

Late Bronze Age Hoard studied by PIXE

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The Freixanda Hoard. Metal hoards are one of the most peculiar cultural features of the so called *Late Bronze Age* (LBA, 13th - 8th c. BC) in Western Europe. These accumulations of goods show great variability both in the sort of objects they include and in the type of places where they are found. They mostly form isolated contexts, the chronology and functionality of which must be deduced from the elements that constitute the deposit itself. The Freixanda hoard (Ourém, Santarém; Portugal) was discovered in a vineyard, some 500 m from the Nabão river, a location without any particular geographical feature. It comprises 9 pieces (**fig.1**): All but pieces are complete. Several pieces show clear signs of use and appear worn or modified. The most remarkable piece is the pair of tongs, of uncommon typology for this period and of exceptional dimensions (28,1 cm long). The single looped unifacial palstaves have a geographical distribution concentrated essentially in the North and centre of Portugal; the one in this hoard gives an element of regional production to the finding. The double looped socketed axes are predominant in the Portuguese area, but they are found as well in Galicia, France and England. Given the presence of worn pieces, a bulk of raw metal and a pair of tongs (a metallurgical tool), the deposit is interpreted as metal collected by a caster craftsman to be used as raw material.



Experimental set-up.

- Micro-beam line of the CMAM (Centro de Micro Análisis de Materiales) of the Universidad Autónoma de Madrid. Beam extracted in air.
- Oxford quadrupole doublet, 200nm Si₃N₄ exit window, FWHM of 40-50 μm @ 4 mm from the window.
- 3 MeV protons, 3.5 > I > 3 nA, measuring times 240-600 s.
- Si(Li) detector 30 mm², He flow, Pb collimator 1 mm Ø, low Z elements.
- Si(Li) detector 80 mm², 15 μm Co filter, medium and high Z elements.
- Measurements on mechanically cleaned areas.

FIGURE 1. The metal hoard of Freixanda (Portugal) featuring 9 objects of four different types.

PIXE results. All the pieces are made of a tin-bronze (Cu-Sn) alloy. Sn is in any point >10% (**fig.2**) but the average of the two measurements taken on each sample gives Sn > 14% (High Tin Bronzes). The variability of Sn in different areas of a piece is observed because during the cooling stage of the casting process in a mould, the Cu-Sn alloys generate metallic phases with different amounts of Sn, giving rise to the typical dendritic structures. This segregation can be cured by re-crystallization of the metal via an annealing heat-treatment. As the maximum solubility of Sn in Cu at the solid state is 14-15%, tin rich alloys always show two different phases (alpha and delta). PIXE spot measurements will detect the corresponding Sn differences. The pair of tongs differ from the general homogeneity in because of the lower Sn content (11.6%).

Impurities. In the metal objects from the LBA in the Iberian Peninsula elements besides Cu and Sn are very scarce. In other Central European and Atlantic areas As, Sb, Ag or Pb may be above 0.5%, and even 1%. In the Freixanda hoard (**fig.3**) both the metals high purity of the impurities pattern are characteristic. We detect Pb, Ni and As in the majority of pieces, while Fe and Sb appear sporadically and Zn and Co are never detected. Only in the knife the impurities are between 0.5% and 1% (mostly As) while the pair of tongs is marked by the purity of the metal (only traces of Ni). The extremely low Fe content (often below MDL), a distinctive trait of a primitive metallurgical technology (no slag formation), suggests a metallurgy previous to the technological change in the furnaces introduced by the Phoenician colonization in the Peninsular South.

The melting lump. Its shape, size and weight (173g) suggest that it could be a scrap of metal adequate for a knife. It is a fully-formed alloy, plausibly created by the re-melting of scraps or objects, with a consequent reduction of the volatile impurities (As, Sb, Pb, Zn) while the concentration of Ni and Ag remains stable.

Conclusions. We stand in front of a recollection of artefacts locally manufactured inside a specific geographical area, with no exotic or foreign elements. The PIXE analyses validate this hypothesis since the low impurities concentrations are typical of the Portuguese and Spanish LBA. The Freixanda hoard manufacturing technology is similar to that of the contemporary hoard of Coles de Samuel (Portugal). The pair of tongs, which would be a tool of the metalworker, stands out within the relative compositional homogeneity of the collection, considered as the metal cache of a founder's hoard. The finding in an unremarkable location, without traces of ritual use, suggests the same. Pb and Fe, at impurity levels, indicate a metallurgical technology previous to the Phoenician influence in the Iberian Peninsula.

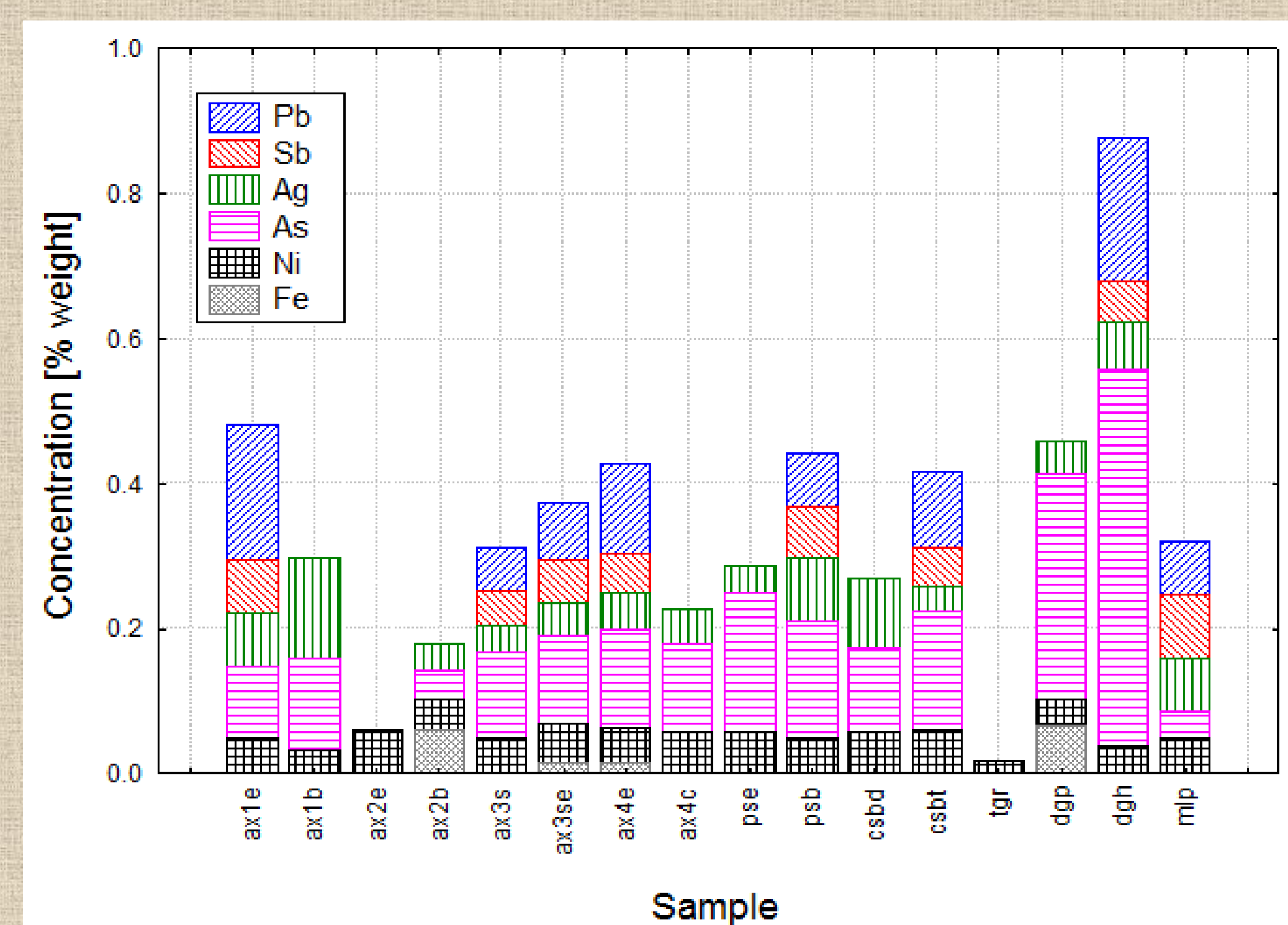
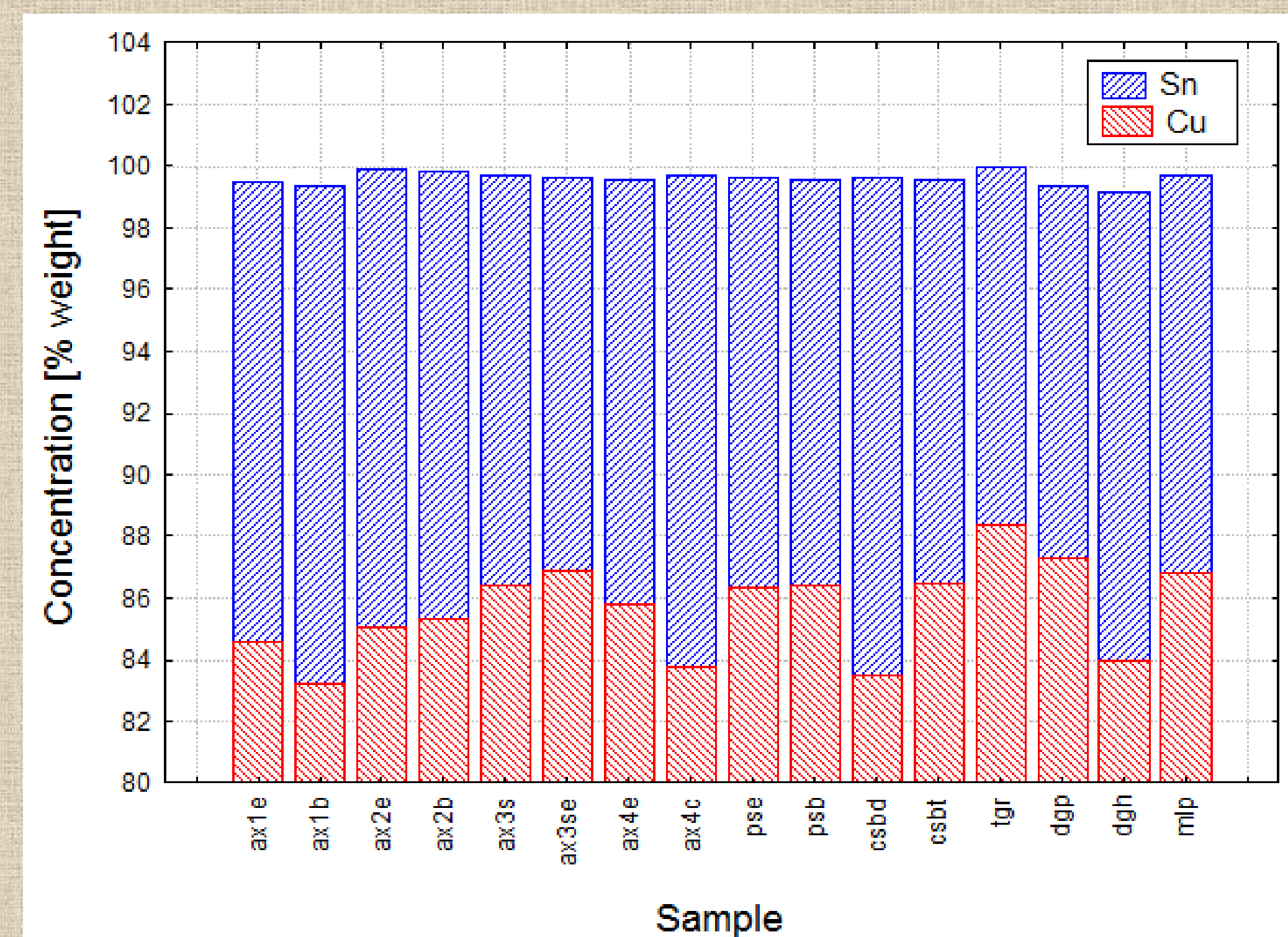


FIGURE 2. (Up) The PIXE results for the bronze major components, Cu and Sn. The measurements labels refer to ax (axes); ps (palstaves); cs (chisel); tg (tongs); dg (dagger) and mlp (melting lump).

FIGURE 3 (Down). The PIXE results for the bronze trace components. Same legends as in figure 2.