



X-RAY, SYNCHROTRON AND NEUTRON IMAGING OF METAL ARTIFACTS FROM THE CHERNAYA MOGILA BURIAL MOUND (X century, Chernigov)

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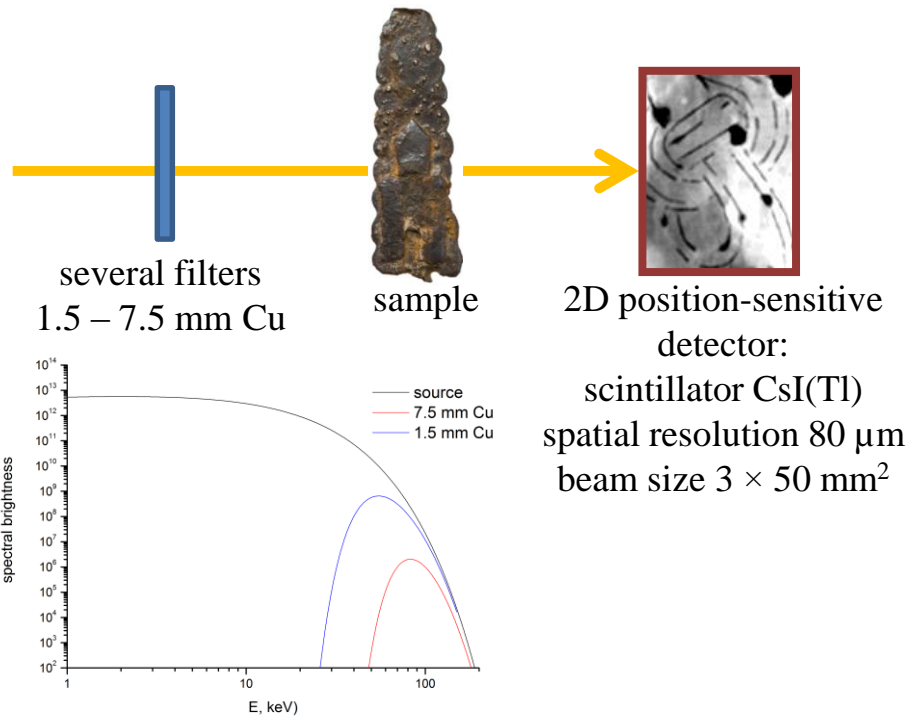
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Experimental methods and Facilities

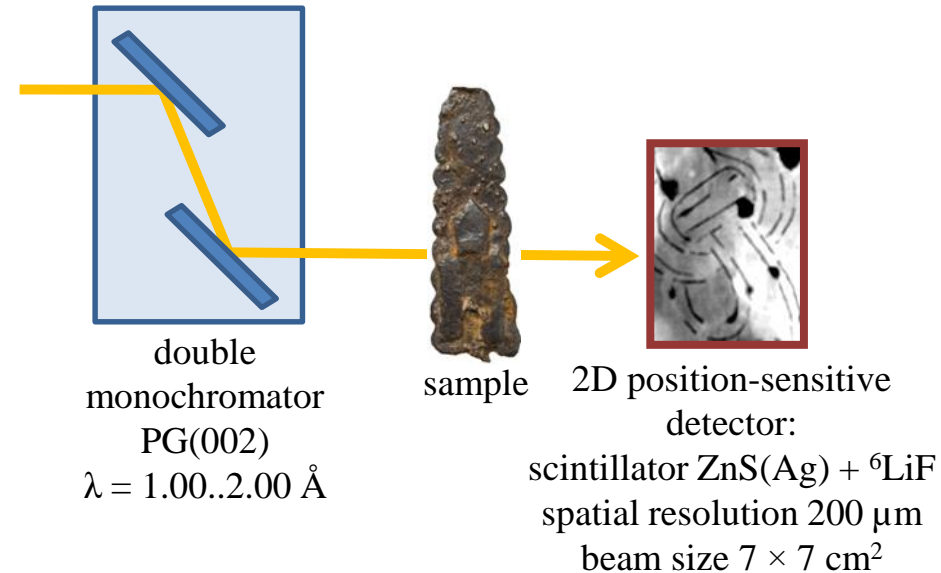
Synchrotron imaging

The Kurchatov synchrotron radiation source
the Tomography facility at the beamline 6.3



Neutron imaging

The IR-8 research reactor
the DRAKON facility



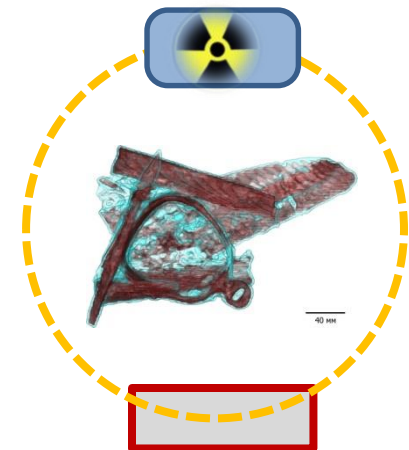
X-ray imaging – Computer tomography

PET-CT tomograph Biograph mCT40 (Siemens)

Spatial resolution (slice thickness) – 0.6 mm

Spatial resolution in the tomography plane during reconstruction – 0.88 × 0.88 mm.

140 kV/80 mA; 140 kV/150 mA; 140 kV/50 mA; 120 kV/20 mA.



The Chernaya mogila burial mound

X century, Chernigov (present-day Ukraine)



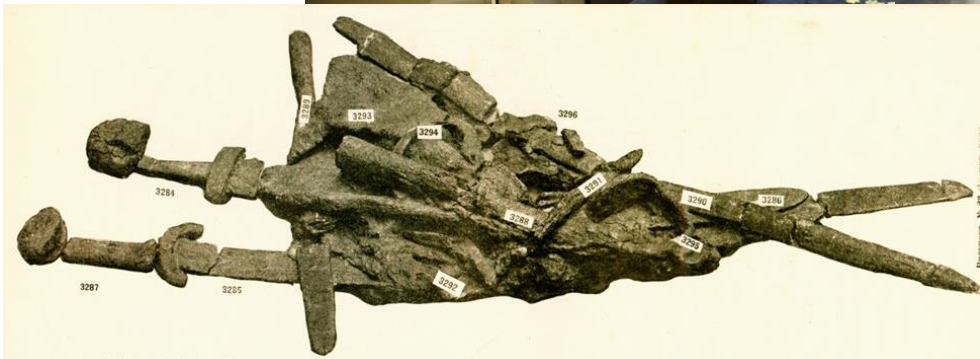
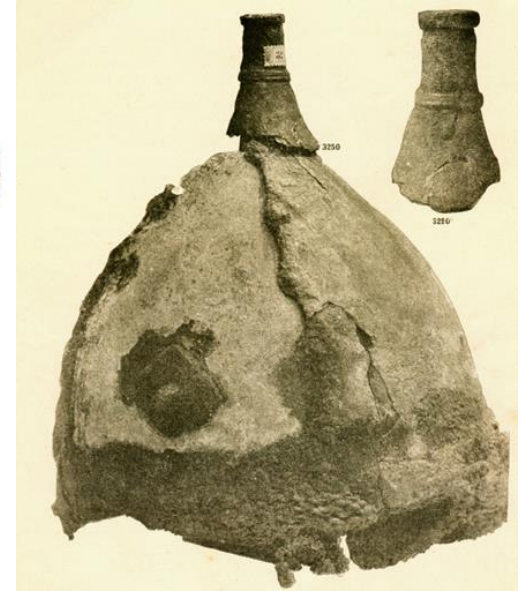
Chernaya mogila burial mound before the start of excavations in 1872. From [*Samokvasov D.Ya. Mogilnye drevnosti Severyanskoy Chernigovshchiny. Moskva: Synodalnaya typografia. 1916 (in Russian)*].



Current view (Yandex.maps)

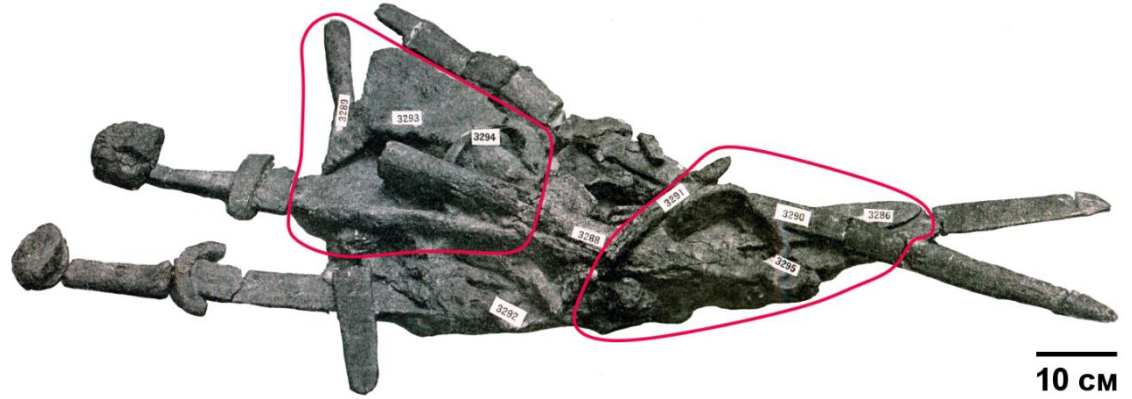
Artifacts from the Chernaya mogila burial mound

X century, Chernigov



Objects from the Chernaya mogila burial mound

X century, Chernigov



weapon sintered conglomerate



scalloped-edged objects –
«Barbarian scepters»



fragment of
the sword



arrowhead

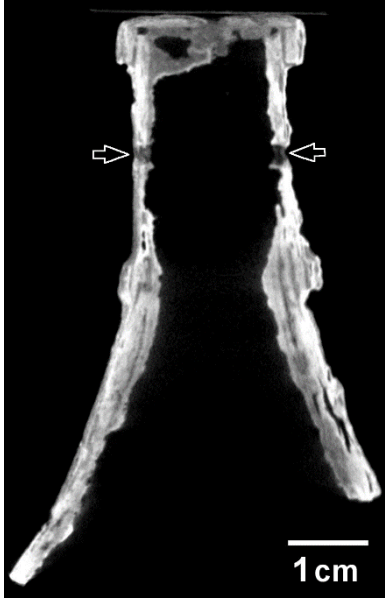


spearhead tip



helmet

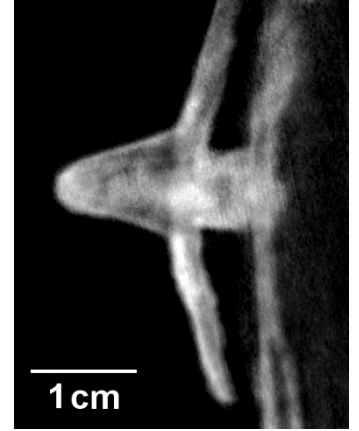
Helmet (decoration details)



N tomography



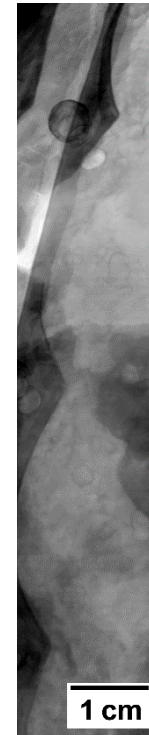
Photo of the helmet



N tomography

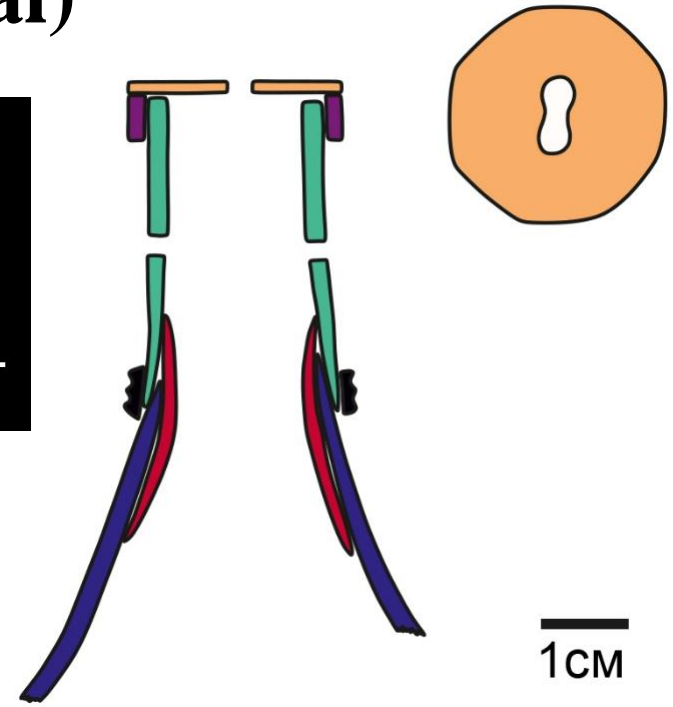
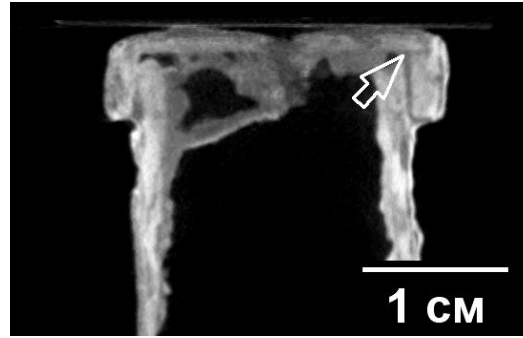
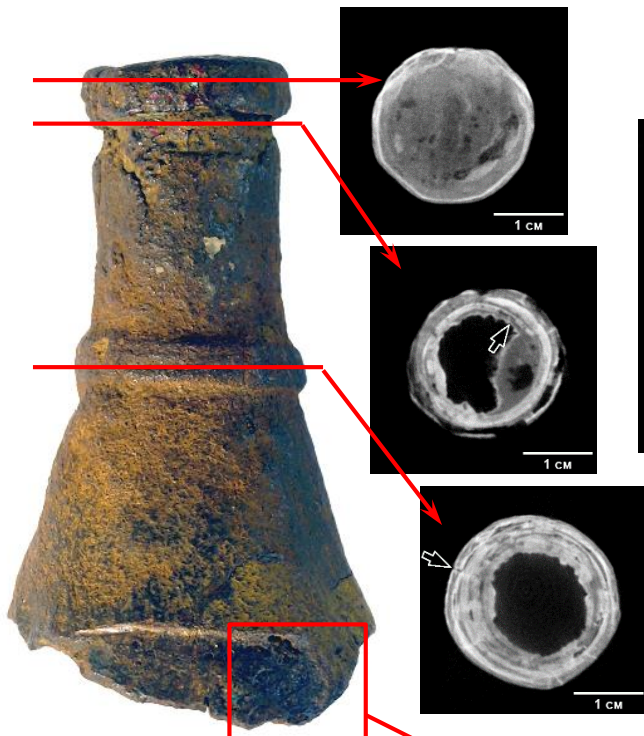


SR radiography



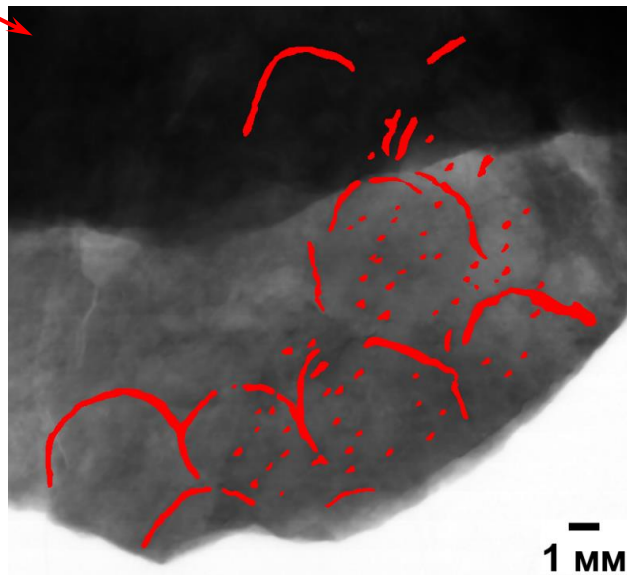
Figured edges of the helmet plates.

Helmet (finial)



Photo

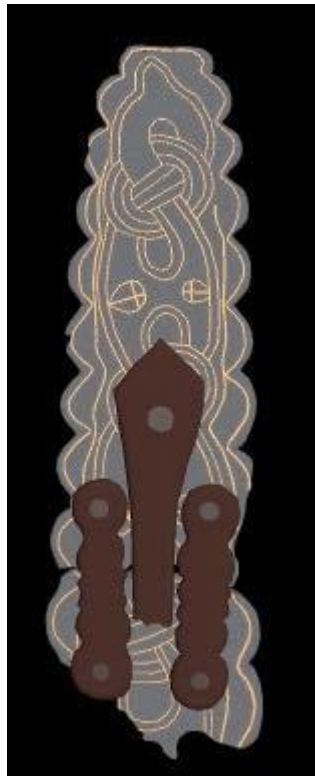
Drawing of the ornament on the lower part of helmet's finial – SR data.



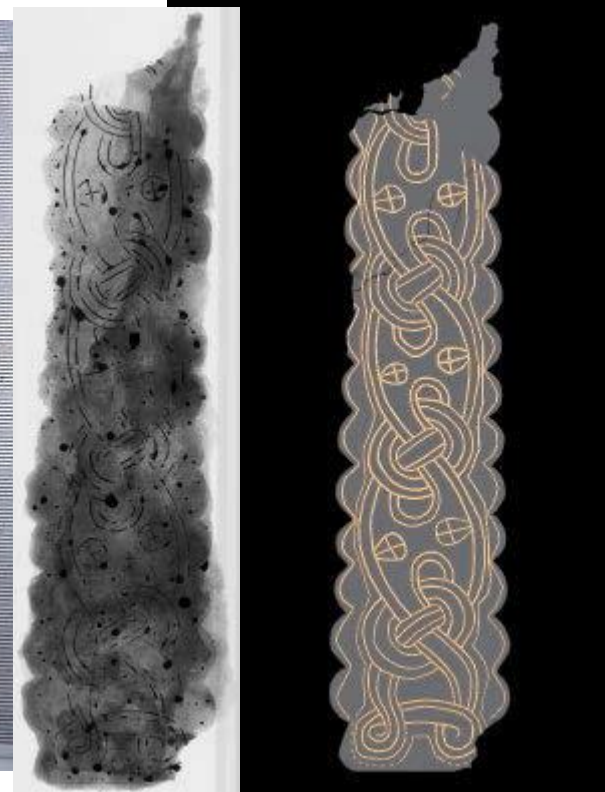
Reconstruction of the structural elements of the helmet's finial:
Orange – plate "plug",
Purple – ring "plug",
Green – cylindrical part,
Blue – the lower conical part,
Red – the strengthening insert,
Black – locking ring.

Scalloped-edged objects «Barbarian scepters»

①

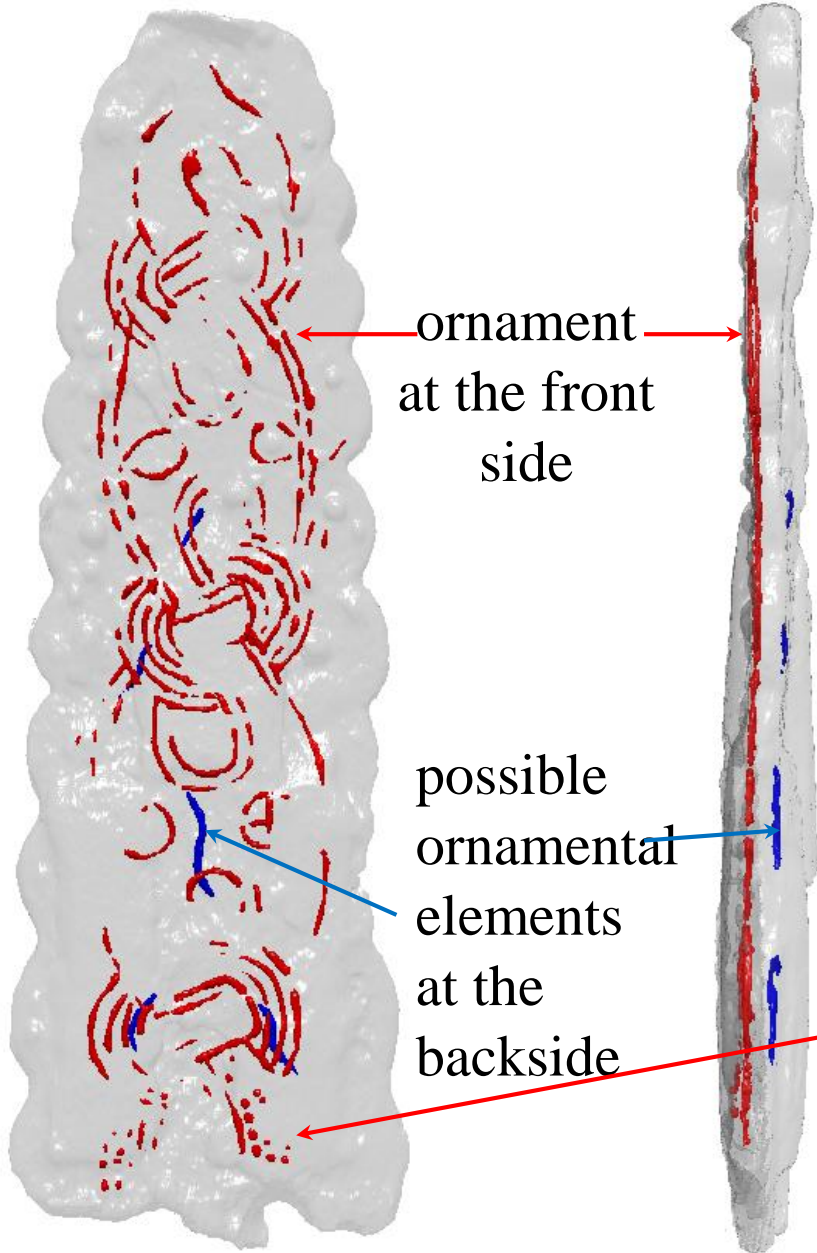


②



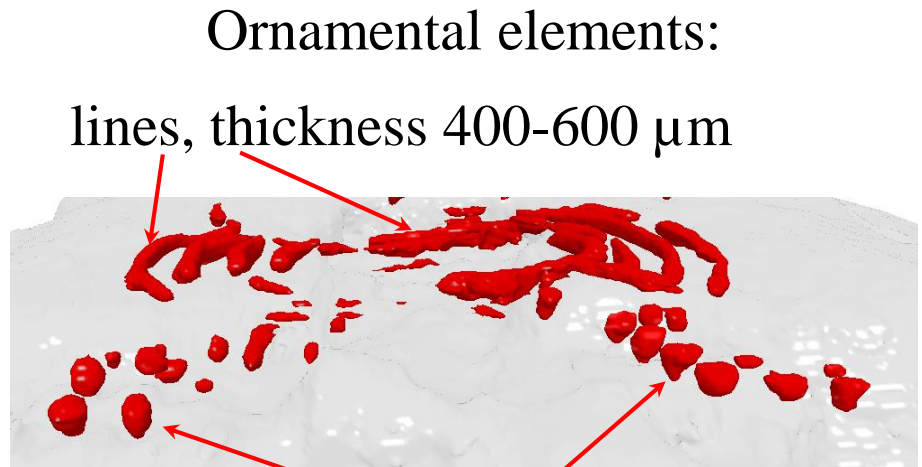
Scalloped-edged object

①



ornament
at the front
side

possible
ornamental
elements
at the
backside



Ornamental elements:

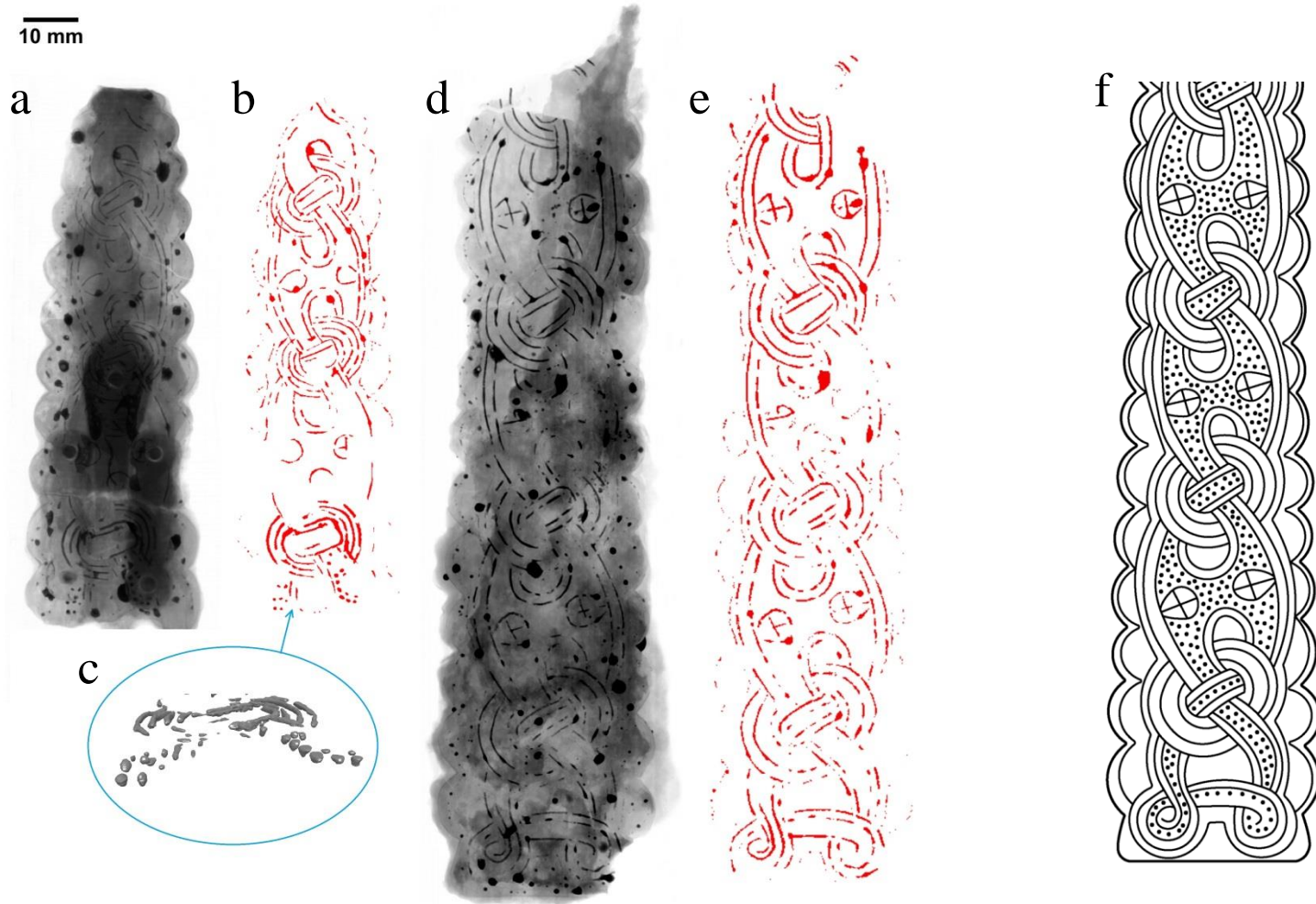
lines, thickness 400-600 μm

«dots»

diameter and depth 500-700 μm

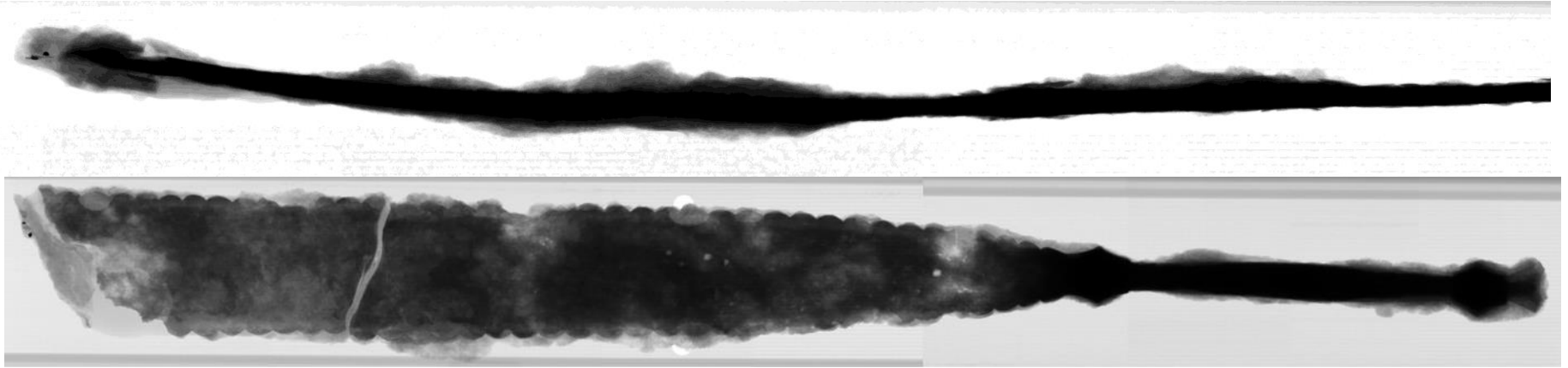
Scalloped-edged objects

① and ②



Radiogram of the object 1 on SR (a), ornament selection on the radiogram (b), preserved "dots" on the object 1 (c), radiogram of the object 2 on SR (d), ornament selection on the radiogram (e), reconstruction of the ornament (f).

Scalloped-edged object ③



Scalloped-edged objects «Barbarian Scepters»

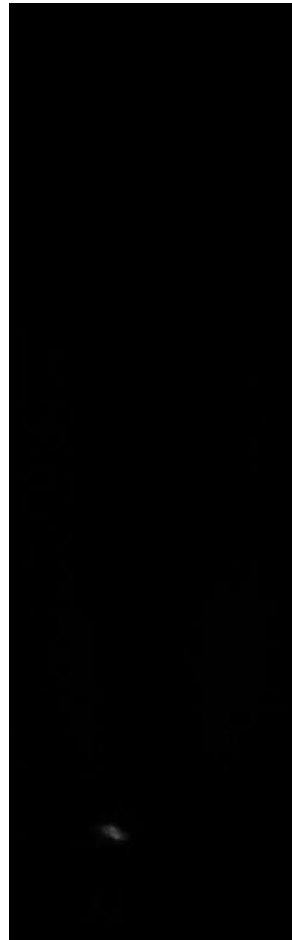
Proposed reconstruction



Arrowhead



Photo of the arrowhead



SR tomography



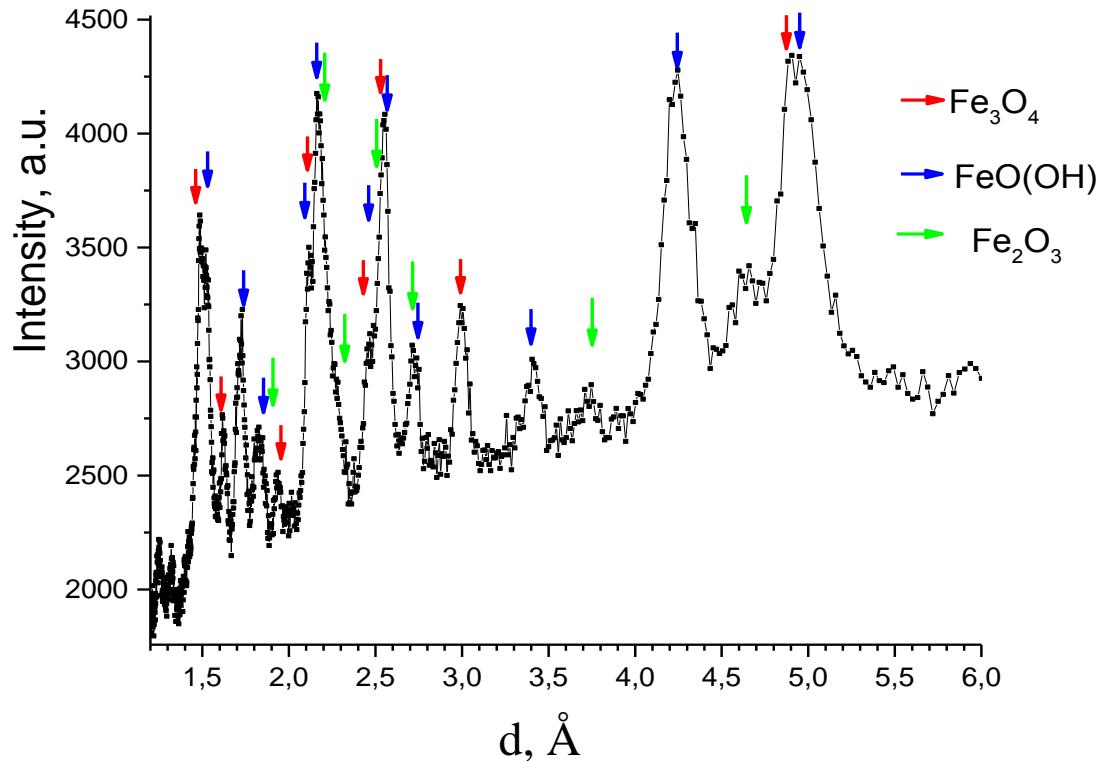
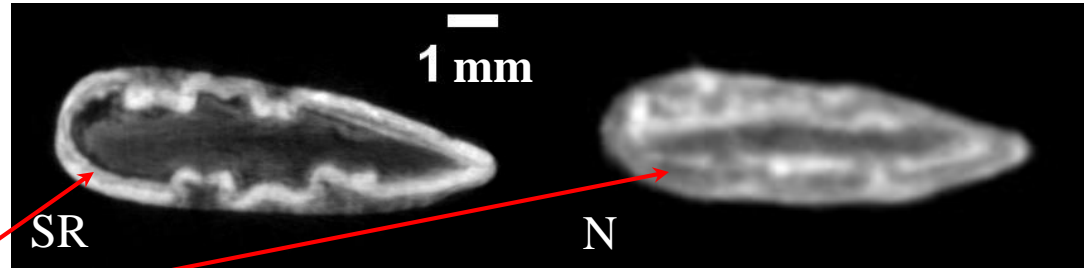
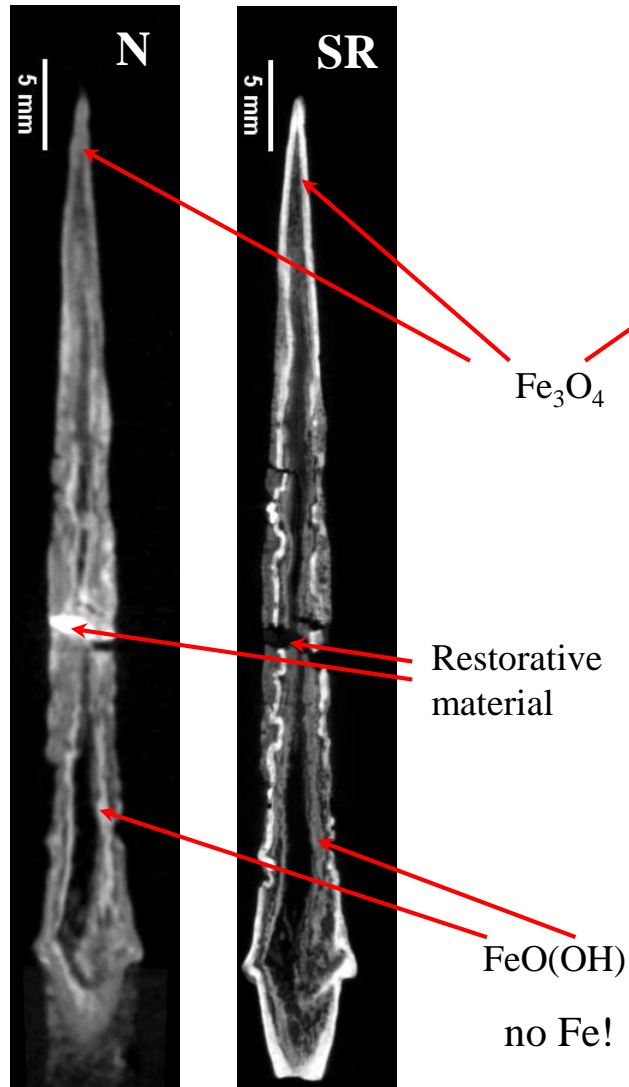
Ornament on both sides of the arrowhead



Drops of a metal incrustation

Arrowhead

preservation

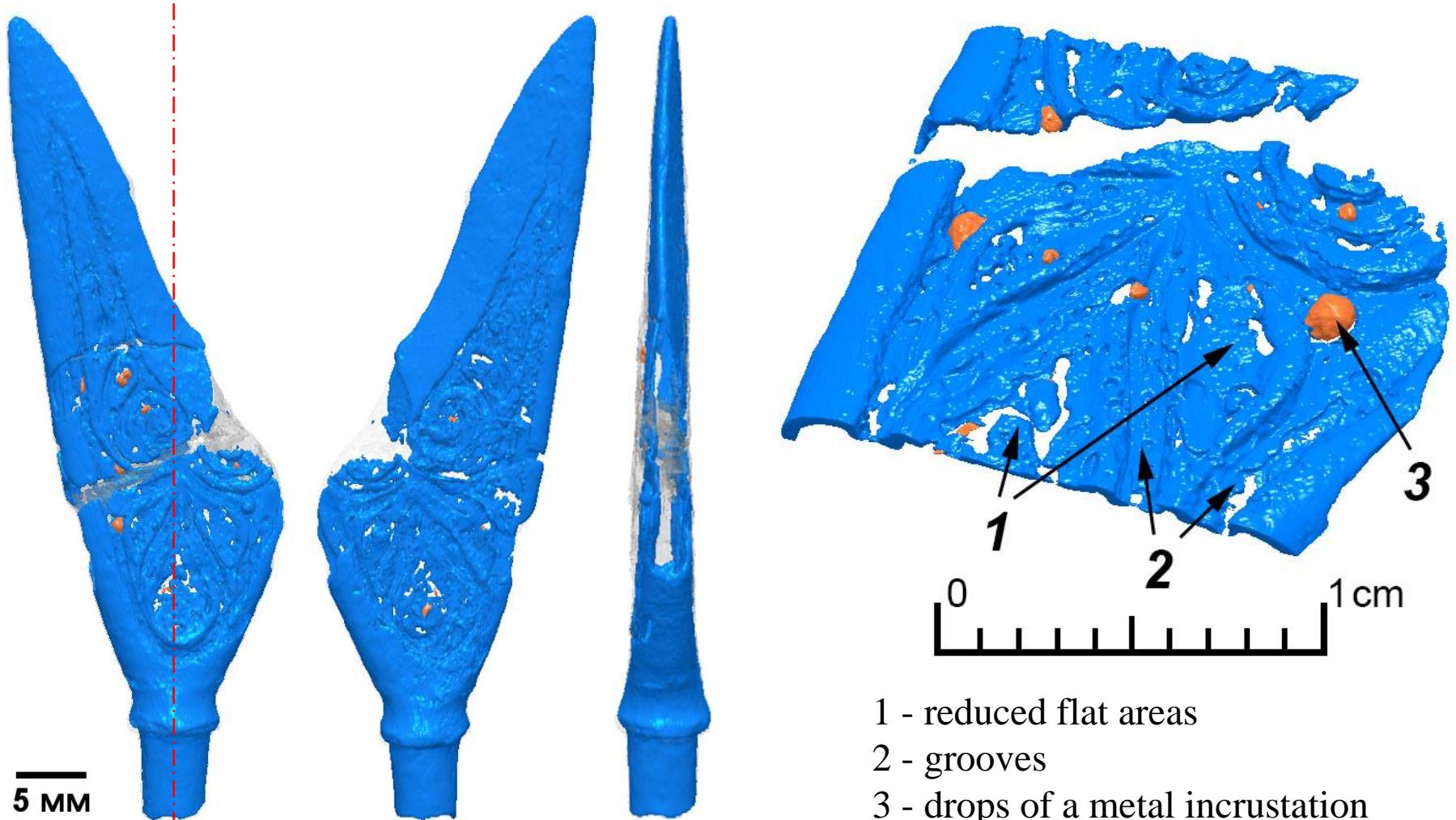


Tomographic slices made using neutrons (N) and synchrotron radiation (SR).

Neutron diffraction, IR-8, DISK, $\lambda = 1.67 \text{\AA}$

Arrowhead (3D reconstruction)

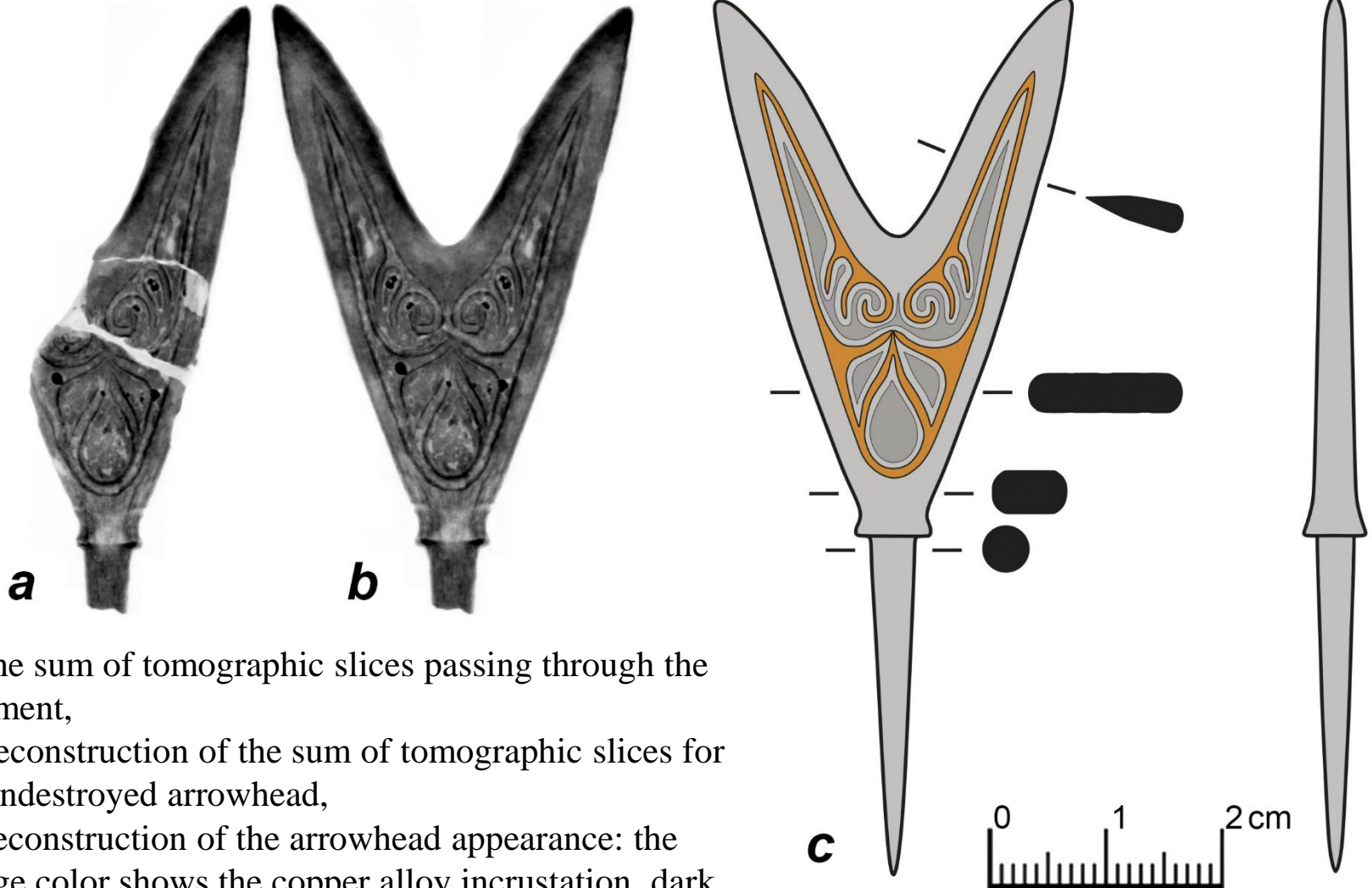
vegetative ornament



Metal incrustation filled the grooves supposedly.

Arrowhead

Reconstruction of the floral ornament



a – the sum of tomographic slices passing through the ornament,

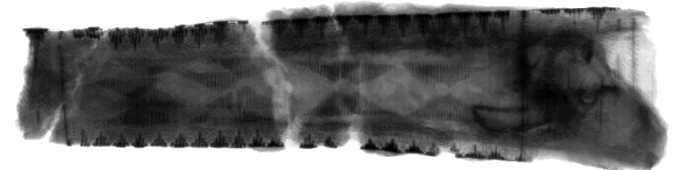
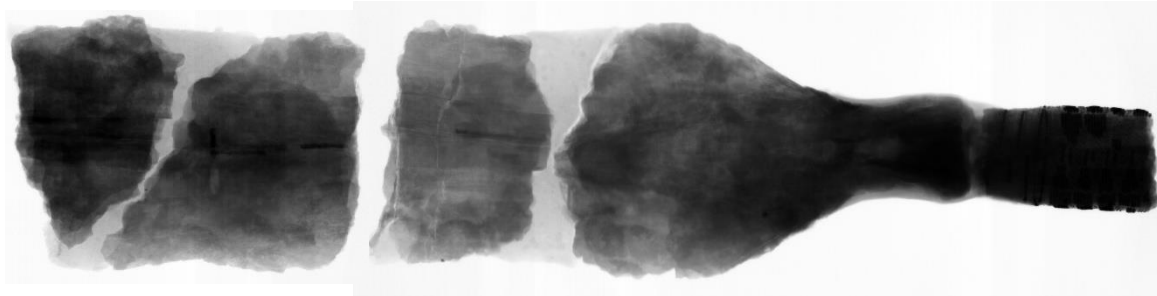
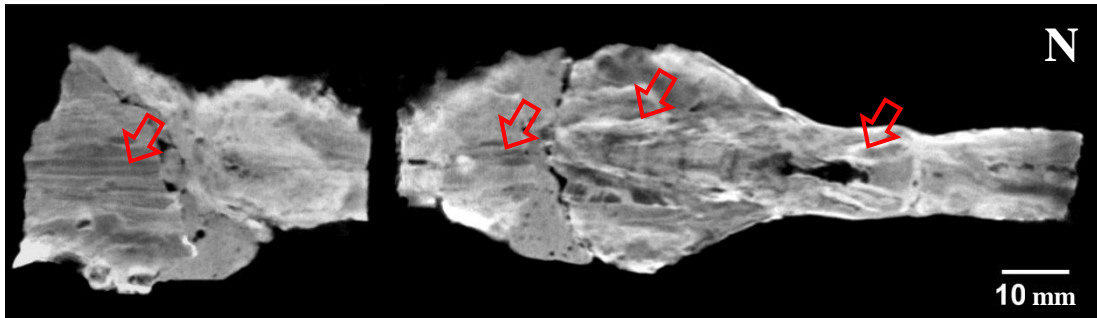
b – reconstruction of the sum of tomographic slices for the undestroyed arrowhead,

c – reconstruction of the arrowhead appearance: the orange color shows the copper alloy incrustation, dark gray – reduced flat areas with the supposed additional decoration.

Spearhead tip

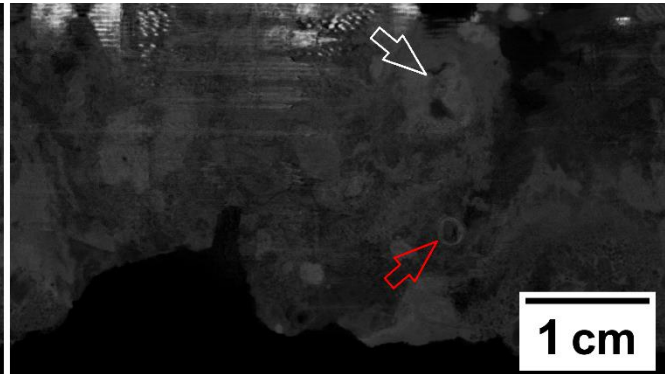
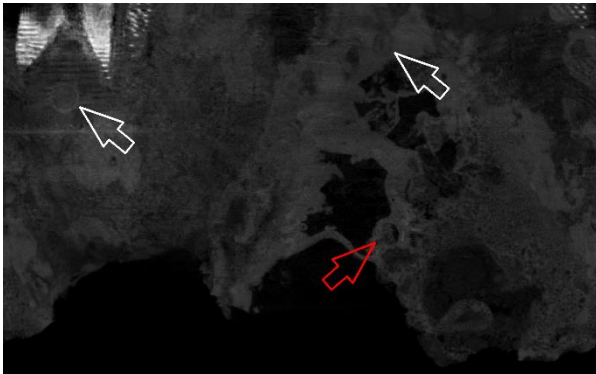
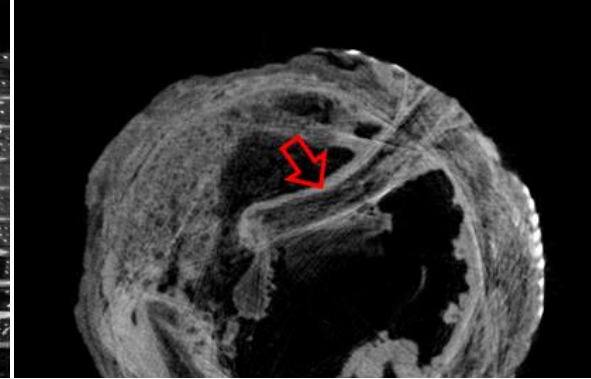
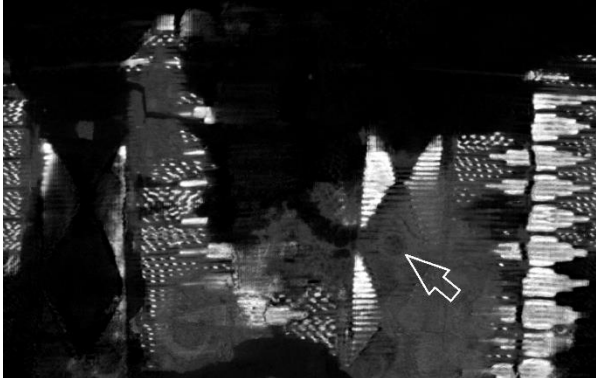


cm



1 cm

Spearhead tip



type I by J.
Petersen
classification

pinholes (white arrows)
preserved pin (red arrow)

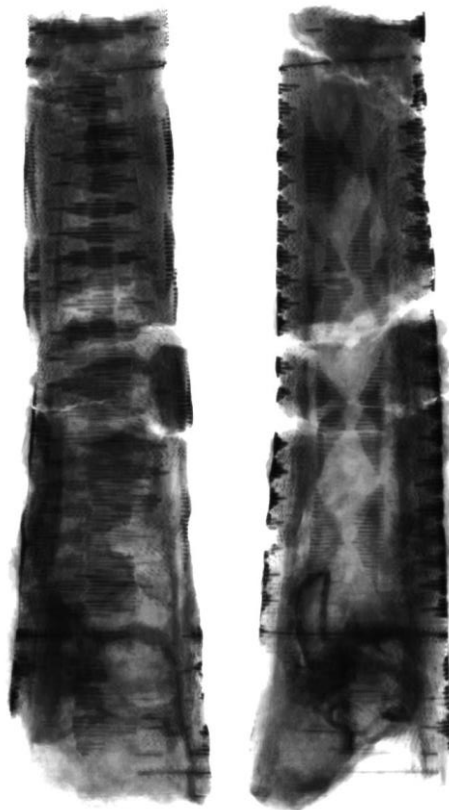
The spearhead tip

Reconstruction of the geometrical ornament

C



Photo of the fragment **C** of the spearhead tip



SR radiograms of the fragment **C**



3D reconstruction



10 mm

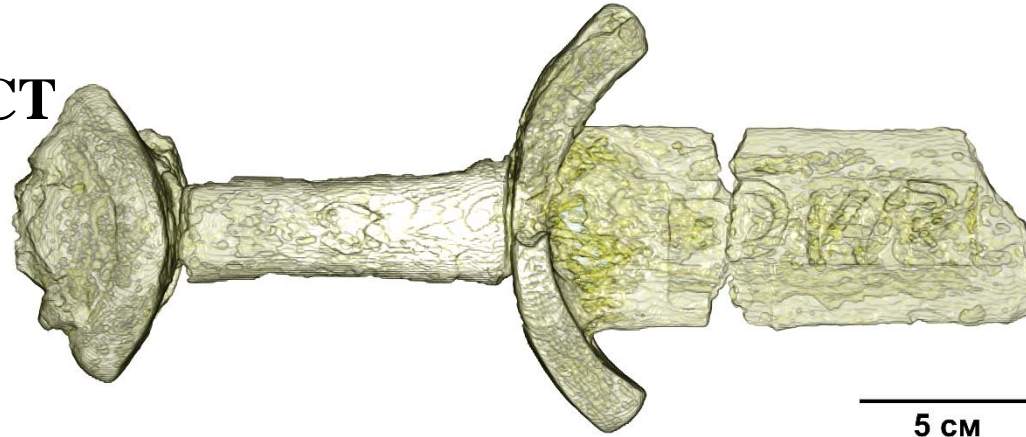
Fragment of the Sword (mark)



Photo

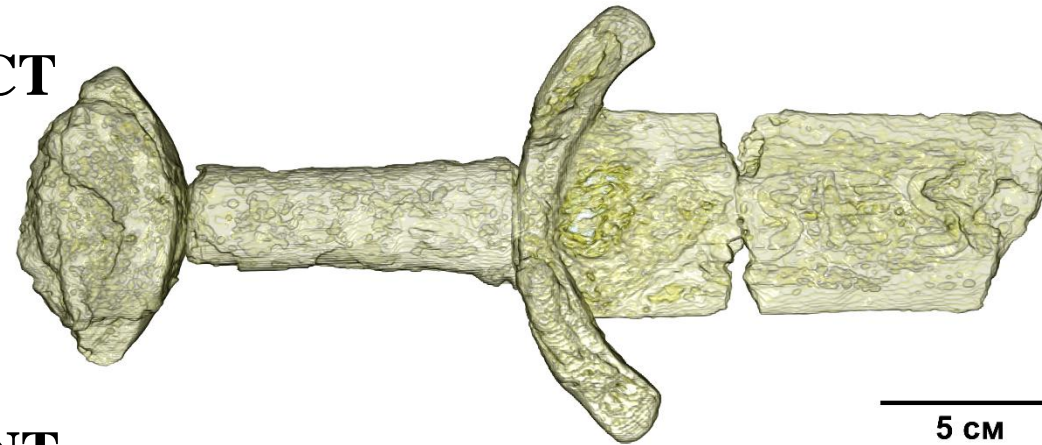
Fragment of the Sword (mark)

CT



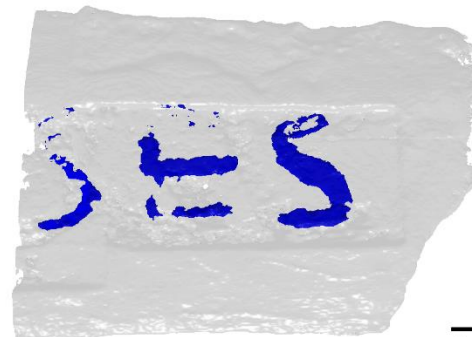
5 cm

CT



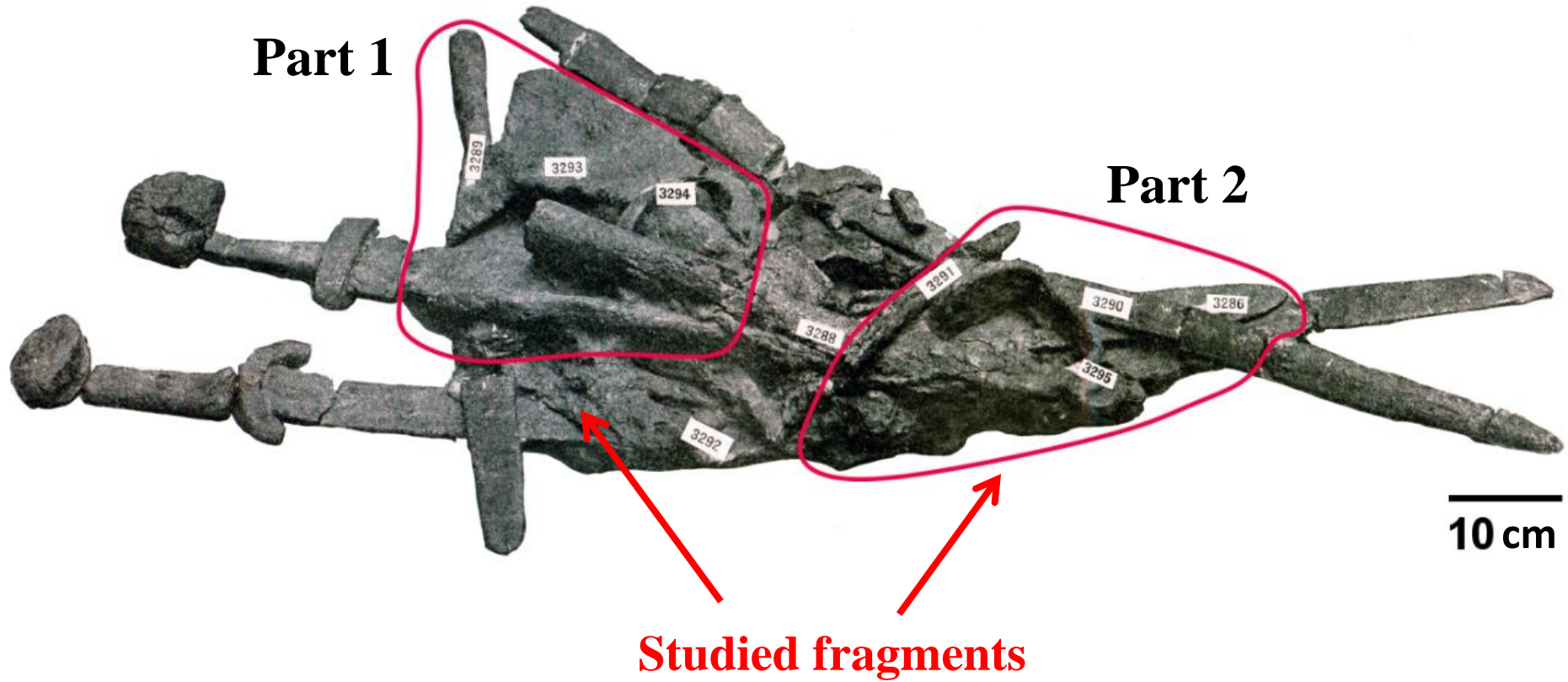
5 cm

NT



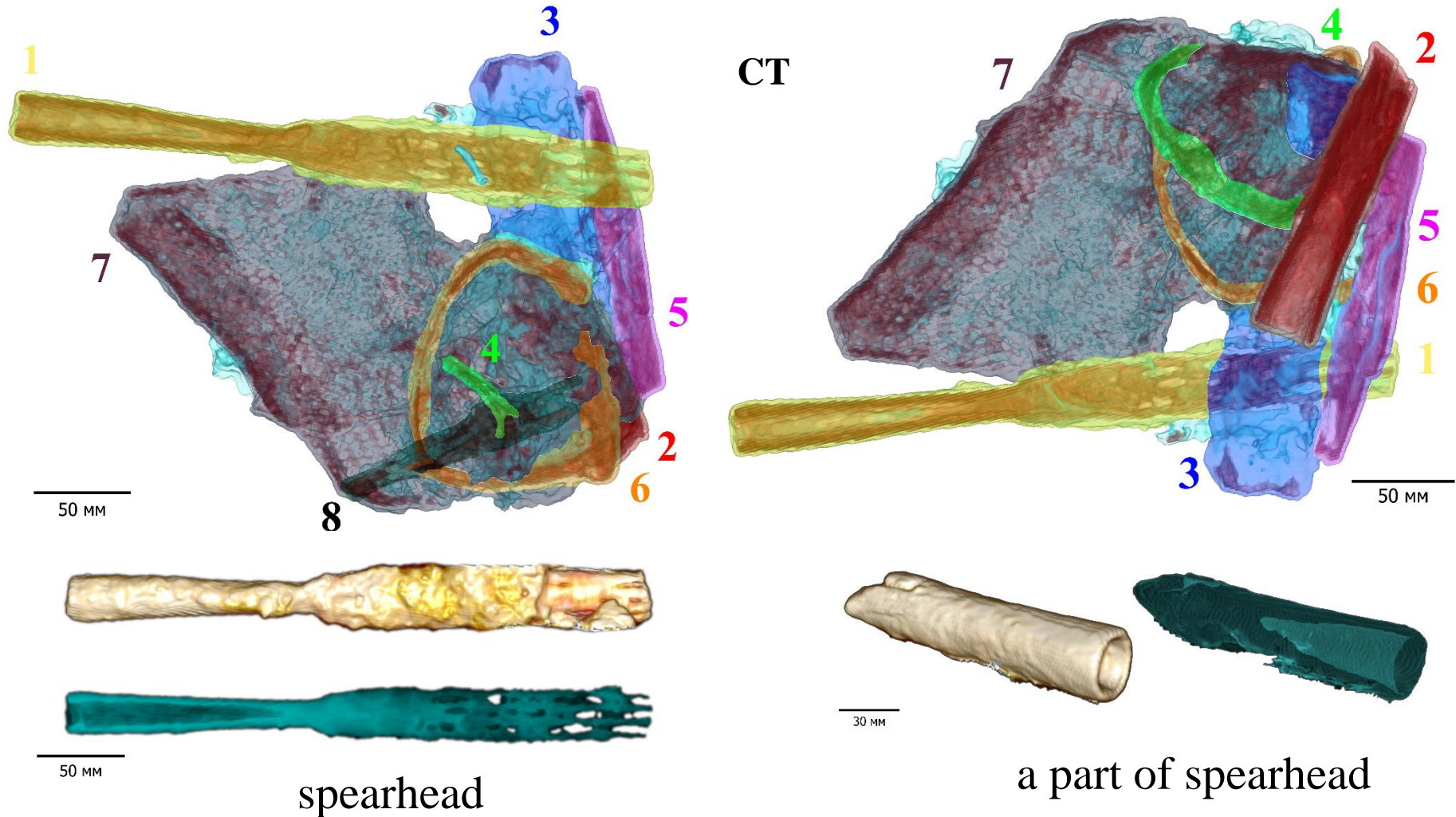
1 cm

Weapons sintered conglomerate



Weapons sintered conglomerate (part 1)

3D reconstruction



spearhead

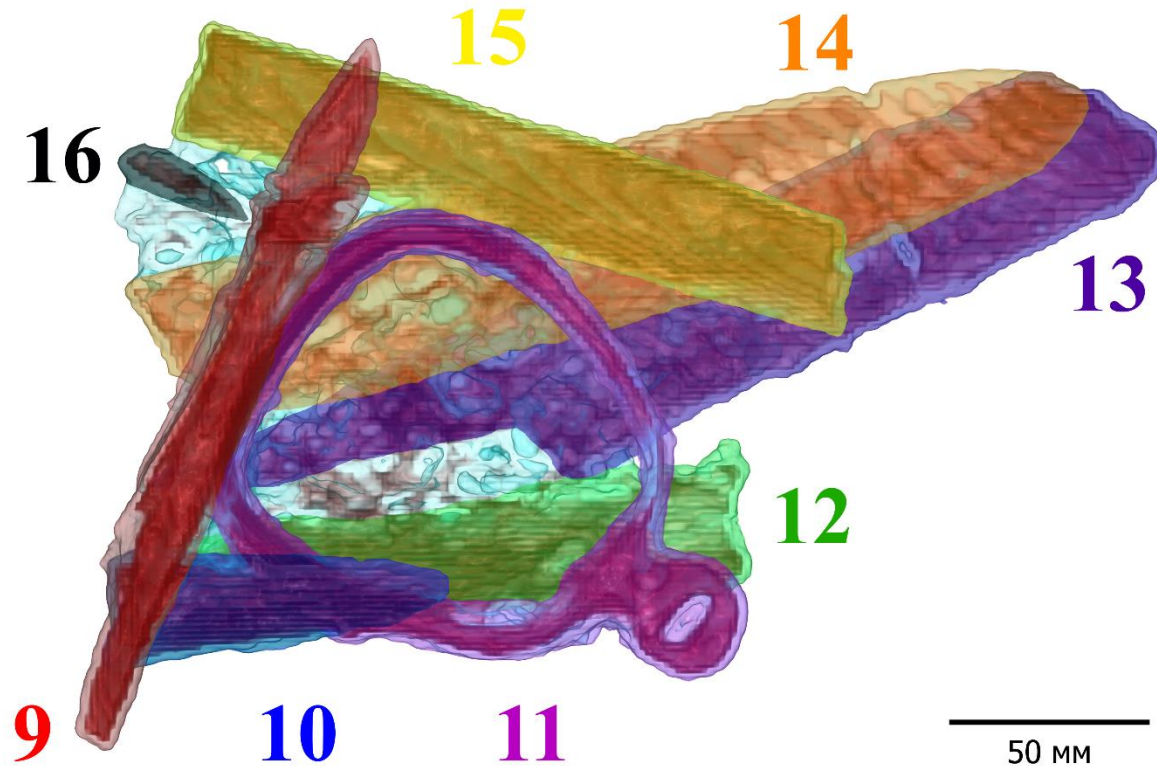
a part of spearhead

1 - spearhead, 2 - a part of spearhead, 3 - sword blade fragment (sword 1), 4 - bracket fragment, 5 - sword blade fragment, 6 - stirrup, 7 - chain armor fragment. The purpose of 8 item is not established.

Weapons sintered conglomerate (part 2)

3D reconstruction

CT



10 - fragment of a spearhead, 11 - stirrup, 13 and 14 - fragments of sword blades (swords 2 and 1 respectively), 15 - fragment of a sabre blade. The purpose of items 9, 12, 16 is not established.

Conclusions

In order to analyze on the artifacts internal structure, assess their preservation, clarify the manufacturing technology and localize possible decorations, a complex of visualization methods was used. It includes: X-ray computer tomography, synchrotron radiography and tomography performed on the Kurchatov synchrotron radiation source, and neutron tomography carried out at the neutron source research reactor IR-8.

The data obtained made it possible to reveal the **design, ornamental and technological features** of the studied weapon items, which were inaccessible for other studies due to their poor preservation.

A photograph of a modern building with a blue and red facade. The building has several windows, some of which are illuminated from within. In the foreground, there is a large, dark green bush with many white flowers. The sky is a clear, light blue. The text "THANK YOU!" is overlaid in the center of the image in a white, serif font.

THANK YOU!