Neutron and X-Ray Computer Tomography for the Study of Undisturbed Iron Archaeological Artifacts

Elodie Granget[1], Ocson Cocen[1,2], Mahdieh Shakoorioskooie[3], Qianru Zhan[3,4], Anders Kaestner[3], David Mannes[3], Laura Brambilla[1]

[1] Haute Ecole Arc Conservation-Restauration, HES-SO University of Applied Sciences and Arts Western Switzerland
[2] École Polytechnique Fédérale de Lausanne, EDMX-Materials Science and Engineering, Switzerland
[3] Paul Scherrer Institute (PSI), Laboratory for Neutron Scattering and Imaging, Switzerland
[4] Institute for Building Materials (IfB), ETH Zurich, Switzerland

The CORINT project

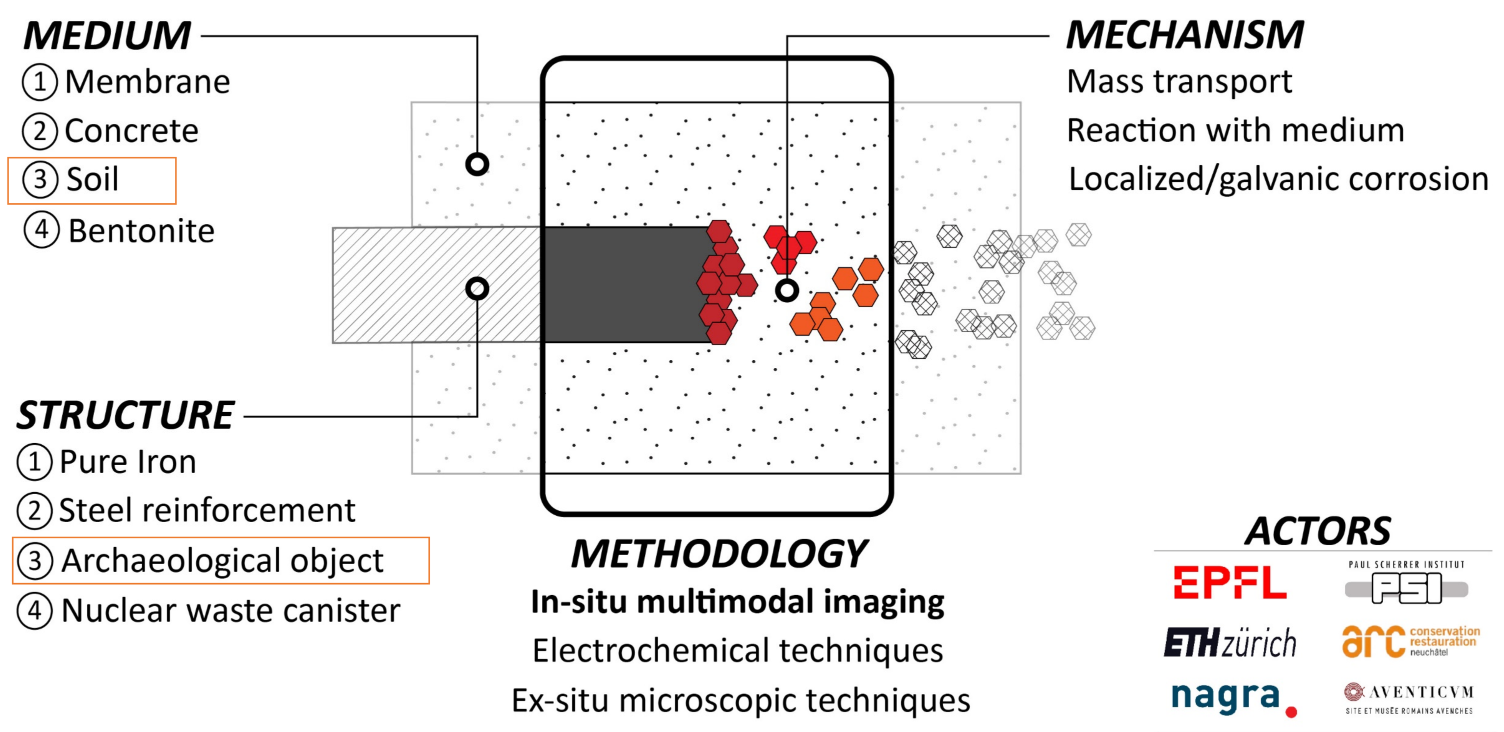

Figure 1: CORINT project plan.

"Elucidating **Cor**rosion by **In**-situ **T**omography" aims to make a breakthrough in fundamental understanding of **iron corrosion process** occurring in **opaque porous media**.

Part of the project includes the study of **Iron Archaeological artifacts (IAA) in the ground**. Their corrosion products developed over a long time in transient conditions are hard to study with traditional methods for multiple reasons:

- **Limited access** while still surrounded by soil.
- **Different** O_2 and H_2O concentration **before** vs. **after excavation.**
- **Corrosion products** may **transform** → relevance of traditional analyses results with soil removal?

Therefore, some questions related to their evolution from the ground to the museum display are still partially unanswered.

Methodology

- Development of a multimodal Quantitative tomography.
  - ✓ Neutron and X-Ray computed tomography (N&X-CT).
  - ✓ Data fusion and Machine Learning (ML) applied to corrosion product identification on tomograms.
- Ex-situ characterization pre- and post-excavation (HE-Arc)
  - ✓ Raman, SEM-EDS, Optical microscopy
  - ✓ Data for ML

Objective

- Characterize IAA's in-situ, undisturbed state.
- Follow alterations occurring on IAA throughout conservation and handling stages.
- Quantify changes in corrosion products.

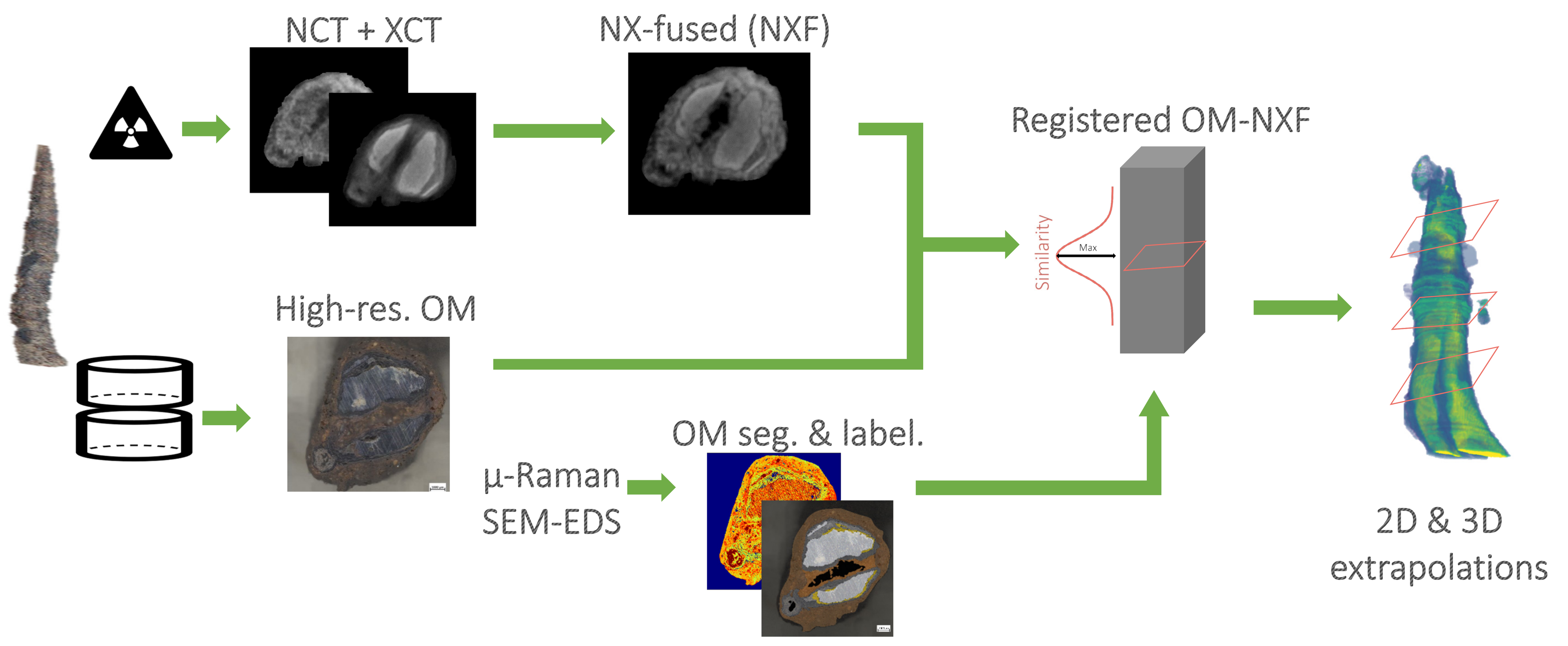

Figure 2: Workflow for multimodal quantitative N&X-CT

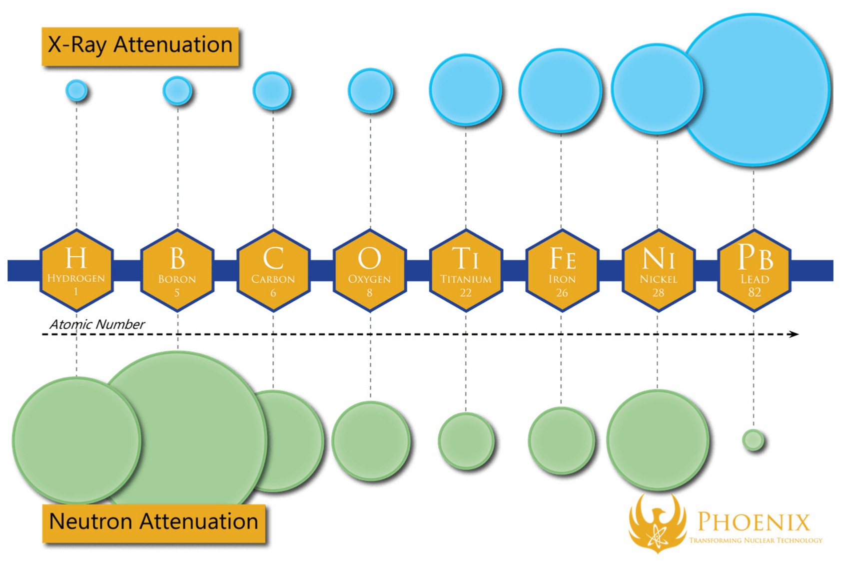

Figure 3: X-Ray and Neutron attenuation of various elements ©Phoenix

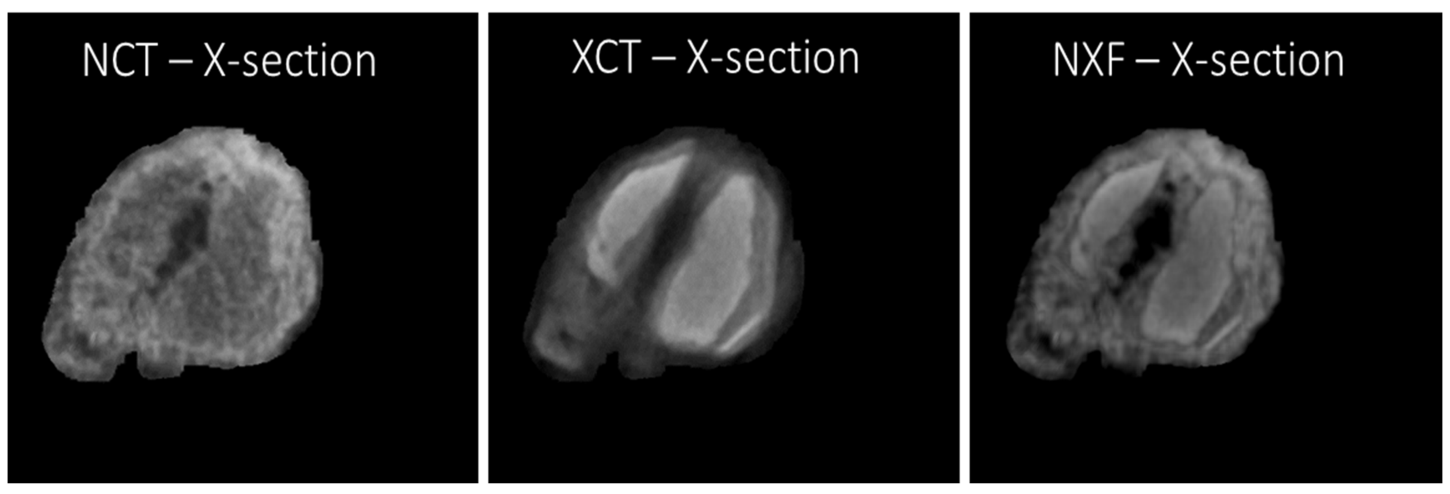

Figure 4: Slice of X-Ray, Neutron and Fused Tomograms (NXF) of IAA

N&XCT

Neutrons and X-Rays are attenuated differently by matter.

- X-Ray attenuation increases with atomic number
- Neutron attenuation is not related to atomic number

Combining both imaging techniques into fused tomograms (NXF) allows for new emergence of new features (Figure 4).

Excavation
- Site in *Bois de Châtel* (CH)
- Sampled with soil
- Stored in O_2-free bags

1st Tomograms
- PSI, SINQ, NEUTRA
- NCT
- XCT

Experiments
- 2 levels of treatment
- Various environments

2nd Tomograms
- PSI, SINQ, NEUTRA
- NCT
- XCT

Visualization
- Tomograms compared (Figure 5)
- Display corrosion product displacement with magnitude and orientation

Analysis
- The displacement vector field = point movement from "before" to "after" positions
- Spatial map of the Jacobian determinant = local volumetric changes. (Figure 6)

Conclusion
- Enhances understanding of nail reactivity, facilitating the comparison of various treatments.

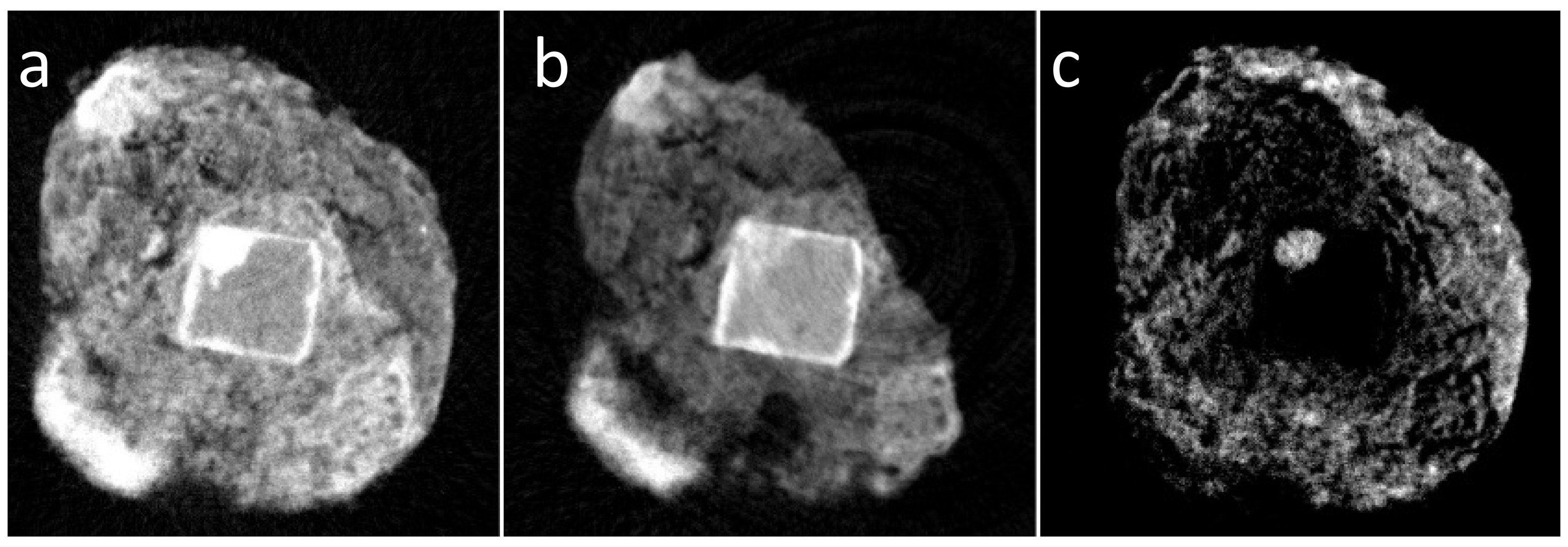

Figure 5: Neutron CT slice. a) before, b) after and c) attenuation difference between time points of nail with adhering soil brushed off and dried at 60°C for 3 days.

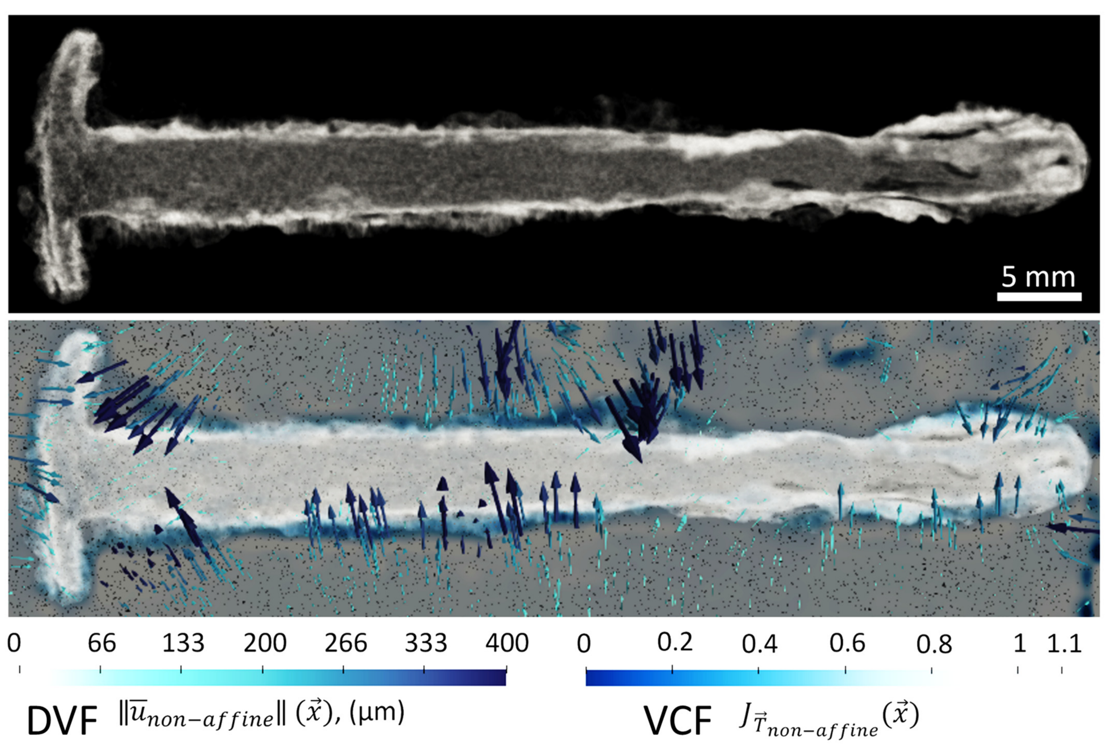

Figure 6: Visualization on a NCT slice of Displacement Vector Field (DVF) and Volume Change Fraction (VCF). Quantify shrinkage after drying in oven.

This is an ongoing project, follow the progress on our website
https://corrosion-corint.ch/

Contact author: elodie.granget@he-arc.ch

The authors greatly acknowledge the funding of the CORINT project by the Swiss National Science Foundation
Grant number: 205883