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COAXING COPPER TO TELL ITS STORY

Finding locations where copper ore was mined in prehistoric times and learning about how metal objects were manufactured during the Bronze Age is key to answering questions about major turning points in European history. Our multidisciplinary team, including archaeologists, geologists and materials engineers, is developing a universal research strategy.

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The search to identify the Central European source mines of the copper ore that was used to make metal objects in the early Bronze Age (ca. 2300-1600 BCE) is driven by a desire to better understand the beginnings of European civilization, including the early days of ruling elites and long-distance trade. Metals, in this case copper and its alloys, played an important role in this process. Mining copper and tin, and the manufacture, exchange and ownership of bronze objects, became so crucial for people in power that efforts to find deposits of the metals and to excavate them played a key role in driving social change in many parts of Europe. The uneven geographical distribution of the resources generated and catalyzed trade; control also needed to be exerted over excavation, distribution, and production.

Archaeology is an academic discipline largely rooted in the physical sciences, which makes it a fertile ground for developing multidisciplinary research. To put it another way, before archeologists can try to explain social processes in prehistoric times, we first need to resolve various research problems using techniques from geology, chemistry, materials engineering, etc. Projects often bring together multidisciplinary teams of specialists, working closely together on formulating research targets and preparing for excavations. This allows each contributor to make the most of his or her expertise, to try to tackle problems stretching across the traditional boundaries of individual fields. It also enables us to discover solutions resulting from new approaches to the initial research question (of copper archaeometallurgy, in our case). This requires all team members to collaborate closely and to step beyond their usual routines.

How do we do it?

In our project, we are developing a new archaeometallurgy research methodology for studying the Early Bronze Age in Central Europe. The methodology combines standard methods used to characterize copper alloy microstructures, analysis of chemical and phase composition in mineralogy and materials engineering, as well as state-of-the-art solutions in geochemical research, including metal isotope geochemistry. When interpreting results, we consider information about the geology of copper deposits located closest to archaeological sites.

Carpathian deposits have many times been named as the source of ore used in metallurgy in the Early Bronze Age. Our project aims to confirm this on the basis of clear geochemical and mineralogical evidence obtained by studying archaeological artefacts. The underlying assumption is that the characteristics of metal objects can be directly related to specific parameters of the source copper ore deposit. This raises the question: how should we go about studying artefacts and deposits so that the results of different studies will be compatible – that is, so they can be combined in order to shed light on the overriding question of the type and origin of the copper ores used and the metallurgic technologies applied?

Here we should briefly describe how archaeologists actually perform physicochemical analysis of metal objects. The "wet method" of analyzing the composition of such an object involves grinding up a sample and dissolving it in acid. The XRF method, in turn, scrutinizes the chemical composition of macroscopic fragments. These methods can only provide information about the average chemical composition. Analysis is often performed following a quantitative approach, which means the more the better, regardless of the quality of the results. The material approach, by contrast, involves testing a small number of samples using many different methods, and so leaves much room for creativity in choosing which particular methods to try. It is a long path which must be travelled in order to obtain results of sufficiently high quality.

Step by step

In terms of geological techniques, we devised our approach together with **Asst. Prof. Sławomir Ilnicki** and **Dr. Krzysztof Nejbert** from the Faculty of Geology, University of Warsaw. Observations on the macroscopic scale and point analysis of microregions (a few microns in diameter and between 10 and 20 cubic microns in volume) provide valuable information about the sample. This allows us to scrutinize any

Photo 1:
Artefacts from a burial site excavated in 1933 in Śliwin, Rewal municipality, Gryfice county, West Pomeranian voivodship (from the collection of the National Museum in Szczecin, MNS/A/22087)

Photo 2
Artefacts from a hoard excavated in 1878 in Babin, site 2, Bielice municipality, Pyrzyce county, West Pomeranian voivodship (from the collection of the National Museum in Szczecin, MNS/A/22072)

G. SOLECKI I A. PIĘTAK/NATIONAL MUSEUM IN SZCZECIN (2) inclusions (particles with a chemical composition different from the rest of the material) and trace their variation. In the field of geology, X-ray microanalysis is a fundamental method commonly used in state-of-the-art mineral studies; in archaeometallurgy, it is an innovative technique opening up new ways of drawing conclusions about the origins of the materials and technologies used to make a given artefact.

The materials engineering research methods are selected and applied by a team at the Faculty of Material Engineering, Warsaw University of Technology: **Asst. Prof. Halina Garbacz, Dr. Piotr Wieciński**, and **Tomasz Onyszczuk**. The team analyzes the chemical composition of copper objects and their inclusions of various origins using electron probe microanalysis (EPMA) in order to examine very small regions of less than 20 cubic micrometers. This method provides a very high resolution, making it possible to analyze the chemical composition of the metal itself and its inclusions/intergrowths. The mineralogy of intergrowths and the metal's composition are important sources of information about the type of ore used to produce the object, as well as being invaluable in characterizing the metallurgic process. Such results are impossible to obtain using traditional chemical analysis methods. Studies of microregions are performed at the Faculty of Geology, University of Warsaw and the Faculty of Material Engineering, Warsaw University of Technology.

With this preliminary research plan ready, we began collecting the artefacts to be tested under our project. The metal objects represent the full range of metallurgic technologies used in the Early Bronze Age, from the 'thread-and-wire' metallurgy of the late Neolithic and Early Bronze to Early Bronze castings (daggers, axes and hoop ornaments, including the entire Early Bronze collection from the National Museum in Szczecin).

We also obtained ore samples from various copper deposits. Especially for this project, our team of geologists conducted field reconnaissance in 2014. We travelled to Romania (Baia Sprie), Hungary (Rudabanya) and Slovakia (Gelnica, Smolnik, Eubietova, Banska Bystrica, Banska Stiavnica and Spania Dolina) to visit copper deposits and collect original samples for comparative analysis.

Collaboration

The scope of involvement of the participating experts from different disciplines has become clarified as the project continued. Geologists conduct preliminary studies into the chemical and mineralogical composition of selected samples, and compare

Photo 3: **Axes from a hoard excavated in 1936 in Ubiedrze, Bobolice municipality, Koszalin county, West Pomeranian voivodship (from the collection of the National Museum in Szczecin, MNS/A/22090)**

Photo 4: **Artefacts from a hoard excavated in 1875 in Bonin, Łobez municipality, Łobez county, West Pomeranian voivodship (from the collection of the National Museum in Szczecin, MNS/A/22092)**

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the results against the mineralogical composition of copper ores from the Carpathian region, classifying artifacts in terms of the raw materials used. Prepared samples are then sent for analysis by materials engineers, who study the mineralogy of intergrowths, microstructures and material properties. Perhaps the most interesting stage is when the results for the metal matrix and the intergrowths are compared. Interpreting the results means matching individual artefact samples with the type of copper deposit and the technology used to produce the artefacts.

The process of resolving the research problems outlined at the start of the project has raised further questions. Samples from copper artefacts are turning out to reveal several different types of microstructure, varying depending on how each element was obtained. This demonstrates that a range of methods of metallurgic production (casting, annealing and hammering) was available.

We are noting regularities in the chemical composition of intergrowths, depending on the type of ore and technology. Studies of intergrowths and the matrix provide further information on the chemical composition of the ore. Knowing the chemical composition of each element of the microstructure enables us to define the composition of the ore used to make that element. Studying intergrowths may also help us learn how individual elements were made, at what temperatures, and by which processes.

Overall, the results of our research will make it easier for future projects to glean as much information as possible from both known and newly discovered bronze artifacts.

The project "Archaeometallurgy of copper: Carpathian metallurgic centers in the early Bronze age," underway since 2013, is expected to conclude in 2016.

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