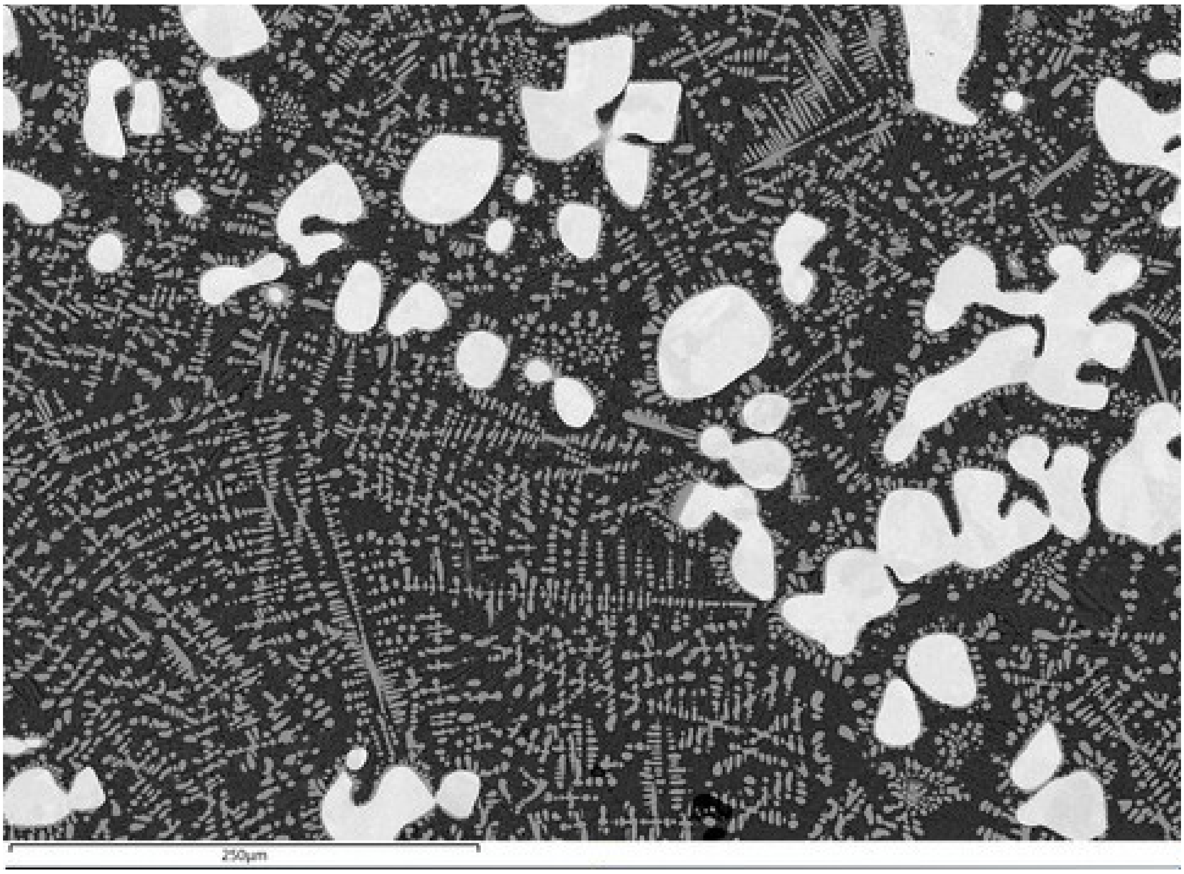
ARCL0098
Archaeometallurgy
2023/24

Term I, 15 Credits, MSc Option
Lectures: Thursday 4-6, Rm B13
Seminars/Practicals: Fridays 2-4, Rm B13



Co-ordinator: Mike Charlton
With contributions from Miljana Radivojević

m.charlton@ucl.ac.uk
Office 210, Tel 020 7679 7498
Office Hours: Fridays 2-3 or by appointment

Assessment deadlines for this module:
1. Data Exercise, Term I, 9 November 2023
2. Standard Essay, Term II, 12 January 2024

IMPORTANT INFORMATION REGARDING ASSESSMENTS:

The **coursework coversheet** is available on the course Moodle pages and here: under "Policies, Forms and Guidelines".

Please enter **your five-digit candidate code on the coversheet and *in the subject line*** when you upload your work in Moodle.

Please use **your five-digit candidate code as the name of the file** you submit.

Please refer to the IoA Student Handbook and IoA Study Skills Guide for instructions on coursework submission, IoA referencing guidelines and marking criteria, as well as UCL policies on penalties for late submission, over-length work and academic misconduct.

The use of software to generate content is not allowed for assessments for this course and will be penalised; the use of software for language and writing review and improvement is permitted, and the software and the way it has been used must be indicated in the relevant boxes on the coursework coversheet. UCL defines language and writing review as checking "areas of academic writing such as structure, fluency, presentation, grammar, spelling, punctuation, and language translation".

1 MODULE OVERVIEW

Module description

The module includes a brief introduction to the concept of metals as a specific class of material, with considerable diversity in properties. It covers some of the basic chemical and physical processes relevant to the primary production of metal, including the principles of ore reduction, slag formation, alloying, refining, and plastic deformation by hot and cold-working. While copper/bronze and iron/steel take centre stage as the most abundant metals in antiquity, individual sessions will address the less common metals and alloys. Examples are drawn from Africa, North and South America, Asia, and Europe spanning the Neolithic through the the start of the industrial age. Current research projects carried out at the UCL Institute of Archaeology will also be highlighted.

Module Aims

- Understand the physical and chemical processes of per-industrial metallurgy.
- Be able to identify different kinds of metallurgical residues.
- Know the basic microstructural and chemical properties of metallurgical residues
- Understand the evolution of preindustrial metallurgy in different parts of the world-wide
- Be aware of the major sources of theoretical discourse linking to archaeometallurgy to broader archaeological concerns

Learning Outcomes

On successful completion of this module students should be acquainted with the general trends of technical and social development in relation to metals. Furthermore, they should have acquired an in-depth understanding of the fundamental physical principles of metallurgy at a level sufficient to undertake guided research in ancient metallurgy, e.g. for their MSc thesis. With a view to being possibly confronted, during later professional practice, with material related to metallurgical activities, students should understand the general outlines of regional and chronological developments in metallurgy. They should recognise relevant evidence such as slags and technical ceramics. In particular, they should be able to pose educated questions leading to a scientific investigation of such remains, and be able to critically evaluate and interpret different types of results and reports following archaeometric studies.

Methods of Assessment

This module is assessed by means of a metallurgical data exercise (counting 40% towards your final mark) and an academic essay of 2000 words (counting 60%). The topics and deadlines for the essay, as well as further notes, are specified below. If students are unclear about the nature of an assignment, they should contact the module co-ordinator. The module co-ordinator is willing to discuss an outline of their approach to the assessment, provided this is planned suitably in advance of the deadline. Students are welcome to suggest their own essay topics, but these should always be agreed with the module co-ordinator in advance.

Communications

- **Moodle is the main hub** for this course.
- Important information will be posted by staff in the **Announcements section of the Moodle page** and you will automatically receive an email notification for these.
- Please post any general queries relating to module content, assessments and administration **in the Moodle Q&A**. The forum will be checked regularly.
- For personal queries, please contact the co-ordinator by email.

Week-by-week summary

Week	Thursdays	4-6 lecture	Practicals Friday 2-4
1	5 Oct	Introduction: Minerals, Metals, and People (MC)	Minerals and metals – hands on Using ternary diagrams
2	12 Oct	Principles of smelting and slag formation (MC)	Video: Inagina: The Last House of Iron; Rocks, ore, and slag
3	19 Oct	The inception and transmission of metallurgy (MR)	Experimental video copper slag data exercise
4	26 Oct	Crucibles, furnaces, copper, and copper alloys (MR)	Metallography (EB)
5	2 Nov	Bloomery smelting and ferritic iron(MC)	Review of slag and metal phases
6	**6-10 November—READING WEEK**		***Data Exercise 9 November***
7	16 Nov	Steel and cast iron(MC)	Video: Ancient Iron: Experimental Archaeology in Sudan
8	23 Nov	Lead, Silver, and Gold (MC, FR?)	Metals Provenance analysis working with data
9	30 Nov	Zinc and brass (MC) module evaluations	Collecting metallurgical chemistry SEM and pXRF
10	7 Dec	Casting and metalworking (JB)	*General Review*
11	14 Dec	Module feedback; Economics of metallurgy (MC)	British Museum Tour

Lecturers (or other contributors): Mike Charlton (MC), Miljana Radivojević (MR), Justine Bailey (JB), Ellie Blakelock (EB)

Weekly Module Plan
The module is taught through lectures and discussions. Students will be required to undertake set readings, complete pre-class activities and make (non-examined) short presentations of case study material in order to be able to actively participate in the discussion.

Thursday 1600-18.00: Live seminar discussions
Friday 12.00-14.00 Practical sessions
Wed: deadline to complete discussion board activity;

Workload
This is a 15-credit module which equates to 150 hours of learning time including session preparation, background reading, and researching and writing your assignments. With that in mind you should expect to organise your time in roughly this way:

20 hours	*Staff-led teaching sessions (lectures, seminars, tutorials, discussion-board sessions)*
10 hours	*Practicals*
50 hours	*Self-guided preparation*
25 hours	*Reading for, and writing, metallurgical data exercise*
45 hours	*Reading for, and writing, the research essay*

2 ASSESSMENT

Each assignment and possible approaches to it will be discussed in class, in advance of the submission deadline. If students are unclear about the nature of an assignment, they should discuss this with the module co-ordinator in advance (via office hours or class Moodle forum). You will receive feedback on your written coursework via Moodle, and have the opportunity to discuss your marks and feedback with the co-ordinator in their office hours.

For more details see the 'Assessment' section on Moodle. The IoA marking criteria can be found in the IoA Student Handbook (Section 12: Information on assessment). The IoA Study Skills Guide provides useful guidance on writing different types of assignment. For **penalties for late submission** see UCL guidance on penalties (Academic Manual Chapter 4 Section 3.12).

Assessment 1: Metallurgical data exercise
This assessment consists of 15 sets of characterisation data (micrographs and compositions) for common metallurgical residues found in the archaeological record. Within 1500 words, you are asked to 1) identify the metal/alloy associated with the data; 2) identify the technological process involved, and 3) provide a brief rationale for the identification, including any ambiguities. This assessment counts toward 40%

of your total mark and is due on ***9 November***. It covers material discussed through week 5 and will be made available at the beginning of the same.

Assessment 2: Standard Essay
The second assignment will be an essay of 2000 words, counting 60% towards the final mark. The deadline for this is ***12 January***. Essay topics are negotiable, and students are encouraged to suggest their own. The writing assignment is the following: "***Present an argument that supports, rejects or modifies the given thesis, and support your response with factual evidence***". You are given a choice of controversial theses that brings this module's subject matter into problematic focus. These are designed to prompt you to take a strong stand and focus on problem-based rather than topic-based writing.

What follows is a list of potential titles, with some introductory reading, but you will be expected to carry out further bibliographic research. In all cases, it is expected that students will combine their own ideas with reference to published case studies.

Please make sure that your essay is well-structured (including subheadings), and try to show some originality or insight: having done your literature review... where do we go from here? what are the main questions remaining? who do you agree or disagree with, and why?

Like the rest of the bibliographic references in this handbook, most of the references below are available online. Please consult with the module coordinator if you need further guidance

<u>Southeast Asian metallurgy represents the spread of Chinese production practices</u>

Murillo-Barroso, M., Pryce, T. O., Bellina, B. and Martinón-Torres, M. 2010. Khao Sam Kaeo – an archaeometallurgical crossroads for trans-asiatic technological traditions. Journal of Archaeological Science 37(7), 1761-1772.

Pigott, V. C. and Ciarla, R. 2007 On the origins of metallurgy in prehistoric Southeast Asia: the view from Thailand 76-88, in La Niece, S., Hook, D.R., and Craddock, P.T. (eds) Metals and Mines - Studies in Archaeometallurgy, London, Archetype, British Museum.

Pryce, T. O., Pigott, V. C., Martinón-Torres, M. and Rehren. Th. 2010. Prehistoric copper production and technological reproduction in the Khao Wong Prachan Valley of Central Thailand. Archaeological and Anthropological Sciences 2, 237-264.

White, J. C. and Hamilton, E. G. 2009.The Transmission of Early Bronze Technology to Thailand: New Perspectives. Journal of World Prehistory 22, 357-397.

<u>Experimental archaeometallurgy is the best means of exposing past metallurgical practices.</u>

Bareham, T. 1994. Bronze casting experiments. Historical Metallurgy 28 (2), 112-116.

Charlton, M., Humphris, J., 2019. Exploring ironmaking practices at Meroe, Sudan—a comparative analysis of archaeological and experimental data. Archaeol. Anthropol. Sci. 11, 895–912. https://doi.org/10.1007/s12520-017-0578-2

Crew, P. 1991. The experimental production of prehistoric bar iron. Historical Metallurgy 25, 21-36.

Pryce. T. O., Bassiakos, Y., Catapotis, M. and Doonan, R. C. 2007. 'De Caerimoniae'. Technological choices in copper-smelting furnace design at Early Bronze Age Chrysokamino, Crete. Archaeometry 49 (3), 543-557.

Metallurgy in the Americas follows the same developmental pathways as those in Eurasia

Aldenderfer, M., Craig, N. M., Speakman, R. J. and Popelka-Filcoff. R. 2008. Four-thousand-year-old year old gold artifacts from the Lake Titicaca basin, southern Peru. Proceedings of the National Academy of Sciences 105(13): 5002-5005.

Maldonado, B., Rehren, Th. and Howell, P. 2005. Archaeological copper smelting at Itziparatzico, Michoacan, Mexico, in Vandiver, P., Mass, J., Murray, A. (eds) Materials Issues in Art and Archaeology VII. Materials Research Society Sumposium Proceedings 852 series. Warrendale, PA: Materials Research Society, 231-240.

Schultze, C. A., Stanish, C. Scott, D. A., Rehren, Th., Kuehner, S. and Feathers, J. K. 2009. Direct evidence of 1,900 years of indigenous silver production in the Lake Titicaca Basin of Southern Peru. Proceedings of the National Academy of Sciences USA 106(41), 17280-17283.

Shimada, I., Gordus, A., Griffin, J. A. and Merkel, J. F. 1999. Sicán alloying, working and use of precious metals: an interdisciplinary perspective, in S. M. M. Young, A. M. Pollard, P. Budd and R. A. Ixier (eds), Metals in Antiquity (BAR-IS 792). Oxford: Archaeopress.

Metals can be accurately provenanced

Blakelock, E., Martinón-Torres, M., Veldhuijzen, H.A. and Young, T. 2009. Slag inclusions in iron objects and the quest for provenance: an experiment and a case study. Journal of Archaeological Science 36, 1745-1757.

Charlton, M.F., 2015. The last frontier in 'sourcing': the hopes, constraints and future for iron provenance research. J. Archaeol. Sci. 56, 210–220. https://doi.org/10.1016/j.jas.2015.02.017

Coustures, M.P., Béziat, D., Tollon, F., Domergue, C., Long, L., Rebiscoul, A., 2003. The use of trace element analysis of entrapped slag inclusions to establish ore - Bar

Iron links: Examples from two Gallo-Roman ironworking sites in France (Les Martys, Montagne Noire and Les Ferrys, Loiret). Archaeometry 45, 599-613.

Radivojević, M., Roberts, B., W., Pernicka, E., Stos-Gale, Z. A., Martinón-Torres, M., Vandkilde, H., Ling, J., Brandherm, D., Bray, P., Mei, J., Kristiansen, K., Rehren, Th., Shennan, S., and Broodbank, C. (2019). The provenance, use and circulation of metals in the European Bronze Age: The state of debate. Journal of Archaeological Research 27, doi:https://doi.org/10.1007/s10814-018-9123-9

Schwab, R., Heger, D., Hoppner, B. and Pernicka, E. 2006. The provenance of iron artefacts from Manching: a multi-technique approach. Archaeometry 48, 433-452.

Wood, J.R., Charlton, M.F., Murillo-Barroso, M., Martinón-Torres, M., 2017. Iridium to provenance ancient silver. J. Archaeol. Sci. 81, 1–12. https://doi.org/10.1016/j.jas.2017.03.002

There was only one recipe for producing tin bronzes in prehistory

Farci, C., Martinón-Torres, M., Álvarez, D.G. 2017. Bronze production in the Iron Age of the Iberian Peninsula: The case of El Castru, Vigaña (Asturias, NW Spain). Journal of Archaeological Science: Reports 11, 338-351.

Dungworth, D. 2000. Serendipity in the foundry? Tin oxide inclusions in copper and copper alloys as an indicator of production process. Bulletin of the Metals Museum 32: 1-5.

Rostoker, W., McNallan, M. and Gebhard, E. R. 1983. Melting/smelting of bronze at Isthmia. Historical Metallurgy 17: 23-26.

Zhou, W., Chen, J., Lei, X., Xu, T., Chong, J. and Wang, Z. 2009. Three Western Zhou bronze foundry sites in the Zhouyuan area, Shaanxi province, China, in J. Mei, and Th. Rehren (eds), Metallurgy and Civilisation. Eurasia and Beyond,62-72. London: Archetype.

Iron in Africa was an independent invention

Alpern, S. B. 1994. Did They or Didn't They Invent It? Iron in Sub-Saharan Africa. History in Africa 32, 41-94.

Bisson, M., Childs, S. T., de Barros, P. and Holl, A. F. C. 2000. Ancient African Metallurgy: The Socio-cultural Context. Walnut Creek, CA: Altamira Press

Holl, A. F. C. 2009. Early West African metallurgies: new data and old orthodoxy. Journal of World Prehistory 22(4), 415-438.

Killick, D. 2004. What do we know about African iron working? Journal of African Archaeology 2(1): 97-112.

3 RESOURCES AND PREPARATION FOR CLASS

Preparation for class

You are expected to read the **essential readings listed below, watch the pre-recorded lectures and complete any online activities on Moodle** each week. Completing the readings is essential for your effective participation in the activities and discussions that we will do, and it will greatly enhance your understanding of the material covered. **Further readings are provided via the online-reading list** for you to get a sense of the range of current work on a given topic and for you to draw upon for your assessments.
Online reading list: *Here*

Recommended basic texts and online resources

There are three books which are particularly useful, as they cover a good deal of the topics of this module. All are suitable for independent reading, sufficiently self-contained, and provide an introduction to the subject as well as offering in-depth follow-up. Unfortunately, the older ones are out of print, but several copies are available in the library. The more recent one is available online, and is an excellent compilation of introductory papers.

Tylecote, R. 1987. The early history of metallurgy in Europe. London and New York: Longman.
ANCIENT HISTORY A 68 TYL, ISSUE DESK IOA TYL 2

Craddock, P. T. 1995. Early metal mining and production. Edinburgh: Edinburgh University Press.
INST ARCH KE CRA, ISSUE DESK IOA CRA 6

Roberts, W. B. and Thornton, C. P. 2014 (eds). Archaeometallurgy in Global Perspective: Methods and Syntheses. New York: Springer.
https://link.springer.com/book/10.1007%2F978-1-4614-9017-3

A detailed introduction to Archaeometallurgy (with a strong British flavour) can be found in the following volume.
Bayley, J., Crossley, D. and Ponting, M. 2008. Metals and metalworking. A research framework for archaeometallurgy. London: Historical Metallurgy Society
INST ARCH KEA Qto BAY, ISSUE DESK IOA BAY 2, or online at: http://hist-met.org/arch_comm.html

HMS Datasheets

The Historical Metallurgy Society produces excellent introductions to archaeometallurgical topics. These are superb starting points for many of the topics covered in this module.

https://historicalmetallurgy.org/publications/hms-datasheets/
(Please consider joining HMS – cheap membership for students!)

Technical ceramics

Crucibles and technical ceramics generally are key elements of archaeometallurgical research. These are some introductory references covering technical ceramics from many periods.

Bayley, J., & Rehren, Th. 2007. Towards a functional and typological classification of crucibles. In: S. LaNiece, D. Hook,&P. Craddock (Eds.), Metals and Mines–Studies in Archaeometallurgy (pp. 46–55). London: Archetype.

Craddock, P. T. 2013. Refractories: ceramics with a purpose. The Old Potter's Almanack 18/2, 9-18.

Craddock, P. T. 2014. Refractories with a purpose II: ceramics for casting. The Old Potter's Almanack 19/1, 2-17.

Freestone, I. C. and Tite, M. S., 1986. Refractories in the ancient and preindustrial world, in W. D. Kingery (ed), High-Technology Ceramics: Past, Present and Future. The Nature of Innovation and Change in Ceramic Technology, 35-63. (Ceramics and Civilization 3). Westerville (OH): The American Ceramic Society.

Kearns, T., Martinón-Torres, M., Rehren, T. 2010. Metal to mould: alloy identification in experimental casting moulds using XRF. Historical Metallurgy, 44 (1), 48-58.

Liu, S., Wang, K., Cai, Q. and Chen, J. 2013. Microscopic study of Chinese bronze casting moulds from the Eastern Zhou period. Journal of Archaeological Science 40 (5): 2402–2414.

Martinón-Torres, M., Rehren, T. 2014. Technical ceramics. In Archaeometallurgy in Global Perspective: Methods and Syntheses, 107-131. Springer New York. Available online.

Rademakers F.W. and Rehren Th. 2016. Seeing the forest for the trees: Assessing technological variability in ancient metallurgical crucible assemblages. Journal of Archaeological Science: Reports 7, 588-596.

Rehren, Th., 2003. Crucibles as reaction vessels in ancient metallurgy, in P. T. Craddock and J. Lang (eds), Mining and Metal Production through the Ages, 207-215. London: The British Museum Press.

Ingots

This is a good reference to follow up our handling session on ingots, as it discusses several types. You will find references to more focused studies on earlier ingots under the readings for each session.

Craddock, P. and Hook, D. 2012. An economic history of the post-medieval world in 50 ingots: the British Museum collection of ingots from dated wrecks. The British Museum Technical Research
Bulletin 6, 55-68.

Some more online resources:

Arch-metals online discussion list. This is an excellent forum to stay informed of archaeometallurgical events, as well as keeping up with ongoing research and debates. You can subscribe here:
https://www.jiscmail.ac.uk/cgi-bin/webadmin?A0=arch-metals

Bibliography for archaeometallurgy by Chris Salter (not up to date!):
http://users.ox.ac.uk/~salter/arch-metals/met-bib-ak.htm

Art and Archaeology Technical Abstracts (AATA):
http://aata.getty.edu/NPS/

In addition to these general resources, the last pages of each issue of the journal ***Historical Metallurgy*** include abstracts of recent archaeometallurgical publications. In this journal, as well as in ***Archaeometry***, the ***Journal of Archaeological Science*** and ***Archaeological and Anthropological Sciences*** you will find many relevant archaeometallurgical studies.

In the reading lists for the different lectures you will find monographs and collections of articles that will be of use as initial sources for your essays. The module Co-ordinator is willing to give you further directions for relevant literature on specific topics, but you are expected (and encouraged) to do your own bibliographic search in preparation for your essays. Don't forget that we expect you to develop (and demonstrate) your research skills!

4 SYLLABUS

Week 1: Introduction—minerals, metals, and people

Mike Charlton

This introductory session will present the outline of this module. In particular, the level of existing knowledge relevant to physical metallurgy and inorganic chemistry will be explored. Also, a range of specialised terminology will be introduced. Then, we will look at the differences between kinds of material, and the specific properties of metals. We may, depending on time and progress, begin to introduce the geological and chemical background to metallurgy.

There is no preparatory reading for this session.

Week 2: Principles of smelting and slag formation

Mike Charlton

Ores, the raw material for metal production, occur in a wide range of different deposits and mineral forms. This session will explore the nature of ores and ore deposits important in the pre-industrial world. We will discuss the treatment of ores, both mechanical (beneficiation) and thermochemical (roasting) that prepare them for the smelting process. Finally, we summarize the smelting process and the formation of slag.

Readings:

Agricola, G., 1950. De Re Metallica. Dover Publications, Inc., New York. (Book II: pp. 25-42).
https://archive.org/details/deremetallica00agri

Rehren, T., Vanhove, D., Mussche, H., 2002. Ores from the Ore Washeries in the Lavriotiki. Metalla 9, 27–46.
https://knappschaft-ausstellung.bergbaumuseum.de/en/archive-metalla/item/metalla-9-1-2002

Week 3: The inception and transmission of metallurgy

Miljana Radivojević

The first two lectures introduced the technical background to identify and understand archaeological remains from extractive metallurgy. Now we turn to questions of more general archaeological interest.

Why was metallurgy invented? How and where did it take place? How many times did this happen? Several explanations have been put forward to address the question of the inception and spread of metallurgy in different areas of the world. In this session, some of the main theories will be addressed, including discussion about the environmental, social and technical stimuli for metallurgy, and theories about technological diffusion versus autonomous developments.

We will also examine the earliest evidence for copper smelting in Europe, presented with the remains of copper slag, malachite beads, ores and artefacts, found in a settlement site in Eastern Serbia dated to ca. 5000 BC.

Readings:

See issues 22/3 and 22/4 of the Journal of World Prehistory for an overview of issues in early metallurgy across the world, and read about your favourite region. If that region is Europe, you can also see the special issue 47/1 of Historical Metallurgy on The origins of metallurgy in Europe.
https://link.springer.com/journal/10963/volumes-and-issues/22-3
https://link.springer.com/journal/10963/volumes-and-issues/22-4

Radivojević, M., Rehren, T., Pernicka, E., Šljivar, D., Brauns, M., Borić, D., 2010. On the origins of extractive metallurgy: New evidence from Europe. J. Archaeol. Sci. 37, 2775–2787. doi:10.1016/j.jas.2010.06.012
https://www.sciencedirect.com/science/article/pii/S0305440310001986

Roberts, B.W., Thornton, C.P., Pigott, V.C., 2009. Development of metallurgy in Eurasia. Antiquity 83, 1012–1022.
https://search.proquest.com/docview/217556466/fulltextPDF/564C231378E74E5DPQ/1?accountid=14511

Week 4: Crucibles, furnaces, copper, and copper alloys

Miljana Radivojević

Since the earliest times, metallurgical remains show a great diversity that is informative of a variety of technological traditions, production scales and sociocultural constraints. Although the process took place after the inception of metallurgy, the development of cost-effective production systems and alloys in several regions during the Bronze Age would lead to more significant processes of craft specialisation and long-distance trade.

In this session, we will use range of case studies to illustrate this variability in metallurgical systems and alloys, as well as the trade of metals and analytical approaches employed to reconstruct all of these.

Readings:

Roberts, B.W., Thornton, C.P., 2014. Archaeometallurgy in global perspective: Methods and syntheses, Archaeometallurgy in Global Perspective: Methods and Syntheses. Doi:10.1007/978-1-4614-9017-3
(chapter 6-technical ceramics)
https://link.springer.com/book/10.1007%2F978-1-4614-9017-3

Ottaway, B.S., 2001. Innovation, production and specialization in early prehistoric copper metallurgy. Eur. J. Archaeol. 4, 87–112.
https://www.tandfonline.com/doi/abs/10.1179/eja.2001.4.1.87

Rehren, T., Boscher, L., Pernicka, E., 2012. Large scale smelting of speiss and arsenical copper at Early Bronze Age Arisman, Iran. J. Archaeol. Sci. 39, 1717–1727. doi:10.1016/j.jas.2012.01.009
https://www.sciencedirect.com/science/article/pii/S0305440312000210

Week 5: Bloomery iron production

Mike Charlton

The discovery of iron, “the democratic metal”, marks the birth of a unique approach to smelting metal in the solid state. Similarly, production required the development of specialised refining practices and sills for exploiting the magical properties that iron imbues. Iron’s economic properties may be more compelling than its material properties, and are linked to many dramatic social changes identified in the archaeological record.

Readings:

Biggs, L., Bellina, B., Martinón-Torres, M., Pryce, T.O., 2013. Prehistoric iron production technologies in the Upper Thai-Malay Peninsula: Metallography and slag inclusion analyses of iron artefacts from Khao Sam Kaeo and Phu Khao Thong. Archaeol. Anthropol. Sci. 5, 311–329. doi:10.1007/s12520-012-0115-2
https://link.springer.com/article/10.1007/s12520-012-0115-2

Chirikure, S., Burrett, R., Heimann, R.B., 2009. Beyond furnaces and slags: a review study of bellows and their role in indigenous African metallurgical processes. Azania Archaeol. Res. Africa 44, 195–215. doi:10.1080/00671990903047108
https://www.tandfonline.com/doi/full/10.1080/00671990903047108

Charlton, M.F., Crew, P., Rehren, T., Shennan, S.J., 2010. Explaining the evolution of ironmaking recipes – An example from northwest Wales. J. Anthropol. Archaeol. 29, 352–367. doi:10.1016/j.jaa.2010.05.001
https://www.sciencedirect.com/science/article/pii/S0278416510000309

Week 6: Reading Week

Data exercise due Thursday

Week 7: Steel and Cast Iron

Mike Charlton

Steel represents the fullest expression of iron’s unique material characteristics in the ancient world, unlocking its functional potential as well as aesthetic properties. Steel can be made in a variety of ways including a strongly reducing bloomery process, case-hardening during smithing, as part of a consolidation step between smelting and smithing, and in specialized crucibles. Beyond steel, we have cast iron—an unsmithable material that finds its origins in China during the second half of the first millenium BC, not becoming viable in Europe until the early first millenium AD.

This lecture will cover the important Fe-C phase diagram and explore both the technological and economic aspects that lead iron to travel down its three distinct pathways.

Readings:

Alipour, R., Rehren, T., 2014. Persian Pūlād production: Chāhak tradition. J. Islam. Archaeol. 1, 231–261. doi:10.1558/jia.v1i2.24174
https://journals.equinoxpub.com/JIA/article/view/24174

Gelegdorj, E., Chunag, A., Gordon, R.B., Park, J.-S., 2007. Transitions in cast iron technology of the nomads in Mongolia. J. Archaeol. Sci. 34, 1187–1196. doi:10.1016/j.jas.2006.10.007
https://www.sciencedirect.com/science/article/pii/S0305440306002135

Lang, J., 2017. Roman iron and steel: A review. Mater. Manuf. Process. 32, 857–866. doi:10.1080/10426914.2017.1279326
https://www.tandfonline.com/doi/full/10.1080/10426914.2017.1279326

Week 8: Lead, silver, and gold-parting

TBD

Lead and silver are geologically and metallurgically closely related, and are hence treated in one session. The vast majority of silver is extracted from lead ores, and lead often appears as a by-product of silver smelting. We will discuss the production and the use of both metals, how they are related metallurgically. Extraction of precious metals introduces some important chemical processes. In addition to cupellation, Justine Bayley will present us with a broader picture of gold-parting as explored through her own research

Readings:

Bartelheim, M., Cortés, F.C., Onorato, A.M., Murillo-Barroso, M., Pernicka, E., 2012. The silver of the South Iberian El Argar Culture: A first look at production and distribution. Trab. Prehist. 69, 293–309. doi:10.3989/tp.2012.12093
http://tp.revistas.csic.es/index.php/tp/issue/view/44

Liu, S., Rehren, T., Chen, J., Xu, C., Venunan, P., Larreina-Garcia, D., Martinón-Torres, M., 2015. Bullion production in imperial China and its significance for sulphide ore smelting world-wide. J. Archaeol. Sci. 55, 151–165. doi:10.1016/j.jas.2014.12.023
https://www.sciencedirect.com/science/article/pii/S0305440314004841

Westner, K.J., Birch, T., Kemmers, F., Klein, S., Höfer, H.E., Seitz, H.M., 2020. ROME'S Rise to Power. Geochemical Analysis of Silver Coinage from the Western Mediterranean (Fourth to Second Centuries BCE). Archaeometry 62, 577–592. doi:10.1111/arcm.12547
https://onlinelibrary.wiley.com/doi/10.1111/arcm.12547

Week 9: Zinc and Brass,

Mike Charlton

Zinc bridges ancient and modern metallurgy. As a metal, zinc is not known before the 10th century AD in Asia, or before the 16th century AD in Europe. However, the alloy of zinc and copper (brass) is common from at least the first millennium BC, but declines dramatically in the west a century later. From the late middle ages, brass becomes the dominant copper alloy for every-day artefacts. We will explore the technical reasons for the strange chronological distribution of brass an zinc, as well as their central role in the development of modern chemistry.

Readings:

Rehren, T., 1999. Small size, large scale Roman brass production in Germania inferior. J. Archaeol. Sci. 26, 1083–1087. doi:10.1006/jasc.1999.0402
https://www.sciencedirect.com/science/article/pii/S0305440399904028

Veronesi, U., Rehren, T., Straube, B., Martinon-Torres, M., 2019. Testing the New World : early modern chemistry and mineral prospection at colonial Jamestown , 1607 – 1610. Archaeol. Anthropol. Sci. 11, 6851–6864.
https://link.springer.com/article/10.1007/s12520-019-00945-x

Zhou, W., Martinón-Torres, M., Chen, J., Liu, H., Li, Y., 2012. Distilling zinc for the Ming Dynasty: The technology of large scale zinc production in Fengdu, southwest China. J. Archaeol. Sci. 39, 908–921. doi:10.1016/j.jas.2011.10.021
https://www.sciencedirect.com/science/article/pii/S0305440311003888

Week 10: Innovation in non-ferrous metal production

Justine Bayley

The previous weeks have largely emphasised the primary production of ancient metals. This week, Justine Bayley will take us through the fascinating world of non-ferrous object production and innovations of the Middle ages

Readings:

TBD

Week 11: Economics of metallurgy

Mike Charlton

The final lecture of the module attempts to tie all the details of our previous discussions together through the unifying concept of economics. We will review the basic stages of production and how we make sense of the archaeological remains and introduce economics as the 'science of scarcity'. Concepts related to human economic behaviour will be discussed and case-studies provided to demonstrate how we can use them to generate a better understanding of the relationships between metals and peoples.

Readings:

Shennan, S., 1999. Cost, benefit and value in the organization of early European copper production. Antiquity 73, 352–363.
https://doi.org/10.1017/S0003598X0008830X