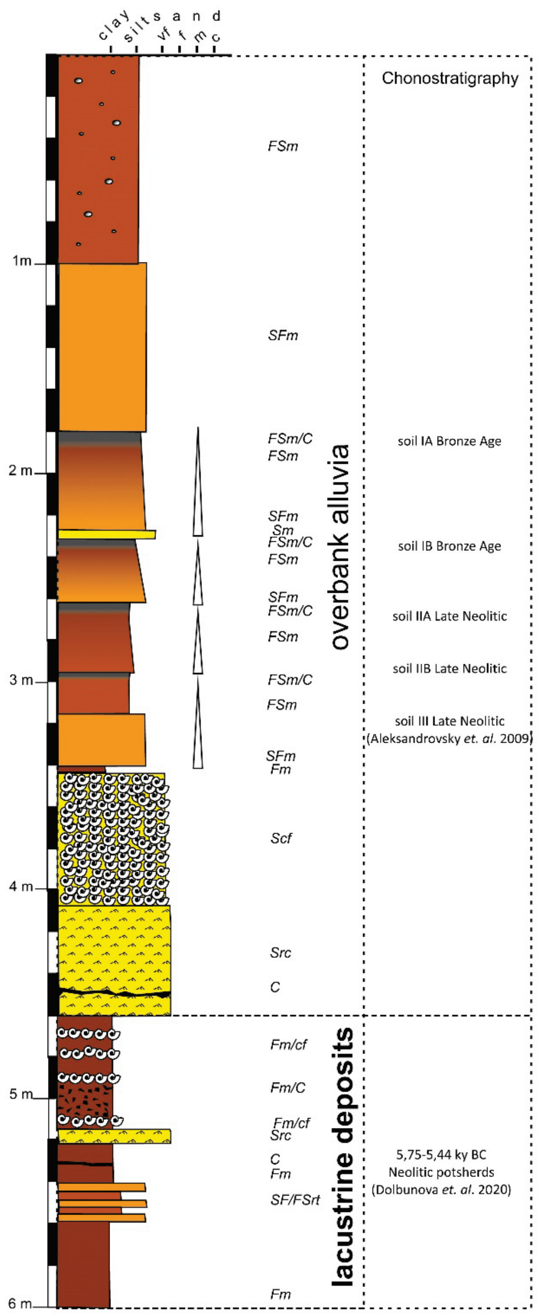

Fig. 6. Sedimentological traits of deposits of RAY4 profile

The upper fluvial unit consists of – from the bottom – as follows: ripple-laminated sand (Src), four layer sets of fining upward sequence recognised as buried alluvial soil (fluvisol) from the Late Neolithic and the Bronze Age. It must be stressed that alluvial soils are developed synchronously with overbank deposits accumulation, and every horizon may be the result of a single flood (Szmańda 2018). Massive silts, sandy silts, and sandy silts with gravels form a layer of diamicton (DFm) that end the sequence of overbank alluvia.

Plant macrofossils

Wild plant species found in wet environments (*Zannichellia* sp., *Polygomum* sp., *Echinochloa crus-galli, Trapa* sp.) were identified by previous archaeobotanical analysis (Tsybryi *et al.* 2014). Other plant remains include *Chenopodium* sp. and *Rosaceae*. They testify to the high humidity here, which suggests the existence of a lake basin and/or periodic flooding during the lower layers' formation.

The rather high amount of charcoal recorded in archaeological layers may have been washed from fireplaces during periodic floods or fluctuations in the water level of the dammed lake. The discrepancy in radiocarbon dates made on charcoal and animal bones from the same layer might be a marker of the washing-out of older layers (Fig. 7). Charcoal in archaeological layers is represented both by single finds – smaller fractions of 0.3–0.6 cm and possible hearth places with macro-charcoal deposition. The anthracological analysis showed a minor taxonomic diversity of charcoals discovered in the layers of sections 1–3 (Table 1). In most of them the remains of *Ulmus* sp. elm were determined. In several layers they were accompanied by the remains of *Salix* sp. willow and/or *Populus* sp. poplar. Elm was represented by a small number of fragments only in layer 18 (section 1), in which willow remains dominated. In one sample from layer 18 (section 1), two charcoals of *Rhamnus cathartica* buckthorn were also found, while the layer *Viviparus* 4 (section 3) featured a fragment of charcoal of *Staphylea pinnata* bladdernut.

In the light of palynological studies at Rakushechny Yar, at the time of the sedimentation of the archaeological layer of Neolithic settlements, steppe vegetation was preponderant. The pollen composition of samples taken at the RAY4 profile testifies to a wider spread of pine–birch forests with a small admixture of oak and elm (Borisova 2011). However, due to the special structural features (air bags), pine pollen can easily be transported over long distances by wind and water. Therefore, even the relatively high content of pine pollen (up to 20% Σ) in the lower layers of Rakushechny Yar does not mean that pine forests were extensive in its vicinity (Borisova 2011).

The taxonomic composition of charcoals from layers of sections 1–3 indicates that the Neolithic communities from the lower Don River valley were quite selective in the firewood they preferred to gather. The main factor influencing firewood collection is assumed to be availability, indicated mainly by the use of the most common taxa and the broad taxonomic range of wood raw materials (e.g. Milisauskas *et al*. 2004; Out 2009). Willows, poplars and elm trees are plants associated with moist habitats. All three taxa could have grown in the immediate vicinity of the river, although *Ulmus* avoids waterlogged soils (e.g. Ralska-Jasiewiczowa *et al*. 2004). It seems that the calorific value of elm wood (1900 KWh/m^3; Ebert 2003) could not be a decisive factor in the selection of this wood as a fuel, as it only slightly exceeds the analogous value determined for pine (1,700 kWh; Ebert 2003). Moreover, the calorific values of willow and poplar wood, also recorded among charcoals, are significantly lower (1,400 kWh; Ebert 2003). It is possible that in the fireplaces the inhabitants burned waste material that remained after having processed wood for other purposes. Elm wood is particularly durable in a wet state, especially when sunk into muddy-bottomed water bodies, where it is quickly petrified (Kokociński, Surmiński 2015). For this reason, elm may have been preferred as a construction material, especially in damp and flooded river valley areas.

Absolute chronology of strata

The set of radiocarbon dates obtained for materials from different areas and strata of the site testify to some of the achieved ages having been influenced by differences in the chronology, number and character of the archaeological layers or by the possible influence of the reservoir effect (Fig. 7, Tsybryi *et al.* 2017). This complicates the precise correlation of different areas and the refining of the radiocarbon chronology. The previous chronology reconstructed for the site encompassed a wide period from the 7th millennium BC to the 6th BC. Different parts of the dammed lake shore zone might have been inhabited, which can be archaeologically traced in the radiocarbon dates.

A new series of samples from archaeological layers 14–17 in section 1 (unit 4) (Figs 8, 9) (Dolbunova *et al.* 2020) were dated to an interval spanning no more than a few decades and centred on 5600 cal. BC. Each archaeological layer was therefore formed rapidly, and the sterile sand deposits separating the archaeological layers do not represent long hiatuses. Much older dates attributed to layer 15 (e.g. 7383±120 BP, SPb-1177, charcoal) might reveal redeposition of organic material to be a genuine problem. Such a discrepancy in dates should be a subject for future discussions and interpretation.

Table 1

Charcoal determinations from layers of sections 1–3

Section	Layer	Size of charcoal fragments (cm)	Taxa						Total
			Ulmus sp.	*Salix* sp.	*Populus* sp.	cf. *Staphylea pinnata* L.	*Rhamnus cathartica* L.	indet. deciduous	
Section 1	shell pit (low viviparus layer) synchronous with layer 14b	0.2-0.8	34						34
	shell pit (middle viviparus layer)	0.2-0.7	40						40
		0.2-1.2	91					1	92
	layer 14a	0.5-0.7	4		1				5
	layer 17 (shell plaform)	0.2-1	7						7
	layer 17 (shell plaform)	0.6-1.5		2					2
	layer 17 (shell plaform)	0.4-1.2	22	4	3				29
	layer 18 (shell platform on elevated part)	0.5-1					2		2
	layer 18 (shell plaform)	0.2-1		71					71
	layer 18 (shell plaform)	0.5-2	7						7
	layer of gray silt with charcoal under layer 18	3	1						1
	layer of gray silt with charcoal under layer 19	0.5-2.2	24	6				1	31
	layer of gray silt with charcoal under layer 19	0.5-2	19	2	1			1	23
	layer of gray silt with charcoal under layer 19	01.01.2004	3						3
	dark-blue silt above layer 20	0.5	4						4
Section 2	Viviparus 4	0.2-1.3	15						15
		1.5-3.5	5						5
	Viviparus 5	1			1				1
Section 3	Unio 5	1.5-2.5	1		1				2
	Unio 8	0.7-2.0	6						6
	Viviparus 4	0.5-0.7	20	5	1	1		2	29
Total			303	90	8	1	2	5	409

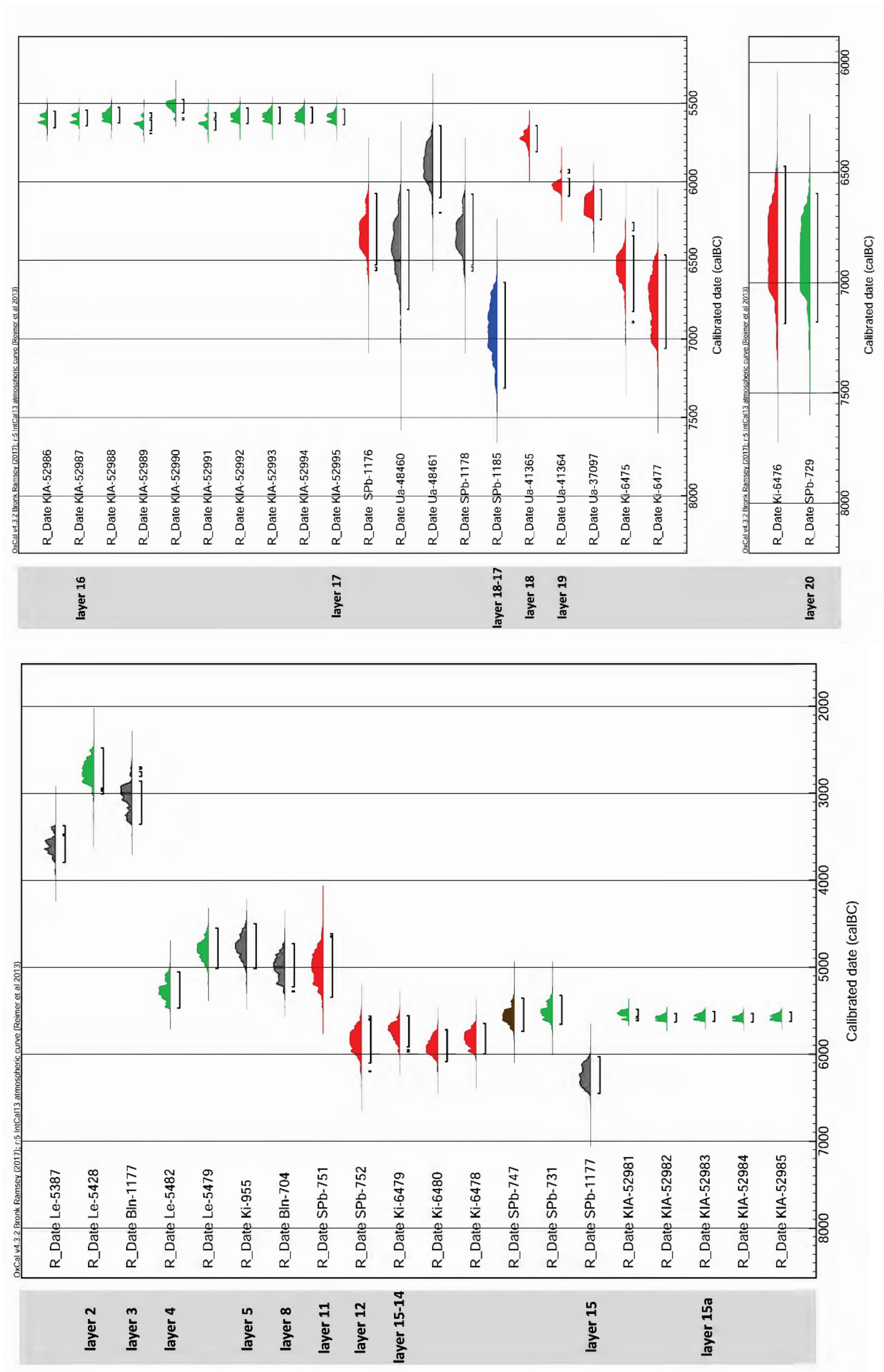

Fig. 7. Radiocarbon dates set for Rakushechny Yar site (excavation I and section 1)

red– food crust, green – animal bones, grey – charcoal, blue – fish bones

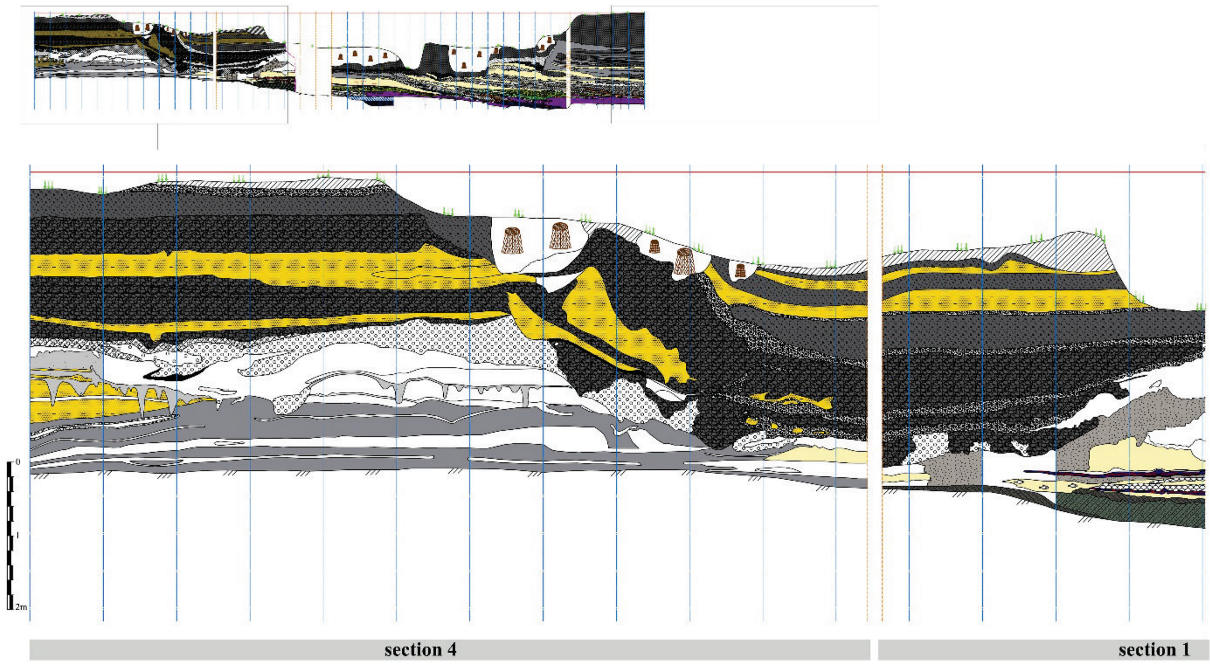

Fig. 8. Generalised stratigraphy: section 4/1 (area 'e' according to Fig. 1)

upper strata consists of loamy sediments, and lower strata of alluvial sands (for section 4) and shell *Unio* layers interlaminated with alluvial sands (for section 1)

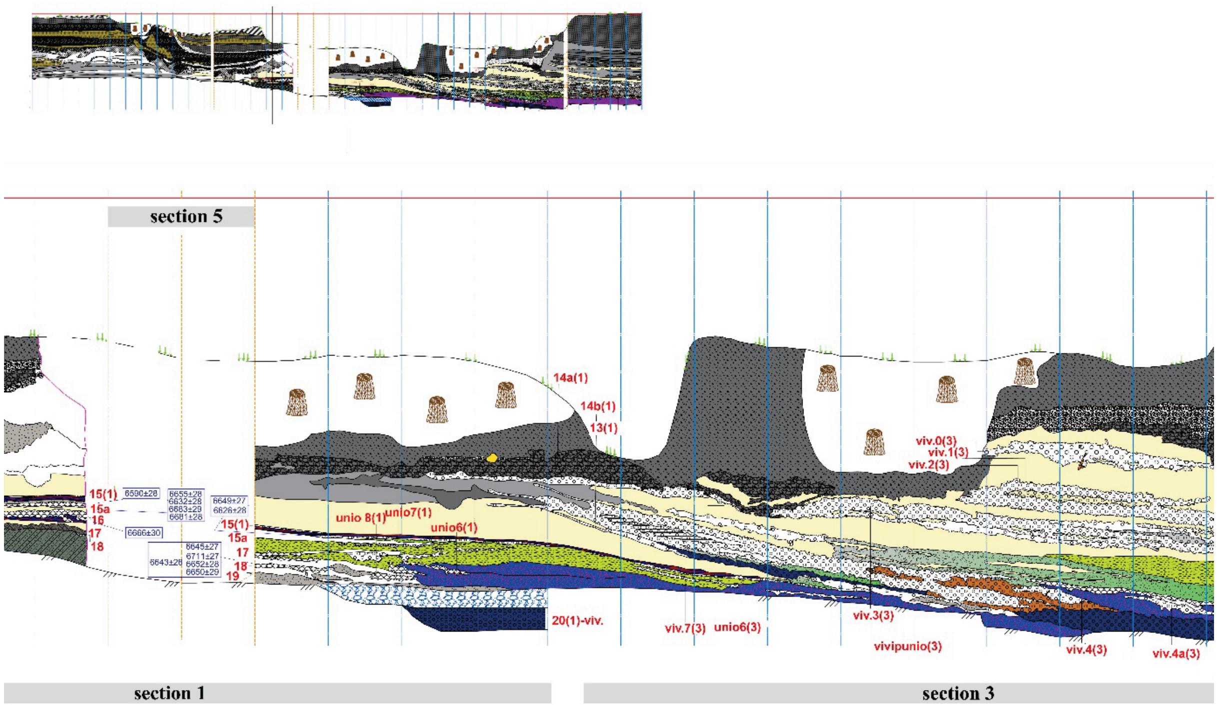

Fig. 9. Generalised stratigraphy: section 1/3

radiocarbon dates are uncal. BP; upper strata consists of loamy sediments (for section 1) and loamy sediments with *Viviparus* shell layers (for section 3), middle strata – white alluvial sand (yellow), lower strata – shell *Unio* layers (for section 1) and *Viviparus* shell layers (for section 3) interlaminated with alluvial sands

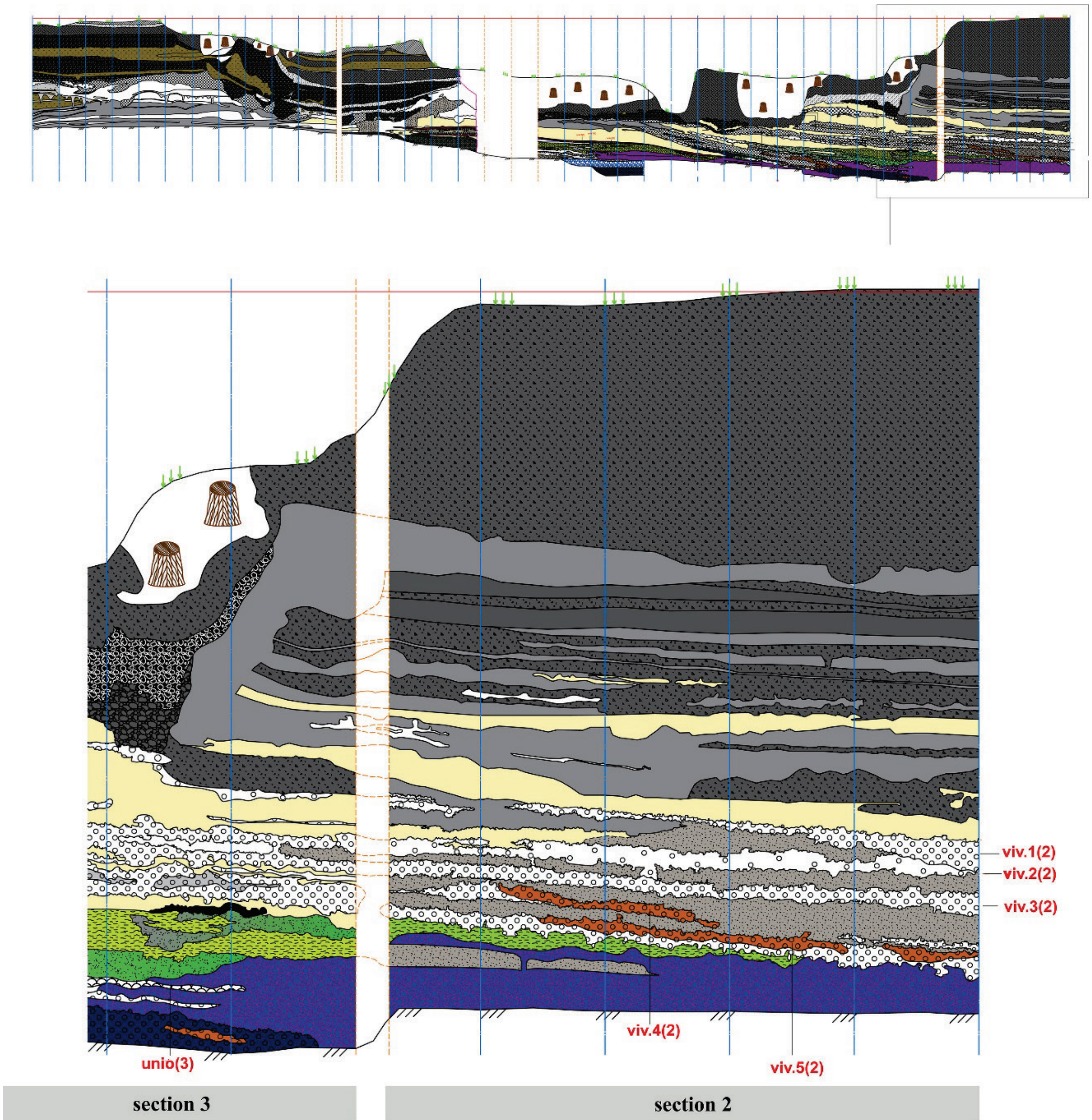

Fig. 10. Generalised stratigraphy: section 2

upper strata consists of loamy sediments, middle and lower strata of *Viviparus* shell layers interlaminated with alluvial sands

Layers 15–20 included in unit 4 adjoin soil X, which was formed at elevation and is dated to 6431–6061 cal. BC (7380±100 BP, Ki-15181, ground) (Tsybryi *et al.* 2017). We might suggest based on stratigraphic observations that the thick shell strata in sections 2–3 and in the lower part of section 1 are among the oldest (Figs 8, 9, 10). They correspond to lower strata of the eastern part of the site (Unit 3), where shell content is rather low comparing to unit 4. Thus, we may suggest that around 5600 cal. BC human activity was centred around the place (section 1) where major remains of shell platforms can be traced.

Archaeological layers and context

The archaeological layers were recorded along the present-day shoreline for about 240 m in a south-eastwards direction (Belanovskaya 1995). The exact inland boundaries of the settlement were not identified. The archaeological layers lie within isolated areas, often at considerable distances from each other, and are of different thicknesses and lengths. The number of defined archaeological layers varies within different parts of the island, which complicates correlation between the strata traced in different excavations. More than 1,000 square metres were uncovered in the 1960s–70s (Belanovskaya 1995). The main excavation (No. I) was located on the northern edge of the island (Fig. 1). T.D. Belanovskaya (1995) noted that only layers of excavations I–III can be correlated stratigraphically with each other. The entire excavation stratigraphy was divided into six horizons (Belanovskaya 1995). The upper archaeological layers 4 and 5 can be attributed to the Eneolithic and the Neolithic, and consist of a thick layer of *Viviparus dilluvianus* shells, which are cemented and protect the lower layers from destruction. The lower horizon contained a number of thin lithological layers (2 to 25 cm in thickness) (Fig. 4). Neolithic archaeological layers 12–23 were separated by sterile layers of sand, and layers 12–10 by loams of 5–10 cm thick. In layers 23–18, no remains of any structures were found, except for clusters of shell heaps with numerous fish bones, charcoal fragments and artefacts. In the overlying Early Neolithic layers 17–11, post pits, hearths on clay platforms, shell piles, and fragments of wattle and daub of dwellings walls were found. It can be assumed that the inhabitants of this settlement were periodically forced to leave it – probably due to the Don River flooding – but then returned to this place (Belanovskaya 1995). These accumulations of shells can be interpreted as platforms constructed in a shore zone inhabited during several months, which were covered by thin layers of sand during spring floods (Dolbunova *et al*. 2020). The Early Neolithic settlements were established in the immediate vicinity of a dammed lake. Meanwhile, a landslide body created a bridge connecting the island with the upland slope in this area.

Only the upper layers of overbank deposits are similar in excavations located in different parts of the island. The thick *Viviparus* shell layer 5 is traced in the new excavation (section 1) and can be seen on archive images in different parts of the island, extending from the cape edge for more than 60 m eastwards. It overlies archaeological layers consisting of shell piles, ash layers and artefacts, which were separated by sterile layers of alluvial origin.

Part of the new area where the works were carried out starting in 2008 was divided into several sections, which were subsequently connected to each other (sections 1–5) (Figs 8, 9, 10).

The low sequence of layers in sections 4 and 1 differs significantly from those in sections 2–3. In section 1, upper strata of *Viviparus* shells (layers 13, 14a, 14b) were deposited above a white alluvial sandy sterile layer, which is replaced by blue loam on the area of section 3 (Figs 8, 9). The latter covers the low strata of *Unio* shell layers (layers 15–19). These layers are 4–10 cm thick and are situated non-uniformly within the area excavated (Fig. 8). The layers are inclined westwards and northwards and are covered with thin layers of sand (bluish, light grey) of 1–3 cm thick. Spots filled with eroded bone parts, charcoal and fragments of red ochre, and parts of skeletons of large fish were found. Under a layer of silty bluish sand of up to 20 cm thick, there is the earliest, 10–20 cm-thick, archaeological layer with the fragments of *Viviparus* shells (layer 20) within lacustrine deposits of the dammed lake. Fragments of treated wooden artefacts were found in this strongly inundated layer. Only remains of decayed wood were found in the overlying layers, which indicate unstable waterlogged conditions. The nature of the layers, the location of the artefacts and the absence of washed vessel fragments testify that these layers were not redeposited. Velichko *et al.* (2011) suggested the washing-out of the shell heaps and cultural remains by floods, probably up to layers 5–7 from excavations I–III of T.D. Belanovskaya. Cultural remains, shell platforms and heaps may have been located for a long time, not in the aquatic environment and not buried by alluvial sediments, but on the surface, which can be indirectly proven by the presence in all sediments of a small group of grains with traits of Aeolian transport (Velichko *et al*. 2011). The layers from the new sections are inclined westwards and northwards. The sequence of inclined silty and sandy layers with shell fragments in section 3 (Fig. 9) probably originates from the processes of the draining of the dammed lake and later fluvial overbank deposition.

Early Neolithic layers of *Unio* shells are situated within new excavations only on the elevated area of section 1. In the area of sections 2 and 3, the archaeological layers are deposited within the horizons with *Viviparus* shells. Inside them, single microlayers marking platforms of *Unio* shells in one or two horizons, spots of burnt shells reaching about 2 m in diameter, and layers of ferrous accumulations of *Viviparus* shells or rich with charcoal were noted. All this points to a significant difference between these shell layers and the archaeological layers with *Unio* shell platforms traced in section 1. The sequence of layers here cannot be compared to the sequence of layers in section 1, and thus the name "*Viviparus* layers 1, 2, 3" was applied here. It is important to note that here, and especially at the upper part of *Viviparus* layer 1, a large amount of washed Neolithic ceramics was traced. Also, a number of datings of bones originating from these layers of sections 2–3 were unsuccessful due to the lack of collagen, possibly because of unstable water conditions in this part of the site. This confirms the existence in this place of a channel that drained the dammed lake reservoir and eroded the lacustrine deposits with Early Neolithic remains.

Raw material sources for pottery production

According to the composition of clays and temper, several paste recipes used for local pottery production (Mazurkevich *et al.* 2016) and sources of mineral raw materials were distinguished, including:

(a) lacustrine clay with aquatic plant macro-remains;

(b) carbonate clay with shells and phyto-zooplankton remains (Diatoms, *Cladocera* etc.)

(c) silty clay with shells and deep-water plankton remains;

(d) several mixed mineralogical types of clays with shells and phytoplankton remains;

(e) carbonate lacustrine clay with aquatic plant macro-remains;

(f) mixed hydromicaceous-smectite clays, with aquatic plant macro-remain and shell debris;

(g) clay with shells and phytoplankton (Diatoms) remains;

(d–f) lacustrine clays resulted from the mixing of different mineralogical types of clays.

In major clay types from which pottery was made, lots of Cladoceran remains were determined. In layers 23–21 of excavation I of T.D. Belanovskaya there are ceramics made of both fine and silty clays enriched with carbonate. Natural inclusions of shells are also present in the paste. Clay with high content of phyto- and zoo-plankton remains, without carbonate and shell inclusions, were used as well. Fine sand from fluvial sediments was used as temper. The same sources of raw materials are typical for the production of pottery from layers 15–22 of section 1 of the new excavation and *Viviparus* layer 3 (section 2).

For ceramics from layer 20 and layers 17–18 from the newly excavated sections, the sources of raw materials that existed previously (a, b, c) were used, as well as new sources of raw materials. These include clays with shells and phytoplankton remains (g), and clays mixed with lot of shells and phytoplankton (d). The clay is also enriched with carbonate. The formation of this type of natural sediment might have been a result of overbank alluvial deposition, possibly during the transition to a drier climate (see also Borisova 2011).

The use of clay with shells and phyto-plankton remains (g), and hydromicaceous-smectite clay with algae and shell debris (f) were traced for the production of ceramics from layer 18 and one of the fill of shell pit 1 that is synchronous with layer 15 (section 1).

For the pottery from layers 19–17 and 15–14 of T.D. Belanovskaya's excavation I, along with the use of shore (a) sediments, the use of new sources can be recorded, and these are represented by carbonate clays with remnants of shore vegetation (e), which were formed in changed conditions in a shore part of the river

The use of shore redeposited mixed clays (d–f) was documented for production of pottery found in the *Viviparus* layer 2 (section 2).

Samples of clay raw materials collected from the site were also analysed: grey and black silty clay ("clay 1") was taken near the shore part of Porechny Island, 20 m from the pit of the former T.D. Belanovskaya excavation; grey clay with plant macrofossils ("clay 2") was taken from the layer on the shore, 5 m from the sampling place of the first sample; light-grey clay ("clay x") was taken from shore sediments near the 2008 trench; the sample "clay 1 (33–39)" was taken from section 1, from a depth of 33–39 cm; and a sample of a loam ("clay 2 [63–78]") was taken from section 1, from a depth of 63–78 cm (Fig. 1).

Several groups of chemical elements with the highest correlation links can be distinguished:

Group 1: SiO_2, Cr ;

Group 2: Al_2O_3, Fe_2O_3, MgO, TiO_2, K_2O, Na_2O;

Group 3: CaO, LOI;

Group 4: P_2O_5, Ba.

Table 2

Chemical composition of potsherds and samples of clay (XRF)

	1 Si02 %	2 AI203 %	3 Ti02 %	4 Fe2O3общ %	5 MnO %	6 MqO %	7 CaO %	8 Na20 %	9 K20 %	10 P205 %	11 LOI %	12 V %	13 Cr %	14 Ba %
1	67.87	13.24	0.9195	5.031	0.0857	1.831	3.13	1.11	2.245	0.8171	3.58	0.0084	0.0119	0.0411
2	69.71	12.13	0.7725	4.88	0.1991	1.404	1.538	0.8365	2.16	1.299	4.86	0.0097	0.0081	0.039
3	66.81	12.77	0.8217	4.739	0.5915	1.524	2.061	0.8846	2.26	1.291	6.1	0.01	0.0092	0.0423
7	63.67	13.29	0.8658	5.164	0.1319	1.708	1.999	1.145	2.32	1.763	7.74	0.0092	0.0095	0.0536
10	60.99	14.75	0.8674	5.973	0.2813	2.333	1.615	0.9409	2.321	0.6355	9.05	0.0107	0.0113	0.0426
16	64.97	13.17	0.8764	5.498	0.1021	1.855	1.691	0.9478	2.443	0.9571	6.97	0.009	0.0103	0.0528
17	65.01	12.56	0.8434	5.491	0.0734	1.643	2.01	0.9429	2.118	2.003	6.96	0.0095	0.011	0.0638
23	66.92	13.37	0.8591	5.409	0.12	2.04	1.573	0.9167	2.116	1.056	5.48	0.0103	0.0101	0.0355
26	64.74	13.41	0.8292	5.58	0.0654	1.797	1.784	0.8687	2.202	1.36	7.19	0.0098	0.0098	0.0516
29	66.9	13.56	0.9002	5.537	0.0872	1.84	1.577	0.9918	2.331	1.246	4.7	0.0098	0.01	0.0508
31	57.87	14.9	0.8484	6.358	0.1361	2.431	2.867	0.8706	2.529	1.028	10	0.0111	0.0107	0.037
32	62.18	13.09	0.8561	5.421	0.0815	1.948	1.938	1.161	2.282	1.335	9.44	0.0095	0.0114	0.0532
34	70.26	11.27	0.7907	4.739	0.081	1.479	1.522	0.8299	1.911	1.621	5.26	0.0089	0.0107	0.0574
36	65.31	15.29	0.9272	6.432	0.0682	2.027	1.503	0.9652	2.426	1.053	3.7	0.0122	0.0112	0.0551
40	66.25	12.88	0.8849	5.367	0.1146	1.905	2.201	1.084	2.224	1.393	5.37	0.0096	0.0115	0.0403
54	70.35	11.86	0.7508	5.084	0.1158	1.739	1.64	0.7398	1.966	0.6841	4.75	0.009	0.0094	0.0314
55	64.83	14.4	0.9165	5.747	0.1265	2.47	1.407	1.034	2.215	0.3261	6.32	0.0092	0.0109	0.0384
58	63.91	12.87	0.7717	5.325	0.0508	2.127	2.063	0.7833	2.05	0.5915	9.27	0.0089	0.0094	0.0362
59	68.1	11.75	0.8381	5.021	0.6841	1.471	1.932	0.8588	2.066	1.258	5.76	0.0079	0.0101	0.0518
RY	68.35	12.66	0.8718	4.953	0.0859	1.726	1.507	0.8632	2.086	1.317	5.27	0.0086	0.0107	0.0582
clay 1	55.75	10.55	0.5605	4.058	0.1146	1.463	10.81	0.7006	1.802	0.1338	13.9	0.0072	0.0073	0.0368
clay 2	77.33	8.408	0.7055	3.469	0.0342	0.9866	2.326	0.8048	1.844	0.03	4	0.0064	0.0114	0.0335
clay x	77.59	8.122	0.734	3.509	0.0394	0.8072	2.589	0.8642	1.943	0.0545	3.73	0.007	0.0162	0.0357
clay1- (33-39)	71.64	10.32	0.7197	4.503	0.0569	1.553	3.075	0.9189	2.065	0.219	4.64	0.0069	0.0103	0.0353
clay2- (63-78)	80.69	2.985	0.4085	1.336	0.135	0.4083	6.555	0.3596	0.7733	2.277	3.88	0.005	0.0039	0.0183

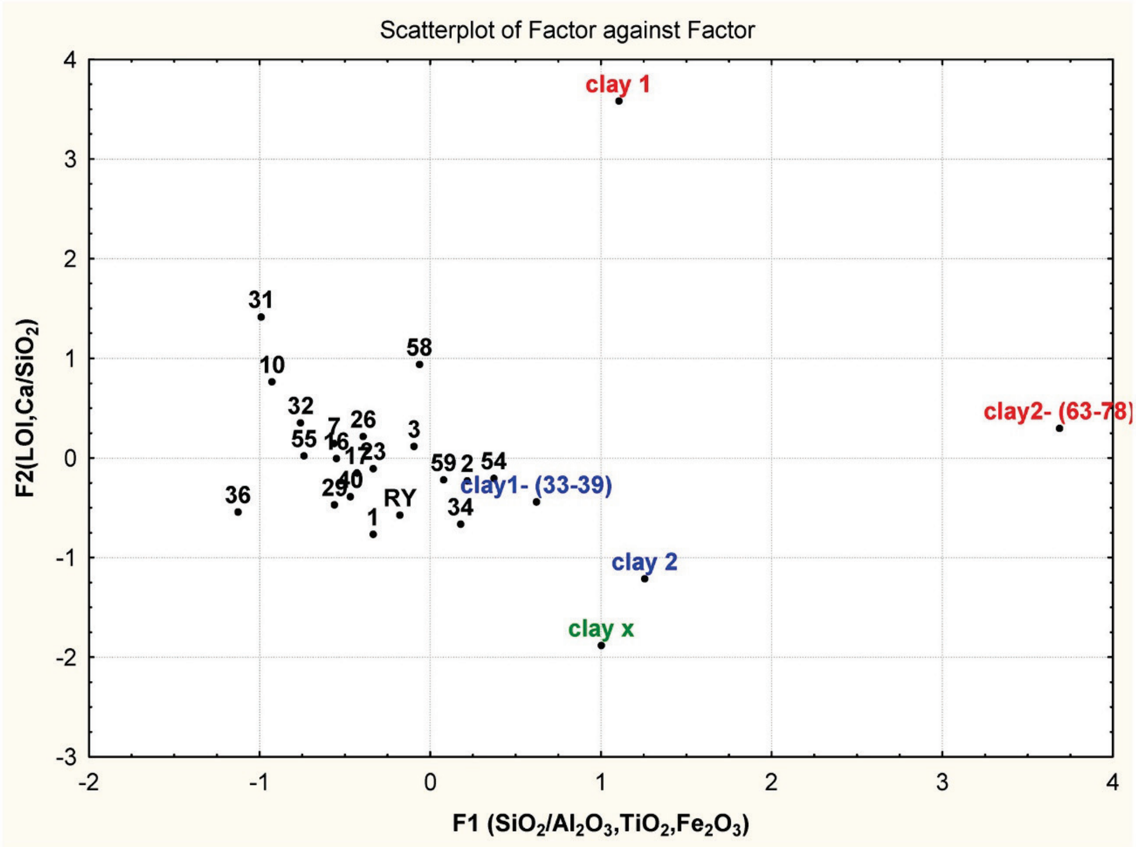

Fig. 11. Distribution of potsherds and local clay sources based on their chemical composition

Based on factor analysis, two main factors were identified: F1 (SiO_2/Al_2O_3, TiO_2, Fe_2O_3) and F2 (Ca, LOI/SiO_2), showing the distribution in the samples of silicate, clay minerals and carbonate components. Comparison of pottery groups' samples and clay raw material (Table 2, Fig. 11) shows that the samples "clay 2", "clay x" and "clay 1 (33–39)" may be regarded as possible sources of raw materials for manufacturing of Early Neolithic pottery from the Rakushechny Yar site. The sample "clay 1 (33–39)" was taken from the archaeological layer at section 1, from which were taken several pottery samples that show a similarity in composition to this clay sample. It can also be noted that the chemical composition of almost all pottery fragments corresponds to the composition of ancient clay deposits in the Don River.

Two ceramic samples (10 and 31) are characterised by increased concentrations of Al_2O_3, Fe_2O_3 and low SiO_2 content. Sample 31 also differs from the other samples according to petrographic analysis. It can be assumed that this sample of ceramics is an "import" and is not made from local raw material sources. Geochemical composition of sample 10 is closer to other pottery samples, than is No. 31. Therefore, it can be assumed that sample 10 was made not from local raw material, but from loams from other areas of the Don River floodplain.

Conclusion

The Rakushechny Yar site allows changes in palaeo-environmental conditions to be traced through very narrow periods of time that coincide with the appearance of the first Neolithic communities in this area. It is rather complicated to assign it to a larger dynamic of environmental regional changes, because investigations of soil formation and environmental changes in the neighbouring Cis-Caucasus area are debatable and not extensively elaborated (Kremenetsky *et al.* 1998; Alexandrovskiy 2000; Dyuzhova 2013). Velichko *et al.* (2014) suggested that a humid regime can be traced within the entire Atlantic period. By contrast, it has been suggested that soils of the Middle Holocene were formed in relatively dry conditions, as evidenced by the study of the most ancient chernozems buried under the mounds of the Black Sea, Azov Sea, Middle Don and Cis-Caucasus area (Zolotun 1974; Alexandrovskiy, Alexandrovskaya 2005). These are characterised by a thinner humus horizon with a high content of carbonates, which shows a lower amount of precipitation. Palynological studies of bottom sediments of the Azov Sea also showed steppe conditions for the Atlantic period that were more arid than in modern times (Dyuzhova 2013). Similar changes in climate and vegetation can be seen in diagrams from lake and marsh sediments of the Buzuluk pine forest in the Middle Don (Kremenetsky *et al.* 1998). This scheme of natural environment development correlates with the soil development reconstruction of the Rakushechny Yar site. Research on the buried soils in the Don and Dnepr basins on the Middle Russian Upland evidenced climate fluctuations throughout the Middle Holocene, and one of the most strongly pronounced periods of arid climate dates to around 6000 cal. BC (Sycheva 2006).

The new studies at the Rakushechny Yar site allowed undisturbed archaeological layers to be identified, and the whole stratigraphical sequence to be described over a wider area, where previously inaccessible Early Neolithic layers were discovered for the first time. The Early Neolithic settlement was established *ca* 5600 cal. BC in the immediate vicinity of a dammed lake created after the landslide developed *ca* 8.5 mill. BP, and its layers are situated within the lacustrine deposits of the dammed lake (low *Unio* layers in section 1). The landslide body created a bridge connecting the island with the upland slope. This dammed lake reservoir was drained by a channel shortly afterwards, and the *Viviparus* layers were formed (in sections 2 and 3). Traces of human activity on the island were recorded in the lacustrine and later fluvial sediments of the Rakushechny Yar site until the Bronze Age (Belanovskaya 1995; Dolbunova *et al.* 2020).

Analysis of the stratigraphy and peculiarities of the buried soils allowed for the reconstruction of the microtopography of the ancient settlement with an older elevation where soil X was formed *ca* 6000 cal. BC, and adjoined to which the earliest layers with shell platforms were deposited *ca* 5600 cal. BC. The peculiarity of the spreading of *Unio* and *Viviparus* shell clusters testifies that they were separate shell platforms and/or piles extending within the same horizon. These layers are covered with thin layers of sand and organic mud (bluish, light grey) 1–3 cm thick, as well as thick deposits of white sterile alluvial sand. The sequence of shell platforms interlaminated with sandy and silty layers could have been deposited in a lake shore zone during water level fluctuations. The alluvial sand layer is more likely connected with the drainage of a dammed lake or with overbank alluvia. Dates obtained from individual layers indicate a very narrow chronological period during which archaeological layers were formed and overlapped by sterile layers: this demonstrates that there was also a high rate of minerogenic deposition in the dammed lake reservoir. The formation of these Early Neolithic layers of around 2 m in thickness took place, apparently for several decades.

Significant differences in traits of layers, along with preservation state of artefacts and ecofacts from sections 1–5 of the new excavations show various conditions that influenced the strata formation.

Geochemical analysis showed that Early Neolithic pottery was made mostly from local sources of raw materials – clay deposits rich in organic matter that had accumulated in the dammed lake formed in the Don River valley floor. Changes in the sources of raw materials may also indicate quite dynamic conditions of the lithological units' formation at the site and nearby.

The sources of such raw materials were located in close proximity to the settlement. It can be suggested that the raw materials located outside the site were not used by the local population, and the pottery was produced at this site. This can be attested also by the reconstructed site function as a seasonal fishing site where pottery production served a narrow range of tasks and was made seasonally on site (Dolbunova *et al.* 2020). The presence of pottery made from similar local deposits but located not near the site indicates that part of the pottery was brought here. One of the samples of pottery belongs to the "import" category, which would suggest even longer distances.

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