Assessment of archaeological ceramics porosity by m-CT analysis.

A.M.Kulkov[1], M.A.Kulkova[2]

[1] SPbSU, Decabristov lane 16, SPb, Russia
[2] Herzen State Pedagogical University, Moika emb. 48, SPb, Russia

Aims

Porosity is one of the important technological characteristic of archeological ceramics. Such properties of pottery as density, strength, the thermal conductivity, durability depend on the amount, volume and type of pores. Pores in ceramics can be open and close. Water absorption and water permeability of the material depends on the open porosity. The increasing of strength and durability and decrease of thermal conductivity is achieved by the increase of close porosity. So, the determination of parameters of close and open porosity is significant in the evaluation of ceramics technological characteristics. Currently, the following main methods are used to determine the porosity of ceramics: mercury intrusion porositimetry (MIP), water Archimedean porosimetry (WAM), helium pycnometry (HP) (Syed M.H., 2015). All of these methods are used for determination of pore amount and they do not allow getting parameters for individual pores. Using of X-ray microCT technique provides new opportunities for studying of pore space in ceramics. MicroCT allows not only to evaluate pore space and amount of pores in a sample, but to characterize individual pores. So, R.Ledevin (Ledevin R. and co-authors, 2017) presents the investigations of porous in ethnographic ceramics. It was shown, that a ratio of volume/area for individual pores in a sample reflects the moulding process and this has not the connection with firing conditions.The aim of this work is the pororsity analysis of Eastern European archeological ceramics, belongs to different cultural traditions (from Neolithic to Early Iron Ages).

Method

It was investigated more than 60 ceramics sherds of Early Neolitic, Middle Neolitic and Early Iron Age pottery from different archaeological sites of the Eastern Europe.

The ceramic samples were scanned with using the SkyScan 1172 device in the Research Centre for X-ray Diffraction Studies of Saint-Petersburg University. The beam energy was 100 kV, a flux – 80-100 μA and aluminum filter with a resolution of 4-6 μm, performing a 180-degree rotation with a step size of 0.4 degrees.

Pore space databases were retrieved from matrix databases using CTan software. The pore spaces inside of ceramics was visualized and investigated at CTVox software. As necessary, VOI (Volume of Interest) containing individual pore was cut out from pore space by Dataviewer corresponding function and clean from noise at CTAn. The individual object analyses of pores were performed by CTAn software, also. The plots of relationships between pore surface and pore volume were built for 400 pores with the pore volume more than 5 mkm for each sample. The VOI was about 600 x 600 x 600 pixels. The plots were built with the help of Origin 9.0.

Results

The data obtained showed the pore space of archaeological ceramics as a whole consists of cracks, pores after burned organics and a big number of small subspheroid pores (with diameter less than 5 microns). 3D visualization of porosity makes possible to determine the origin of these pores. Sometimes one can identify the type of organic inclusions.

Several investigated vessels had been found in the Podolje site located on territory of the Ladoga Lake basin. The pore space of one of the pottery (Early Metal period) (sample #1743) (fig.1) was formed in result of burning of the great number of grass and plant grains (fig 2). Some grass grain replics (fig. 2 a,b,c,d,g) can belong to *Elytrígia*, the plant grain at fig. 2e was not identified. Also, it was found the antenn of insect (fig 2 f). According to the amount and shapes

of pores, we can suggested that grass was special additives to clay past as a temper. Less amount of floristics replics was found in different ceramic sherds, but the most of them look like random additives that were in the clay composition naturally (fig.3).
Results of porosity analysis for 50 sherds are shown at fig. 4. The ratio of open/close porosity degreases from Neolithic to the Early Iron Age ceramics. It should be remember that evaluation of open porosity in this case depends on the VOI selection. So, one need to use statistically significant results for classifies ceramics by open/close porosity ratio.

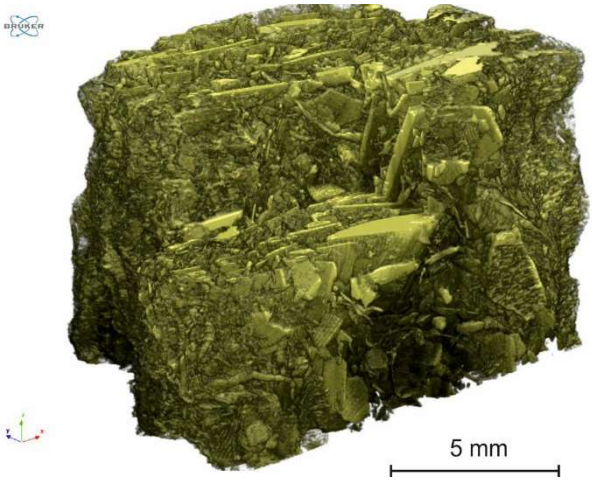

Figure 1: Pore space of sherd #1743 (Podolie site).

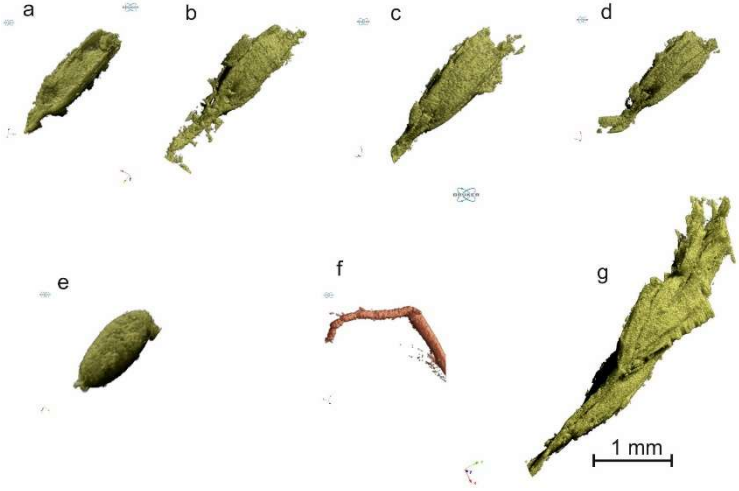

Figure 2: Reconstruction of individual pores from sherd #1743 (Podolje, Early Metal Age).

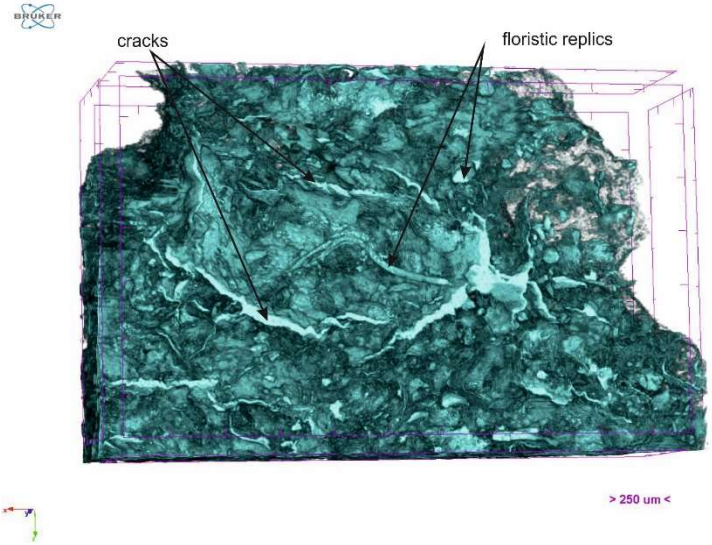

Figure 3: Pore space of sample #133 Suvorovo (Early Iron Age).

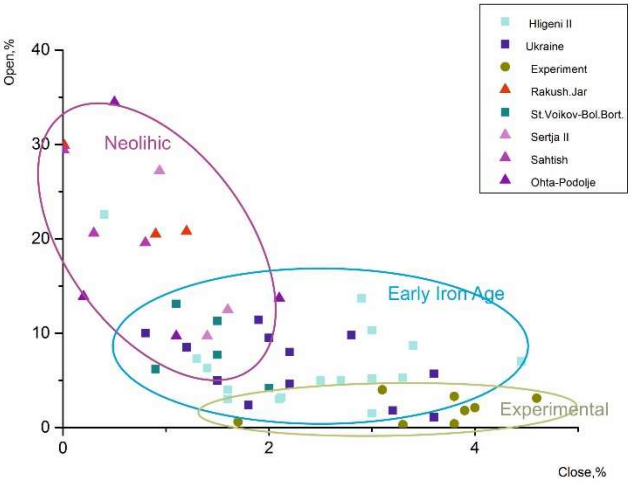

Figure 4. Open/close porosity data for ceramics of different ages.

Geomethric parameters (3D-dimensions, volume, surface area, shpericity and so on) of individual pore can be received by CTAn (parameter “Individual object analysis”). At this stage the ratio volume/surface area for pores was obtained. Figure 5 shows the plot of volume vs surface area for three samples. We can assess the distribution of pores by means of a size and

a shape. The pores located close to the line of a perfect sphere has sphere-like shapes, unlike the pores located near “surface ares” axe has plate-like shapes. It is necessary to mention, that the most strength and density ceramics have the small spheric pores.

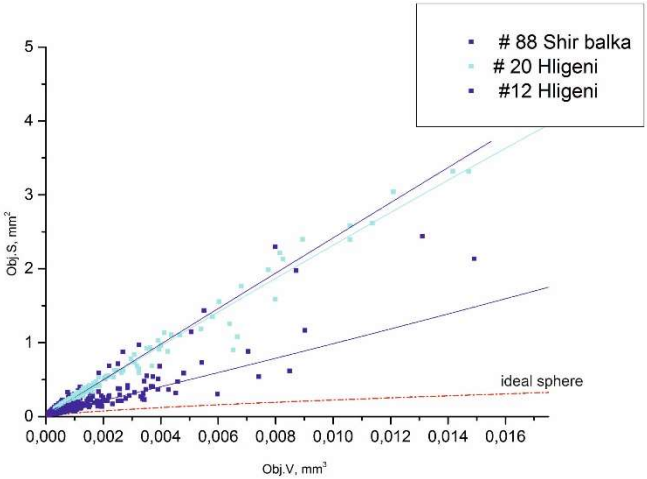

Figure 5. Pores distribution in archeological ceramic samples.

Conclusion

Quality analysis of pore space by m-CT allows to identify the origin of pores in result of thermal shock, the cracks around mineral inclusions, the burning of random or special organic additives and etc. There is possibility to determine the type of organic additives on the base of 3D pore visualization. So, analysis of pore space inside of ceramics gives the possibility to reconstruct the clay and temper compositions for pottery moulding.

Relationship between open and close pores inside is the technological parameter which reflects the quality pottery moulding. For example, lower values of open/close porosity ratio are typically for more dense and high quality Iron Age pottery.

The pore size distribution and shape of pores can be evaluated by ratio suface/volume of pore. Pores of high quality ceramics show the low variation of size distribution and the shapes close to sphere. The presense of burned organic in ceramics leads to high variations of pore sizes. Data obtained by quantitive analysis of pore shapes and distributions can be used for assessment of ancient ceramics making production.

References:

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