SHOE NAIL 2637 1370.B. – HYPOEUTECTOID STEEL – ROMAN TIMES – SWITZERLAND

Artefact name	Shoe nail 2637 1370.B.
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The object

Credit HE-Arc CR, V.Chappuis.

Fig. 1: The block-lifted object before conservation.

Description and visual observation

Description of the artefact	Nail from a block-lifted Roman shoe (Fig. 1). The forged nails were hammered into the leather soles on a bucking tool. Average dimensions of the shoe nails: L = about 14mm; diamter = 11mm; W = up to 0.8g.
Type of artefact	Shoe nail
Origin	Hofstetterfeld, near Roman Necropolis, Sursee, Lucerne, Switzerland
Recovering date	None
Chronology category	Roman Times
chronology tpq	50 A.D.
chronology taq	100 A.D.
Chronology comment	2nd half 1st century AD.

Burial conditions / environment	Soil
Artefact location	Denkmalpflege und Archäologie des Kantons, Luzern
Owner	Denkmalpflege und Archäologie des Kantons, Luzern
Inv. number	2637 1370.B.
Recorded conservation data	Block-lifted (in plaster), desiccated storage with silica gel.

Complementary information

Burial environment: Dense sand-clay soil, humid.

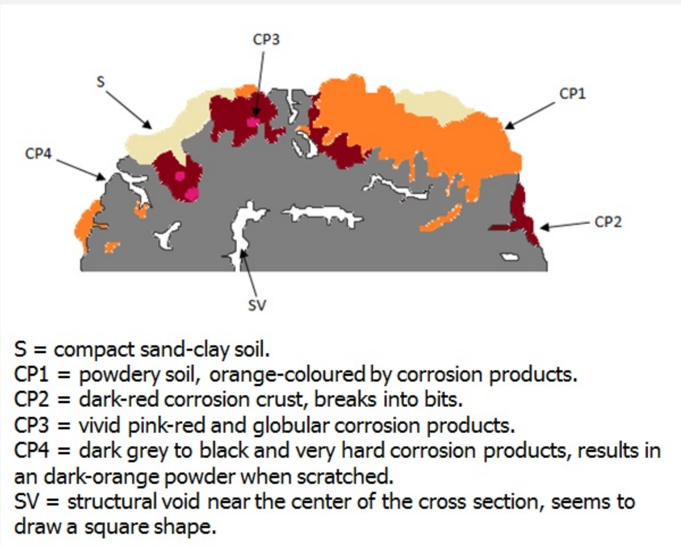
Study area(s)

Credit HE-Arc CR, V.Chappuis.

Fig. 2: Incomplete shoe from which the nail was sampled (in red circle),

Binocular observation and representation of the corrosion structure

The schematic representation below gives an overview of the corrosion layers encountered on the nail from a first visual macroscopic observation.

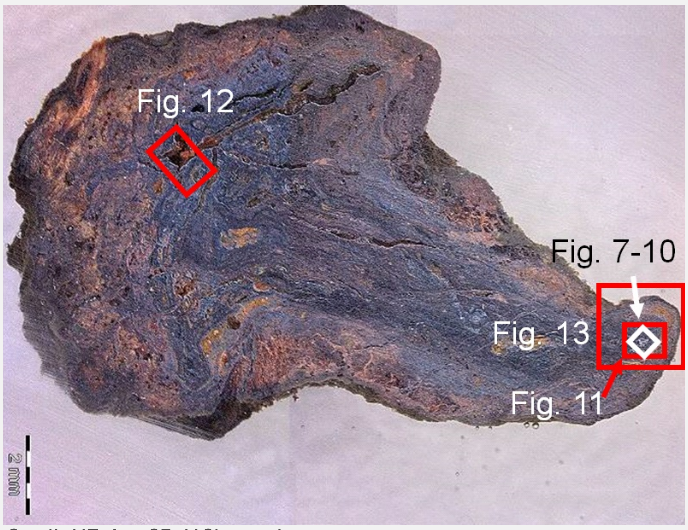


Credit HE-Arc CR, V.Chappuis.

Fig. 3: Preliminary stratigraphy based on the observation of a broken nail,

MiCorr stratigraphy(ies) – Bi

Sample(s)



Credit HE-Arc CR, V.Chappuis.

Fig. 4: Micrograph of the cross-section showing the location of figs. 7 to 13,

Description of sample	A longitudinal cut through the nail (Fig. 4). Dimensions: L = 16.4mm; W = about 12.0mm.
Alloy	Hypoeutectoid steel
Technology	Forged
Lab number of sample	HE-Arc CR 1457-S1.
Sample location	HE-Arc CR, Neuchâtel, Neuchâtel
Responsible institution	HE-Arc CR, Neuchâtel, Neuchâtel
Date and aim of sampling	2013, metallography and elementary composition of the metal

Complementary information

Nothing to report.

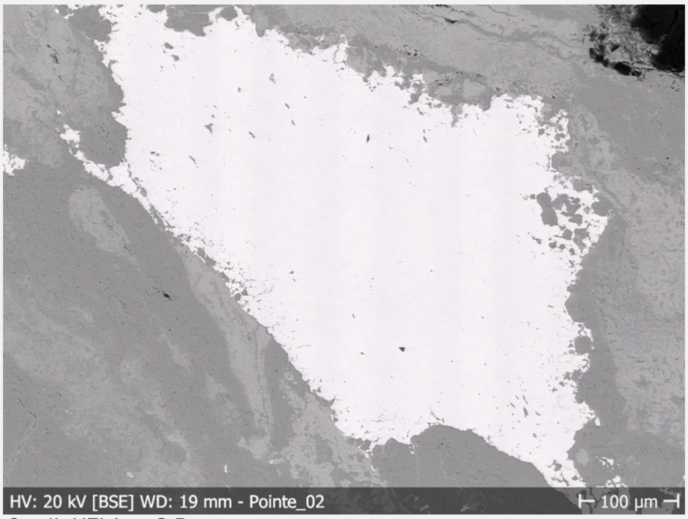
Analyses and results

Analyses performed:
Metallography (Nital etched), SEM/EDS

Non invasive analysis

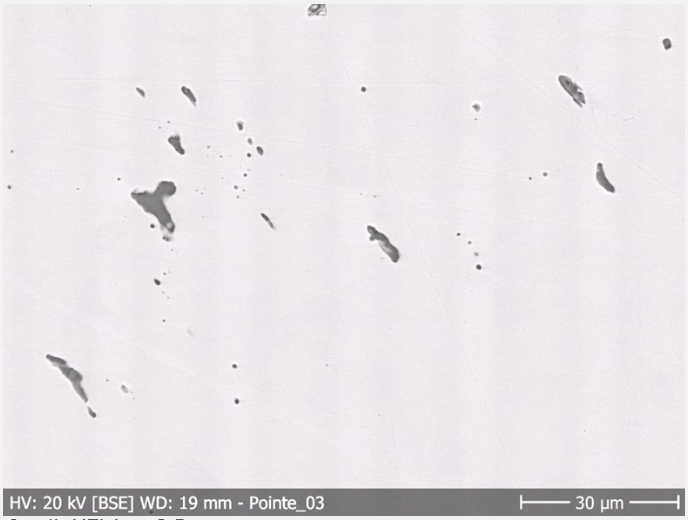
Metal

The remaining metal is an hypoeutectoid steel (Fig. 7 and 8), containing Fe, Si and O slags inclusions (possibly fayalite FeO,SiO2), and consisting of less than 1% of the total volume of the highly mineralized nail. After Nital etching, it shows intergranular corrosion on one of its sides (Figs. 9 and 10).



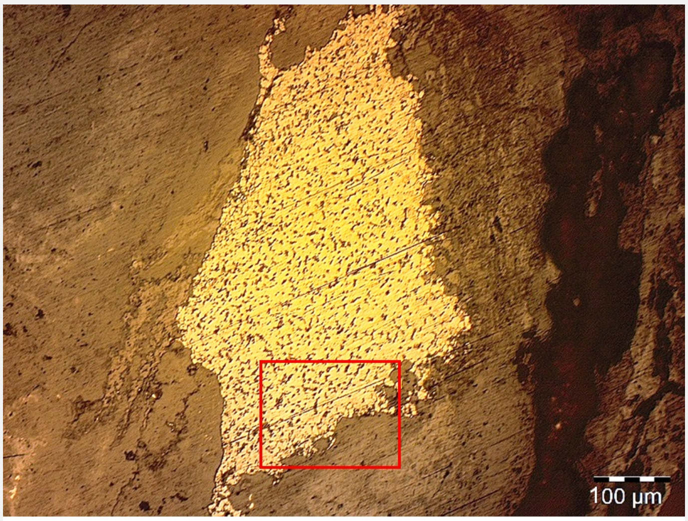
Credit HEI Arc, S.Ramseyer.

Fig. 7: SEM, BSE-mode picture of remaining metal,



Credit HEI Arc, S.Ramseyer.

Fig. 8: SEM, BSE-mode picture of inclusions in remaining metal,



Credit HEHE-Arc CR, V.Chappuis.

Fig. 9: Micrograph of the metal sample from Fig. 7 (detail, rotated 90°), Nital etched, bright field,

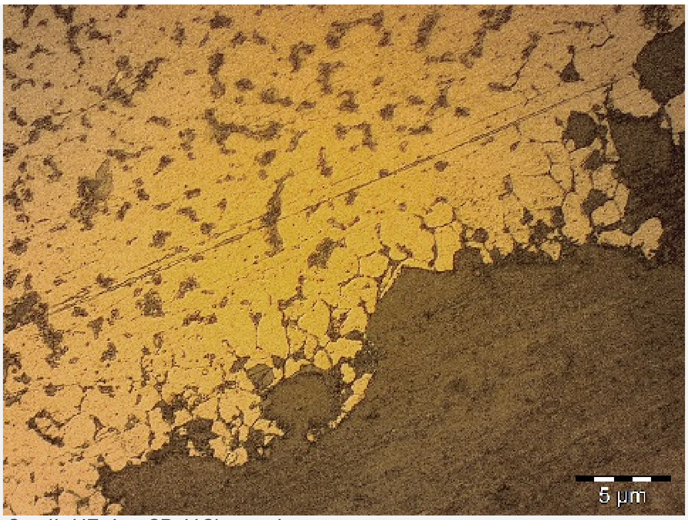


Fig. 10: Micrograph of the selected area of Fig. 9, Nital etched with no clear grain structure, bright field, Intergranular corrosion and grey phase (perlite?) are observed,

Credit HE-Arc CR, V.Chappuis.

Microstructure	Recrystallized grain structure
First metal element	Fe
Other metal elements	C

Complementary information

Nothing to report.

Corrosion layers

The metal is heavily corroded and the thickness of the corrosion crust is irregular, varying from 0.8 to 3.8mm, with an average of about 2mm. The corrosion has replaced most of the metal (Fig. 4). Between corrosion layers the limit of the original structure is visible. Some leather fibers seem to be preserved as pseudomorphic structures in voids of the metal core (POM1, Figs. 11 and 12). The carbon mapping (Fig.13) shows the presence of carbon in these areas. This can also be due to the penetration of the mounting resin in the cracks.

Si, Al, P and K can be considered external markers, helping to determine the limit of the original surface (Fig. 13 and Table 1). The outer layer of corrosion products (CP1-3) ranges from dark grey to orange in bright field and contains less O and Fe on its borders than the inner layer (CP4-5, Figs. 4 and 13, Table 1). The SEM pictures show a marbling appearance of the inner corrosion layer (CP5). Cl and S do not seem to be present in the sampled nail.

Table 1: Elementary presences in stratigraphic layers based on SEM-EDS elemental mapping (Fig. 13). Y = yes; N = no; NA = not applicable (not observed). + = more compared to other layers; - = less compared to other layers. *Probably pushed back by coating resin. **Though SEM-EDS analysis showed that the metal is an iron-carbon alloy with inclusions of Si, Al, P and K.

Elements / Layers	Fe	O	C	Al	Si	K	P
S1	Y-	Y	N	Y++	Y+	Y	Y-
CP1	Y	Y	Y-	Y	Y	Y-	Y
CP2	NA	NA	NA	NA	NA	NA	NA
CP3	NA	NA	NA	NA	NA	NA	NA
CP4	Y+	Y+	N	Y-	Y-	N	Y-

CP5	Y+	Y+	N	N	N	N	Y--
NMM	N	Y	N	N	Y++	N	NA
POM	Y+	Y-	Y	N	N	N	N
SV	N	N*	Y	Y-	N	N	N
M1	Y++	N	N**	N	N	N	Y--

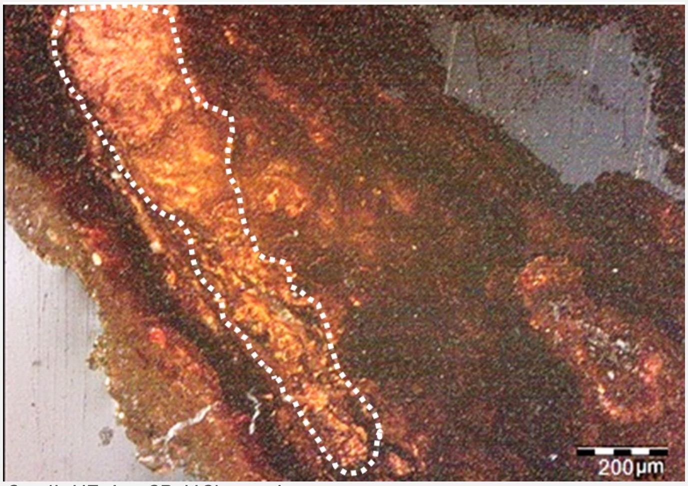


Fig. 11: Micrograph of the metal sample, bright field. The deliminated zone shows what could be leather pseudomorphic fibers filling a void,

Credit HE-Arc CR, V.Chappuis.

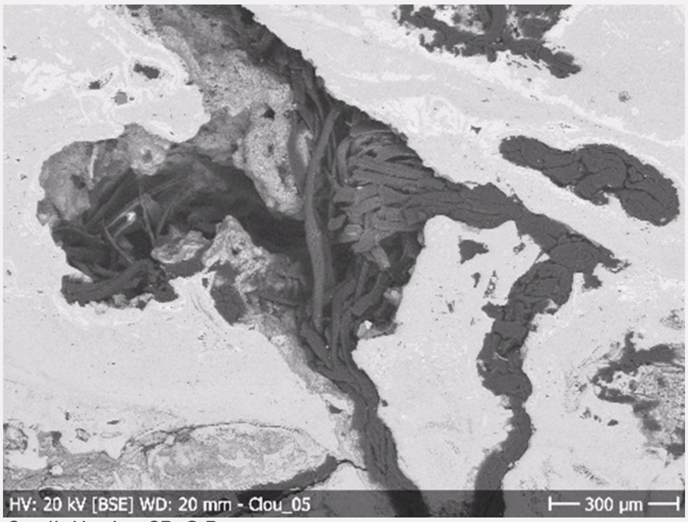


Fig. 12: Micrograph (SEM - BSE-mode) of another void filled with fibers in the head of the nail,

Credit He-Arc CR, S.Ramseyer.

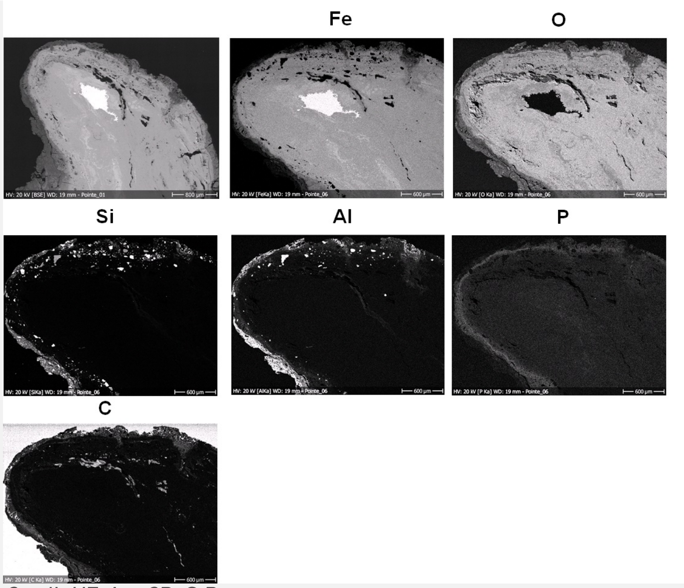


Fig. 13: Elemental chemical distribution of the selected area from Fig. 4 (90° counter-clockwise rotated). SEM-EDS,

Credit HE-Arc CR, S.Ramseyer.

Corrosion form	Uniform - intergranular
Corrosion type	None

Complementary information

Nothing to report.

MiCorr stratigraphy(ies) – CS

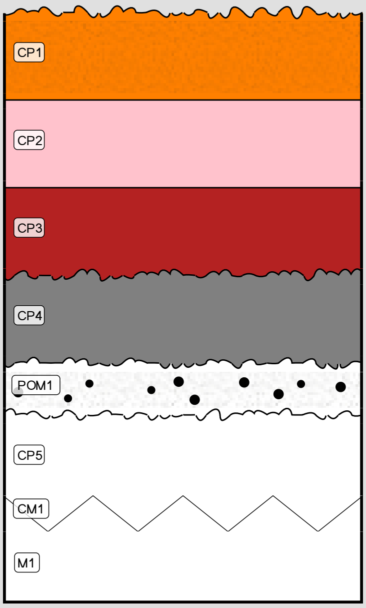


Fig. 6: Stratigraphic representation of the object in cross-section using the MiCorr application. This representation can be compared to Fig. 14.

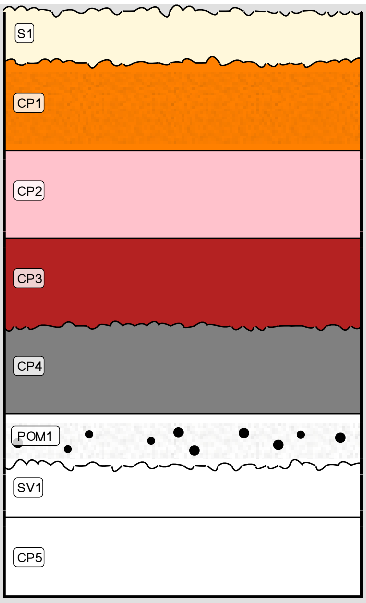


Fig. 5: Stratigraphic representation of the object in cross-section using the MiCorr application. This representation can be compared to Fig. 14.

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

Based on the analyses carried out, the schematic representation of the stratigraphy of corrosion layers was corrected (Fig. 14). The following strata were identified:

S1 = sand-clay soil, compact, cemented when dry, powdery when abrazed, very thin particle size (usually about and less than 0.1mm). Undefined thickness (soil).

CP1 = powdery orange (loosely coherent) and matte corrosion crust, sometimes forming humps. Partially mixed with S1 and POM layers (diffused interfaces). 1 to 5 millimeters thick.

CP2 = vivid red or pink dots, more brittle than powdery (loose cohesion) and mostly matte, only two or three observed, always above CP3 interfaces. Usually 1 mm spheric diameter.

CP3 = dark reddish corrosion product, forming smooth, matte and brittle layers that are parallel to CP4, with a clean and regular interface. The corrosion products are generally hard, but sometimes break up into grains, resulting in a more irregular interface. The layer is approximately 0.5mm thick.

CP4 = dark grey to black corrosion product, smooth with pseudo-metallic reflection (a bit glossy), very hard, when scratched results in orange powder, with somewhat irregular shape and thickness (ranging from 0.3 to 2mm).

CP5 = dark grey to black corrosion product, generally a bit darker than CP4. Smooth with pseudo-metallic reflection, even harder than CP4 and when scratched it turns into an orange coloured powder. Irregular interface regarding CP4. Clear transition and somewhat parallel from CP4 to CP5. As regards its thickness, it fills the remaining volume.

NMM = silica and calcareous inclusions.

POM = mostly powdery and grain-like material, ranging from orange to dark brown in colour, somewhat glossy and similar to crystals when illuminated. A few fiber-like zones are present, which are more satin than glossy. They are dark brown to charcoal black, very brittle and break into a powdery and grain-like material. POM is located above or close to CP3 and CP4 layers, sometimes mixed into S1 or CP1 layers with a diffused interface. Overall, the stratum is approximately 0.2-0.3mm thick.

SV = structural void, present as fissures that either pass through the different layers, or are present at corrosion interfaces, especially at the CP4/CP5 interface. The void is 0.1 to 0.3mm thick and partially filled with POM in the outer layers.

M1 = glossy with metallic reflection.

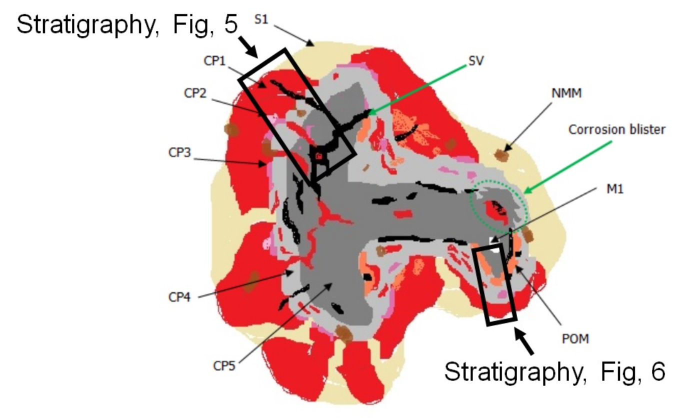


Fig. 14: Improved stratigraphic representation of the nail from visual observations and analyses and visualization of the two stratigraphies of Figs, 5 and 6,

Credit HE-Arc CR, V.Chappuis.

Conclusion

The nail is apparently made of a hypoeutectoid steel, with what may be a pearlite phase. Roman shoe nails are forged and pushed through leather soles by hammering them against a hard foot-shaped buckering device. This requires the steel to be strong, but not too brittle, otherwise it will be prone to breaking when pushed through the soles or when in use for marching on hard surfaces. This nail is almost entirely mineralized. Its original shape seems however to be preserved within the corrosion layers. In addition to this, what appears to be leather fibers seem to be preserved in either mineralized or organic form.

References

References object

1. Volken Marquita. "Le fer et la peau: le cuir et ses outils en milieu urbain romain". In: Chardron-Picault Pascale (dir.). Aspects de l'artisanat en milieu urbain: Gaule et Occident romain. Actes du colloque international d'Autun, 20-22 septembre 2007. Revue Archéologique de l'Est, 28e supplément. RAE, Dijon, 2010, pp.415-424.

2. Volken Marquita, Volken Serge et Paccolat Olivier. "Les clous de chaussures du site de Pfyngut: les bases d'une typo-chronologie." In: Paccolat Olivier (dir.). Pfyn/Finges, évolution d'un terroir de la plaine du Rhône. Le site archéologique de "Pfyngut" (Valais, Suisse). Cahiers d'archéologie romande 121, Archaeologia Vallesiana 4, Lausanne, 2011, pp.315-388.