

A COMPLEX COMPARATIVE STUDY OF EARLY MEDIEVAL SPLIT BLOOMS FROM PANNONIA

Béla TÖRÖK¹, Árpád KOVÁCS¹, Péter BARKÓCZY¹, László KÖLTŐ², András FEHÉR³ and Béla M. SZŐKE⁴

¹ Institute of Physical Metallurgy, Metalforming and Nanotechnology, University of Miskolc, Hungary; ² Rippl-Rónai Museum, Kaposvár, Hungary; ³ ISD Dunaferr Zrt., Dunaújváros, Hungary; ⁴ Institute of Archaeology, Hungarian Academy of Sciences, Budapest, Hungary



IRON IN ARCHAEOLOGY

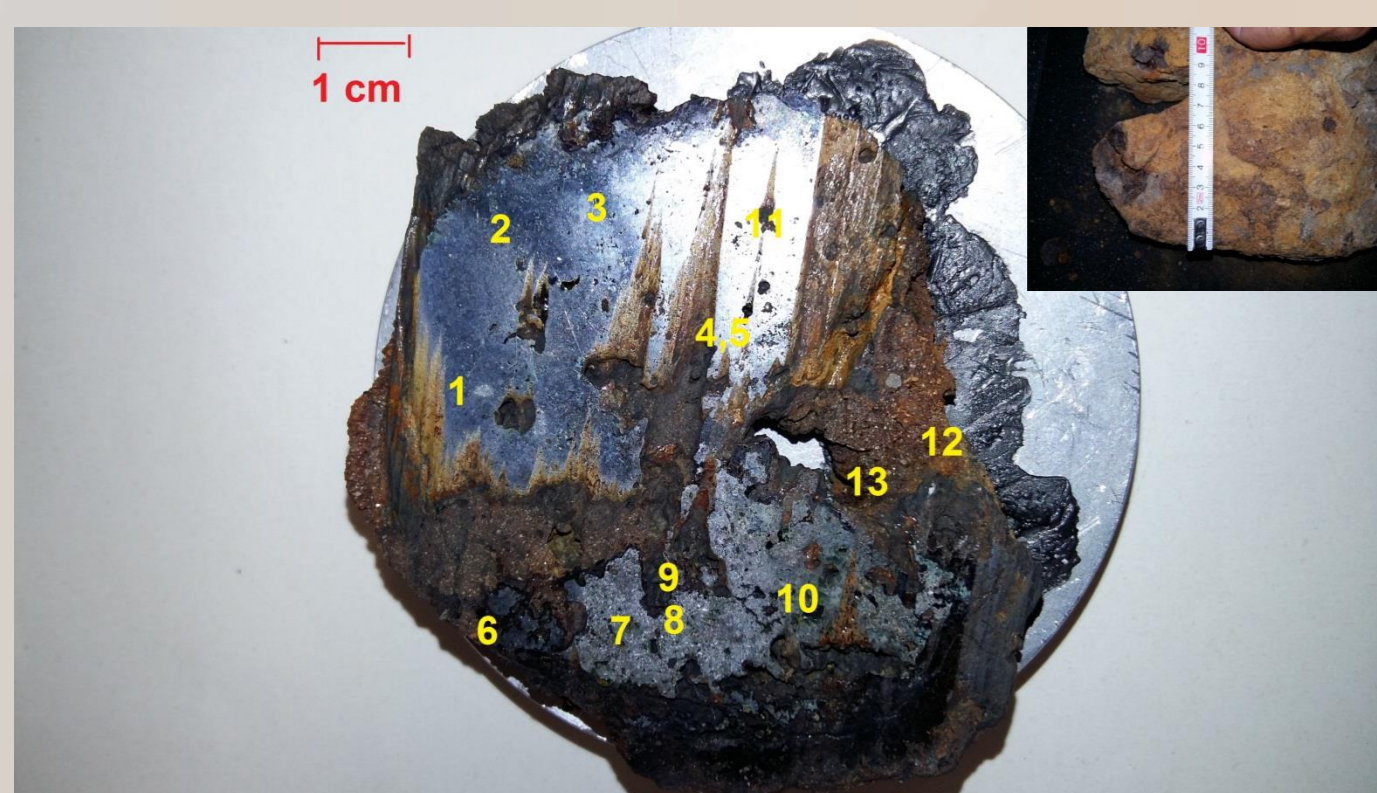
Bloomery Smelters and Blacksmiths in Europe and Beyond
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Introduction

This study presents a complex archaeometallurgical examination and a comparison of their results made on heavy iron blooms from two different Pannonian sites (Lábod-Petesmalom and Zalavár-Vársziget) in Hungary. The samples were prepared and chemical analysis was carried out where energy dispersive X-ray fluorescence method (XMET8000 Expert) and optical emission spectrometer (OES-ARL 34000). The complements of the microstructure and their proportions were identified by metallographic examinations where scanning electron microscope (Zeiss EVO Ma10) with energy dispersive spectroscope (EDAX) and optical microscope (Zeiss Axiomager M1m with AxioVision software) were used in 2016-2017.

The normal weights of early medieval blooms are regularly no more than 1-3 kg, however heavier blooms were unearthed on some Roman and Medieval sites. There is a special group of blooms known as split, or semi-split blooms. These blooms had been deeply notched with an axe when those were still glowing hot. The reason of the cutting was to satisfy the early metallurgist that his product has good enough quality either for further working or trade. The complex examination of the blooms has been very useful to acquire a deep knowledge of their material characteristics. This investigation can serve important information to define the characteristics of the metallurgical processes at that time.

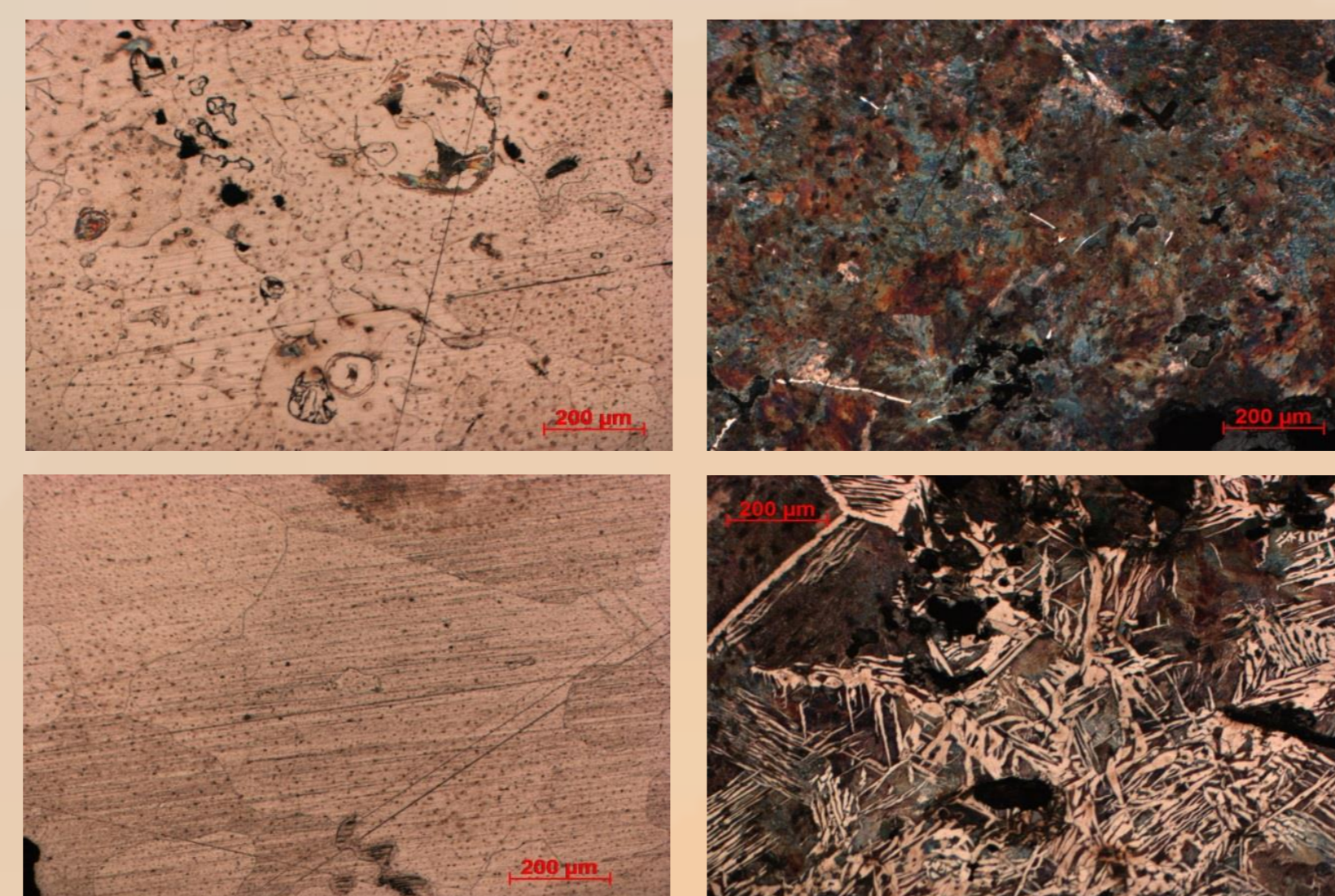
Chemical compositions of the oxidic (slaggy) area used ED-XRF (Wt%):
Mg:1.64-1.87, Al:2.35-2.99, Si:13.22-14.56, P:0.56-0.91,
K:0.56-0.81, Mn:0.75-1.77, Fe:77.10-80.92



Cross-section of the prepared sample with the SEM-EDS measuring places

Middle of the metallic area – slag inclusions and gas lunkers

Around the middle area – ferrite with large grain size



In the edge of the metallic area – perlite with slag inclusions and corroded parts

Towards the edge – ferrite-perlite structure with Widmanstätten-ferrite and inclusions

Blooms from Zalavár-Vársziget

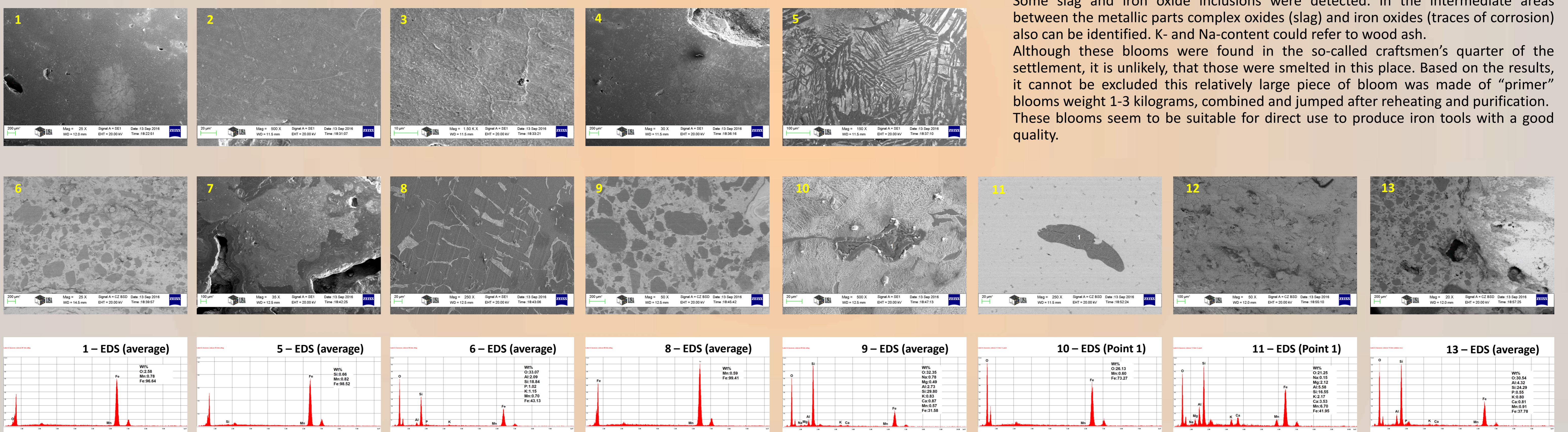
Two unusually large iron blooms (Z1 and Z2) were unearthed on the excavation site of Zalavár-Vársziget (Zala county) in 2011. The extensive settlement (Mosaburg) was the seat of the easternmost county of the Caroling Empire in the 9th century. One of the blooms (Z1) was examined by the Archaeometallurgical Research Group of the University of Miskolc (ARGUM) using various methods (XRF, OM and SEM-EDS).

An examinable sample was cut off from the bloom by waterjet cutting (marked with yellow lines above). The cross-section of the sample have been polished and etched in 2% nital solution.

The metallic areas have different heterogeneous microstructures which are containing less than 1% Mn. Typically, almost pure ferrite structure with large grain size could be found in the middle of these metallic areas. The fraction of pearlite increased towards to the edge of these areas. However, more or less separated parts with inclusions and relatively high amount of pearlite in their inner areas could be detected.

Some slag and iron oxide inclusions were detected. In the intermediate areas between the metallic parts complex oxides (slag) and iron oxides (traces of corrosion) also can be identified. K- and Na-content could refer to wood ash.

Although these blooms were found in the so-called craftsmen's quarter of the settlement, it is unlikely, that those were smelted in this place. Based on the results, it cannot be excluded this relatively large piece of bloom was made of "primer" blooms weight 1-3 kilograms, combined and jumped after reheating and purification. These blooms seem to be suitable for direct use to produce iron tools with a good quality.



A bloom from Lábod-Petesmalom

A heap of iron slag, numerous fragments of breastwalls and tuyères (thin walled, funnel shaped „Avar-type” as well as straight and thick walled „Fajsz-type”) have been found on the shore of a pond in Petesmalom, near village Lábod (Somogy county) in 2003. The excavation revealed a former bloomery workshop with ore roasting pits which are covered with a thick layer of iron ore dust. On the basis of the type of the tuyères and other ceramic fragments, the iron production was dated to 8th and 9th centuries.

About 50 meters away from the slag occurrences an extraordinary size split iron bloom (L1) was found. In its immediate surrounding there were no other finds.

A cylindrical sample was cut off from the bloom (see above) and its longitudinal section was examined by Qualitest Laboratory of Dunaferr Zrt. and the ARGUM used OM and SEM-EDS. Chemical analyses on the surface of the sample were also carried out used OES and pXRF. Four different areas can be identified on the mosaic OM-image (marked with red):

- 1) Compressed ferritic microstructure with a small amount of perlite can be analysed. The small and thin perlite grains are located along the borders of the ferrite. Slag inclusions could also be detected.
- 2) This microstructure is contrary to the previous one. On the borders of the pearlite colonies a ferrite-steadite network can be examined which contains the most amount of the measured phosphorus. Steadite, which has the lowest smelting point in this microstructure, also appears in the middle of the ferrite grains. In liquid state the steadite can solve carbon from the austenite, that is why ferrite appeared between pearlite and steadite.
- 3) Only pearlite colonies with a thin steadite network can be observed. It is supposedly resulted by a heterogeneous distribution of the carbon and phosphorous contents. This is a very solid area without porosity and bubbles, but relatively large bubbles appear on the borderline of this area.
- 4) A Widmanstätten-ferritic microstructure with pearlite and some slag inclusions can be examined. The surface of the bloom is covered by slag containing embedded ferrite grains.

During the smelting and reheating, liquid phase no occurs in the areas 1 and 4. These areas indicate a usefully malleable and tough raw material. However, the low smelting point of steadite network in the area 2 and 3 might cause hot brittleness which could destroy the further use. It seems that this bloom consists of different kind of materials of which qualities are basically influenced by the P-content.

Average chemical composition of the sample used OES (Wt%):
Fe: 96.00, C: 0.40, Mn: 0.40, Si: 0.80, S: 0.01, P: 0.86, Mg: 0.32, Ca: 0.87

Chemical compositions of the different areas of the sample used pXRF (Wt%):

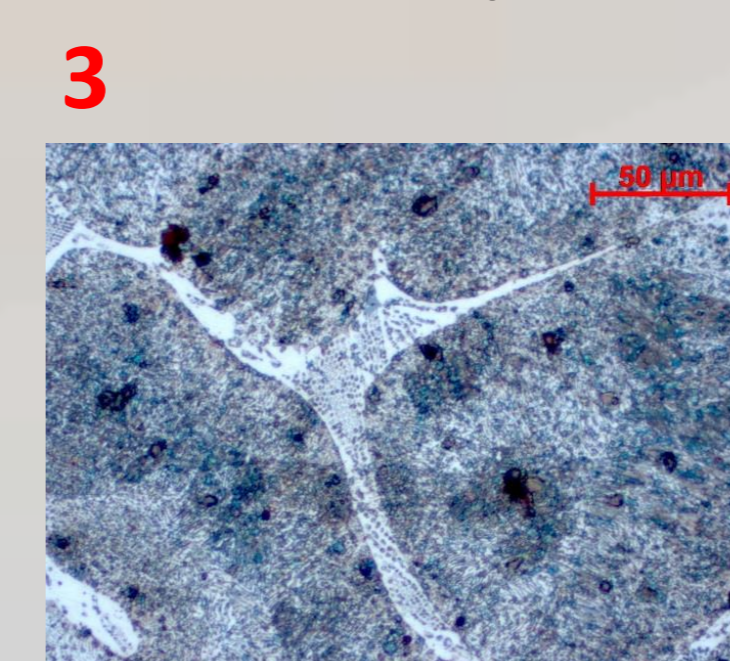
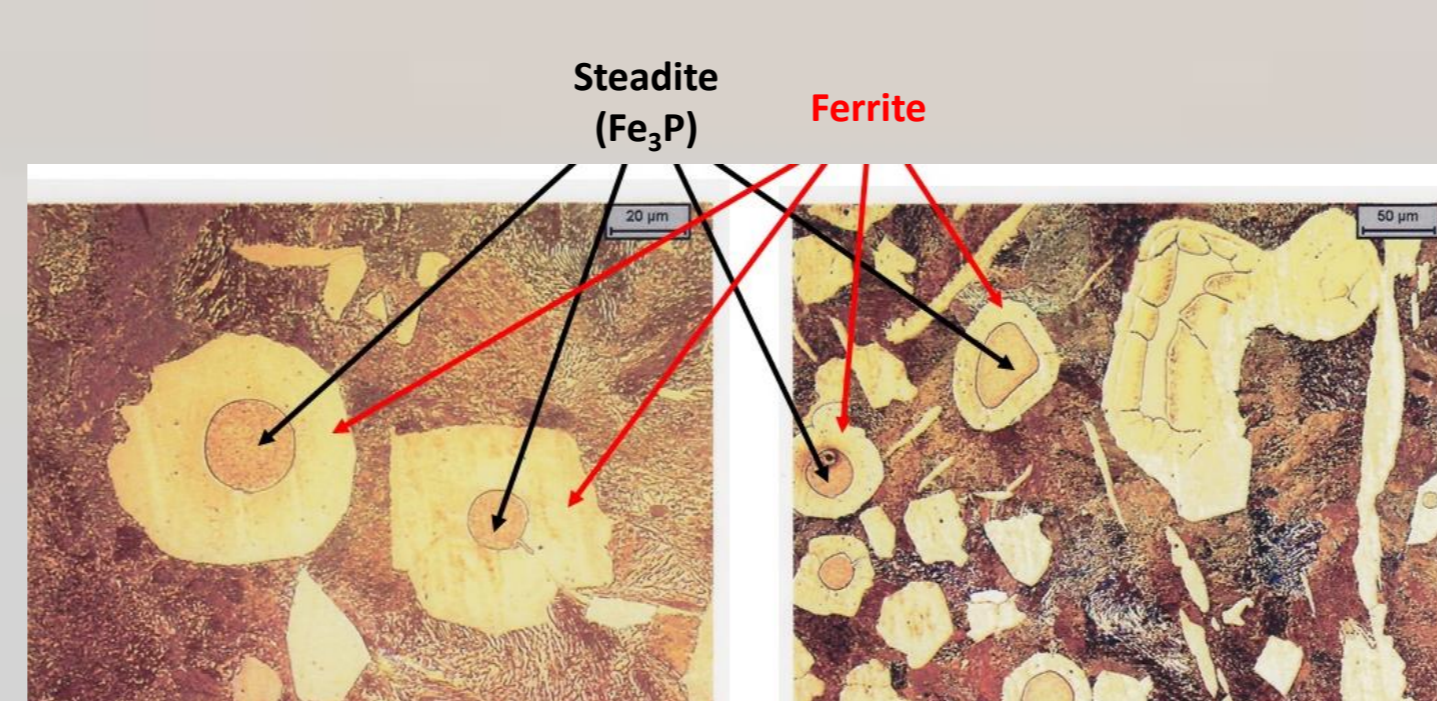
- 1: Fe:98.84-99.08, Si:0.52-1.02, P:0.0-0.27, As:0.09-0.11
- 2: Fe:97.30-99.29, Si:0.21-1.11, P:0.35-0.56, As:0.12-0.14
- 3: Fe:91.83-99.14, Si:0.24-4.58, P:0.41-1.63, As:0.10-0.12, Mn:0.0-1.28
- 4: Fe:94.96-99.22, Si:0.46-3.10, P:0.13-0.17, As:0.09-0.12, Mn:0.0-0.63



Steadite on the borderline of pearlite



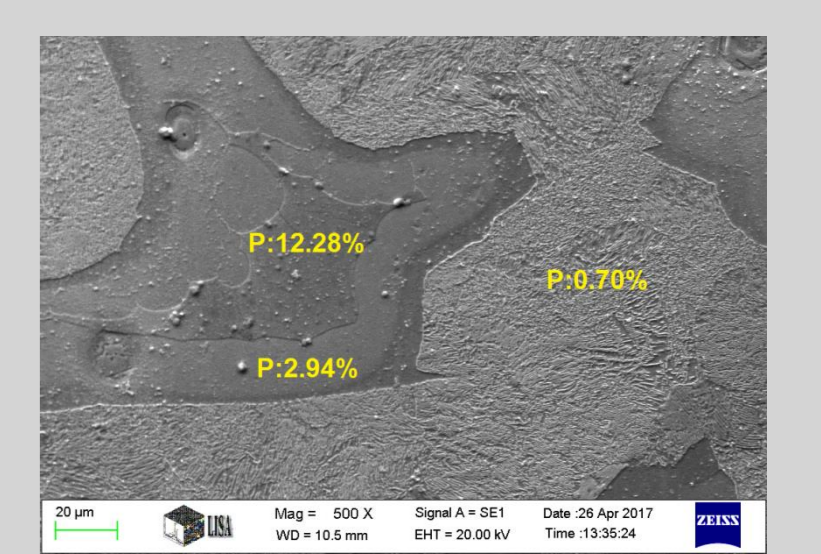
Mosaic OM-image of the examined sample



Pearlite with thin steadite network



A local P-segregation



Ferrite grains in slag



MISKOLCI
EGYETEM
UNIVERSITY OF MISKOLC



Archaeometallurgical Research Group
of the University of Miskolc
<http://www.argum.hu>
<http://www.archeometallurgia.hu>
bela.torok@uni-miskolc.hu

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