

THE IDENTIFICATION OF ORGANIC TEMPER IN NEOLITHIC POTTERY FROM RUSSIA AND BELARUS

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Introduction

The reconstruction of pottery technology is important for the understanding of the development of human society and its cultural and historical processes. Ceramics were the first artificial material developed by man. In order to manufacture pottery, a series of complex technological operations are applied. These include the choice of raw materials, the recipe selected for the ceramic paste, a variety of manufacturing techniques and firing conditions.

The reconstruction of each of these operations is also a complicated task, which includes the determination of the composition of the ceramic paste, and the identification of naturally occurring and artificially added inclusions. The use of traditional methods, such as petrographic analysis in thin section by polarised light microscopy, is not always sufficient to identify the organic inclusions, in particular when they burn out of the clay during firing.

In these cases, the application of high resolution 3D computed microtomography (micro-CT) is a powerful technique used to visualise and characterise the internal structure of the artefacts. It is a non-destructive method that produces images of the internal microstructure of an object. The great advantage of microtomography is that quantitative information such as volume, size, shape, distribution and connectivity of the pores can be obtained through the entire 3D volume of the samples, from micro-scale to nano-scale (Oliveira *et al.* 2012; Machado *et al.* 2013; Kulkova and Kulkov 2015). Along with organic inclusions naturally occurring in the clays, ceramics might include different types of organic temper deliberately added by the potter. In many cases, organic admixtures in ceramics burn out of the clay during the firing process, making their identification difficult.

The micro-CT method is a valuable instrument for the reconstruction and visualisation of porosity left after burning off the organics.

The application of micro-CT, along with thin section analysis of the ceramics, allows us to obtain detailed information about the composition and distribution of the organic inclusions in a ceramic body. In this paper, analyses were carried out by petrography and micro-CT on some Neolithic potsherds from the Eastern European sites of Rakushechny Yar, in the Low Don River region of southern Russia, Okhta 1 and Podolje 1 in St. Petersburg, and Ladoga Lake regions of northwestern Russia, and the site of Gronov 3 in Belarus (Figure 1).



Figure 1. Map and location of the archaeological sites discussed in the text.

The Eastern European Neolithic sites

The site of Rakushechny Yar (Figure 1) is the earliest archaeological site in Eastern Europe where almost all components of the Neolithic “package” were found (Belanovskaya 1995). The earliest ceramics have been dated to ca. 6800 cal BC. The ceramic making technique is complicated and includes multiple technological operations (see Mazurkevich and Dolbunova, 2015). The ceramics include a variety of flat-bottomed vessels with different shapes, rims and bases. The ceramics are rarely decorated, although some pots have walls and bases covered by red ochre. The ceramics found in the lowest cultural layers were made using similar technological methods: they are made of plastic raw materials using coils, with flat rims and wall surfaces treated with the



Figure 2. Podolije 1: remains of fishing fence (trap for fishing in shallow water; excavation and photo by Dr. T.M. Gusentsova, 2013).

smoothing-scratching technique¹. The silt-clays used came from both deep- and shallow-water from the Don River basin (Kulkova *et al.* 2015).

The site of Okhta 1 is located in the centre of St. Petersburg at the confluence of the Neva and Okhta Rivers (Figure 1). This is the only Neolithic–Early Metal Age site in St. Petersburg. The collection of archaeological finds includes about 1200 objects, comprising pottery, stone tools, wood carvings, and amber jewellery. The ceramic assemblage of Late Neolithic–Early Metal Age (3200–3000 cal BC) are characterised by Pit-Combed wares tempered with asbestos, feather and down, and chamotte or grog (Kulkova *et al.* 2014).

The site of Podolije 1 is located on the southern shore of Lake Ladoga (Figure 1). The archaeological finds include different types of pottery, a collection of stone and bone tools for hunting and fishing, amber adornments and wood remains from fishing constructions (Figure 2). The site was dated by radiocarbon from the 5th to the 3rd millennia BC (Gusentsova *et al.* 2014). Two thousand large fragments of sherds from 104 vessels were found at the site. The Pit-Combed decorated pottery tempered with organics was dated to ca. 3700 cal BC (Kulkova *et al.* 2016).

¹ A pottery technique obtained by applying layers of clay (ochre or liquid clay) to leather hard pottery, smoothing this and then scratching the surface with a sharp tool to create texture.

The multilayer site Gronov 3 is located in the Sozh river basin, in Eastern Belarus (Tkacheva 2014), and different ceramic types attributed to the Neolithic were found.

Methods and sampling

The ceramic sherds from these sites were analysed in polished thin section by polarised light microscopy and binocular optical microscopy (ca. 80 samples from Rakushechny Yar, ca. 50 samples from Okhta 1 and Podolije 1). Some of these samples contained organic inclusions, which were difficult to identify by polarised light microscopy: five were selected for micro-CT analysis.

The samples were scanned using the SkyScan 1172 device of the “Geomodel” Research Centrum of St. Petersburg State University with a beam energy of 120 kV, a flux of 80 μ A and aluminum filter with a resolution of 4–6 μ m, performing a 180-degree rotation with a step size of 0.4 degrees. CTvox and CTan software was used for the visualisation of voids left by organic temper (e.g. shells) and the distribution of sand inclusions. A Leica polarised light microscope with a x65.7 zoom was used for the study of the ceramic pastes in thin section.

Results

According to micro-CT and petrographic analyses, several types of organic admixtures were artificially added to the ceramic pastes, each showing differences in distribution and shape of the inclusions.

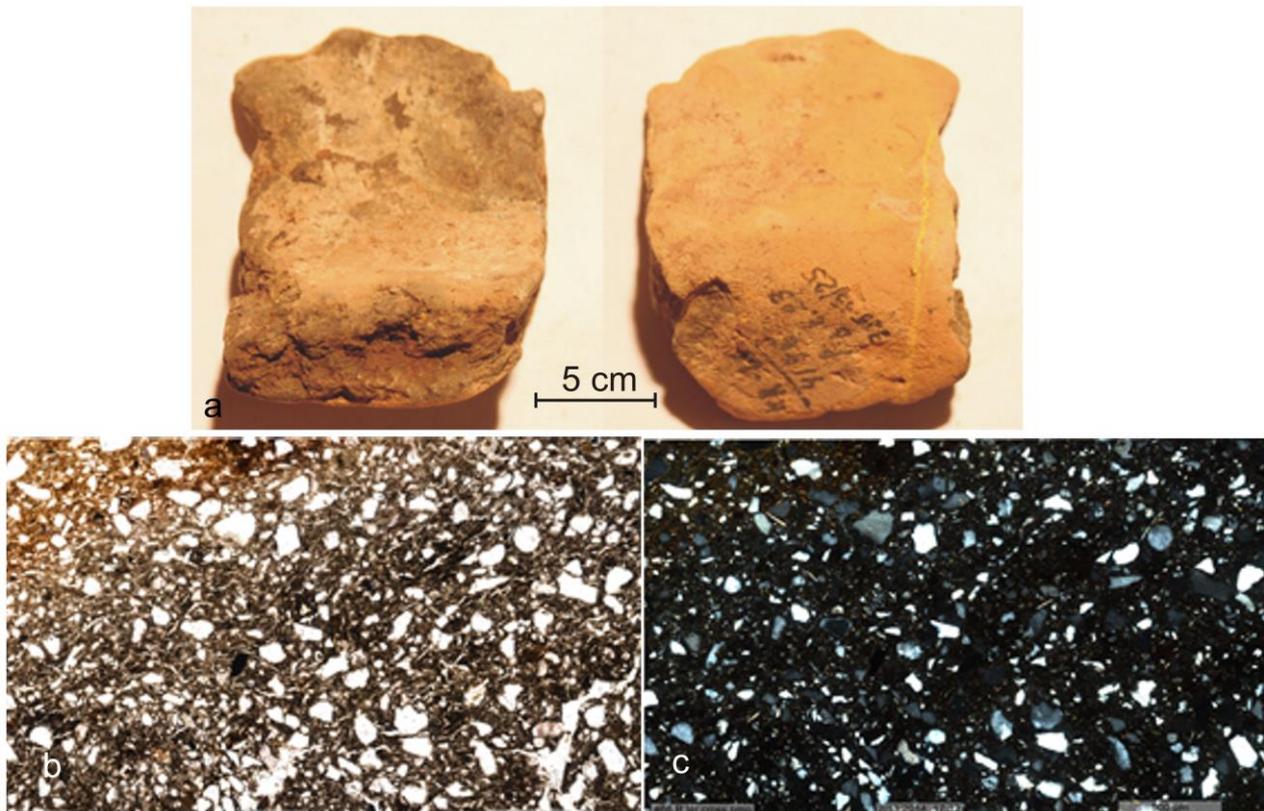


Figure 3. Rakushechny Yar: a) sample analysed from the bottom part of ceramic sample № 66. Microphotographs of the ceramic thin section: b) in plane-polarised light and c) in cross-polarised light (scale: 500 μm).

The ceramics from Rakushechny Yar

An undecorated base of a thin-walled (6 mm thickness) and low porosity vessel (sample № 66; Figure 3a)² was analysed in thin section (Figures 3b and c). The ceramic paste consists of hydromica clay with clastic components (ca. 15%), which include quartz, feldspar, and mica. In addition, abundant burnt organic material (10%) is present. The abundant sand (30%) and ground dry clay fragments (15%) were added as temper. The sand temper (0.3–0.7 mm in size) is moderately rounded and includes quartz, feldspar, mica, and amphibole. The firing took place in an oxidising atmosphere, for a short time and at a temperature of ca. 650–800°C. Micro-CT analysis allowed 1) the determination of the shape and distribution of voids present inside the sherd, indicating aquatic vegetation naturally present in the clay, and 2) the visualisation of the sand temper (10%)³ distribution (Figures 4a and b), which is uniform.

Sherd № 68 (325- 19/135 (2309)) – the rim of a thin-walled (8 mm thick) dense ware vessel (Figure 5a)

² Registration number: 325 - 33/25 (4196).

³ The clays from the alluvial deposits contain naturally present aquatic plants and a very low amount of sand, as well as clastic material (0.005–0.03 mm in size).

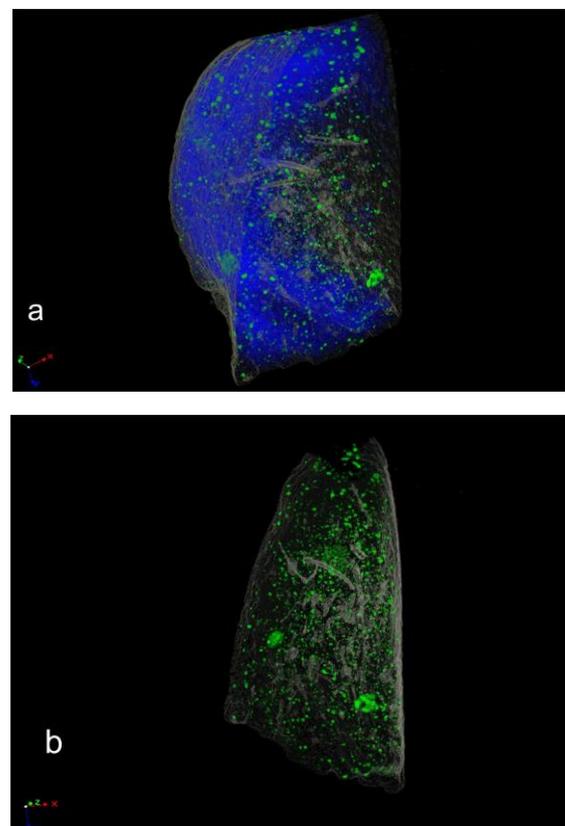


Figure 4. Rakushechny Yar: micro-CT analysis of ceramic sample № 66.

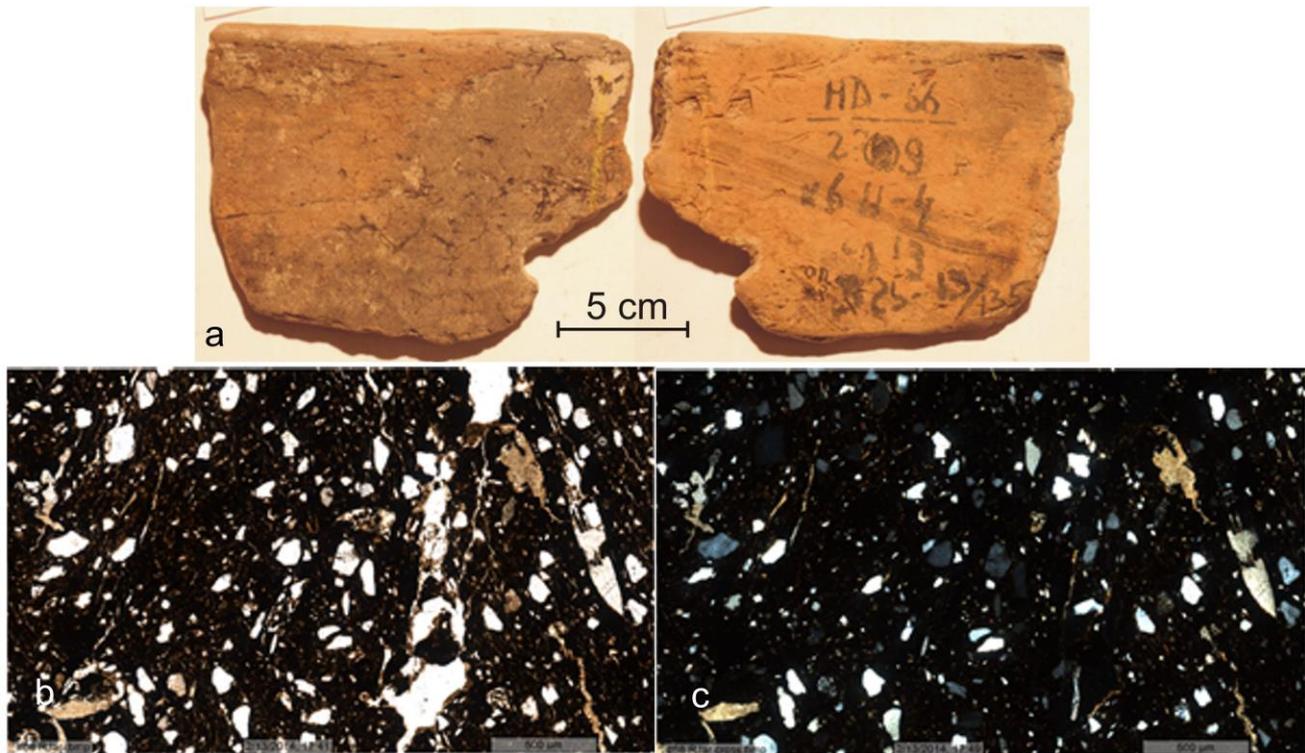


Figure 5. Rakushechny Yar: a) rim of vessel № 68. Microphotographs of the ceramic in thin section: b) in plane-polarised light and c) in cross-polarised light (scale: 500 μ m).

was also sampled. In thin section (Figures 5b, c) the ceramic paste consists of hydromica clay with carbonate and clastic components (ca. 25%), which include quartz, feldspar, and mica. The clay includes highly degraded shell inclusions and abundant burnt organic material (20%). The sand (10%; grain size 0.25-0.7 mm; moderately rounded grains) was added as temper, including quartz, feldspar, mica, and amphibole. The sherd was fired in an oxidising atmosphere for a short period of time and at a temperature of 650-800°C. As in the previous sherds, clay containing aquatic vegetation was used.

Microtomography allows reconstruction of the shapes of the plant inclusions in the sherd. The visualisation of the voids of plant remains in lengthwise and transverse sections are shown in Figure 6a. The 3D reconstruction of voids allows the types of plant inclusions to be determined. The main type is a perennial plant typical of the shallow water floodplain in the lower Don River, *Stuckeniapectinata*, syn. *Potamogetonpectinatus* (Figure 6b). This plant type is widespread in alluvial clay deposits, and it was used by ancient potters for vessel making. The visualisation of the pore distribution inside a sherd can also be evidence of N (scrappy) (Kahl and Ramminger 2012) technique of coil manufacturing. The distribution of sand temper (10%) is uniform inside the sherd (Figure 7). On the basis of the data of the microstructure characteristics and high

porosity of this sherd, we suggest that this type of ceramics might have been used just for storage of food and not for cooking (see Tite *et al.* 2001)⁴. A lot of carbonate and shell inclusions would have decomposed in the case of multiple firing actions.

A ceramic from Okhta 1

An interesting example (№ 3363; Figure 8a) of a friable thin-walled (7 mm thickness) ware of Pit-Combed pottery found at Okhta 1 was analysed. Petrographic analysis (Figures 8b-d) shows that the ceramic paste consists of smectite clay with clastic components (ca. 20%). The clastic components include quartz, plagioclase, mica (grain size 0.06-0.09 mm), and organic material was added as temper. The pores left by the organics (35%) are elongated with meshwork structure and lengths of 0.2-2 mm. The type of porosity is evidence that feather or down was mixed with clay. The firing took place in an oxidising atmosphere and for a short period of time.

The 3D porous visualisation of the results of micro-CT analysis, are shown in Figure 9. There are clear differences between the voids left by the shells and those left by the feathers. Crushed shells and feathers were deliberately added to the ceramic paste. The 3D

⁴ Food-crust was not identified on this potsherd, but it was present on the body walls of other ceramics at the site.

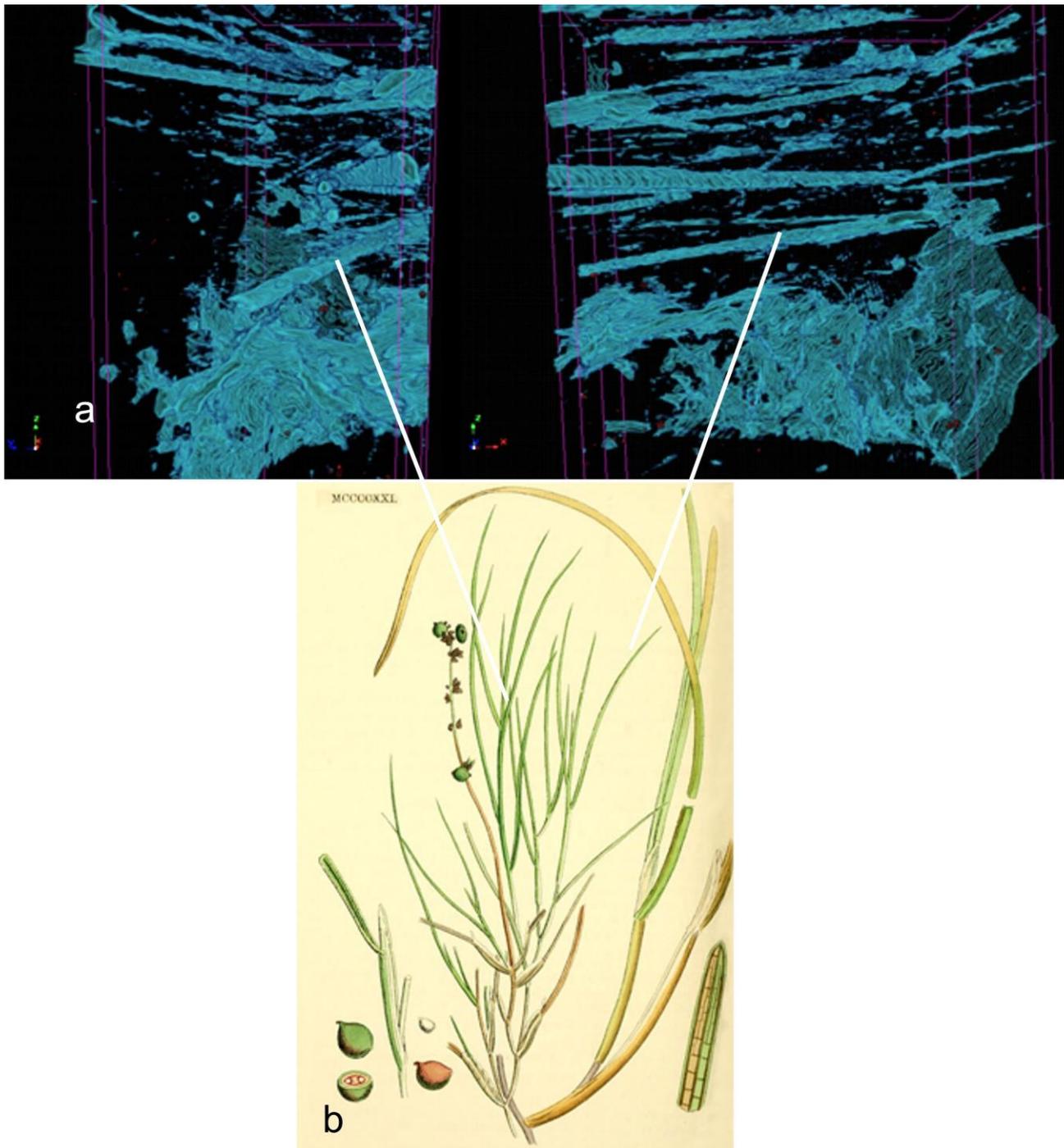


Figure 6. Rakushechny Yar: a) reconstruction of plant inclusions on the basis of 3D visualisation of the porosity of ceramic sample № 68; b) *Stuckeniapectinata*, syn. *Potamogetonpectinatus*.

structure of the feather stems and barbs suggest that the feathers come from waterfowl. As no traces of carbonates are visible in thin section, the firing temperature was higher than 780°C and no shells were preserved.

The ceramics from Podolje 1

Six samples of Pit-Combed pottery from Podolje 1 were analysed in thin sections, including a friable thin-walled sample (8 mm thickness) of pottery (№

1743). Petrographic analysis showed that hydromica (illite) clay with hydrotroilite inclusions was used for pottery making, quartz sand (15%) and plants (34.5%) were added as temper (Figure 10). The chemical analysis did not detect carbonates (e.g. shells). In the 3D data plant parts were recognised (Figure 11) and identified as sedges (*Cyperaceae*). The analysis of the sand fraction, on the basis of micro-CT, shows a bimodal size distribution, allowing us to conclude that sand was added as temper.

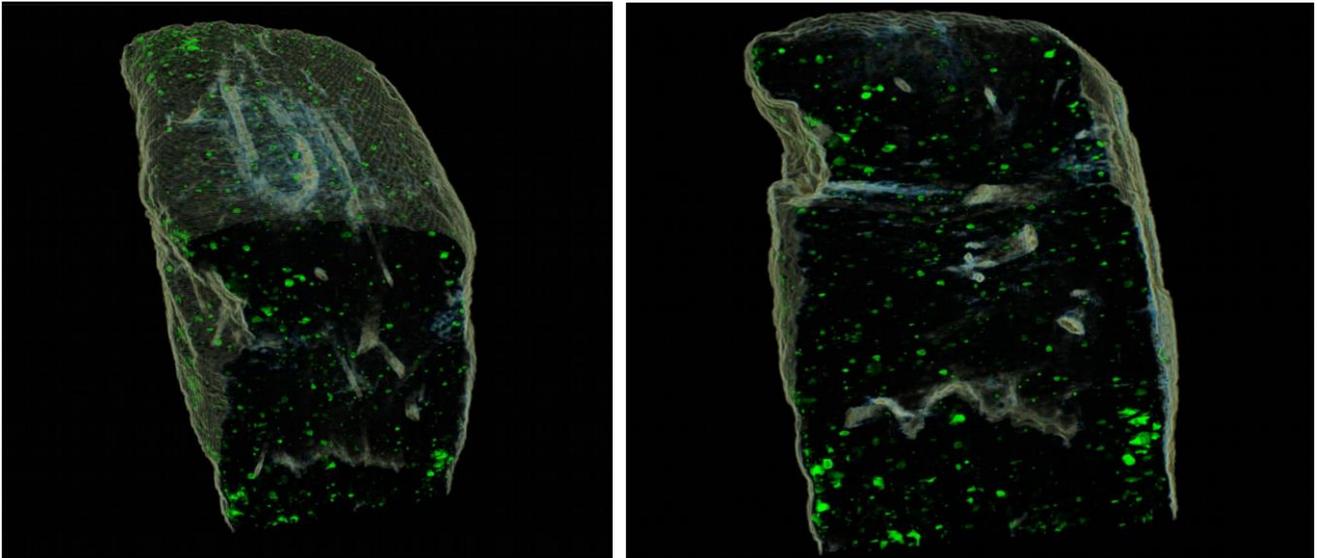


Figure 7. Rakushechny Yar: sand distribution in the ceramic body of ceramic sample № 68 in two orientations, on the basis of micro-CT analysis.

Another thin-walled (8 mm thickness), friable ceramic was also analysed (sample № 1744). A hydromica (illite) clay with inclusions of vivianite was used for moulding, and crushed shell (15%) and grog (5%) were used as temper (Figure 12). The shell fragments are 2-3 mm long. On the basis of micro-CT analysis, the use of shell as tempering material can be confirmed, as their distribution range can be automatically calculated with a programme available with micro-CT (Figure 13). The firing temperatures were not in excess of 780°C, as the shell fragments are still intact.

The ceramics from Gronov 3 (Belarus)

A dense and thin-walled (8 mm thickness) sample (№ 306), decorated by notches was analysed from Gronov 3. The ceramic paste consists of smectitic clay with organics and clastic material (ca. 20%), including feldspar and quartz (grain size 0.05-0.1 mm). Coarse sand (15%; grain size 0.5-1 mm) was used as temper. Some grains are well-rounded. Porosity (15%) from the burning of natural fibers was identified in thin section (Figure 14). The lengths

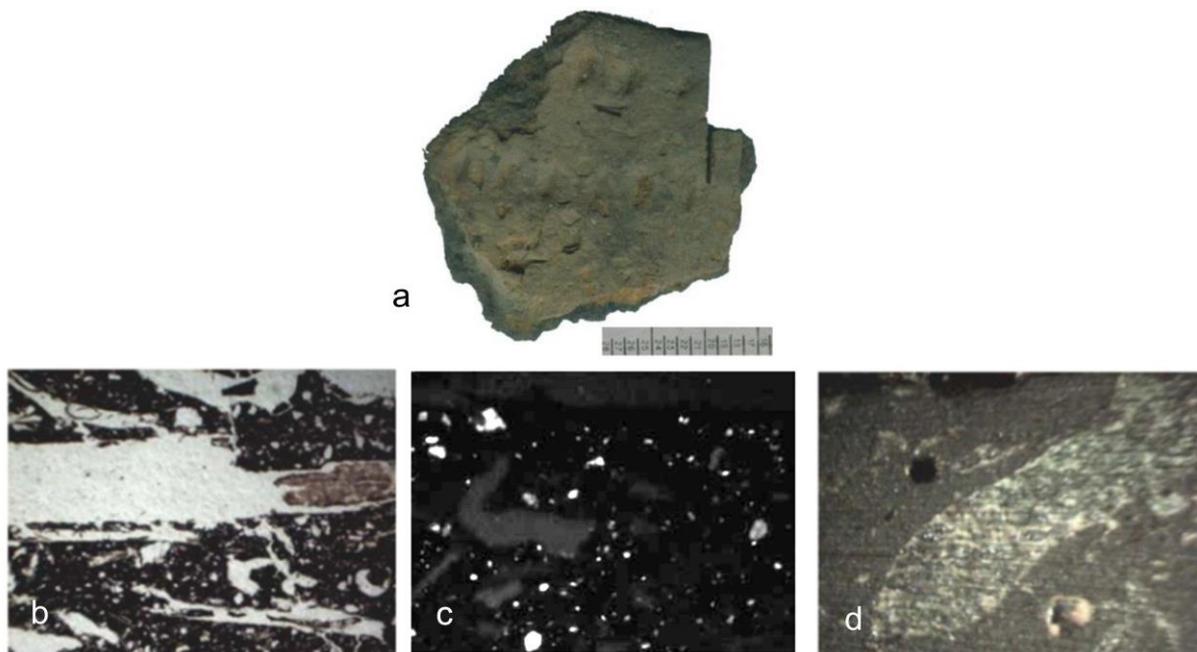


Figure 8. Okhta 1: a) sample № 3363; microphotographs of the ceramic sample thin sections in b) plane-polarised light; c) cross-polarised light (scale: 500 µm), and d) binocular view of the polished surface (x 15).

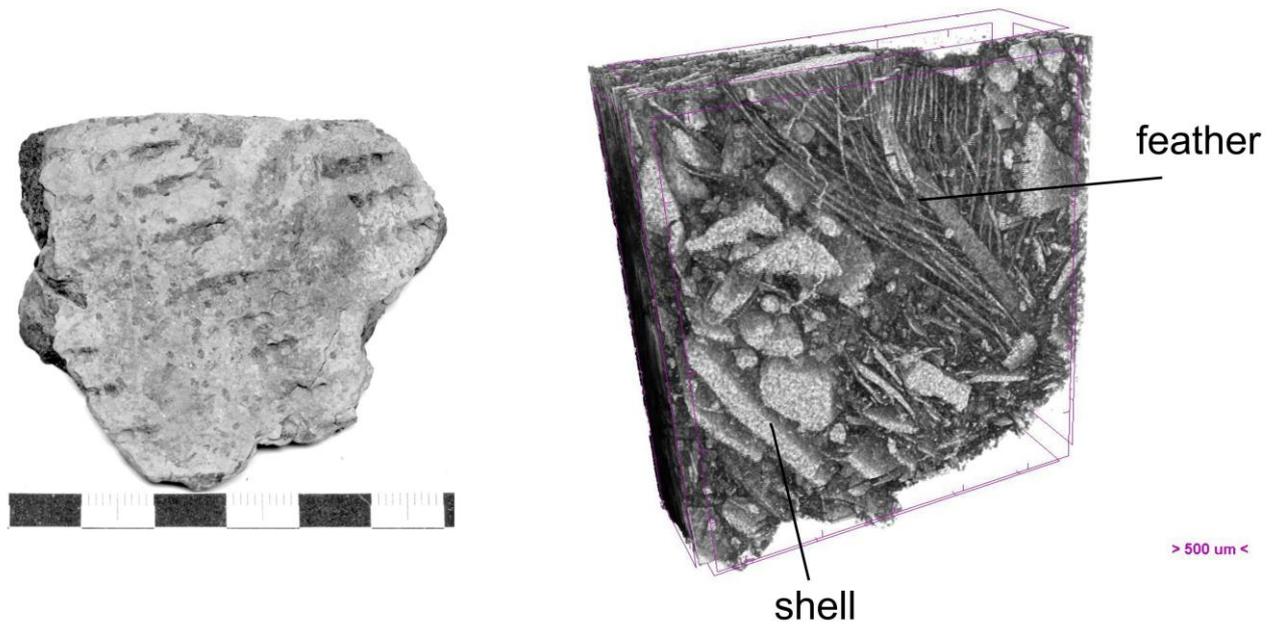


Figure 9. Okhta 1: sample № 3363 and reconstruction of shells and feathers added as temper on the basis of 3D visualisation of the porosity in ceramic sample № 3363.

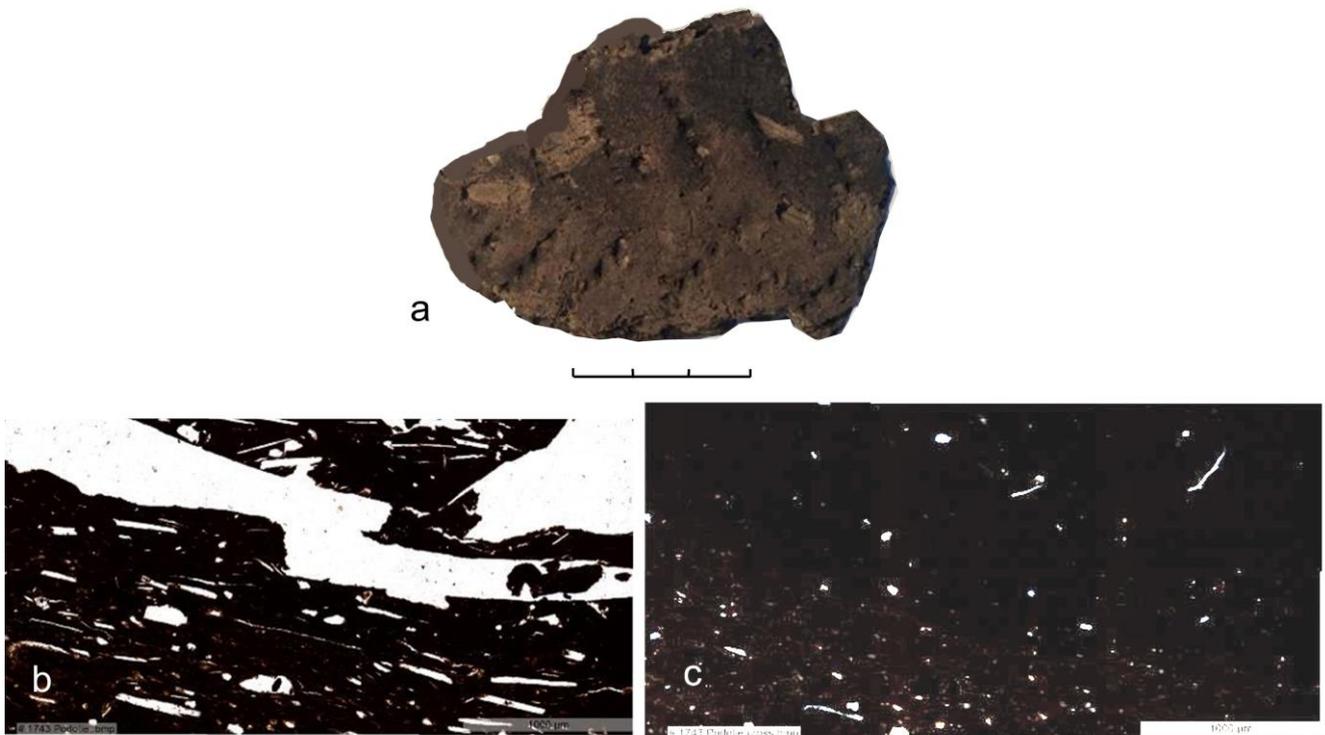


Figure 10. Podolje I: a) ceramic sample № 1743. Microphotographs of the sample thin section in b) plane-polarised and c) cross-polarised light (scale: 1000 µm).

of pore sizes vary between 3 and 5 mm. Micro-CT analysis and 3D visualisation of the porosity allowed us to identify the use of animal hair as temper (Figure 15). The red-brick colour of the ceramic surfaces is

evidence that the firing was short with temperatures of about 750-850°C.

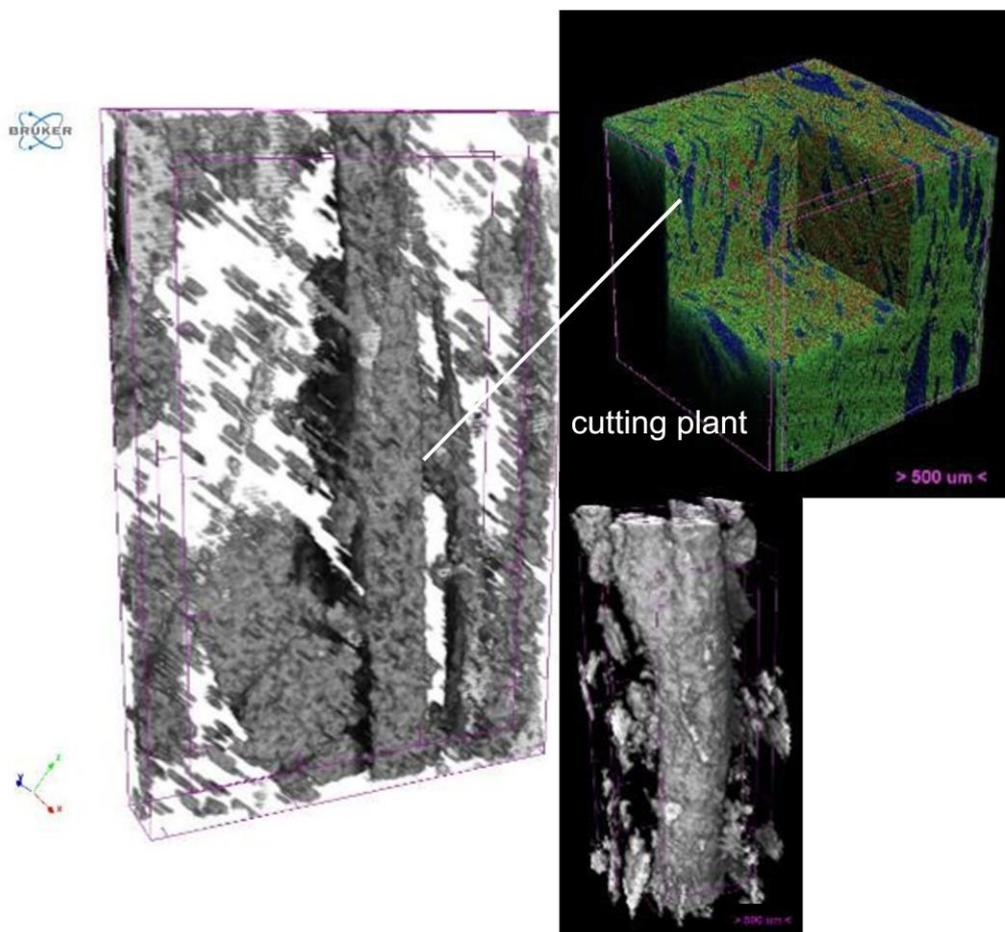


Figure 11. Podolje I: reconstruction of plant temper on the basis of 3D visualisation of porosity of ceramic sample № 1743.

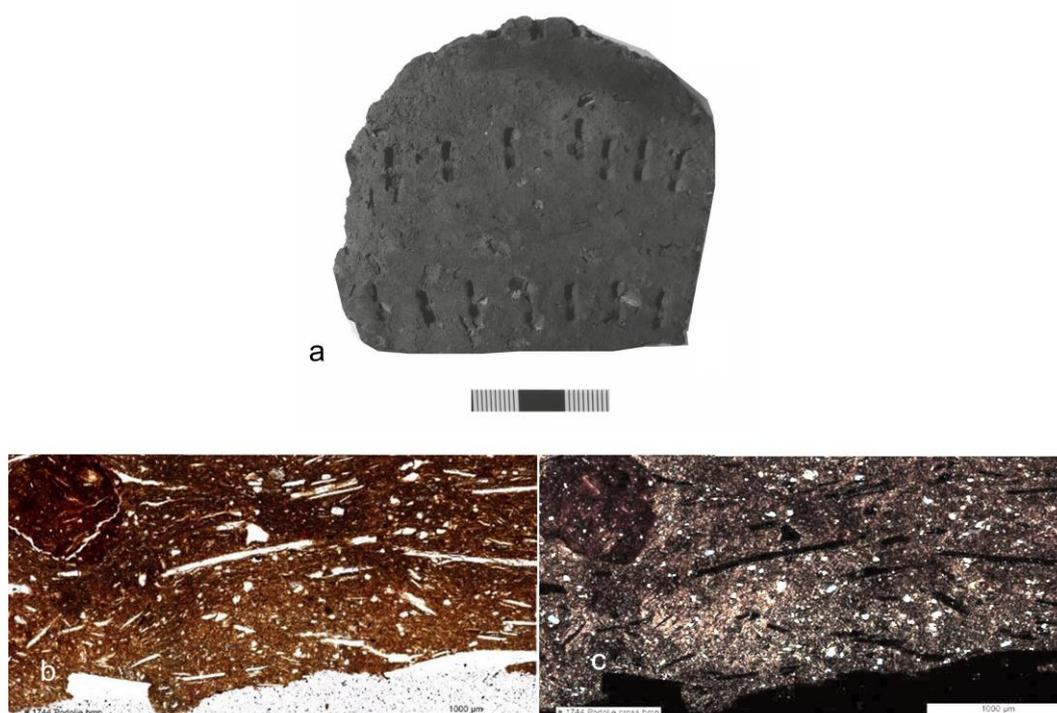


Figure 12. Podolje I: a) ceramic sample № 1744. Microphotographs of the sample thin section in b) plane-polarised and c) cross-polarised light (scale: 1000 µm).

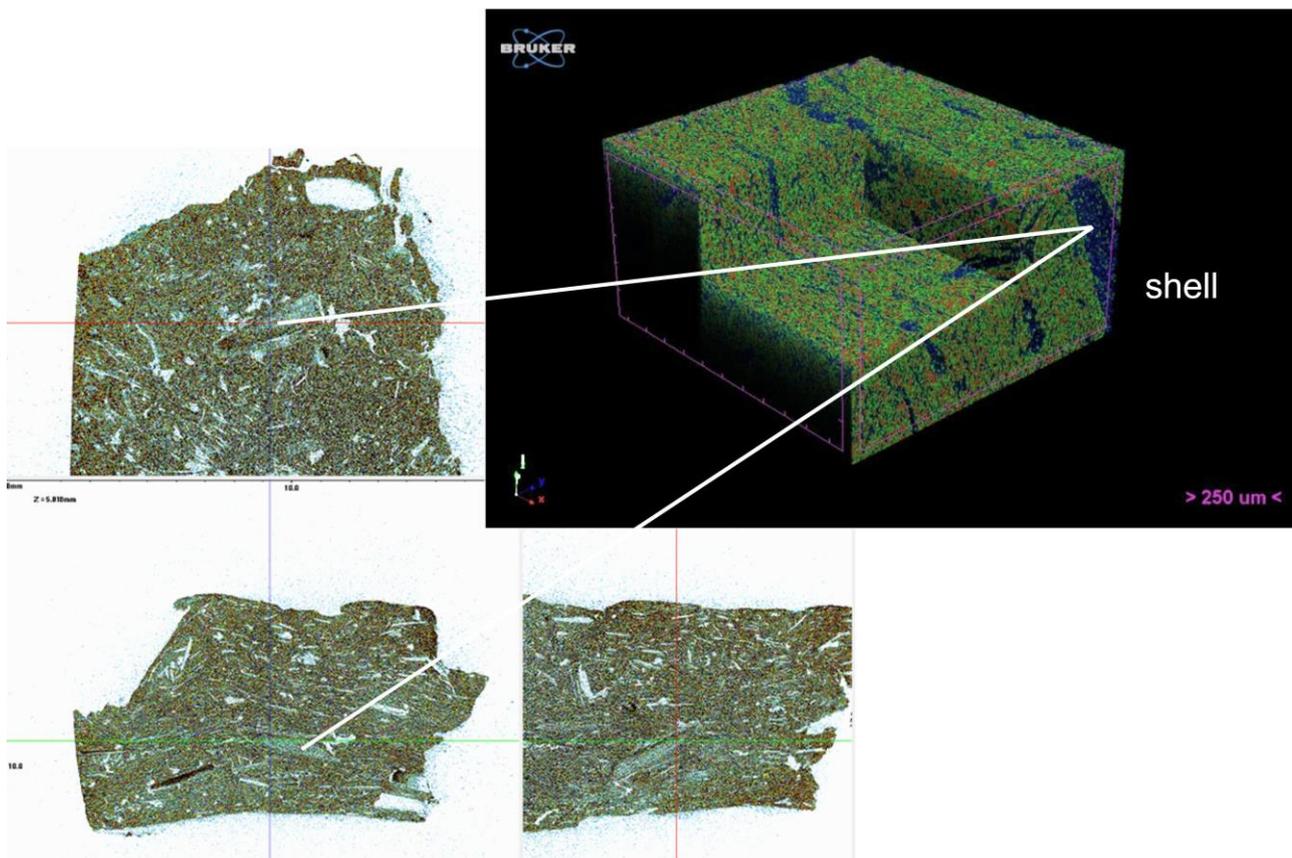


Figure 13. Gronov 3: micro-CT analysis of ceramic sample № 1744.

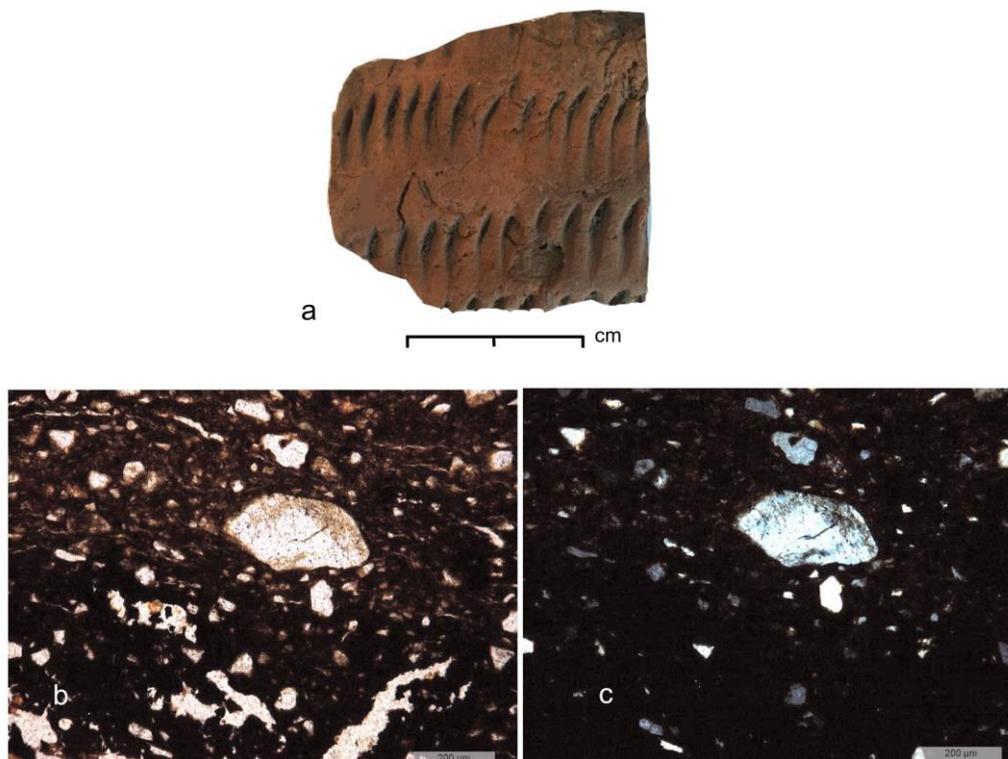


Figure 14. Gronov 3: a) ceramic sample № 306. Microphotographs of the sample thin section in b) plane-polarised and c) cross-polarised light (scale: 200 µm).

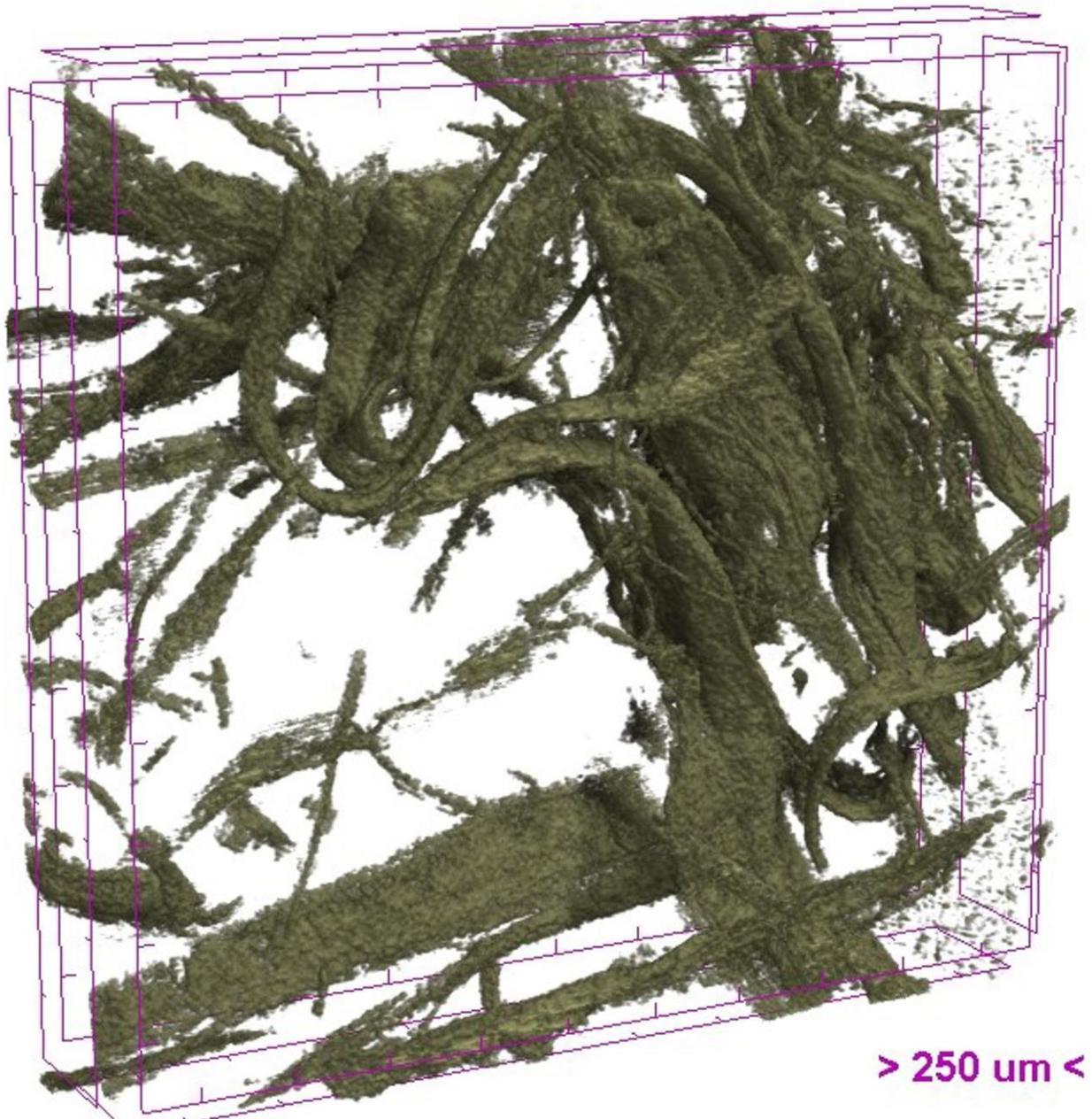


Figure 15. Gronov 3: reconstruction of hair on the basis of the 3D visualisation of porosity of sample № 306.

Conclusion

The investigations of the inner structure of Neolithic ceramics with the help of micro-CT, allow us to differentiate a variety of organic inclusions on the basis of the morphology of voids and their distribution. This method is important for the differentiation of naturally occurring and artificially added inclusions (temper).

One of the most important things in the study of ceramic structures is the detailed visualisation and reconstruction of porosity in a sherd. 3D void visualisation allows us to identify the pores left during burning of different organic types. It is difficult to differentiate by visual and thin section

examination the pores of a shell, feather and plant remains, especially when the firing temperature exceeded 780°C as shells decompose and no traces of material are visible in the ceramic body. In this case 3D reconstruction of porosity is essential and in some cases, with plant voids, it allows the determination of the species.

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