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

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Experimental methods and Facilities

**Synchrotron imaging**
The Kurchatov synchrotron radiation source, the Tomography facility at the beamline 6.3

- Several filters 1.5 – 7.5 mm Cu
- Sample
- 2D position-sensitive detector: scintillator CsI(Tl)
  - Spatial resolution 80 µm
  - Beam size 3 × 50 mm²

**Neutron imaging**
The IR-8 research reactor, the DRAKON facility

- Double monochromator PG(002)
  - λ = 1.00..2.00 Å
- Sample
- 2D position-sensitive detector: scintillator ZnS(Ag) + 6LiF
  - Spatial resolution 200 µm
  - Beam size 7 × 7 cm²

**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)


Current view (Yandex.maps)
Artifacts from the Chernaya mogila burial mound
X century, Chernigov
Objects from the Chernaya mogila burial mound
X century, Chernigov

scalloped-edged objects – «Barbarian scepters»

fragment of the sword

arrowhead

spearhead tip

helmet
Helmet (decoration details)

N tomography

Photo of the helmet

SR radiography

Figured edges of the helmet plates.
Helmet (finial)

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.

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

Photo
Scalloped-edged objects

«Barbarian scepters»

①  ②
Scalloped-edged object

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
Neutron diffraction, IR-8, DISK, $\lambda = 1.67$ Å

Arrowhead preservation

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

Fe$_3$O$_4$

Restorative material

FeO(OH)

no Fe!
Vegetative ornament

Arrowhead (3D reconstruction)

vegetative ornament

1 - reduced flat areas
2 - grooves
3 - drops of a metal incrustation

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

- Pinholes (white arrows)
- Preserved pin (red arrow)

Type I by J. Petersen classification
The spearhead tip

Reconstruction of the geometrical ornament

Photo of the fragment of the spearhead tip

SR radiograms of the fragment

3D reconstruction
Fragment of the Sword (mark)

Photo
Fragment of the Sword (mark)
Weapons sintered conglomerate

Part 1

Part 2

Studied fragments
Weapons sintered conglomerate (part 1)
3D reconstruction

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.
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.
THANK YOU!