

Ahmad N. Abu-Baker's STSM

“The use of MiCorr application to diagnose the corrosion of archaeological brass artefacts from Jordan”

1. Determining the study areas of artefacts

2. Creating a conceptual representation of their corrosion stratigraphy with the aid of a binocular (Bi) microscope

3. Creating a digital representation of the corrosion stratigraphy from the binocular observation using the MiCorr modelling programme

4. Analysing the composition of the alloy and corrosion products of the artefacts

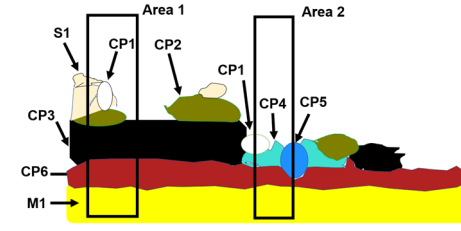
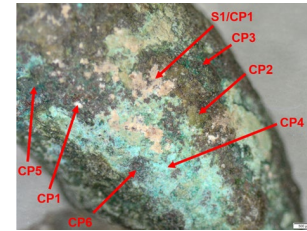
5. Creating a digital representation of corrosion stratigraphy from the microscopic examination of the cross-sections (CS) of the artefacts using the MiCorr modelling programme

6. Synthesising the binocular/ cross-section examination of the corrosion structure for the artefacts



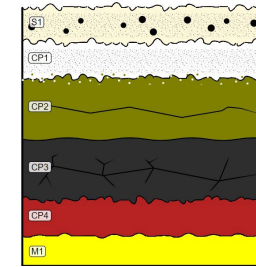
1. Determining the study areas

2. Conceptual Bi representation of the corrosion structure

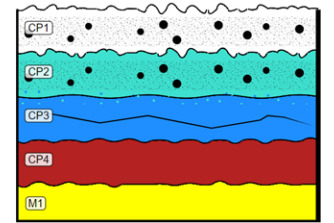


Buckle

3. Digital Bi representation of the corrosion structure



Area 1



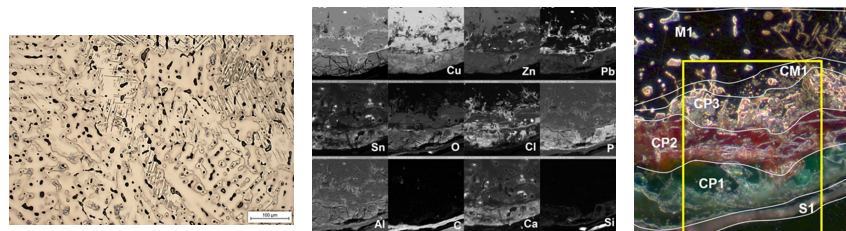
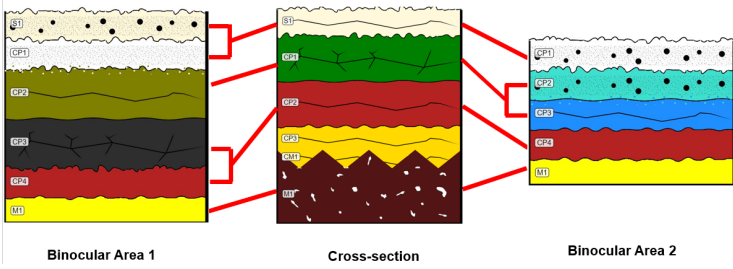
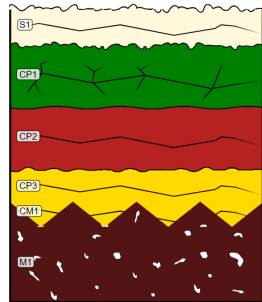
Area 2

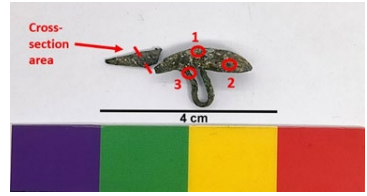
4. Analysing the artefact

Element	P1	P2	P3
Cu	69	70	69
Zn	8	6	8
Pb	6.7	7.7	8.7
Sn	2.3	2.4	2.7
Si	11	13	7.6
P	0.7	0.5	2.3
Fe	0.2	0.3	0.3
Al	1.3	0	1.4

6. Synthesising the Bi / CS corrosion structure

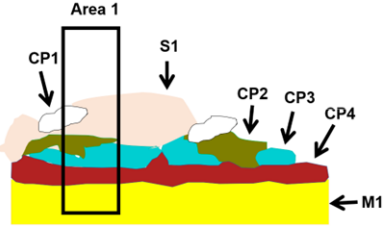
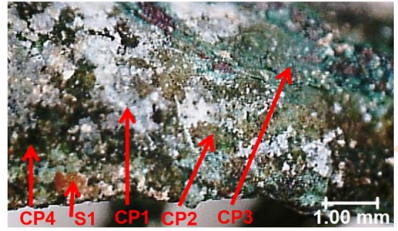
5. Digital CS representation of the corrosion structure



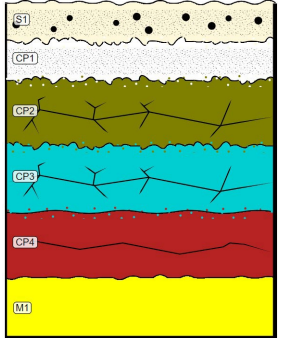


1. Determining the study areas

2. Conceptual Bi representation of the corrosion structure



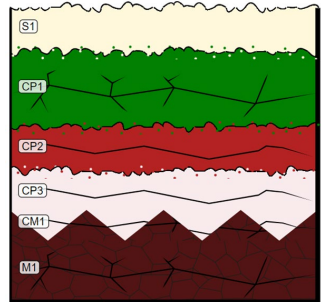
3. Digital Bi representation of the corrosion structure



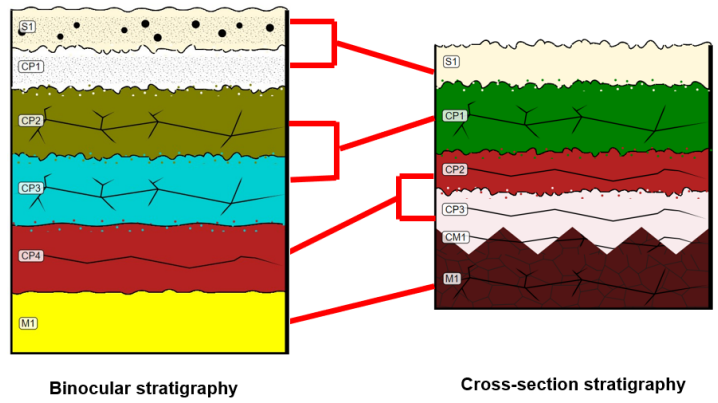
4. Analysing the artefact on CS

Element	Point 1	Point 2	Point 3
Cu	65	70	64
Zn	15	14	19
Pb	1	1.2	0.6
Sn	0.2	1.7	0.5
Si	11	7	10
P	1.7	2	1
Fe	0.3	0.3	0.3
S	1.5	0.4	0.7
W	2	1.7	3.5
Al	2.3		

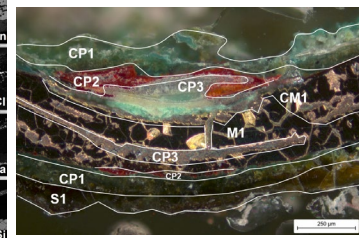
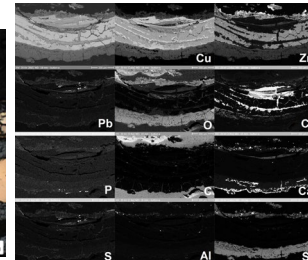
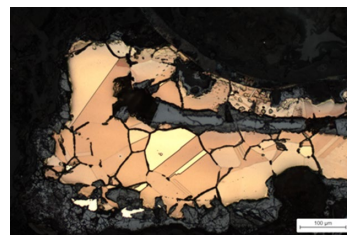
5. Digital CS representation of the corrosion structure



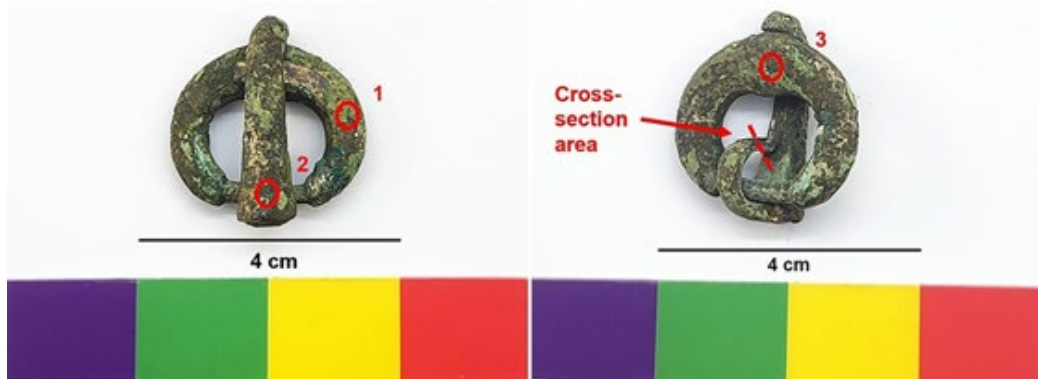
6. Synthesising the Bi / CS corrosion structure



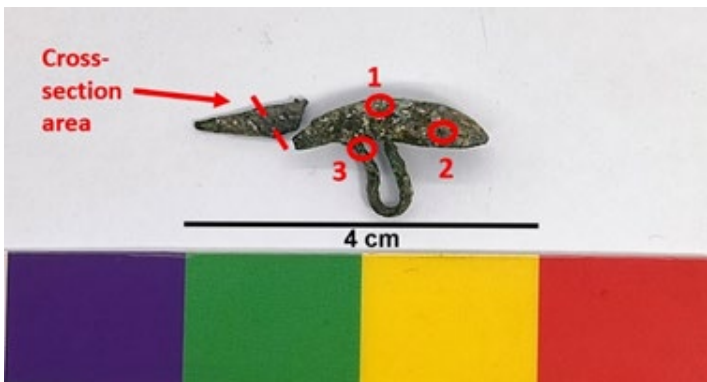
Button



1. Determining the study areas of artefacts



Study areas of the buckle



Study areas of the button

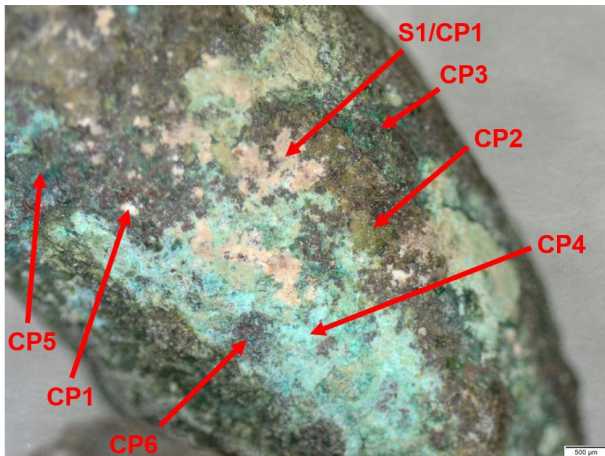
- Two copper-alloy artefacts, a buckle and a button, excavated from the Byzantine cemetery at the Khirbet Yajuz archaeological site, Jordan.
- Three spots for XRF analysis on each artefact.
- A cross-section sample was taken and prepared for analytical investigation using optical microscopy (OM) and SEM-EDS.

2. Conceptual Bi representation of the corrosion structure and 3. Digital translation using MiCorr

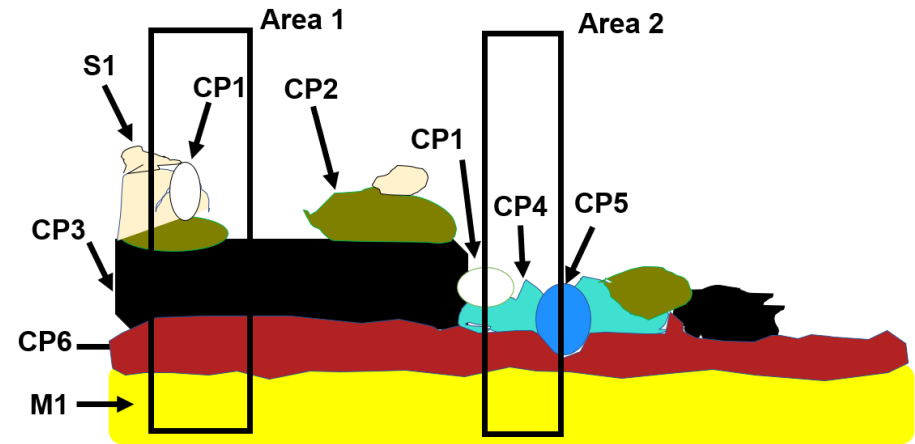
Buckle

The buckle's strata as observed under binocular microscope

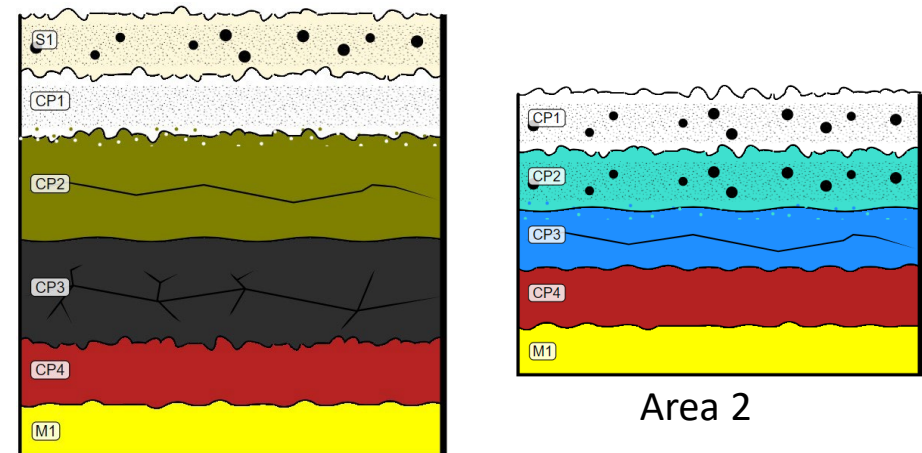
Strata	Type of strata	Principle characteristics
S1	Soil	Light brown soil sediments intermixed with CP1
CP1	Corrosion product	White corrosion spots
CP2	Corrosion product	Olive-green corrosion layer
CP3	Corrosion product	Black corrosion layer
CP4	Corrosion product	Blue-green corrosion product
CP5	Corrosion product	Blue corrosion product
CP6	Corrosion product	Red-brown corrosion product
M1	Metal	Yellow metal



Location of the different strata of the buckle



Stratigraphic representation of the corrosion structure



Area 1

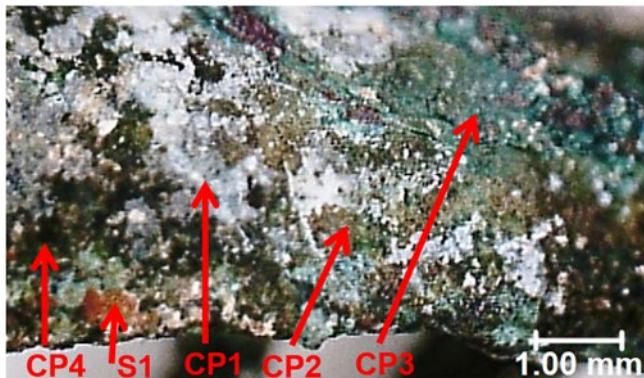
Area 2

Micorr stratigraphic representation of the corrosion structure

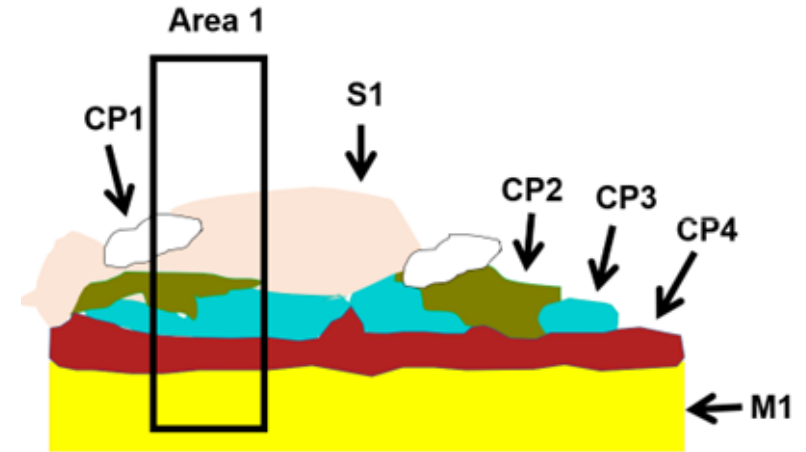
Button

The button's strata as observed under binocular microscope

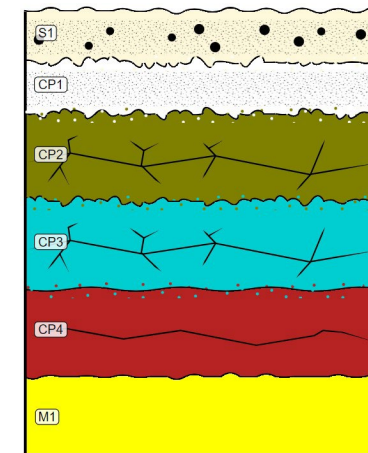
Strata	Type of strata	Principle characteristics
S1	Soil	Light brown soil
CP1	Corrosion product	White corrosion spots
CP2	Corrosion product	Olive-green corrosion layer
CP3	Corrosion product	Blue-green corrosion product
CP4	Corrosion product	Red-brown corrosion product
M1	Metal	Yellow metal



Location of the different strata of the button



Stratigraphic representation of the corrosion structure



Micror stratigraphic representation of the corrosion structure

4. Analysing the composition of the alloy and corrosion products of the artefacts

Buckle

Non-Invasive methods

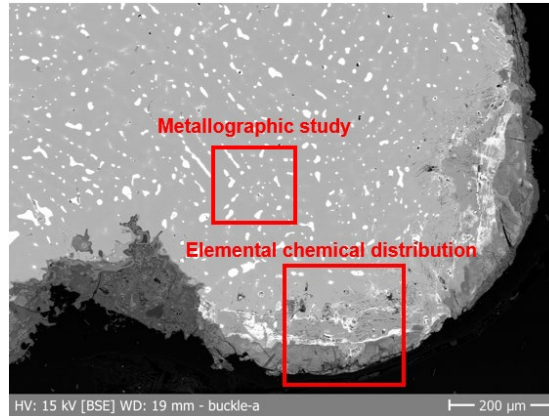
XRF analysis of the buckle

Element	P1	P2	P3
Cu	69	70	69
Zn	8	6	8
Pb	6.7	7.7	8.7
Sn	2.3	2.4	2.7
Si	11	13	7.6
P	0.7	0.5	2.3
Fe	0.2	0.3	0.3
Al	1.3	0	1.4

Invasive methods

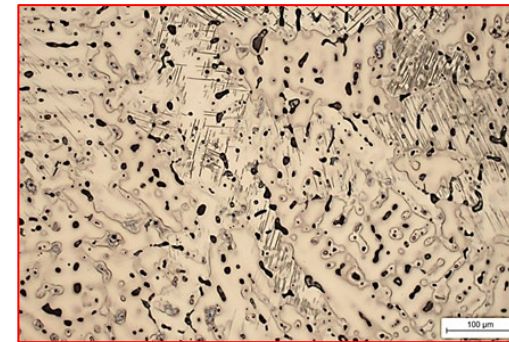
Metal

SEM-EDS analysis



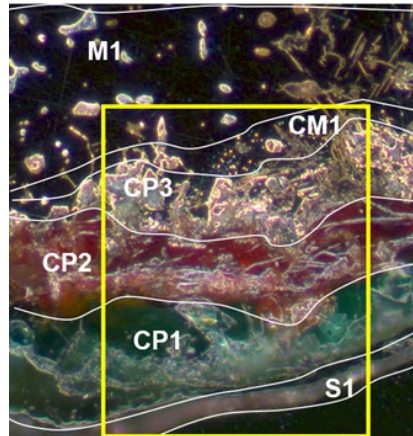
Element	Wt. %
Cu	83
Zn	9
Sn	3
Pb	5

OM



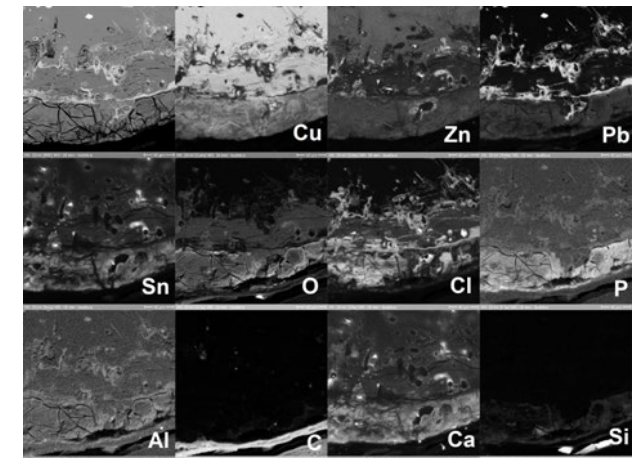
- As-cast dendritic microstructure
- Air porosity and lead globules
- Cored dendrites and strain lines
- Cold-worked without annealing

Corrosion layers



Dark field OM

- **S1:** Si, Al, and Ca from soil deposits
- **CP1:** Cu, Zn, Pb, C, O, P, and Cl containing corrosion products
- **CP2:** mainly Cu and O
- **CP3:** Cu, Cl, and selective leaching of Zn



SEM-EDS elemental mapping

Button

Non-Invasive methods

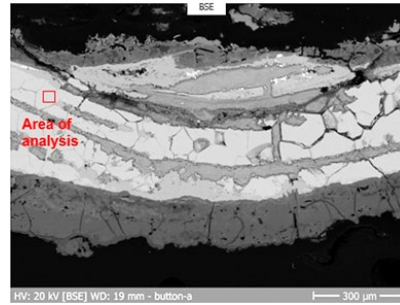
XRF analysis of the button

Element	Point 1	Point 2	Point 3
Cu	65	70	64
Zn	15	14	19
Pb	1	1.2	0.6
Sn	0.2	1.7	0.5
Si	11	7	10
P	1.7	2	1
Fe	0.3	0.3	0.3
S	1.5	0.4	0.7
W	2	1.7	3.5
Al	2.3		

Invasive methods

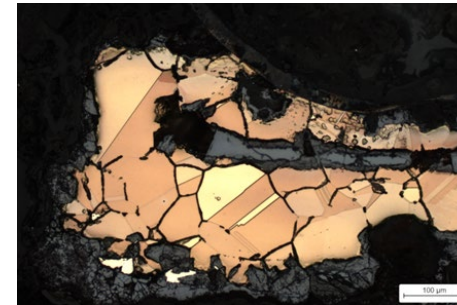
Metal

SEM-EDS analysis



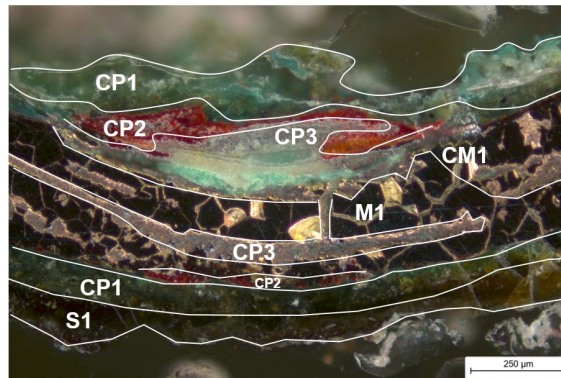
Element	Wt. %
Cu	77.5
Zn	22.5

OM



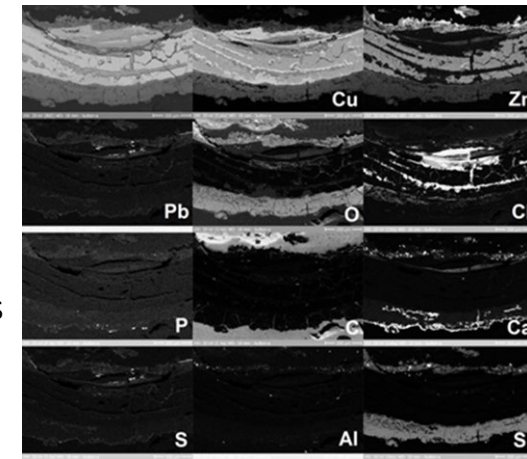
- Recrystallized microstructure
- Annealing twins
- Intergranular cracks due to selective corrosion

Corrosion layers



Dark-field OM

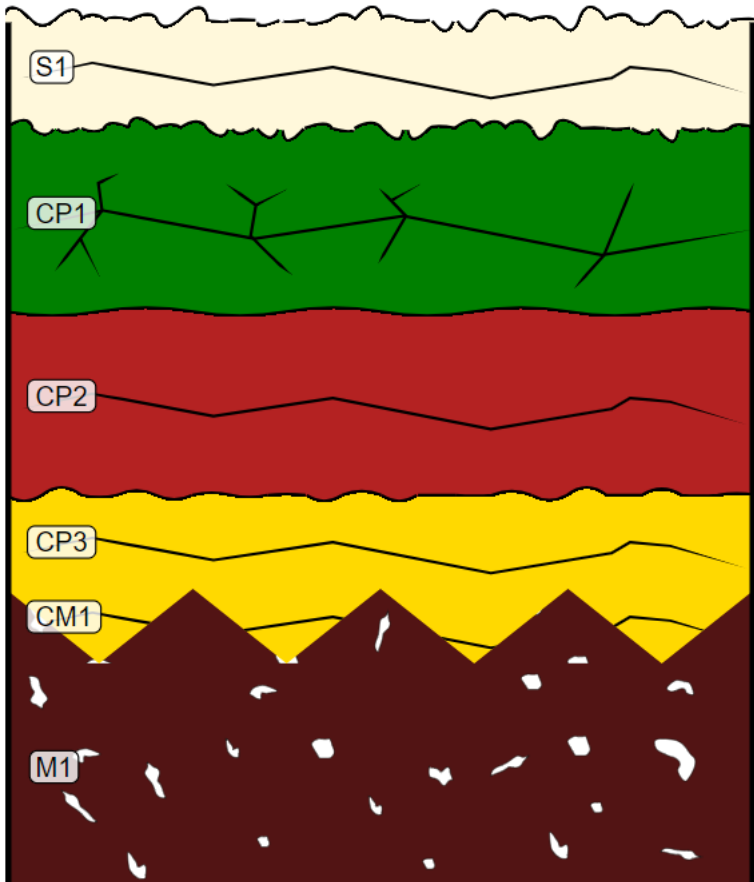
- **S1:** Si, Al, and Ca from soil deposits
- **CP1:** Cu, Zn, Pb, O, and P containing corrosion products
- **CP2:** mainly Cu and O
- **CP3:** Cu, Cl, and selective leaching of Zn



SEM-EDS elemental mapping

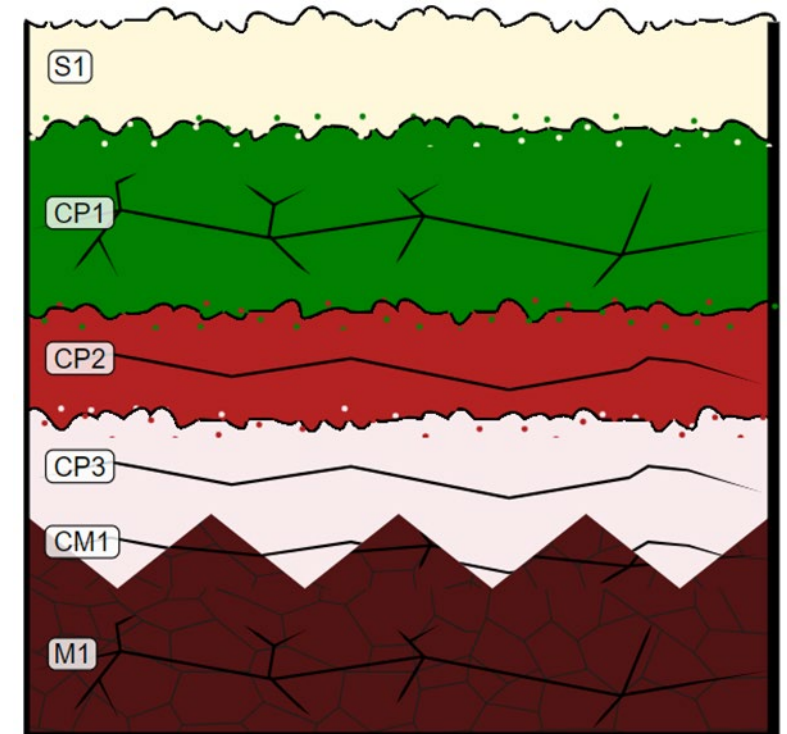
5. Digital cross-section (CS) representation of the corrosion structures

Buckle



Stratigraphic representation of the buckle's cross-section (dark field) using the MiCorr application

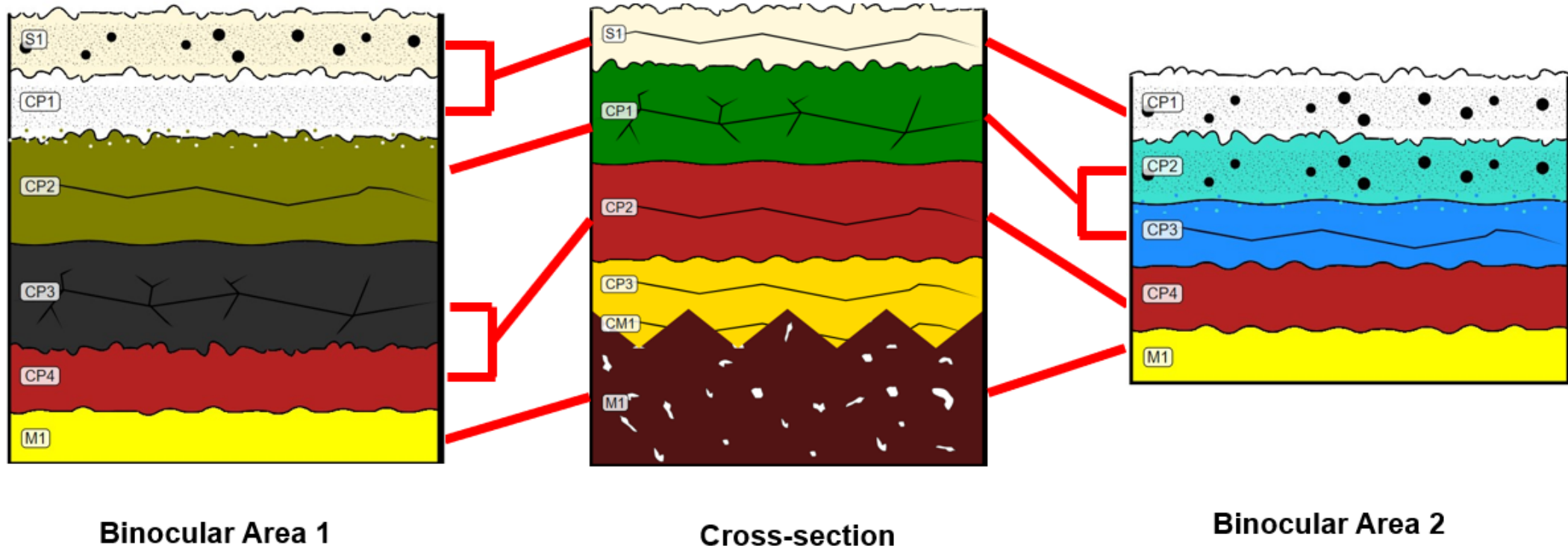
Button



Stratigraphic representation of the button's cross-section (dark field) using the MiCorr application

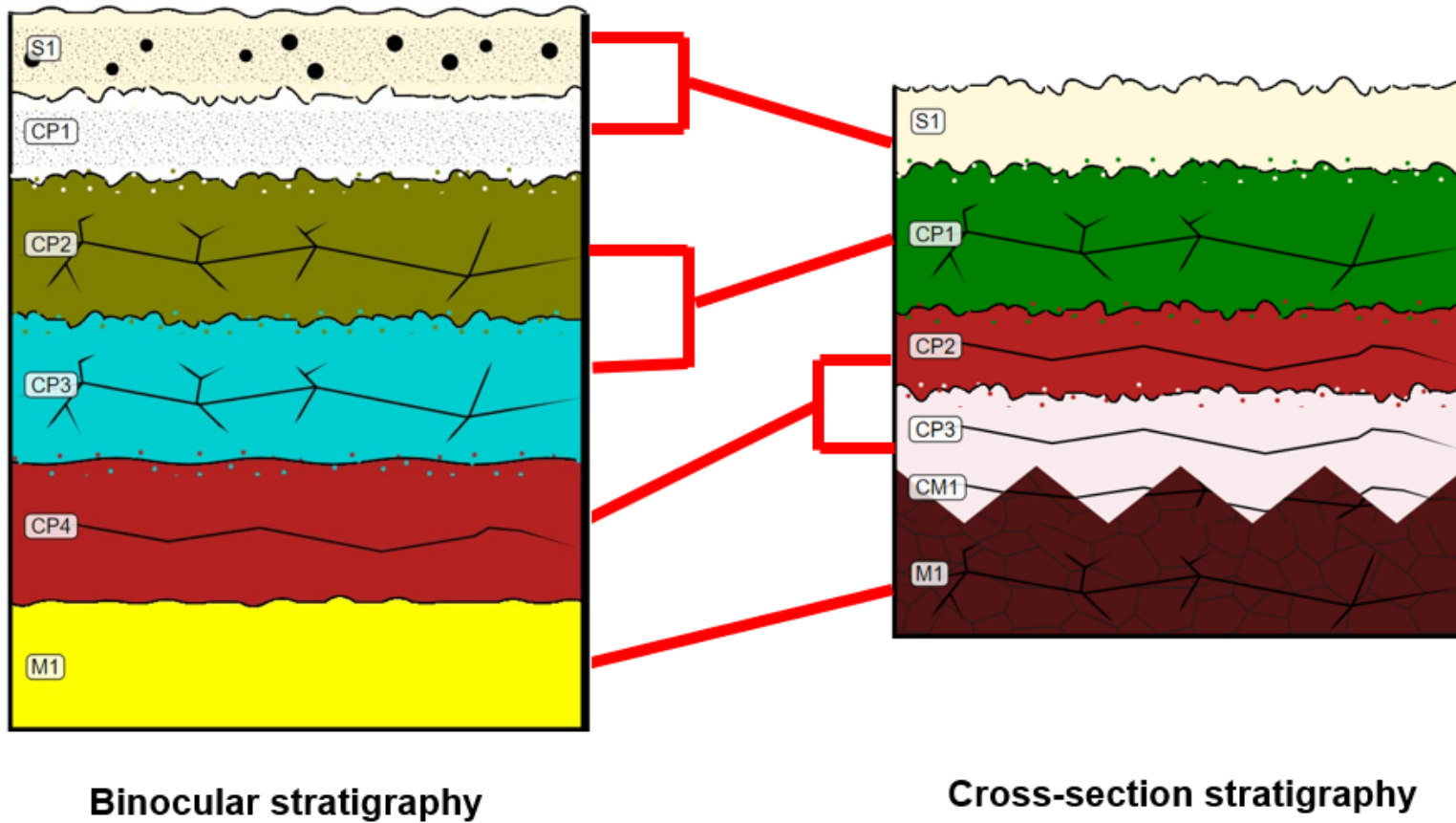
6. Synthesising the Bi / CS examination of the corrosion structure for the artefacts

6.a) Buckle



Stratigraphic representation side by side of binocular view and cross-section (dark field) of the buckle

6.b) Button



Stratigraphic representation side by side of binocular view and cross-section (dark field) of the button

Conclusion

- The buckle is a quaternary alloy of Cu-Zn-Sn-Pb, while the button is made of a brass alloy (Cu-Zn).
- The original surface has been preserved and corresponds to the interface between CP1 and CP2 for both artefacts.
- CP3 corrosion structure presents the phenomenon of dezincification, i.e. a selective leaching of zinc from the alloy.
- The metastable conditions of the artefacts indicated the beneficial effects of the stable phosphate corrosion products, despite the presence of chloride ions in the burial soil and the poor environmental conditions in the storage area.
- The investigation of the internal corrosion was complementary to that of external corrosion and helped in providing complete information about the corrosion of these artefacts.
- The MiCorr application was effective in diagnosing and creating the stratigraphic representations for the corrosion structures of the two brass artefacts. These corrosion stratigraphy representations and accompanying information will form two new files which will be added to the MiCorr database and made available to other users.