FROM BOOM TO BUST ON THE ATLANTIC FRINGE - COPPER SUPPLY NETWORKS IN THE IRISH LATER BRONZE AGE. AN INTRODUCTION TO A RECENTLY FUNDED RESEARCH PROJECT

A FELLENDÜLÉSTŐL A BUKÁSIG AZ ATLANTI PEREMVIDÉKEN – RÉZELLÁTÁSI HÁLÓZATOK A KÉSŐ BRONZKORI ÍRORSZÁGBAN. BEVEZETÉS EGY ÚJONNAN INDULÓ PROJEKTBE •

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Abstract

A recently funded project aims to investigate and identify the primary ore sources employed in the production of copper during the Later Bronze Age (1500–800 BC) in Ireland. We introduce the project and its objectives, with a focus on analytical methodologies.

Kivonat

Az újonnan indult kutatási projekt célja a réz előállításához használt elsődleges ércforrások vizsgálata és azonosítása a késő bronzkori Írországban (Kr. e. 1500–800). A cikkben bemutatjuk a projektet, annak célkitűzéseit, különös tekintettel a kutatás során alkalmazott vizsgálati módszerekre.

KEYWORDS: IRELAND, LATER BRONZE AGE, COPPER, METALWORK PRODUCTION, SOCIAL NETWORKS

KULCSSZAVAK: ÍRORSZÁG, KÉSŐ BRONZKOR, RÉZ, FÉMFELDOLGOZÁS, KÖZÖSSÉGI KAPCSOLATOK

Introduction

Throughout the European Bronze Age (c. 2500–800 BC), metallurgy played a crucial role as a catalyst for significant societal change. Despite regional variations, archaeological evidence suggests that the adoption of this new technology and the development and use of metal tools, ornaments and weapons had a profound impact on the economic dynamics, social hierarchies and political structures of the communities of the time (Pare 2000; Kienlin et al. 2009; Roberts et al. 2014; Earle et al. 2015). In particular, the rapid development and adoption of metallurgy across Europe led to an escalating and widespread demand for raw materials that were not always available locally, such as gold, copper, and later tin, but which were essential for metalwork production.

As shown by laboratory studies on Chalcolithic and Bronze Age copper-base metals from different European regions (e.g., Melheim et al. 2018; Canovaro et al. 2019; Holmqvist et al. 2019; Ling et al. 2019; Radivojević et al. 2019; Nørgaard et al. 2021; Aragón et al. 2022; Berger et al. 2022; Bottaini et al. 2022; Brandherm et al. 2022; Čivilytė et al. 2023; Artioli et al. 2024; Bruyère et al. 2024, just to mention a representative group of papers from recent years), the search for these new raw materials in areas beyond their direct control would have led Bronze Age communities to make new contacts in order to obtain them. This would have provided the basis for the establishment of new networks of exchange and a complex web of interactions, still to be fully explored, facilitating connections between societies that had previously been isolated from one another.

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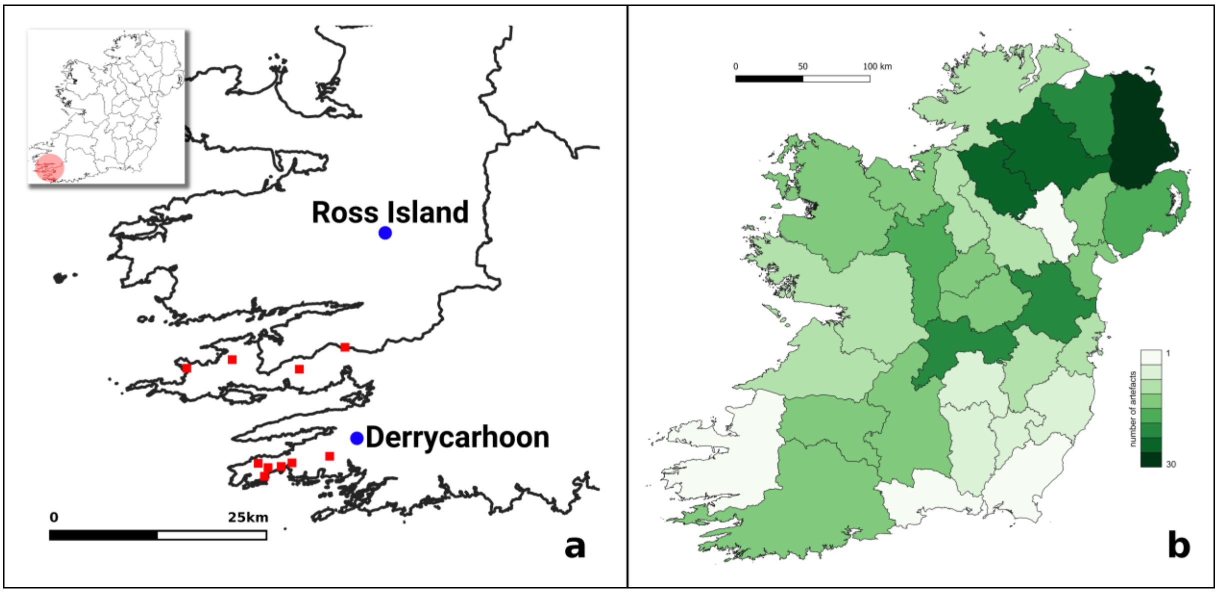

Fig. 1.: (a) Location of the copper mining sites cited in the text (based on O'Brien 2013, 192). Red squares refer to Mount Gabriel-type mines. (b) Geographical distribution of the artefacts to be analysed in the project by county.

1. ábra: (a) A szövegben említett rézbányászati helyek (O'Brien 2013, 192 alapján). A piros négyzetek a Mount Gabriel-típusú bányákat jelzik. (b) A vizsgálandó régészeti leletek földrajzi eloszlása megyék szerint.

In Ireland, for example, early metal artefacts appear around the middle of the 3rd millennium BC. This may be due to the mobility of specialised metalworkers or the limited migration of small, skilled groups from mainland Europe, possibly related to the expanding Beaker network, which fostered links across Atlantic Europe (Case 1966; O'Brien 2023a, 147).

Copper objects in circulation during this first phase included a limited range of artefacts, including copper and bronze flat axes, halberds and daggers (Harbison 1969a; 1969b). They were predominantly made from unalloyed copper, with arsenic in the 1–5% range, and other impurities, namely antimony and silver. The presence of this distinctive arsenic-antimony-silver trace-element pattern was found to be characteristic of ore from Ross Island, Co. Kerry (**Fig. 1A**). The use of this mine dates back to around 2400 BC, making it one of the oldest known copper mines in north-west Europe (O'Brien 1995, 43). Analytical data indicate that Ross Island was the sole source of copper for Ireland during the Beaker period, supplying not only the island but also much of Britain (Northover 1982, 51; Rohl & Needham 1998, 87; Northover et al. 2001, 40; Bray 2012, 72) and, eventually, Brittany (Gandois et al. 2019).

The introduction of tin alloys, generally accepted from 2200–2100 BC onwards (see O'Brien 2023b, 304 for further discussion), and the subsequent widespread adoption of tin bronze as the standard copper alloy during the Irish Bronze Age, brought about changes in the Irish mining industry, which materialised with the decline in the exploitation of arsenic-rich ores at Ross Island. While the existence of Irish tin mined during this period is not currently supported by archaeological findings (Budd et al. 1994; Warner et al. 2010), it is noteworthy that the abandonment of Ross Island is documented to have occurred around 1900–1800 BC (O'Brien 2011, 354). Interestingly, this period coincides with the beginning of the exploitation of new copper resources, characterised by shallow deposits of oxidised ores.

These new deposits proved to be less rich but more accessible to copper miners than the copper ore previously mined on Ross Island. The newly established mines were located on Mount Gabriel and other sites on the West Cork Peninsula (O'Brien 1994; 2003, 49; Briggs 2003). The supply of copper from Mount Gabriel-type mines continued until about 1400 BC (O'Brien 2013, 193), marking an era of increasing scale of metal production and a diverse range of products.

During the Later Bronze Age (i.e., the Middle Bronze Age, c. 1600/1500–1200 BC, and Late Bronze Age, c. 1200–800 BC), evidence for copper mining in Ireland becomes increasingly scarce. After the exhaustion of the Mount Gabriel-type mines, the only evidence of Irish mining activity is documented at Derrycahoon, which remains active until around 1100 BC (O'Brien 2019, 137; among others, see also O'Brien & Hogan 2012; Kearney & O'Brien 2021; O'Brien 2022). If by the end of the

Early Bronze Age Ireland was no longer self-sufficient in copper and had lost its role as the main supplier of this raw material to the rest of the Atlantic Archipelago, the abandonment of Derrycarhoon marks the definitive end of pre-historic mining on the island, which had begun more than a millennium earlier on Ross Island. Interestingly, as Irish copper mining experienced a significant decline, we witness a notable expansion in the scale and variety of metal artefacts produced on the island, which became particularly pronounced during the Late Bronze Age (Eogan 1964; Ó Faoláin 2004).

Within this context, a question that aligns with the central line of inquiry of the project 'From Boom to Bust on the Atlantic Fringe: Copper Supply Networks in the Irish Later Bronze Age' arises: Where did the copper used by Later Bronze Age Irish metalworkers come from?

In contrast to the well-documented nature of the origin of copper in the Beaker period/Early Bronze Age, the prove-nance of the raw material for Irish Later Bronze Age metalwork represents a significant gap in the available data. To date, only nine copper-base Middle and Late Bronze Age axes from Ireland have been analysed for both elemental composition and lead isotope ratios. Although statistically limited, the available data are sufficient to suggest that the end of mining activity in Ireland marked a significant shift in the supply of copper. Indeed, if Irish copper fuelled metalworking throughout the island until the mid-2nd millennium BC, none of the axes analysed appear to have been made from Derrycarhoon ore, and only one object has analytical characteristics consistent with the Mount Gabriel mines. Six objects are consistent with the geochemistry of the Great Orme (Wales), while three others have lead isotope compositions similar to those typically associated with copper ores from southern Spain. The available data, although based on an extremely limited number of objects, suggest a clear change in copper supply from the beginning of the Later Bronze Age at the latest, when Ireland went from being a net exporter to a net importer of copper, suggesting that copper arrived in Ireland via a rather complex long-distance network (O'Brien 2022: 168-173).

The project

Project aims

As outlined above, although the archaeological evidence from Derrycarhoon suggests that Irish mining continued into the Middle Bronze Age, it is undeniable that the archaeological record points to a gradual decline in local copper mining across Ireland in the second half of the 2nd millennium BC. The mines explored during the Beaker/Early Bronze Age phase appear to have been exhausted, while the Derrycarhoon exploitation phase does not extend beyond the beginning of the Late Bronze Age.

Based on these premises, the 'From Boom to Bust' project aims to identify the sources of copper that supplied Irish metalworkers with this raw material between the mid-2nd and early 1st millennium BC. At the same time, an extensive radiocarbon dating programme on organic materials directly associated with metal artefacts will be undertaken to provide a reliable chronological framework for examining the changing patterns of copper supply over the course of the Later Bronze Age.

Archaeometallurgical analyses

Tracing the origin of raw materials used in the production of artefacts is a key issue in archaeological research, contributing to the understanding of exchange networks and interactions between past communities at different geographical scales. Provenancing methodologies are often based on the observation that finished objects retain certain chemical and isotopic characteristics of the raw materials used in their production. This principle is not limited to metal artefacts, but also applies to other materials such as lithic tools (Kuzmin et al. 2020; Pétrequin et al. 2017), pigments (Velliky et al. 2021), and glass (Henderson 2013).

In the field of archaeometallurgy, the most common and widely used analytical approach for identifying the copper mining centres involved in meeting the demand for metals is to determine the isotope ratios of trace-element lead present in a metal artefact and compare them with the isotope ratios of ores that could have served as the source of that metal. The reliability of the isotope approach is due to the fact that the isotopic signature of lead is preserved during the metallurgical processes, meaning that the isotopic ratios of lead in a particular ore are reflected in the metal produced from that ore (Hauptmann 2020, 488-491; Villa 2009; Ceuster et al. 2023).

In addition to lead isotope analysis, chemical analysis intended mainly for the identification of trace element patterns is considered as a valuable complementary tool in identifying sources of raw materials for metal artefacts. Indeed, different geological sources and mining regions often have characteristic trace element patterns, and its combination with lead isotope analysis can be critical where isotope fields overlap or where isotope analysis alone has limitations in distinguishing potential sources (Pernicka 2014).

Fig. 2.: Group of objects analysed within the project from the Archaeology & Palaeoecology teaching collection at the School of Natural and Built Environment, Queen's University Belfast. 1. Unknown; 2-5. "Ireland"; 6. Clogher (Co. Tyrone); 7. Portora (River Erne, Co. Fermanagh); 8. River Bann.

2. ábra: A projekt keretein belül megvizsgált tárgyak csoportja a Queen's University Belfast, School of Natural and Built Environment régészeti és paleoökológiai tangyűjteményéből. 1. Ismeretlen lelőhelyű tárgy; 2-5. „Írország"; 6. Clogher (Tyrone megye); 7. Portora (Erne folyó, Fermanagh megye); 8. Bann folyó.

However, this combined approach of isotopic and trace-element analysis is not without limitations of its own and can present challenges that sometimes prove insurmountable. From an analytical perspective, for example, the recycling and re-melting of scrap metal artefacts made from ores from different deposits can be a major limitation, as chemical and isotopic signatures can be obscured during the process, making it difficult to identify and differentiate the original sources (cf. Pernicka 1999; Bray et al. 2015; Pollard et al. 2018; Radivojević et al. 2019). In other cases, the chemical and isotopic signatures of different deposits may be very similar and overlapping, making it very difficult to distinguish them individually (cf. Stos-Gale & Gale 2009, 202; Vlad et al. 2011, 54; Ceuster et al. 2023, 19602).

Within the framework of our project, archaeometallurgical analyses will be carried out on a selected range of artefacts from across Ireland (**Fig. 1B**) and held in national and regional museums, including the National Museums of Northern Ireland, the British Museum, the Hunt

Museum in Limerick and the Navan Centre & Fort in Armagh. These artefacts, comprising approximately 200 objects, mainly consist of palstaves, socketed axes, swords, and spearheads. The geographical spread of the sample aligns with the general distribution of Later Bronze Age metalwork deposits, which cluster towards the north and east of the island, away from the ore sources that fuelled Irish metalwork production particularly during the Early Bronze Age (**Fig. 2**). It is not envisaged to undertake additional analyses on Irish copper ores as part of this project, as the ore bodies known to have been mined during prehistory in the island are reasonably well characterised and their exploitation mostly predates the study period (Northover et al., 2001; O'Brien 2004; 2022).

Analyses will be conducted on metal shavings drilled from the bulk of the relevant artefacts, in order to avoid any possible distortion from surface corrosion layers. Samples will be then analysed through a multi-analytical protocol that combines Multi-Collector Inductively Coupled Plasma Mass Spectrometry (MC-ICP-MS) for lead isotope analyses, and Energy-Dispersive X-ray Fluorescence (ED-XRF) for major, minor and trace-element analyses. As an alternative to ED-XRF, Inductively Coupled Plasma Mass Spectrometry (ICP-MS) can occasionally be employed for trace element analysis.

The choice to use ED-XRF as the main technique for chemical analysis rather than IPC-MS, which has traditionally been the most widely used technique in archaeology for provenance studies of raw materials, has several reasons in the context of our project. Most importantly, comparative studies have shown that ED-XRF performed on drill samples of copper-base archaeological objects is competitive in terms of sensitivity with a number of other techniques, such as Neutron Activation Analysis (NAA), Atomic Adsorption Spectroscopy (AAS) and Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES), and that it provides reliable results (Lutz & Pernicka 1996). The credibility and effectiveness of ED-XRF in carrying out trace element analyses is also supported by the fact that it is now part of the standard analytical methodology in a range of specialist archaeometallurgical laboratories, having been used routinely in a number of recent studies (Pernicka 2013; Nørgaard et al. 2019; 2021; Berger et al. 2022; 2023; Cornelis et al. 2023).

The case for ED-XRF as the primary technique for major, minor and trace element analysis over ICP-MS is further strengthened by the preservation of the relevant sample material during analysis. This is a clear advantage, especially when the amount of metal to be sampled needs to be minimised, as it allows MC-ICP-MS lead isotope analysis to be performed on the same drill shavings used for ED-XRF, significantly reducing the sample volume required to obtain reliable results. Finally, ED-XRF is known to be faster, allowing a greater number of objects to be analysed, and less expensive to run, reducing financial pressures on the project budget.

Radiocarbon dating

Archaeometallurgical analyses can help to determine the movement of the metal in space at a given point in time. To provide data with a diachronic dimension, taking into account temporal variation and historical context, our project will also undertake a programme of radiocarbon dating of organic materials directly associated with sampled metal objects. Through this broader approach, the project aims to understand how the spatial movement of metals has changed through time, and to capture shifts in metal supply patterns during the Later Bronze Age.

At present, the chronology of metalworking phases in the Irish Bronze Age is still largely dependent on typological comparisons with relevant British material, due to the limited availability of radiocarbon dates from the archaeological contexts of diagnostic Irish metalwork types (Brindley 2001; Becker 2011). New radiocarbon determinations of organic remains directly associated with metal objects will therefore have a dual impact. On the one hand, they will provide, for the first time, an independent and more reliable chronological framework than is currently available for Irish Middle and Late Bronze Age metalwork. Secondly, they will allow archaeometallurgical data to be interpreted within a robust chronological framework, and spatial changes in metal supply patterns revealed by elemental and lead isotope analyses to be placed within the same framework. This will be instrumental in relating both the metalworking stages and metal-supply patterns identified by this project to other economic and societal changes evident in the archaeological record of the period.

In a broader perspective, properly contextualised archaeometallurgical data become a crucial tool. Not only do they help to identify changes in the composition of the metal pool available at different metalworking stages and potential sources of supply, but they also help to assess how these changes relate to other transformations in the archaeological record. These changes include aspects such as population density, land use, settlement patterns and the emergence of powerful chiefdom-type polities that controlled key economic resources and trade. By undertaking this analysis, our project aims to facilitate the contextualisation of these developments within a broader insular and European framework.

Conclusions. Unravelling ancient networks through raw-material studies

Recent decades have seen a remarkable development in the archaeological study of the circulation and origin of raw materials during European prehistory, which has greatly improved our understanding of the use of resources in the past. This increased emphasis on material mobility has become an essential tool for reconstructing ancient trade networks and human interactions, improving our understanding of the socio-economic dynamics associated with exchanges and contacts between communities living in different regions.

However, the development of research in this area has not been uniform across Europe. The Irish Later Bronze Age is paradigmatic in this respect, highlighting a gap in our knowledge of the provenance of the copper used for domestic metalwork production. While the picture is sufficiently clear for the first millennium of copper processing (c. 2500–1500 BC), with Irish miners extracting sufficient copper to meet domestic demand and exporting surplus outside the island, the scenario becomes considerably blurred for the Later Bronze Age. From the mid-2nd millennium BC, the Irish mining industry appears to go bust, while copper-base metalwork manufacturing clearly booms. In the absence of local mining, where did the raw materials come from to meet the demand for domestic metalwork production? The data available so far, based on a dozen or so recently analysed objects, is inconclusive, although it suggests with some degree of certainty that the raw materials must have come from outside Ireland.

The data provided by our project aims to fill this gap in our knowledge, by shedding new light on the processes that governed the circulation of metal during the Later Bronze Age in Ireland. The close integration of state-of-the-art archaeometallurgical analysis and scientific dating methods will allow us to combine minor/trace element and lead isotopic 'fingerprints' of Irish Later Bronze Age metalwork with a radiocarbon-based chronological framework for reliably dating changes in the copper supply patterns inferred from the statistical analysis of these 'fingerprints'.

This, in turn, will allow us, for the first time, to assess the relationship between changes in copper supply patterns and other major transformations in the archaeological record of the Irish Later Bronze Age, and it will also permit us to trace new connections between Ireland, the wider Atlantic world and the rest of Europe, enabling us to re-assess the role of a geographically peripheral region such as Ireland within this/these network(s). The project will thus make a significant contribution to the ongoing international debate on the interconnection and interaction of Later Bronze Age communities across Europe and the Mediterranean.

Contribution of authors

Carlo Bottaini Conceptualization, Writing – Original Draft, Writing – Review and Editing, Visualization, Funding acquisition. **Dirk Brandherm** Conceptualization, Writing – Original Draft, Writing – Review and Editing, Visualization, Funding acquisition.

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