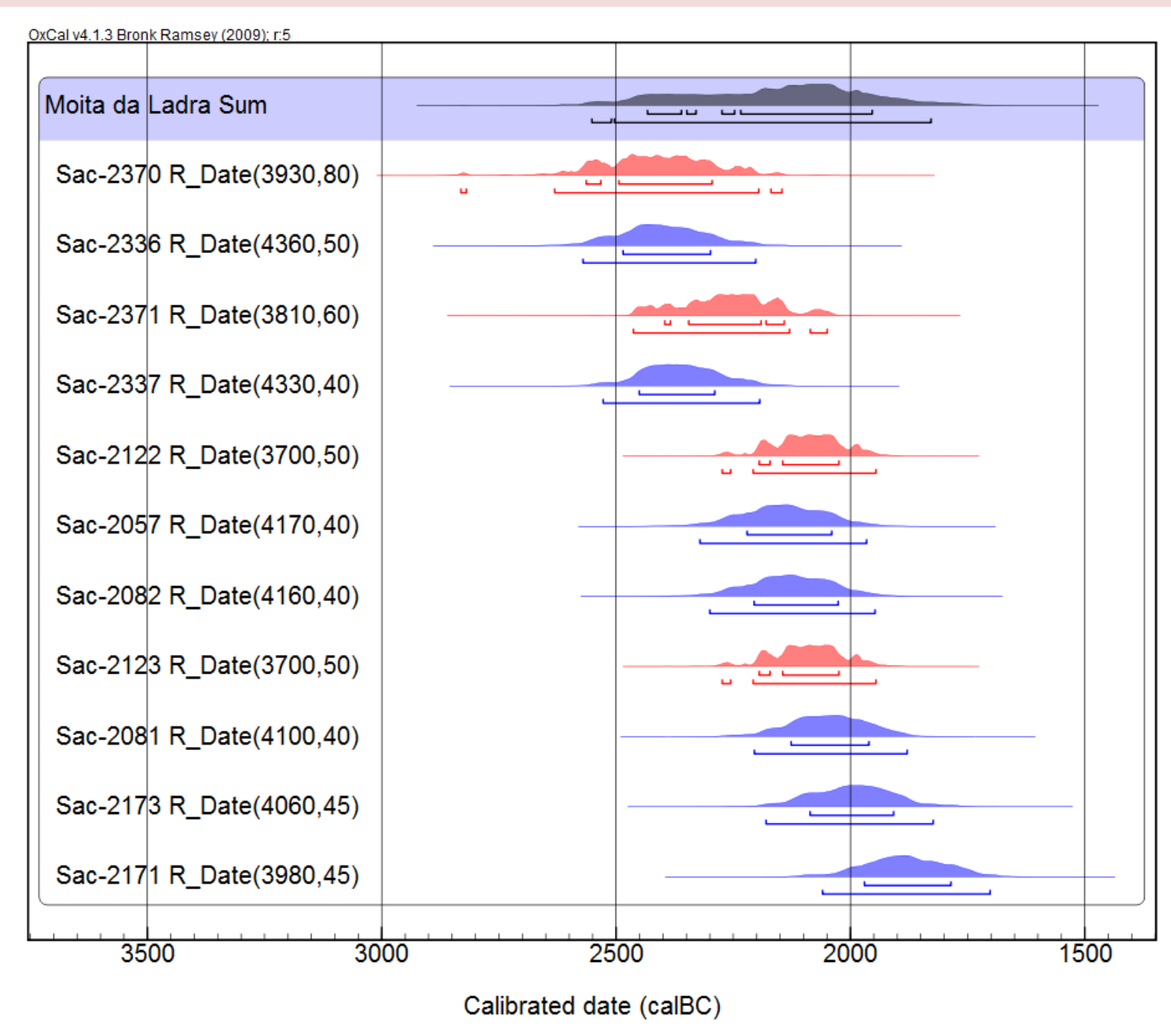
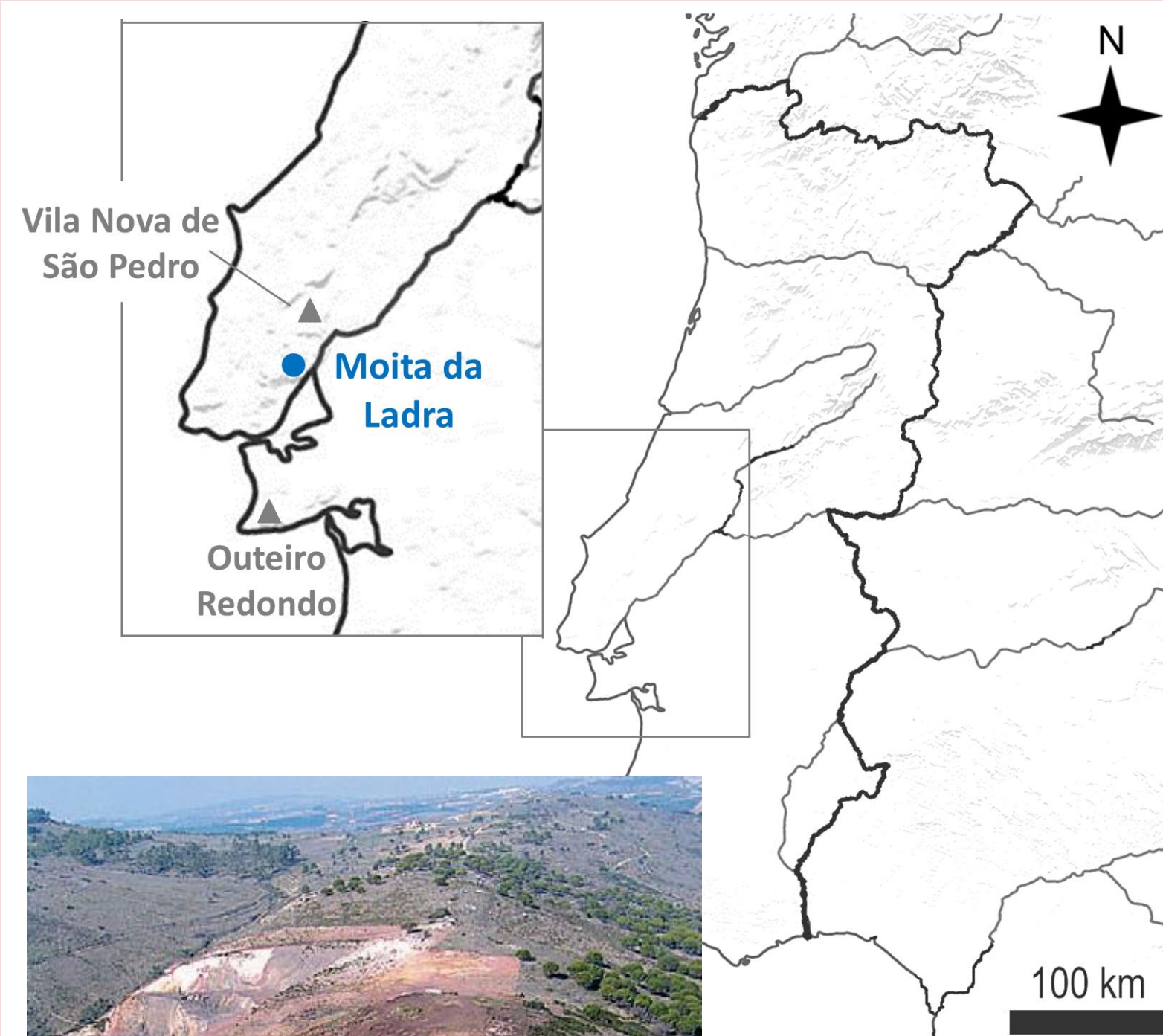




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Introduction

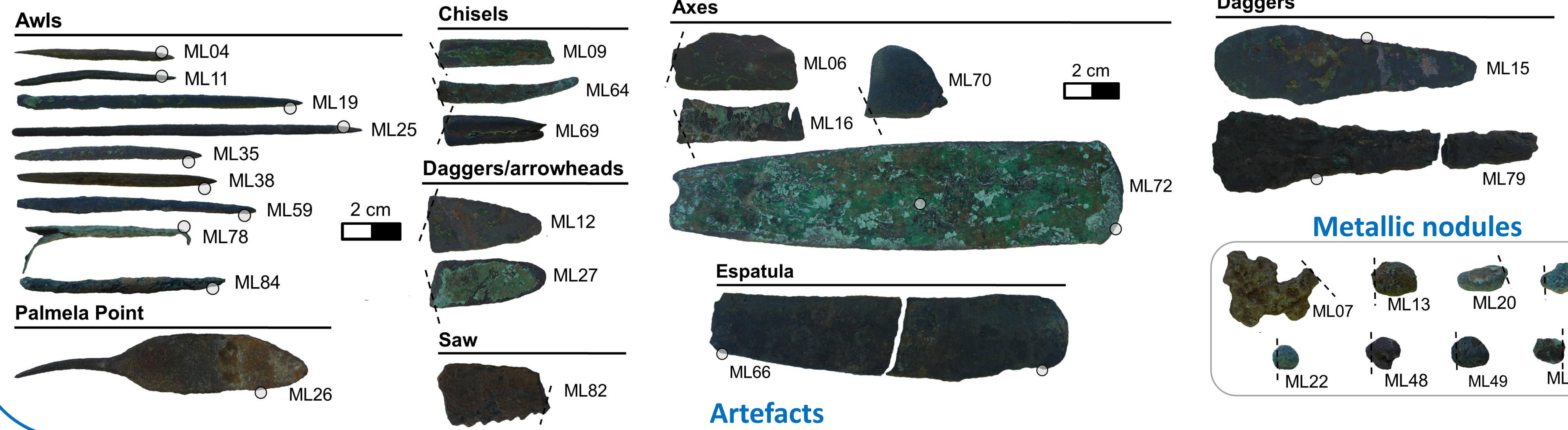
The archaeological site of Moita da Ladra is an emblematic settlement located at Vila Franca de Xira (Portugal), occupied predominantly during the second half of the 3rd millennium BC (Chalcolithic period). The present study focuses on the chemical and microstructural characterization of selected artefacts and metallic nodules (metallurgical remains) found there. Its goal is to contribute to a better comprehension of the primitive copper-based metallurgy on the Portuguese Estremadura, where other important chalcolithic sites are located.



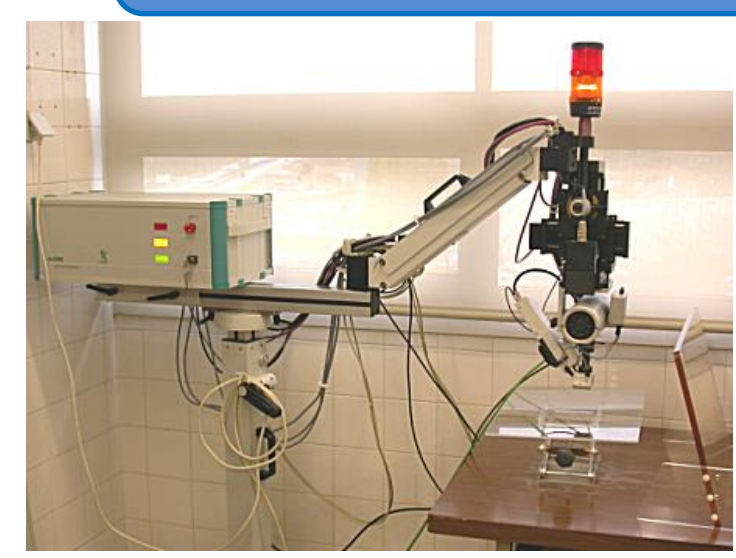
Radiocarbon dating of the archaeological contexts of Moita da Ladra established a chronology of 2440-1950 cal BC (1 σ) or 2560-1820 BC (2 σ).

Collection

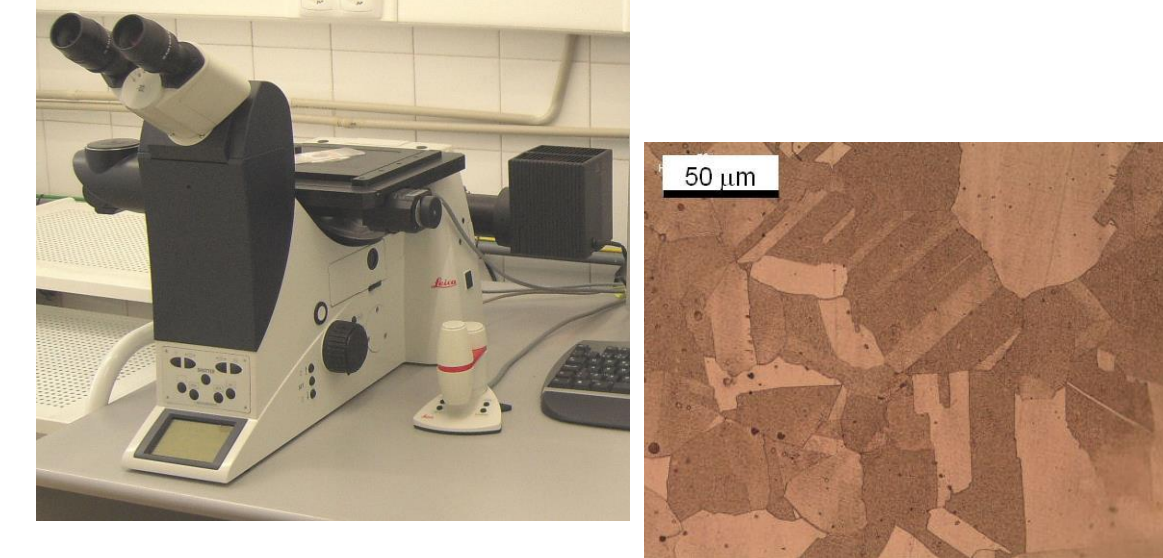
A diverse collection of **62 copper-based artefacts** and **8 metallic nodules** was characterized using different analytical techniques to identify the elemental composition and manufacture procedure.



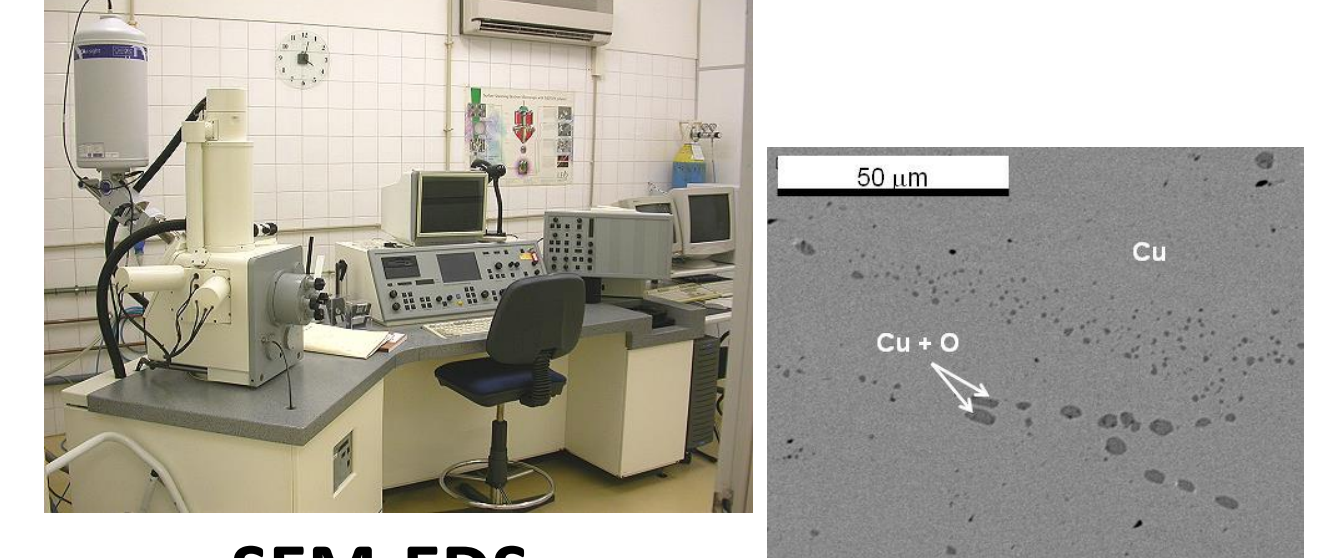
Methods



Micro-EDXRF
Elemental composition



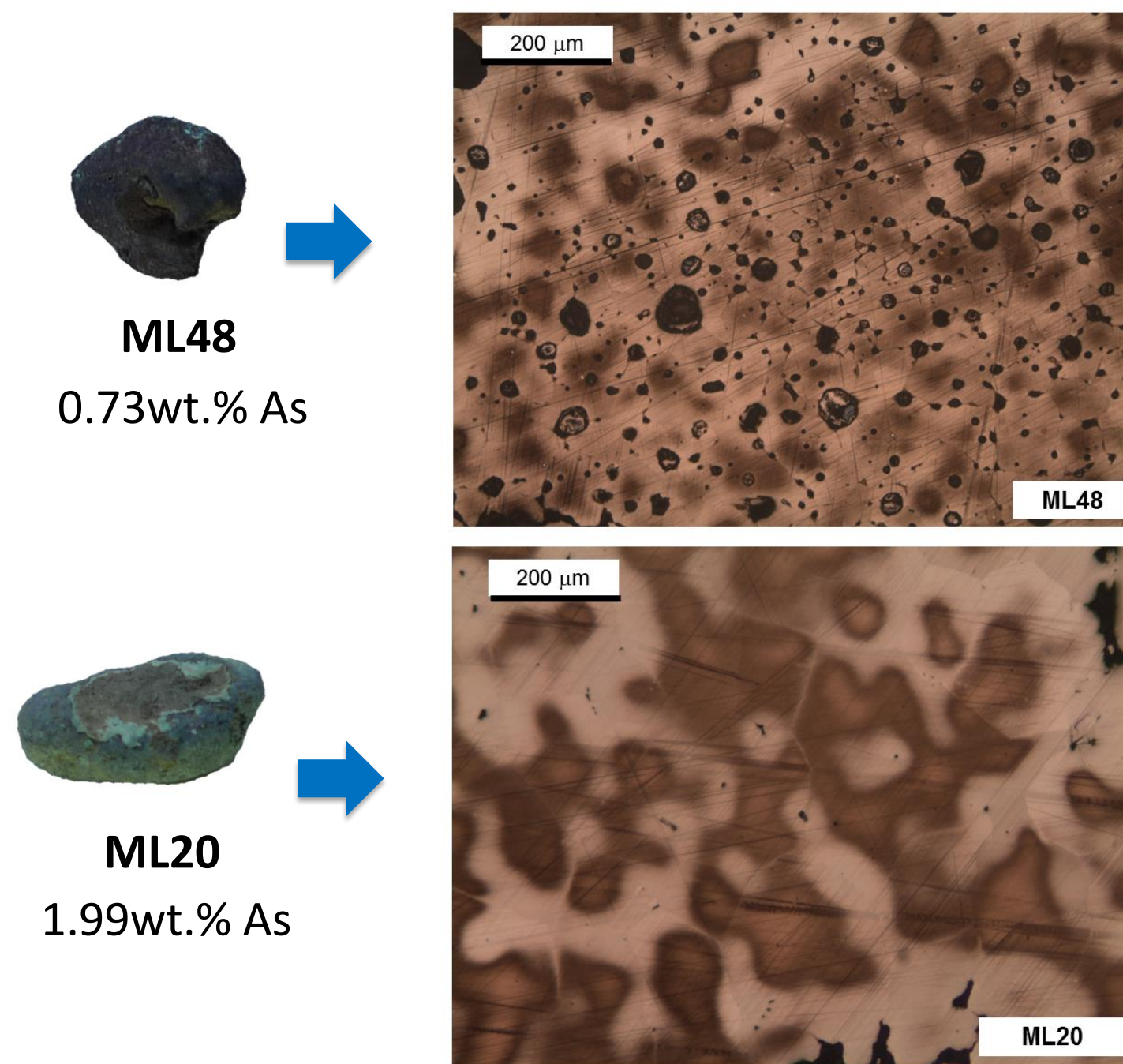
Optical Microscopy
Manufacture procedure



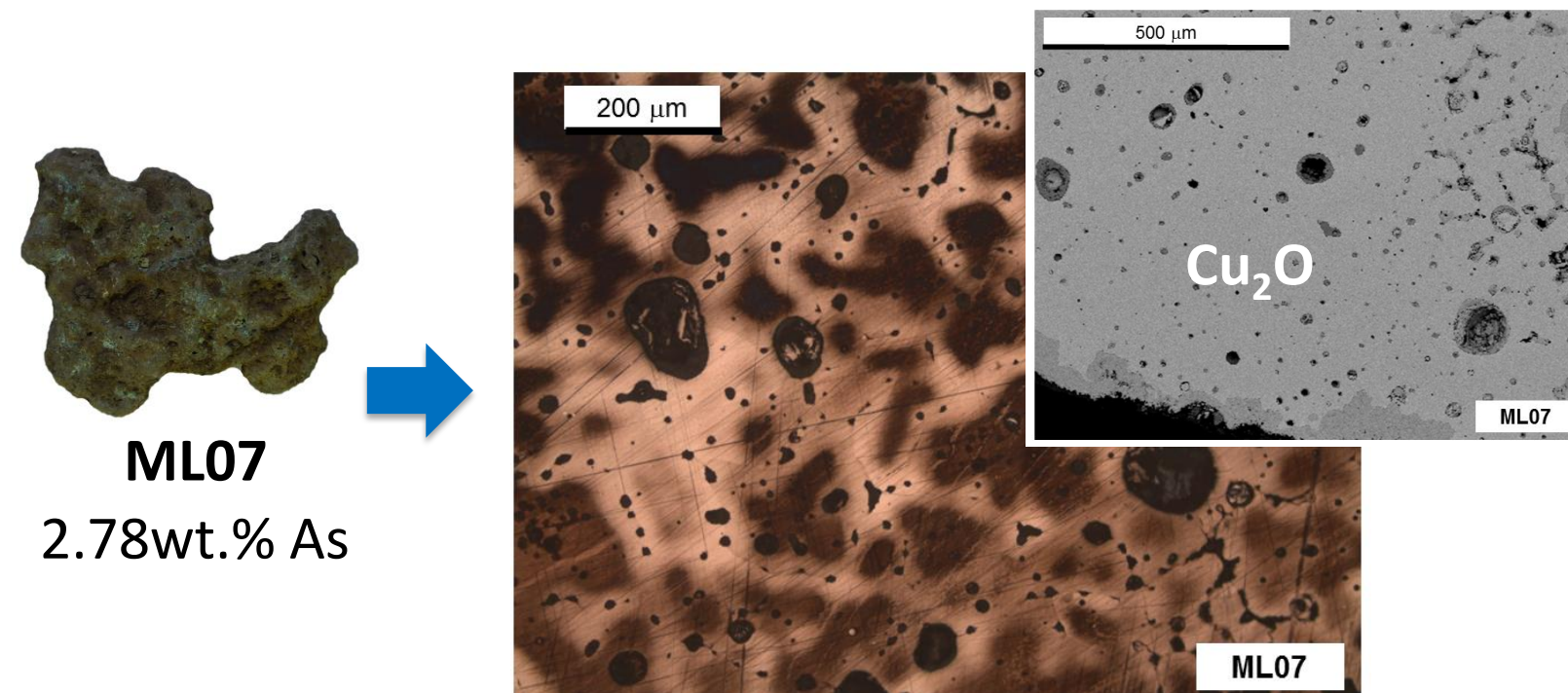
SEM-EDS
Phases and inclusions

Metallic Nodules

Metallic nodules are composed of **Cu and Cu + As** (As > 2 wt.%) with Fe < 0.05 wt.% (below the quantification limit).

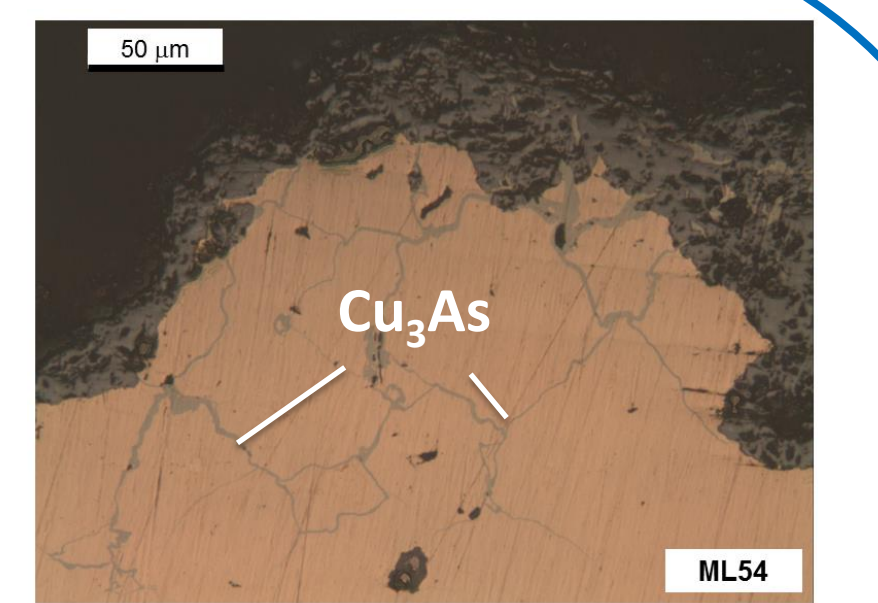
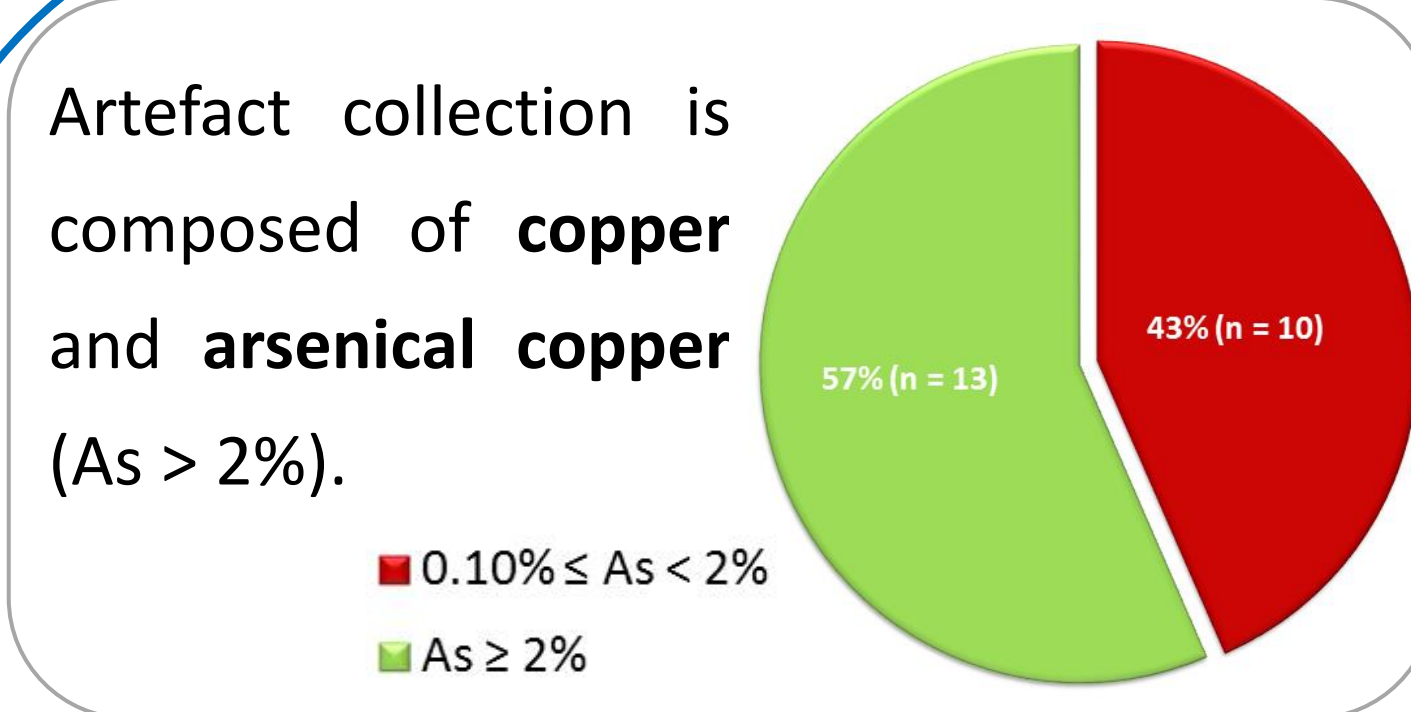


↑ As content → ↓ copper oxides (Cu₂O) density:
deoxidant effect of As.

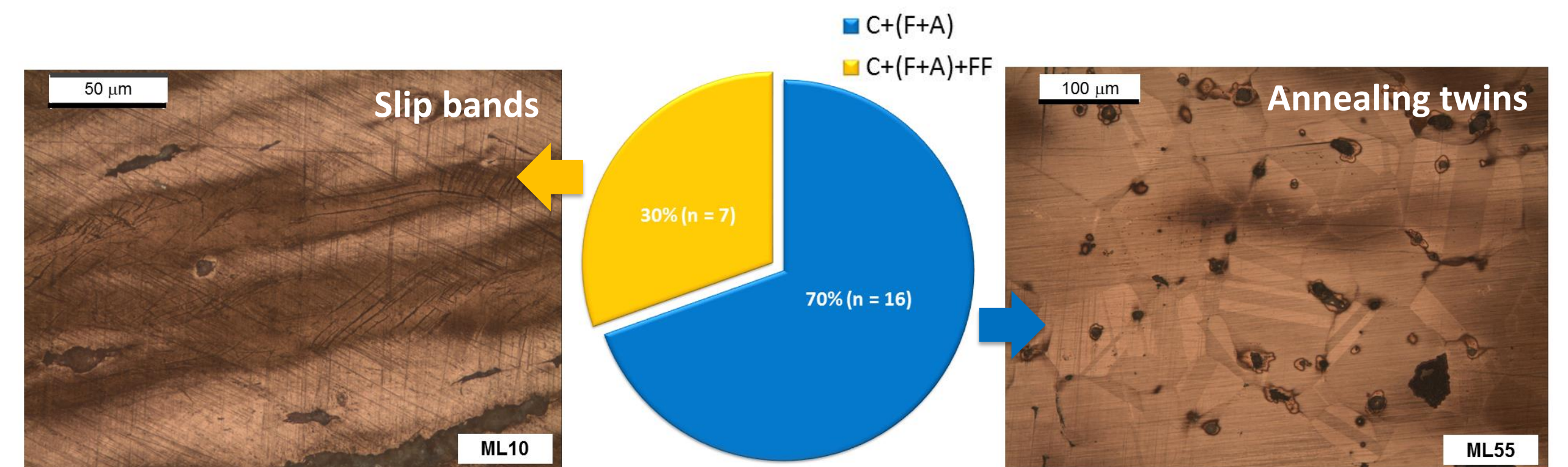


An exception is ML07 that presents high As content and high Cu₂O density, indicating an oxidizing atmosphere. This evidences the variability of conditions of smelting operations.

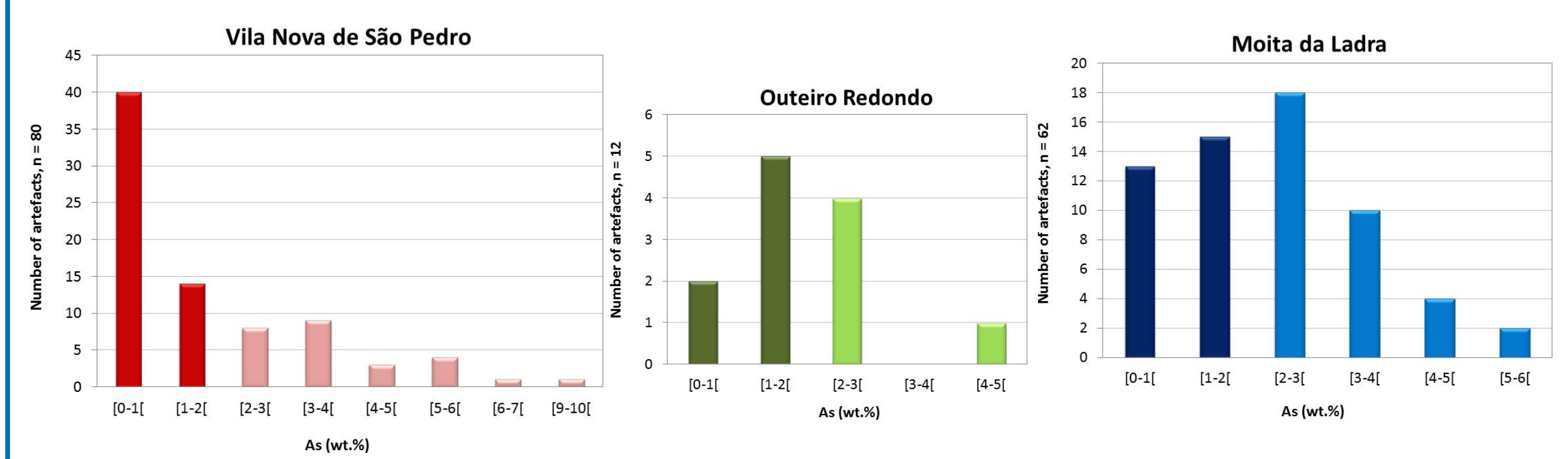
Artefacts



Presence of arsenic rich phase (long term deposition [1]).



Artefacts were shaped with **forging and annealing** operation cycles (F + A) and only 30% of the artefacts received a **final forging (FF)**. Possible correlations among typologies, As content and the final forging operation could not be established.



Possible explanations: different raw materials, different typologies of analysed artefacts, large or small use of recycling operations.

Conclusions

The elemental composition of the metallurgical production remains are consistent with copper and arsenical copper artefact production. The presence of 39 artefacts, in a very fragmented state, suggest the existence of local recycling operations.

The elemental composition of the metallic nodules (0.37 wt.% < As < 4.78 wt.%) are similar to those of the artefact collection (0.10 wt.% < As < 5.47 wt.%), which are also consistent with the overall picture of Chalcolithic copper and arsenical copper production in Central Portugal.

References

[1] F. Pereira, R. J.C. Silva, A.M.M. Soares, M.F. Araújo, M.J. Oliveira, R.M.S. Martins, N. Schell, Effects of long term aging in arsenical copper alloys, *Microscopy and Microanalysis* (submitted).

Acknowledgements

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