STUDY OF A BRONZE VESSEL OF THE DUEI TYPE, INLAID WITH GOLD AND SILVER (WARRING STATES PERIOD), WITH THE OBJECT OF CHARACTERISING THE WAY IT WAS MADE AND ITS CONDITION

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METHODS USED:

- light-optical microscopy
- scanning electron microscope (SEM), coupled with an energy-dispersive X-ray spectrometer (EDS) and a retro-diffused electron detector (ERD)

RESULTS:

We studied the lower part of the vessel. The results of our analyses and observations are given in plates 1 to 6. Here we present an overview of the results.

1. Preliminary observations

We took several samples from this object:

- a sample of the parent metal and silver inlay from a gap on the base of the vessel
- a sample of gold inlay from high on the side of the vessel, at the edge of a gap in the inlay
- a sample of a metallic deposit resembling copper
- a sample of mineralised textile remains originating inside the base

2. Metallographic study

When the metal sample was taken, two fine threads of silver inlay were recovered. They had become detached, and we noticed that the inlay motif, at least in the decoration of the base, combines fine threads of silver and copper. We carried out a microsection with the parent metal of the vessel as well as with the silver thread and the associated copper thread.

The parent metal

The parent metal is a leaded bronze containing 9.8 to 11% tin and 1.5 to 2.3% lead. The alloy is rough-cast and presents a characteristic dendritic structure, with an abundance of globules of lead that are generally of small size. Small islands of pure copper can also be observed scattered all over the surface of the microsection. We will discuss these islands of copper below in connection with the corrosion study.

The silver threads

The metal making up the inlay threads is a binary alloy of silver and copper containing 4.5 to 7.9% copper. The fine silver thread under study presents a cold-hammered structure. It has a roughly trapezoidal section and shows traces of corrosion (oxides and chlorides).

The "copper" threads

The metal used to make these threads is again a leaded bronze, with a greater lead content than in the parent metal (ca. 4% lead and 9 to 10% tin).
It presents a dendritic structure, with relatively marked traces of deformation all around its periphery. This thread has a triangular section.
The noticeable difference in the composition of the alloy, as well as the pronounced signs of deformation, permits the conclusion that this is in fact a bronze thread applied to the bronze vessel, and not a fragment of the vessel that has become detached.

The inlay decoration would therefore seem to have been executed, at least on the base, not by inserting silver threads into grooves on the surface of the bronze vessel, but rather by inlaying a complete decoration made up of juxtaposed threads of different metals.
The silver threads correspond to a metal that has been reheated, probably to improve its resistance to breakage. The bronze threads were cut directly from rough-cast metal. This decoration was hammered into the base.
On other parts of the object (the supports of the handles, for example), the decoration appears instead to have been carried out by direct incision of the bronze.

The gold inlay

The metal used is a ternary alloy of gold, silver and copper, with 35 to 39% silver and 5 to 6% copper.
The gold leaf was inserted in two parallel tongs to produce the fine threads.

The results of analysis are given in the following table:

	Cu	Sn	Pb	Fe	Ag	Sb	Bi	Si	Ni	Co	As
Bronze of the vase	88.7	9.8	1.5	P	P	P	nd	P	P	P	P
	86.7	11.0	2.3	P	P	P	P	P	P	nd	nd
	87.7	10.4	1.8	P	P	nd	P	P	nd	nd	nd
	87.8	10.1	2.1	P	P	P	P	P	P	nd	nd
Bronze of the threads	85.8	10.3	1.5	P	P	P	nd	P	nd	P	nd
	86.8	9.6	2.3	P	nd	P	nd	P	P	P	nd

	Cu	Sn
Silver thread	95.5	4.5
	92.1	7.9

	Au	Ag	Cu
Gold inlay	58.4	35.6	6.0
	54.8	39.4	5.8

As regards the EDS analysis, the accuracy of measurement is in the order of % for a detection threshold of 1000 ppm, under optimal conditions. Values below % are indicative of the presence of an element; in the table these are marked "P" Undetected elements are indicated by "nd". The results are given in weight of element and standardised at 100%.

3. Study of the corrosion and patination processes

The corrosion is marked and generalised. It covers the entire surface of the microsection of the parent metal of the vessel.
In the thickness of the metal one can observe:
- selective corrosion of the interdendritic phase, resulting in the formation of chlorine-lead-copper and chlorine-copper-tin compounds
- selective corrosion of large globules of lead, which are almost totally replaced by cuprite. The copper oxide in these inclusions is transformed into pure copper. This phenomenon results in the formation of the small islands of copper observed in the microsection
- transcrystalline corrosion diffused over the entire surface of the microsection

On the surface of the metal we observe a zone of uniform corrosion with an overall composition of chlorine, lead, tin and copper, where the metallographic structure has been strongly modified by the diffusion of the elements that make up the alloy.
Locally, we see an arrangement of superimposed layers of products of corrosion chlorinated with copper and lead, as well as the development in depth of pockets of chlorinated corrosion, which then represents corrosion by pitting.

The original surface of the metal is emphasised by the presence of silicated mineral particles incorporated into the products of metal corrosion. These mineral particles correspond to the burial environment of the object.

The products of metal corrosion are well developed, particularly on the interior of the base. They correspond to oxides and carbonates of copper (cuprite, malachite, azurite), to chlorine-copper compounds, and to carbonates and oxides of lead (cerussite, litharge).
In the sample studied we did not note the presence of products of tin corrosion (tin oxides).

4. The textile elements

The textile remains found in the base of the vessel were studied. The threads are made up of long, continuous fibres with a slight twist, roughly triangular or oval in section. These characteristics evoke a fibre of the silk type.

The fibres are totally mineralised into chlorine-copper-lead compounds. The textile remains have become incorporated into the corrosion products, where they may be completely encapsulated. In the microsection studied, moreover, "phantom" textile fibres incorporated in the corrosion products can be observed.

CONCLUSION:

The vessel under study presents a group of technical characteristics resulting from the way it was made that conform to those of ancient China.

In addition, it manifests characteristics of change that may be obtained in a bronze from evolution over a long period in the damp, confined environment of a tomb.

Plate 1: Detailed views of inlay decoration on the side of the vessel (stereomicroscope, x 4.5).
Top: zone that was not cleaned, showing the light-brown earthy patina tinged with red and green, and a textile impression.
Bottom: cleaned zone, showing the silver inlay on a metal of a green to brownish-red colour.

Plate 2: Detailed view of inlay (stereomicroscope, x 4.5).
Area high on the side of the vessel, gold inlay

Plate 3: General view of metal samples in microsection.
Top: sample of the vessel's parent metal showing the corrosion products on the surface, particularly well preserved on the interior of the base (stereomicroscope, x 30).
Bottom: detail of inlaid metal threads: silver to the left, "copper" to the right (stereomicroscope, x 46).

Plate 4: General views of metal threads in microsection.
Top: silver thread, roughly trapezoidal in shape, showing pronounced surface change (light-optical microscope, x 200).
Bottom: "copper" thread, showing the heavily deformed dendritic structure (light-optical microscope, x 320).

Plate 5: Detailed view of the surface of the metal in microsection, on the inside of the base (SEM, ERD, x 130). Note the presence of mineral particles, which delimit the original surface of the metal, under abundant corrosion products (cuprite, malachite).

Plate 6: Detailed view of textile remains.
Textile fibres associated with products of corrosion (azurite) (stereomicroscope, x 46).

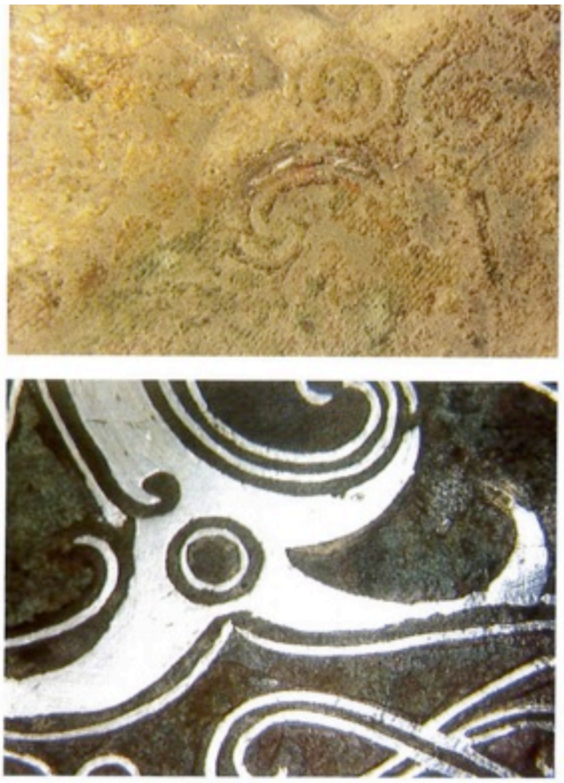

Plate 1

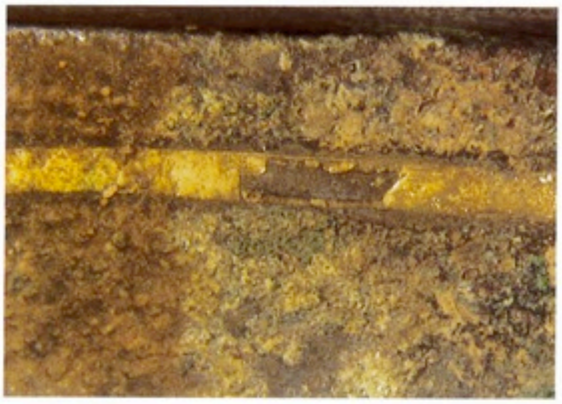

Plate 2

Plate 3

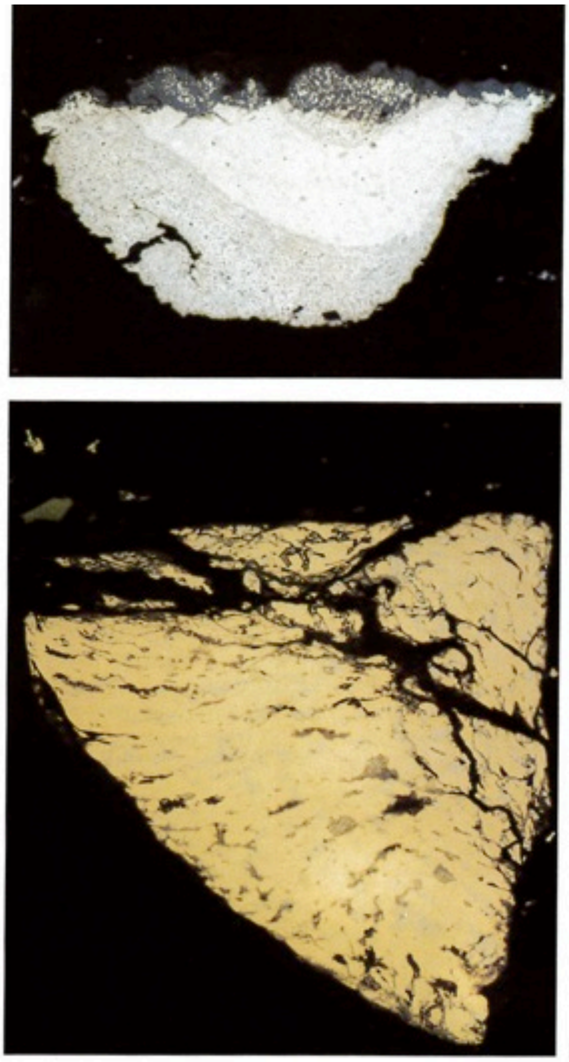

Plate 4

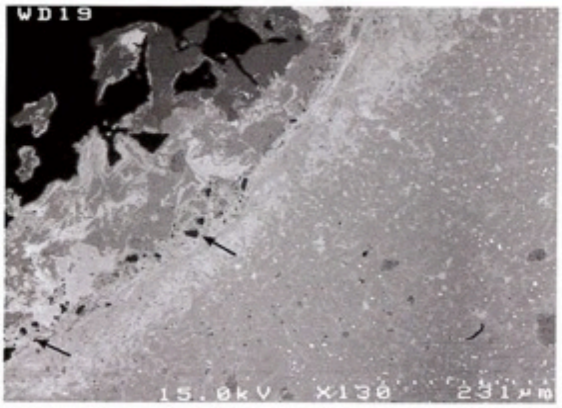

Plate 5

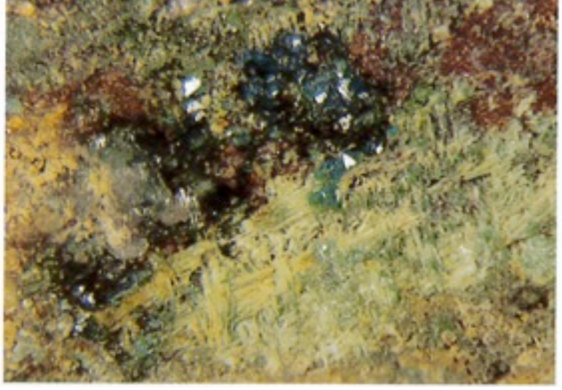

Plate 6