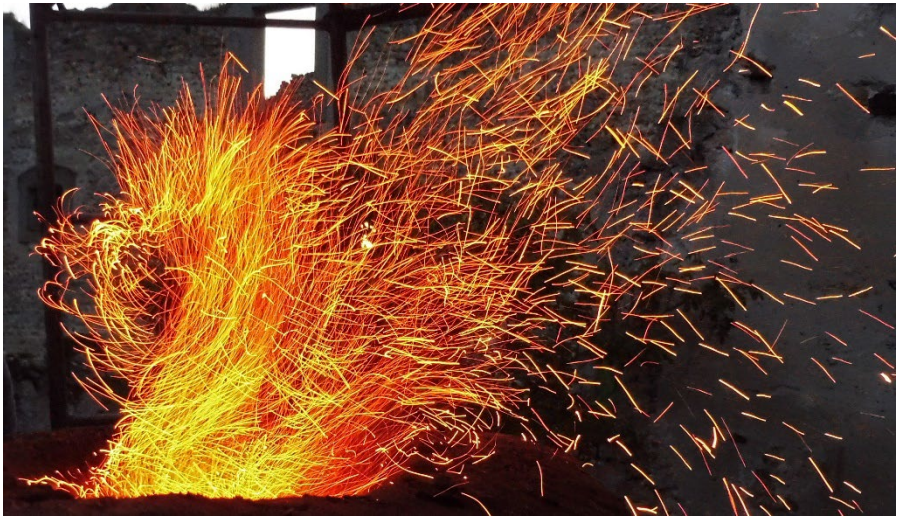
Paleometallurgy/Conservation: Complementarity or Antagonism? Towards Conservation 2.0 for Metallic Objects



A WORKSHOP, OCTOBER 23 – 24, 2023, JERUSALEM

Under the auspices of: the French Centre National de la Recherche Scientifique (**CNRS**), the Centre de Recherche Français à Jérusalem (**CRFJ**) and the Israel Antiquities Authority (**IAA**).

With the par cipa on of the Laboratoire Archéométrie et Prévision de l'Altéra on (**LAPA-NIMBE/IRAMAT, CNRS, CEA, Université Paris-Saclay**).

Day 1: Israel Antiquities Authority National Campus of Archaeology (IAA), Rupin St 11, Jerusalem.
Day 2: French Research Center in Jerusalem (CRFJ), Shimshon St 3, Baaka, Jerusalem.

Organization/contacts:

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Workshop Program

Day 1: 23/10/2023 - IAA Building, Jerusalem

9:00: Arrival/welcome of participants, coffee
9:45: Welcome speech: Dr. Yuval Baruch, Head, IAA Archaeological Division
10:00-11:00: Philippe Dillmann: 'Determining the corrosion processes on archaeological iron: from analogue studies to conservation issues'.
11:00-11:30: Break
11:30-12:30: Delphine Neff: 'New approaches to the conservation and stabilization of metallic objects'.
12:30-13:00: Discussion
13:00-14:30: Lunch
14:30-15:00: Adi Eliyahu-Behar and Naama Yahalom-Mack: 'Preservation of Iron in Archaeological Sites of the Southern Levant: A View from the 1st Millennium BCE'.
15:00-15:30: Erez Ben-Yosef: 'Analyzing copper-based alloys: opting for destructive'.
15:30-16:00: Sylvain Bauvais: 'Setting up research into iron paleo-metallurgy in France and Israel'.
16:00-17:00: Discussion

Lunch for organizers and guests

Day 2: 24/10/2023 - CRFJ, Jerusalem

9:00: Arrival/welcome of participants, coffee
9:45: Welcome speech: Pr. François-Xavier Fauvelle, Director of the CRFJ
10:00-10:30: Yarden Pagelson: 'The Utilization of Iron in Roman Iudaea: From Microstructures to Economics'
10:30-11:00: Joppe Gosker, Sylvain Bauvais and Mónika Schönléber: 'Saladin's mace?'
11:00-11:30: Yoav Bornstein, Assaf Yasur-Landau, Thomas E. Levy and Tzilla Eshel: 'Seven wrought-iron blocks from Iron Age underwater excavations at Tel Dor: Approaching the research with conservation in mind'
11:30-12:00: Helena Kupershmidt, Ilia Reznitsky, Ilan Naor and Ayelet Ram-Grinstein: 'Finding the balance between conservation and research'
12:00-12:30: Mimi Lavi: 'Double, double toil and trouble: two huge bronze cauldrons from Tel Lachish, Israel'
12:30-14:00: Lunch
14:00-15:00: Discussion

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Abstracts

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Day 1

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Determining the corrosion processes on archaeological iron: from analogue studies to conservation issues

Philippe Dillmann[1]

1 CNRS Research Director, Laboratoire Archéomatériaux et Prévision de l'Altération, NIMBE/ IRAMAT, CNRS,CEA, Université , France

Understanding the century-long corrosion of iron-based archaeological artifacts is a crucial aspect in developing efficient conservation and restoration strategies. Furthermore, for modeling the behavior of materials intended for century-long applications, such as steel containers for the safe storage of nuclear waste, archaeological artifacts can be regarded as analogs. The long-term corrosion of iron alloys involves a complex succession and interaction of processes that depend on the environment, the nature of the material, and the physico-chemical characteristics of the thick corrosion layers that form on these artifacts over centuries. To unravel this complexity, it is essential to employ multi-scale characterization methods on cross-sectional samples taken from the objects. In some cases, processes at the nanometer scale play a significant role in controlling corrosion rates. This presentation will address these various aspects and provide examples of corrosion processes in different environments. Additionally, it briefly discusses the archaeological and historical information that can be gleaned from the corrosion products. Lastly, important concepts, such as that of the original surface, will also be touched upon.

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New approaches to the conservation and stabilisation of metallic objects

Delphine Neff[1]

1 CEA Research Director, Laboratoire Archéomatériaux et Prévision de l'Altération, NIMBE – IRAMAT, CNRS, CEA, Université Paris-Saclay, France

The conservation of metallic cultural heritage is a societal issue. Research projects are developed to understand the physico-chemical processes involved in the long term decay of ancient metals and during the conservation treatments. The special feature of old metal objects is that the layers of corrosion products must be preserved because they contain information about the object's original surface. Protection of ancient metallic artefacts is based on desalinisation treatments on one side and protection treatments on the other side.

The desalinisation treatments are connected to the presence of chlorinated phases inside the corrosion layers that endanger the archaeological artefacts when they are reexposed to air after their excavation. The description of the corrosion layers formed during the burial period and the location of the chlorine phases inside them is a key point to optimise the dechlorination treatments. These treatments are mainly conducted in alkaline baths. However some parameters like the aeration state of the solution as well as the temperature can be optimised. Specifically these treatments can be conducted in subcritical conditions (temperature above 100°C under few tenth bars) in order to accelerate the treatment from several months to few days.

The protection treatment aim to improve the corrosion resistance after the restoration. They are based on the use of organic compounds to prevent the artefacts from further corrosion. These treatment are coatings, inhibitors and/or converters that modify the surface properties of the corroded artefacts. The crucial issues are to develop green protection treatments to preserve the users and the environment. Among them carboxylic compounds applied via a sol-gel process are developed.

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For both desalinisation and protection treatment the description of the corrosion layers and their interaction with the chemicals used (alkaline solution, organic compounds etc…) is of primary importance to understand the physico-chemical processes involved. At the NIMBE/LAPA laboratory, multiscale and multitechniques analyses and recorrosion experiments in marked media are performed in order to study these processes involved in both stabilisation and protection of cultural heritage metals.

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Analyzing copper-based alloys: opting for destructive

Erez Ben-Yosef[1]

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The analytical study of copper-based archaeological artifacts provides important insights on various topics concerning ancient societies, including social structure, trade connections, technological evolution, and more. Analytical techniques have evolved significantly over the years, offering non-destructive methods that yield data while preserving the integrity of the artifacts (e.g., pXRF, LA-ICP-MS, etc.).

Notwithstanding these methods and their increasing accessibility to archaeological research, in this paper I argue that destructive analysis is still necessary for achieving reliable and significant insights. I also argue that while referring to such analyses as "destructive" is technically correct, in practice the damage to the artifact is minimal, and in many senses negligible. This is an important point, as barriers to research can rise from merely using the "destructive" terminology, which immediately and even unwittingly creates tension between the researcher and the conservator.

When considering the application of destructive methods, two issues need to be addressed: (1) the museological value of the artifact, which, arguably, lies in its aesthetic, and (2) the availability of the artifact for future research, which is mostly related to the availability of its original material for future studies. My main argument is that in the vast majority of cases these two issues can be easily addressed. Accordingly, when proper documentation is done prior to sampling (preferably high-resolution 3D scanning), there is no justification for any restriction on conducting the typical destructive analyses needed for extracting valuable information from copper-based archaeological artifacts.

Using several case studies from our archaeometallurgical laboratory at Tel Aviv University I will demonstrate the importance of destructive analysis for

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achieving reliable results and the minimal damage incurred by a typical such analysis (namely, drilling). The examples include Chalcolithic mace heads and axes, Nabataean coins, and Egyptian figurines. Methods to reduce damage and to restore the objects to their original form will also be presented.

Thousands of artifacts, located in museums and storage rooms, hold invaluable information about our past, access to which is frequently denied by curators and conservators. The points mentioned above are presented as an initial step towards fostering discussions that will, hopefully, enhance access to this information. Its significance to our society is, at the very least, equal to the preservation intentions of the artifact guardians.

Preservation of Iron in Archaeological Sites of the Southern Levant: A View from the 1st Millennium BCE

Adi Eliyahu-Behar[1] and Naama Yahalom-Mack[2]

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[2] Institute of Archaeology, Biblical archaeology department, Hebrew University of Jerusalem Israel

The study of iron objects from archaeological contexts holds significant importance for the study of forging skills and technological advancements. However, corrosion present a challenge in gathering data related to these aspects. This paper discusses the preservation state of iron artifacts recovered from Iron Age contexts in the southern Levant, building upon the microscopic analysis of c. 60 objects. It has been found that objects dating to the Iron Age generally exhibit poor preservation, characterized by extensive corrosion and noticeable swelling due to oxidation. The latter sometimes render object unidentifiable. Examination of the microstructure often reveals three distinct zones, with secondary exterior corrosion layers, incorporating foreign materials like quartz, calcite grains, and occasional pseudomorphs of vegetal matter, a central zone exhibiting a black, shiny surface, and the artifact's core, typically lacking recognizable micro-structure or completely lost to corrosion, leaving a cavity. The central black, shiny zone is of primary interest due to its relative preservation. It is here that pseudomorphs indicative of the original metallic structure can be observed, as well as microscopic islands of metallic iron. Notably, several well-dated iron artefacts exhibit remarkably good preservation, among them arrowheads recovered from a cremation burial in Hazor. This phenomenon is yet to be explained.

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Setting up research into iron paleo-metallurgy in France and Israel

Sylvain Bauvais[1,2]

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2 Laboratoire Archéomatériaux et Prévision de l'Altération, NIMBE/IRAMAT, CNRS, CEA, Université Paris-Saclay, France

Since the early 2000s, research into iron paleometalurgy in France has developed considerably, with a number of PhD theses and collective research programmes. This research has been developed through numerous archaeological excavations of production sites (primary and secondary), both programmed and, above all, preventive. In terms of archaeometric approaches, we have also developed specific study protocols for the different materials resulting from these excavations. In particular, the typomorphological and micrographic study of forge slag has been one of the crucial contributions of the last twenty years to the compression of the 'chain of operations' in iron metallurgy. The development of provenance approaches for ferrous products has also been one of the most important developments of recent decades. Finally, the possibility of radiocarbon dating steel products has opened up new perspectives for understanding the exchange and use of iron in societies.

Does the strong and intense development, which has taken place in France and the countries of North-Western Europe, stem from a particular research context? If so, how can we characterise it, and how can we explain the fact that this phenomenon did not develop until much later, particularly in Israel.

This paper will attempt to explore the disparity between research into iron paleometalurgy in France and Israel. It will attempt to put forward proposals for development and partnership between our two archaeological research systems, which are among the most highly developed in the world.

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Day 2

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The Utilization of Iron in Roman *Iudaea*: From Microstructures to Economics

Yarden Pagelson[1]

[1] *PhD Candidate, Ben-Gurion University of the Negev*

Recent decades have seen a growth in archaeometallurgical studies in Isreal, including iron and steel metallurgy. From the beginning, these have tended to focus on the onset of iron metallurgy during the eponymous Iron Age (Eliyahu-Behar et al., 2013; Eliyahu-Behar and Yahalom-Mack, 2018; Stech-Wheeler et al., 1981). More recently, attention has been given to subsequent periods up to modern times. However, so far, the Roman Period has received little attention (Knox et al., 1983), despite being a notable period both in terms of the volume of sites and modern interest, which in combination have yielded many excavations and, as a result, artifacts.

Recently, a study has been performed to examine various aspects of iron metallurgy in Roman Iudaea. Taking advantage of the large number of artifacts, sampling focused on selecting specific test cases of artifacts from well-dated and, most importantly, well-preserved contexts. In this talk, preliminary results of the metallographic analysis will be presented, constituting a foundation for a broader discussion of the semi-products used by blacksmiths, recycling occurrences, and the period's iron economy.

Citation List:

Eliyahu-Behar, A., Yahalom-Mack, N., 2018. Reevaluating Early Iron-Working Skills in the Southern Levant through Microstructure Analysis. J. Archaeol. Sci. Rep. 18, 447–462. https://doi.org/10.1016/j.jasrep.2018.01.040

Eliyahu-Behar, A., Yahalom-Mack, N., Gadot, Y., Finkelstein, I., 2013. Iron Smelting and Smithing in Major Urban Centers in Israel during the Iron Age. J. Archaeol. Sci. 40, 4319–4330. https://doi.org/10.1016/j.jas.2013.06.009

Knox, R., Maddin, R., Muhly, J.D., 1983. Iron Objects from Masada: Metallurgical Studies. Isr. Explor. J. 33, 97–107.

Stech-Wheeler, T., Muhly, J.D., Maxwell-Hyslop, K.R., Maddin, R., 1981. Iron at Taanach and Early Iron Metallurgy in the Eastern Mediterranean. Am. J. Archaeol. 85, 245–268. https://doi.org/10.2307/504169

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Saladin's mace?

Joppe Gosker[1], *Sylvain Bauvais*[2, 3] *and Mónika Schönléber*[4]

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[4] *Research Fellow, Avicenna Institute of Middle Eastern Studies, Hungary*

Analyzes on an iron mace from Vadum Yacov have delivered some remarkable results. The fortress of Vadum Iacov, excavated by the late Roni Ellenblum, was conquered and destroyed by the army of Saladin in 1179 AD. A treatise on weapons written for Saladin discusses the production of maces in detail. With the object and the text so well aligned we decided to translate the original Arabic text to English and investigate the object in greater detail. The unexpected results are a reminder that in archaeology you never know what you will find: could this mace have been gilded?

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Seven wrought-iron blocks from Iron Age underwater excavations at Tel Dor: *Approaching the research with conservation in mind*

Yoav Bornstein[1], Assaf Yasur-Landau[1, 2], Thomas E. Levy[2, 3] and Tzilla Eshel[1, 4]

[1] *School of Archaeology and Maritime Cultures, University of Haifa*
[2] *Recanati Institute for Maritime Studies, University of Haifa*
[3] *Center for Cyber-Archaeology and Sustainability, Qualcomm Institute, University of California, San Diego*
[4] *Zinman Institute of Archaeology, University of Haifa*

In May 2023 an underwater excavation was held at Tantura bay next to Tel Dor. During the excavation, seven heavy (5-10 kg) block-shaped artifacts covered with a layer of sediment have been recovered. Surrounding these artifacts, pottery dating to the 7th century BCE was identified, suggesting that this may have been a cargo of a wreckage or evidence of intense harbor activities. While the artifacts are undergoing desalination, microscopic, FTIR, and ED-XRF analyses were conducted on sediment pieces that were detached during the extraction process. In addition, all artifacts were scanned in a computed tomography (CT) scanner. It became evident that the artifacts are made of iron and the desalination process was adjusted accordingly. The CT scan gave further indication on the internal structure, showing a less dense core vs the outer parts. This helped to determine the section that will be extracted for metallurgical research, and to compare between the artifacts, showing that they have similar internal density structures thus minimizing the planned destructive analyses. This observation is significant as unprocessed wrought iron is rare in the archaeological record of the Iron Age; most were found so far in Europe while none were found in the Levant.

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Finding the balance between conservation and research

Helena Kupershmidt[1], Ilia Reznitsky[2], Ilan Naor[2] and Ayelet Ram-Grinstein[2]

[1] *Head, Metals Conservation Laboratory, Israel Antiquities Authority*
[2] *Conservators, Metals Conservation Laboratory, Israel Antiquities Authority*

The Metal conservation laboratory of IAA treats tens of thousands of different archaeological metal objects and coins representing a rich and varied cultural heritage.

The conservation of ancient finds is a responsibility shared between several different professions, conservators, archaeologists and researchers, each participating group has different needs and views regarding the conservation goals and standards including metallurgical data.

The use of analytical tools helps us understand the structure, corrosion pattern and material of an object and help us reach a better decision regarding its treatment.

This paper aims to demonstrate our long-term experience of cooperation between conservators, archaeologists and researchers and discuss how to improve it to make preservation more effective and widely understood.

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Double, double toil and trouble: two huge bronze cauldrons from Tel Lachish, Israel

Mimi Lavi[1]

[1] *Head, Conservation Laboratory, The Institute of Archaeology, Hebrew University of Jerusalem Israel*

In 2015, in the excavations of Tel Lachish, two huge bronze cauldrons were discovered. The cauldrons, which were found one on top of the other, were located under the threshold of the Canaanite temple. The conservators of the Institute of Archaeology of the Hebrew University of Jerusalem were involved in the excavation and care of the cauldrons from the very first moment of their exposure in the field, during the research, and their preparation for museum display. The conservation work of the two objects was long and intensive and included new and creative methods of treating the object and stabilizing the material. In the lecture, we will talk about the special challenges that the cauldrons presented and the solutions created to deal with them.

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Notes:

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