

# COMPOSITIONAL AND MICROSTRUCTURAL CHARACTERIZATION OF GRAVE GOODS FROM ANTA DO MALHÃO AND SOALHEIRONAS:

AN INSIGHT INTO THE DIACHRONIC USE OF ARSENICAL COPPER FROM THE 3RD TO THE 2ND MILLENNIUM BC

Pedro Valério<sup>a</sup>, Rui J.C. Silva<sup>b</sup>, António M. Monge Soares<sup>a</sup>, Maria Fátima Araújo<sup>a</sup>, João Luís Cardoso<sup>c</sup>

<sup>a</sup> Centro de Ciências e Tecnologias Nucleares (C2TN), Departamento de Engenharia e Ciências Nucleares, Instituto Superior Técnico, Universidade Lisboa

<sup>b</sup> I3N/CENIMAT, Department of Materials Science, Faculty of Science and Technology, Universidade NOVA de Lisboa

<sup>c</sup> Universidade Aberta; Centro de Estudos Arqueológicos de Oeiras, Câmara Municipal de Oeiras; ICAREH

## Archaeological background

Grave goods were recovered by archaeological excavations at two burial sites in southern Portugal: Anta do Malhão (AM) and Soalheironas (SO).



AM-1



AM-2

AM megalithic monument had a **dagger** and a **Palmela point**, in addition to a ceramic carinated vase and a ceramic cup, which attribute the burial to a late phase of the Horizon of Ferradeira (c. 2250-2000 BC).



Soalheironas (cist 4)

Anta do Malhão



SO necropolis comprised two cists with metals, namely cist 1: a **throwing point** and a ceramic carinated vase; and cist 4: a **dagger** and an Atalaia ceramic cup, which ascribe the necropolis to an early phase of the Southwestern Bronze Age (c. 2000-1500 BC).



SO-1



SO-2

## Elemental composition

Micro-EDXRF results of grave goods (n.d.: not detected)

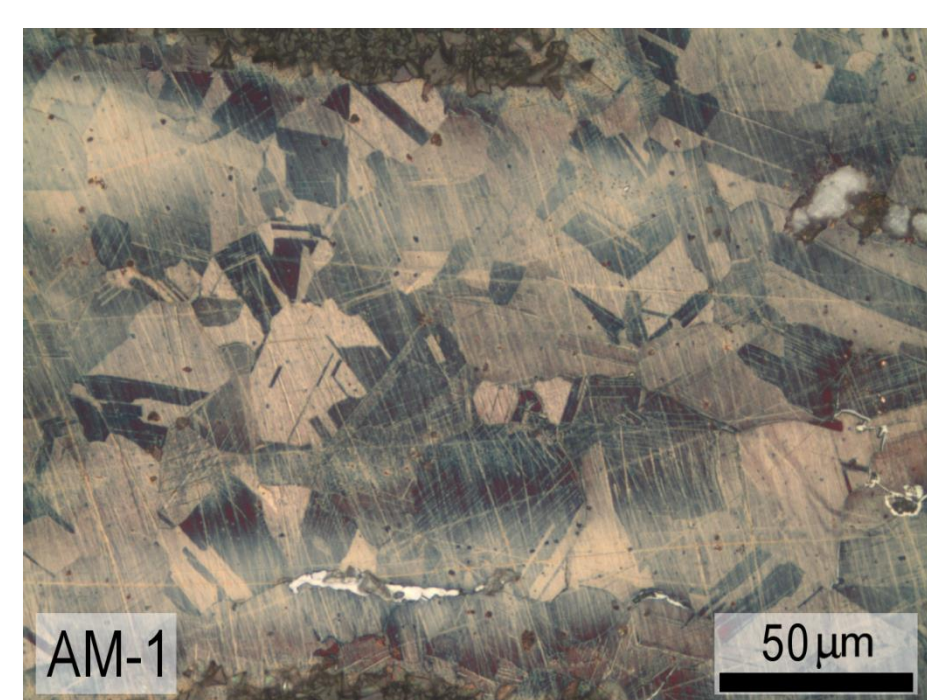
Artefact	Reference	Cu (%)	As (%)	Pb (%)	Fe (%)
Dagger	AM-1	96.5	3.4	n.d.	<0.05
Palmela point	AM-2	97.7	2.2	n.d.	<0.05
Dagger	SO-1	96.8	3.1	n.d.	<0.05
Throwing point	SO-2	97.9	2.0	n.d.	<0.05

## Microstructural features

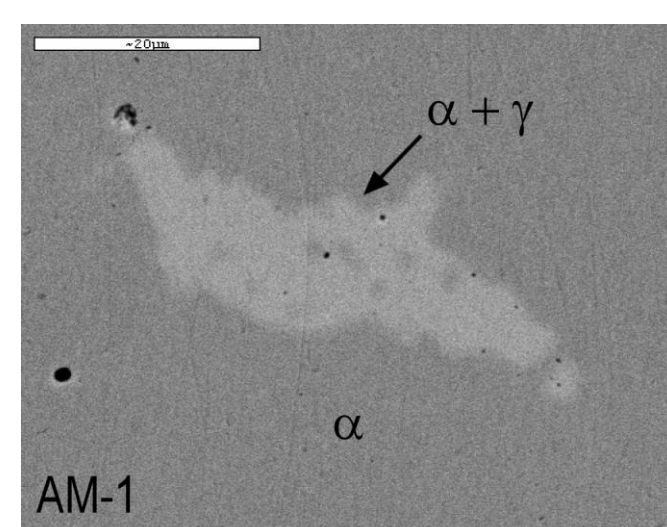
Optical microscopy and SEM-EDS characterization of grave goods

(F: Forging; A: Annealing; FF: Final Forging; ↑: high amount; ↓: low amount)

Artefact	Reference	Phases	Inclusions	Post-casting
Dagger	AM-1	$\alpha$ and $\gamma$	Cu-As-O	(F + A) + FF↓
Palmela point	AM-2	$\alpha$	Cu-As-O	(F + A) + FF↓
Dagger	SO-1	$\alpha$ and $\gamma$	Cu-As-O↑	(F + A) + FF(?)
Throwing point	SO-2	$\alpha$	Cu-As-O	(F + A) + FF↓

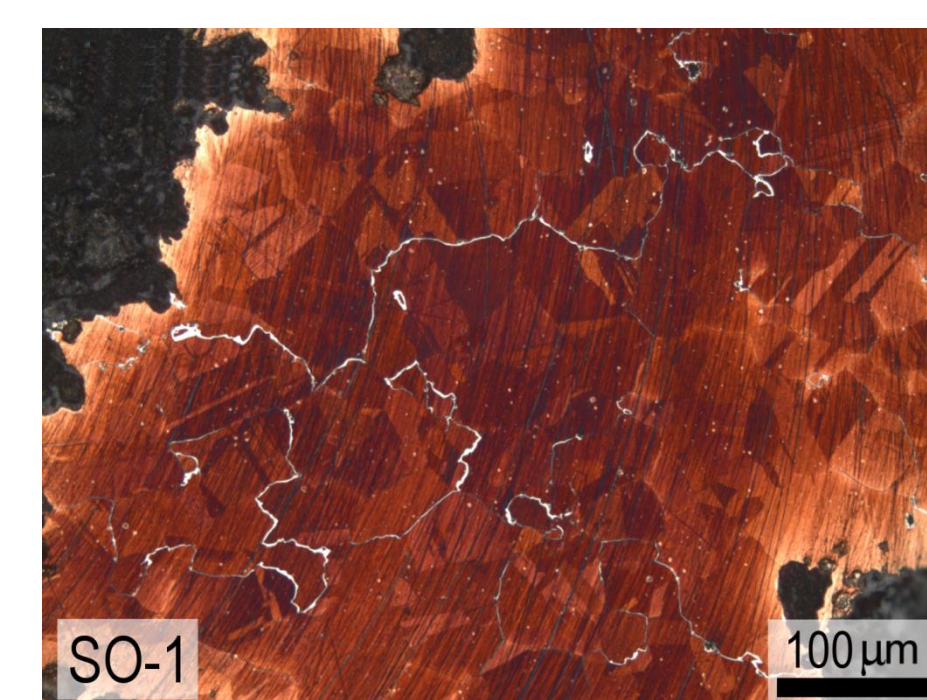
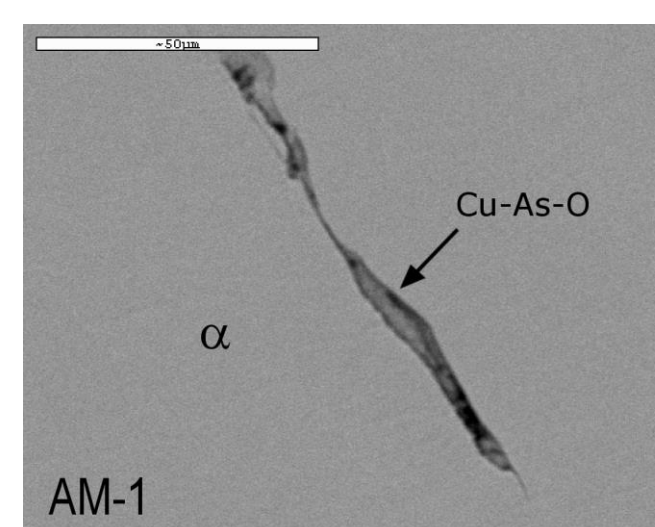


Typical microstructure with deformed grains, annealing twins and slip bands



←  $\alpha + \gamma$  eutectic fast cooling

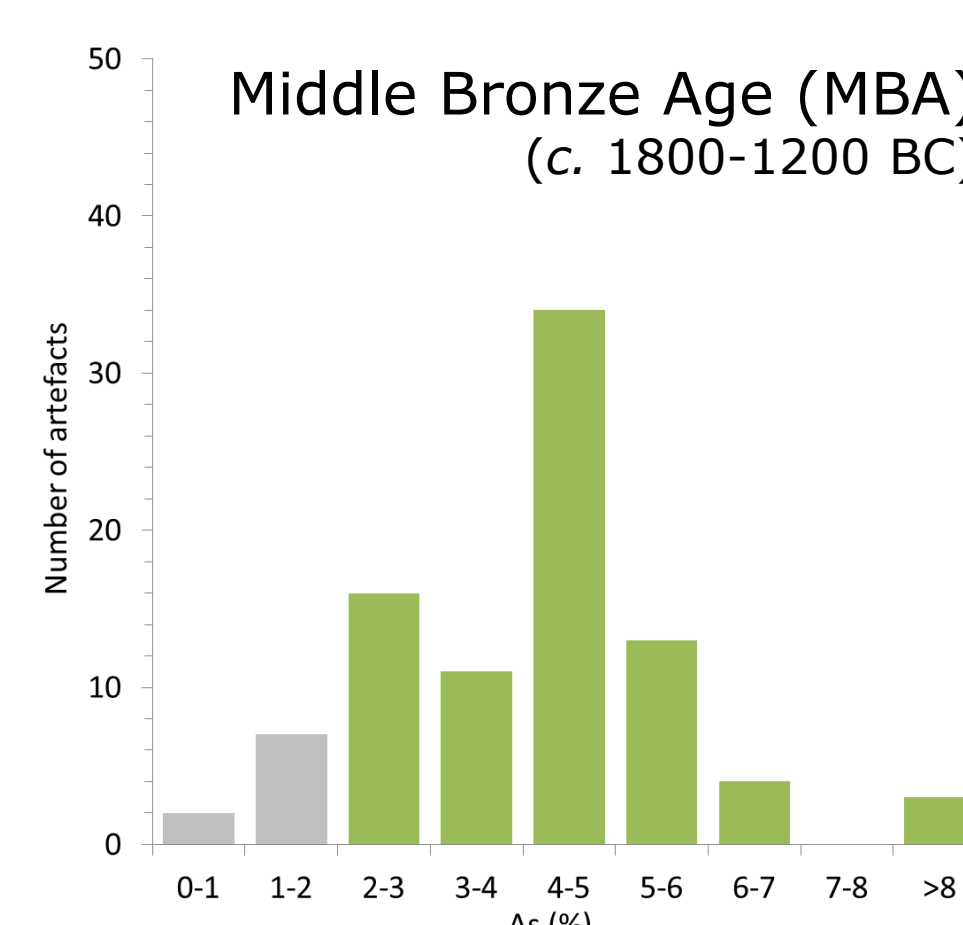
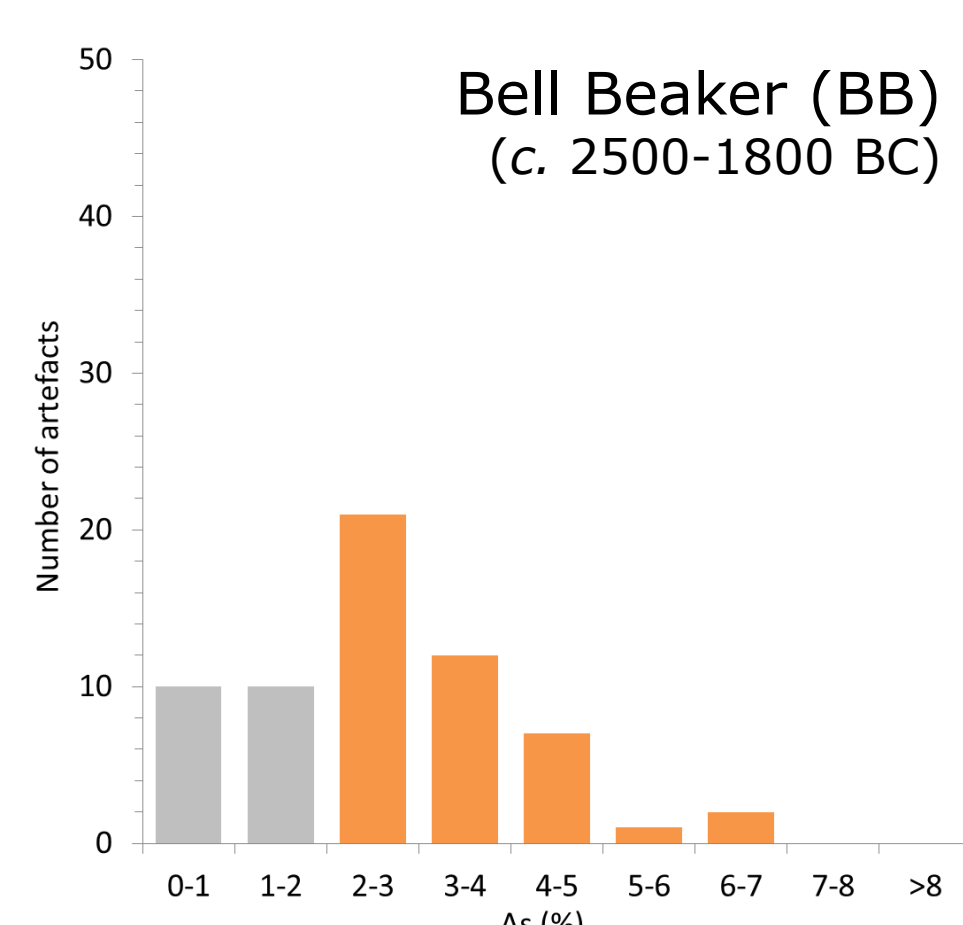
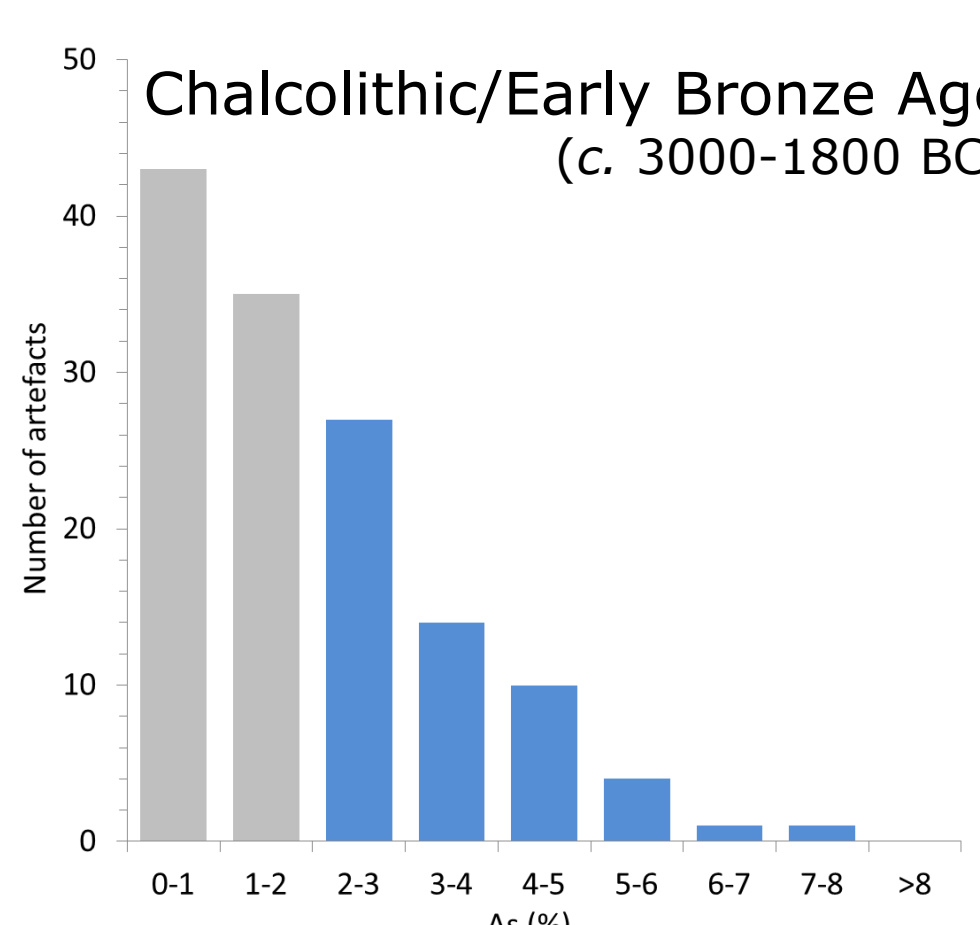
elongated inclusion → high deformation



Intergranular  $\gamma$  phase ( $\text{Cu}_3\text{As}$ ): long-term precipitation from a supersaturated Cu phase [1]

## Prehistoric metallurgy of copper in SW Iberia

Increased use of arsenical copper (As>2%) in BB and MBA communities [2]



Chalcolithic arsenical copper results from the natural presence of As in copper ores [3]

Increased use of final cold work during the MBA, although the hardness is unrelated with As% [4]

High As% not related with hardening, but with silvery colour ( $\text{Cu}_3\text{As}$ )

Early arsenical copper alloys used for prestige goods such as daggers

## Final remarks

The technological features of the grave goods from Anta do Malhão and Soalheironas perfectly fit the metallurgical tradition of communities inhabiting the Southwestern Iberia during a period of transition from the 3rd to the 2nd millennium BC.

Arsenical copper alloys began to be used for prestige goods of the 3rd millennium BC, becoming the standard for artefacts of the 2nd millennium BC, thus indicating the growing awareness of MBA metallurgists of the aesthetic and practical value of this silvery alloy.

## REFERENCES

- [1] F. Pereira, R.J.C. Silva, A.M.M. Soares, M.F. Araújo, M.J. Oliveira, R.M.S. Martins, N. Schell (2015). Effects of long-term aging in arsenical copper alloys. *Microscopy and Microanalysis* 21, 1413-1419.
- [2] P. Valério, J. Soares, M.F. Araújo, L.C. Alves, C. Tavares da Silva (2019). The composition of São Brás copper hoard in relation to the Bell Beaker metallurgy in southwestern Iberian Peninsula. *Archaeometry* 61/2, 392-405.
- [3] S. Rovira Llorens (2016). Chalcolithic metallurgy in Southwestern Iberia: a personal overview. *Menga. Revista de Prehistoria de Andalucía* 7, 53-67.
- [4] P. Valério, A.M.M. Soares, M.F. Araújo, R.J.C. Silva, L. Baptista (2016). Middle Bronze Age arsenical copper alloys in Southern Portugal. *Archaeometry* 58/6, 1003-1023.