Supplementary material:

Application of image analysis for the identification of prehistoric ceramic production technologies in the North Caucasus (Russia, Bronze/Iron Age)

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Supplement 1. Scanning conditions of the 3D μ-CT for the archaeological ceramics

For the pore topology, 1080 images were taken. Four images for each angle were gathered and the first two images were skipped. The CT images were reconstructed as a volume using the edge enhancement filter.

Sample no.	Voltage (kV)	Current (μA)	Acquisition time (mS)	Magnification	Voxel size (μm³)	BHC
Ran1_329	103	70	750	13.000	3.85^3	9
Ran1_KB3kc1	129	80	1000	14.546	3.44^3	9
Ran1_549_1	109	80	750	13.637	3.67^3	9
	120	80	1000	47.503	1.05^3	10

Table S1. Measurement condition of the 3D μ-CT for the pore topology of three samples.

For the pore topology, 1080 images were taken. Four images for each angle were gathered and the first two images were skipped. The CT images were reconstructed as a volume using the edge enhancement filter and BHC factor 8.

Sample no.	Voltage (kV)	Current (μA)	Acquisition time (mS)	Magnification	Voxel size (μm³)
Ran1_278_x	132	102	750	1.687	29.63^3
Ran1_527_20	127	100	750	1.950	25.64^3
Ran1_313_2	131	101	750	1.652	30.27^3
Ran1_538_16	130	100	750	1.656	30.19^3
Ran1_449	127	90	750	2.500	20.00^3
Ran1_619_23	137	99	750	1.897	26.35^3
Ran1_601_7	140	93	1000	1.721	29.05^3
Ran1_514_2	140	96	1000	5.271	9.49^3
Ran1_489_46	140	99	1000	2.586	19.33^3
Ran1_N18_49	132	80	1000	1.674	29.88^3
Ran1_541_11	130	80	1000	1.739	28.75^3
Ran1_167_4	133	70	750	4.857	10.29^3
Ran1_298_3	104	80	750	3.043	16.43^3
Ran1_225_4	104	70	750	2.755	18.15^3
Kab2_1697_1	135	100	750	1.700	29.37^3
Kab2_482_13	130	92	750	2.000	25.00^3
Kab2_1260_4	122	100	750	2.349	21.29^3
Kab2_482_1	110	87	750	2.500	20.00^3
Kab2_1396_4	122	78	500	2.641	18.93^3
Kab2_1763_1	135	103	750	1.951	25.62^3
Kab2_1408_1	114	100	750	2.214	22.58^3
Kab2_1235_1	131	90	750	2.000	25.00^3
Kab2_1195_6	130	79	750	2.000	25.00^3
Kab2_1976_1	139	90	750	1.849	27.04^3
Kab2_650_10	105	80	750	3.539	14.13^3
Kab2_1587_1	140	98	1250	1.977	25.29^3

Kab2_853_1	140	90	1000	2.194	22.79^3
Kab2_2258_5	104	80	750	2.500	20.00^3
Kab2_1253_3	121	70	750	2.480	20.16^3
Kab2_1603_4	125	80	750	2.267	22.06^3
Kab2_416_9	130	70	750	2.000	25.00^3
Kab2_516_26	102	70	750	2.889	17.31^3
Kab2_294_1	131	70	750	2.000	25.00^3

Table S2. Measurement condition of the 3D µ-CT for the alignment of the pore complex and sand grains.

Supplement 2. Image segmentation, processing and analysis

The image analysis was performed with the Matlab software. The main functions used for this study is presented in the following table.

	2D analysis	**3D analysis**
Image visualization	imread(); dlmread(); imshow()	fopen(); fread(); reshape(); imshow(), isosurface(); patch();
Conversion of image data type	rgb2gray(); im2bw(); size()	Int16(); double(); imbinarize(); size(); dim(); gpuArray(); gather()
Image data modification	imfill(); imdilate(); imerode(); imcomplement() including calculation and logical decision of arrays	histeq(); imfill(); imdilate(); imerode(); imcomplement(); sum(); A(~B) = 0; imclearborder() including calculation and logical decision of arrays
Acquisition of target properties	bwconncomp(); regionprops()	Bwconncomp(); regionprops3(); labelmatrix(); ismember()

Table S3. Examples of main functions used for the image analysis by Matlab in this study.

The color values of the Polarized light microscopic images were converted into the gray scales and the sand grains were segmented using the corresponding thresholds.

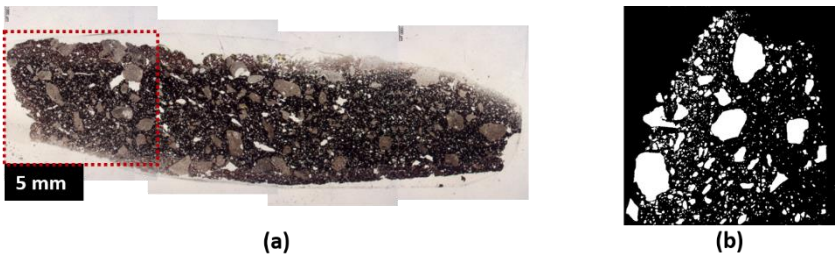

Figure S1. (a) Polarized light microscopic images (plane polarized light) of the cross section; (b) segmented image of sand grains (white).

The studied objects were segmented from the 2D matrix of the intensity according to the measuring element per pixel (1^2 µm²) using the pore threshold.

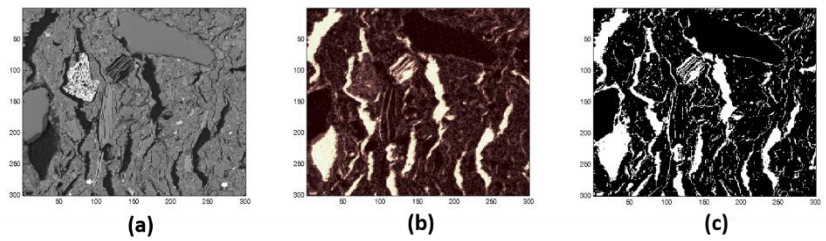

Figure S2. Visualization of the 2D matrix according to the intensity of (a) BSE and (b) Carbon and segmented image of pores from the matrix (measurement area=300x300 µm²).

Images acquired by the 3D µ-CT were segmented using the multiple thresholds of the studied objects. Due to the heterogeneous structural elements and the asymmetric form of the sample, different intensity depending on the scanning area should be used for the segmentation.

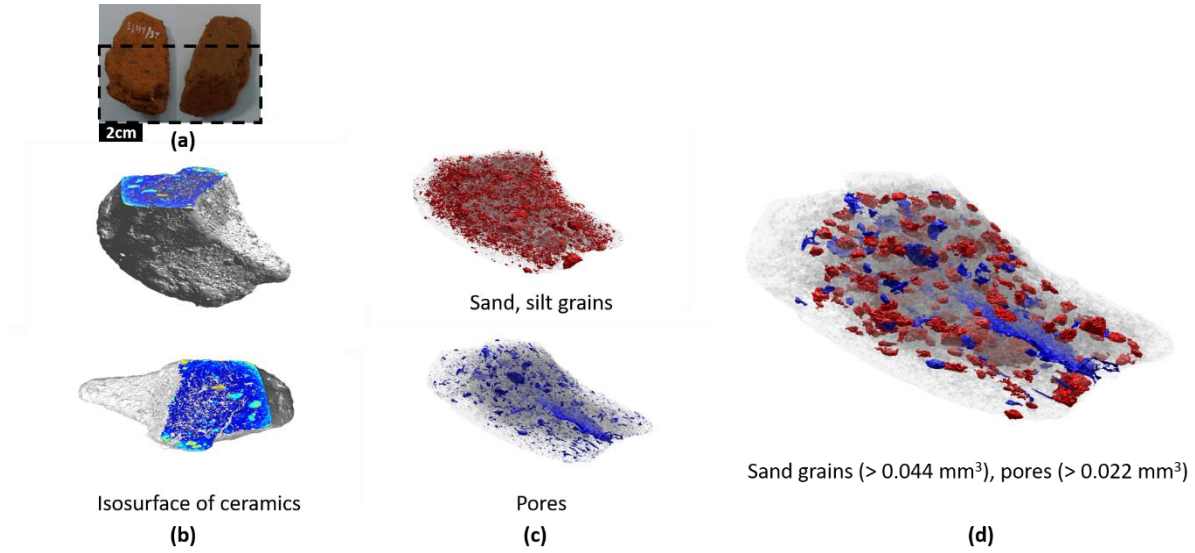

Figure S3. (a) Original ceramic sherd and its ROI in the box of the black dashed line; (b) Isosurface of the sample with Isocaps of the exposed cross section; (c) Segmentation of sand/silt grains and pores; (d) Segmentation of sand grains and pores with the specific volume size.