



ROUND BRACELET WITH UNIFORM INCLINED INDENTATIONS B3482 - LEADED BRONZE - LATE **BRONZE AGE - SWITZERLAND**

Artefact name Round bracelet with uniform inclined indentations B3482

Marianne. Senn (EMPA, Dübendorf, Zurich, Switzerland) & Christian. Degrigny (HE-Arc CR, Neuchâtel, **Authors**

Neuchâtel, Switzerland)

Url /artefacts/397/

▼ The object



Fig. 1: Leaded bronze bracelet (after Paszthory 1985, Tafel 137).

▼ Description and visual observation

Description of the artefact

Bracelet with uniform inclined rib after Paszthory (1985, 207). Dimensions: $\emptyset = 4 \text{cm}$; WT =

18g (Fig. 1).

Type of artefact Jewellery

Origin Les Eaux-Vives, Genève, Geneva, Switzerland

Recovering date None

Chronology category Late Bronze Age

B.C. ∨

1000

chronology taq

Chronology comment Hallstatt B2/3 (1000BC _ not defined)

Burial conditions /

environment

chronology tpq

Lake

Artefact location Musées d'art et d'histoire, Genève, Geneva

Owner Musées d'art et d'histoire, Genève, Geneva Inv. number B3482

Recorded conservation

Not conserved

Complementary information

Nothing to report.

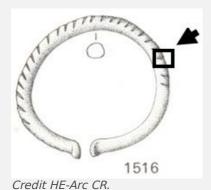


Fig. 2: Location of sampling area,

> Binocular observation and representation of the corrosion structure

Stratigraphic representation: none.

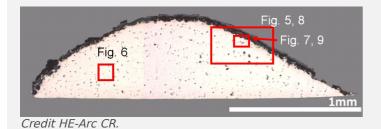


Fig. 3: Micrograph of the cross-section showing the location of Figs. 5 to 9,

Description of sample The sample is a section from the central part of the bracelet (Fig. 2). Its dimensions are: L = 2.5mm and W = 0.65mm. The corrosion layer is relatively thin (Fig. 3).

Alloy Leaded Bronze

Technology As-cast

Lab number of sample MAH 77-110-5

Sample location Musées d'art et d'histoire, Genève, Geneva

Responsible institution

Musées d'art et d'histoire, Genève, Geneva

Date and aim of sampling

1977 and 1991, study of the corrosion layer, metal composition

Complementary information

Nothing to report.

★ Analyses and results

Analyses performed:

Metallography (etched with ferric chloride reagent), Vickers hardness testing, ICP-OES, SEM/EDS.

▼ Non invasive analysis

The remaining metal is a porous leaded bronze (Fig. 5 and Table 1). In bright field dark-blue copper sulphide (Fig. 5, Table 2) and tiny dark-grey Pb inclusions (Fig. 5) can be seen. The Sn-rich eutectoid alpha + delta phase appears in light-blue (Fig. 5) and incorporates Pb-rich inclusions. The etched leaded bronze has the dendritic structure of an as-cast metal (Fig. 6) with an average hardness HV1 90. After etching the inclusions have turned darker (Fig. 6) while the eutectoid phase appears whiter.

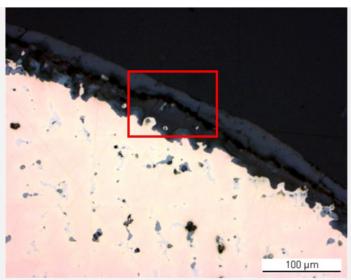
Elements	Cu	Sn	Pb	Sb	Ag		As	Со	Zn	Fe		
mass%	90.93	6.43	1.40	0.52	0.26	0.20	0.18	0.04	0.02	0.02	<0.01	

Table 1: Chemical composition of the metal. Method of analysis: ICP-OES, Laboratory of Analytical Chemistry, Empa.

Elements		Cu	Total
Dark-blue inclusion	21	80	101

Table 2: Chemical composition (mass %) of dark-blue inclusions on Fig. 5. Method of analysis: SEM/EDS, Laboratory of Analytical Chemistry, Empa.

Fig. 5: Micrograph of the metal sample from Fig. 3 (detail), unetched, bright field. In pink the metal with porosity (black), light-blue the alpha-delta eutectoid, dark-grey lead inclusions and dark-blue copper sulphide inclusions. The rectangle marks the detail image of Fig. 7,



Credit HE-Arc CR.

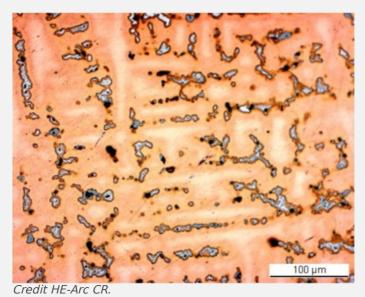


Fig. 6: Micrograph of the metal sample from Fig. 3 (detail), etched, bright field. The leaded bronze has the dendritic structure of an as-cast metal with the Sn-rich eutectoid alpha + delta phase appearing in white at the dendrites borders

Microstructure Dentritic structure with pores and inclusions

First metal element Cu

Other metal elements Sn, Pb

Complementary information

Nothing to report.

▼ Corrosion layers

The interface between the metal and corrosion products is irregular (Fig. 5). The corrosion crust has an average thickness of 70µm and is composed of two layers separated by a large fissure (Fig. 5). In bright field, the inner layer includes remnant metal (Sn-rich eutectoid phase, Figs. 5 and 7) and is dark-grey (Fig. 5) while in polarised light it is orange-brownish (CP3, Fig. 8). This Cu depleted layer is rich in Sn, Fe, Si and O (Table 3 and Fig. 8). At the metal - inner layer interface a corrosion product (CP4, light-grey in bright field, greenish in polarised light) shows a slight increase in Cu and Sn content but a decrease of the Fe content (Table 3). In bright field, the outer dense layer is light-grey (CP2, Fig. 5) while in polarised light it appears black with superimposed red to orange areas (CP1, Fig. 8). It is depleted of Cu and richer in Fe. The Sn content is variable but increases in the top brown areas (Table 3 and Fig. 9).

Elements O Cu Sn Pb Fe Si S Total

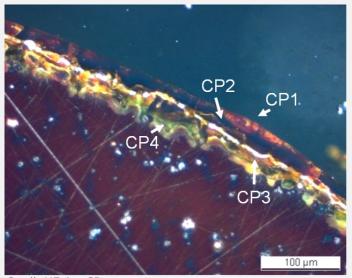
CP1, outer brown area	36	6.7	24	2.5	27	4.3	<	102
CP2, outer black layer (average of 2 similar analyses)	34	9.0	14	2.8	34	4.3	<	99
CP3, inner orange-brown layer (average of 2 similar analyses)	31	16	18	2.4	21	5.2	<	95
CP4, inner greenish layer (average of 2 similar analyses)	36	29	19	1.5	14	6.1	<	107

Table 3: Chemical composition (mass %) of corrosion layers from Fig. 8. Method of analysis: SEM/EDS, Laboratory of Analytical Chemistry, Empa.



Fig. 7: SEM image (detail of Fig. 5, reversed picture), SE-mode. From bottom right to top left: the metal, the inner and outer corrosion layers separated by a large fissure. The red arrow indicates a remnant of the Sn-rich alpha-delta eutectoid,

Credit HE-Arc CR.

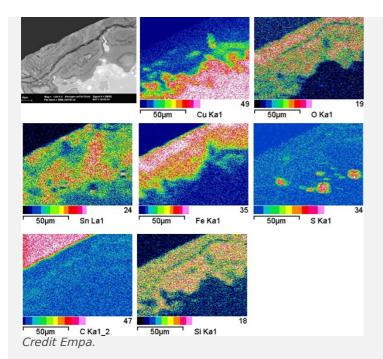


stratigraphy of Fig. 4, polarised light. From bottom left to top right: the metal with blue inclusions and porosities in white, the inner corrosion layer in green, red and orange waves, the fissure in white and the outer corrosion layer in black and red (top zone),

Fig. 8: Micrograph similar to Fig. 5 and corresponding to the

Credit HE-Arc CR.

Fig. 9: SEM image, BSE-mode, and elemental chemical distribution of the selected area of Fig. 7. The S mapping includes the copper sulphide and Pb inclusions, because of a peak interference. Method of examination: SEM/EDS, Laboratory of Analytical Chemistry, Empa,



Corrosion form Uniform - selective

Corrosion type Type II (Robbiola)

Complementary information

Nothing to report.

(CP1)	
CP2	
СРЗ	
CP4	
[M1]	

Fig. 4: Stratigraphic representation of the object in crosssection using the MiCorr application. This representation can be compared to Fig. 8, Credit HE-Arc CR.

▼ Synthesis of the binocular / cross-section examination of the corrosion structure

Corrected stratigraphic representation: none.

★ Conclusion

The leaded bronze shows an as-cast structure. The metal surface is selectively corroded, showing a remnant Snrich phase in the inner corrosion layer. Because of this remnant metallic structure, the corrosion type is similar to a type 2 corrosion after Robbiola et al. 1998. In this case, two corrosion processes have occurred in parallel: a

typical Cu depletion and Sn enrichment, but at the same time a surface enrichment with Fe and Si that could be explained by an Fe-rich lake environment.

▼ References

References on object and sample

Reference object

1. Paszthory, K. (1985) Der bronzezeitliche Arm- und Beinschmuck in der Schweiz. PrähistorischeBronzefunde X-Bd. 3, München, 243, Tafel 137. **Reference sample**

- 2. Empa report 137'695/1991, P. Boll. 3. Rapport d'examen, Laboratoire Musées d'art et d'histoire, Genève (1977-110), 1977 and 1991.

References on analytic methods and interpretation

4. Robbiola, L., Blengino, J-M., Fiaud, C. (1998) Morphology and mechanisms of formation of natural patinas on archaeological Cu-Sn alloys, Corrosion Science, 40, 12, 2083-2111.