Report on actualistic casting pre-experiments – The copper hammer and adze-axes from the Carpathian Basin

Historical Metallurgy Society Coghlan Bequest
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The transition from the Neolithic to the Bronze Age in Europe represents one of the most profound technological changes in later prehistory. Significant social transformations can be observed, with individual status increasingly conspicuous during the Bronze Age. As an entirely novel material, metal must have had a major impact on society. How can we determine and qualify this impact? In my own research I am trying to investigate these issues through the experimental exploration of early copper technology. In order to apply the experimental results to the archaeological record I think it important to carry them out as actualistically as possible, meaning in this case using materials and technologies which would have been available in the Copper Age of South-Eastern Europe.

Source	Production technique
Coghlan 1943, 52	Bi-valve, two part closed mould. He dismisses the idea of the axes being forged from solid metal.
Childe 1944, 9–10	Cold hammering of copper led to creation of shaft-hole axes
Berciu 1939–1942	Lost wax, although he thinks some might have been completely forged
Garasin 1954, 71	Notes hammer marks on most as well as a casting seam on one of the Serbian shafthole axes, but does not commit.
Pittioni 1957	Cast in open moulds, shaft hole might have been cored later, finished by hammering. Native and smelted copper was used. Notes diversity in production techniques
Coghlan 1961	After metallographic analysis and reading Pittioni's article, Coghlan thinks some axes were cast in open moulds, with the shaft having been cored later
Charles in Renfrew 1969, 40–42	Simple shape cast with core in place, forged into final stage
Vulpe 1975, 18	Cast in one piece open mould, and hammered into final shape while still warm. Shafthole was made using clay or stone peg.
Patay 1984, 13	Cast in one piece open mould due to asymmetry of objects. Shafthole was made by piercing the still liquid metal with a pole or with core in place while casting.
Mareş 2002	Lost wax, or two-part mould

The most suitable artefacts to study for this purpose are copper axes, as they are emblematic of this period and region and provide a good sample size. Little consensus exists regarding their function due to a lack of experimentation and systematic analysis. They have been subjected to a wide range of interpretations, as tools, weapons, status symbols or ritual objects.
Unfortunately not a single mould fragment exists in the archaeological record which makes it extremely difficult to ascertain the production technique used for these objects. Metallography can be used to try and answer questions of production technique, but so far not nearly enough axes have been analysed in a strategic way. Although a number of the publications in table 1 include the analysis of microstructures, notably Pittioni (1957), Coghlan (1961) and Mares (2002), the literature does not provide conclusive evidence for the mould material used. The same can be said about the actual shape of the moulds, as moulds can potentially be one-part open moulds, or closed bi-valve moulds. The debate on these issues is still ongoing. This diversity in opinion regarding the production technique of these axes seen in table 1, is of course partly due to the lack of any mould finds in the archaeological record. However a very careful experimental and more detailed metallography should be able to narrow the possible techniques considerably.

The complete lack of moulds for the copper axe-adzes and indeed hammer-axes in the archaeological record could be due to two reasons. The moulds have either not yet been found, or they were cast into a material which does not survive archaeologically. Having excavated in Eastern Europe myself, I know that late Neolithic and Copper Age pottery sherds are often simply thrown out due to their sheer quantity. This is especially true for undecorated sherds, the most likely pieces to have been part of moulds. Archaeologically invisible moulds could be made from sand, as various scholars have pointed out recently. (Goldmann 1981; Ottaway and Seibel 1998) Moulds made from sand would simply disintegrate, leaving nothing for the excavator to find.

Due to the considerations mentioned above I decided to cast in clay and sand moulds. Both open and closed moulds would be used as there is no consensus, which shape was used to cast these axes. Casting both in open and closed moulds makes it possible to compare the microstructure of the experimentally produced axes to the archaeological ones, and start a reference collection for future use. The next problem concerned the actual technique employed for melting the metal. Again not a single casting site is known from the archaeological record, although judging through my own experiments; they could easily have been misinterpreted as hearths. A trial run during my MA with a bowl furnace supplying the air from below the crucible was not successful. In

September 2006, I worked with a Swiss group 'Experiement A'. We cast bronze for 5 days using different furnace designs and air supplies. The most efficient model was based on a tuyère found at Sanskimost, in Bosnia and Herzegovina (Fiala 1899, 90–91). Although the tuyère dates to the Bronze Age and the copper axes are much earlier, I decided to use this technique, as they must have melted the metal somehow, and it would not influence my end result of producing actualistic copper axes. It was for this project that I applied successfully to the Coghlan bequest.

Bellows

As can be expected, there are no surviving bellows from the archaeological record. I therefore made similar leather bag bellows to the ones used by 'Experiment A' as they were easy to use and made from entirely organic materials. I used old leather coats from charity shops, which is by far the cheapest way to buy leather. In order to connect the two bellows to the one tuyère a pair of leather 'trousers' were made (Figure1).

Pipes, tuyères, crucibles and moulds

The pipes connecting the bellows to the tuyère via the leather 'trousers' as well as the tuyères, crucibles and moulds were made using Devon earthenware clay mixed with sand at a proportion of about 2:1. The objects were then fired at 750º C in an electric kiln.

Figure 1. The finished furnace, tuyère, pipes and bellow

Furnace construction

A whole was dug into the ground and lined with the same clay mixture as was used for the pipes, tuyères, crucibles and moulds (Figure 1). The platform or flat area by the side of the hole was made to scrape the charcoal onto when placing the crucible inside the furnace. This helps keep the charcoal soil free inside the furnace. If too much soil gets into the furnace, the silica content vitrifies, which lowers the temperature as it is mixed with the charcoal, creating pockets were no combustion takes place. A small fire was lit inside the furnace to dry the clay slightly before adding the charcoal.

Casting session 1

Remembering the problems during the last casting session, I only added a small amount of copper to the crucible. This would not fill the mould but the first session should simply test if the set up was working properly. Once the furnace was full with glowing charcoal, the charcoal was scraped onto the side platform, and the crucible was placed directly underneath the tuyère opening, with about 5–7cm between the rims of the crucible and the tuyère. The charcoal was then piled over the crucible and up to the 'eyes' of the tuyère. In order to test if the copper was molten it was possible to insert a green willow shoot into the crucible. Running the shoot along the bottom of the crucible one could feel if there were any lumps left. Once the copper had melted; it was also possible to feel a slight 'bubbling' when inserting the shoot into the crucible. It took two hours and 30 minutes to melt the metal. This was mainly due to the bellows, as they were not as efficient as anticipated. The leather of the finger loops stretched which made it difficult to grip when operating the bellows. The two students helping me with the bellowing had never bellowed before, so that the first hour or so was spent practicing and the air flow was not always constant. This was a recurring problem, as I had different students helping me each time. The wooden tongs I used were simply made by splitting a branch someway up and tying a little wedge between the two sides. The mould was tied together using a leather strap, and situated in a small trench. For the first cast, the mould had not been pre-heated. The charcoal was scraped aside, the tongs were used to grab the crucible with one arm, and with my other arm I was holding a stick onto the rim of the crucible in order to stop the charcoal from blocking the pouring cup. The process of pouring the copper worked surprisingly well for the first trial. As anticipated it was only enough copper to fill the bottom half of the mould (Figure 2). The surface of the copper was fairly smooth but very porous or spongy (Figure 3), quite unlike the archaeological axes. It was interesting to observe the complete vitrification of the 'mouth' of the tuyère (Figure 4).

Figure 2. The partly filled mould after casting session 1

Casting session 2

This time the process was repeated as above, but the crucible was filled to its full capacity, and some amendments to the bellows meant that they were working more efficiently. The same two part clay mould was used, as I had not yet managed to fill it, although this time it was preheated next to the furnace. Despite these alterations, it took two hours to melt the metal. After pouring the metal, I noticed that I had not managed to fill the mould again, although I had weighed the amount of copper which could fit into the crucible, and it was equal to the weight of the axe, the mould had been made after. Again the surface was porous although slightly more solid feeling (Figure 5).

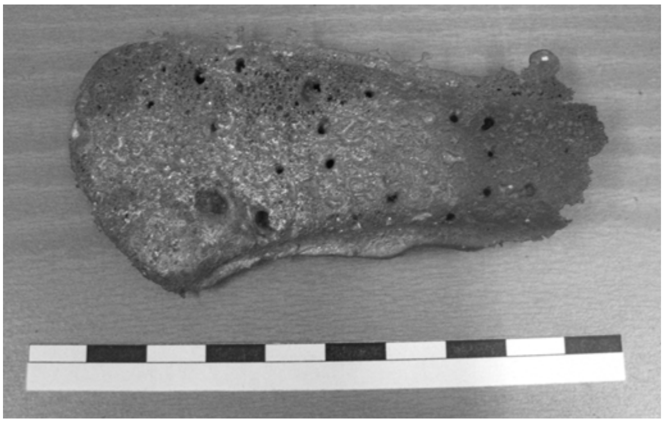

Figure 3. The cast from session 1

Figure 4. The partly vitrified tuyère

Fig. 5: Showing cast from session 2

Casting session 3

In order to finally fill the mould, I made a larger crucible for the third casting session. This time it took three and a half hours to melt the copper. When I attempted to take out the crucible with one arm I realised that it was too heavy and had to use both arms to pour. This meant that I could not hold the charcoal off, which blocked the pouring cup after having poured only a little copper. I poured the rest of the copper onto the clay surface next to the furnace and realised that there was a ring around the crucible wall of un-melted copper. As the crucible had been in the furnace for three hours it could only mean that the diameter of the crucible was too large for the tuyère opening. The axe piece from the last cast was the most solid casting without any obvious porosity (Figure 6).

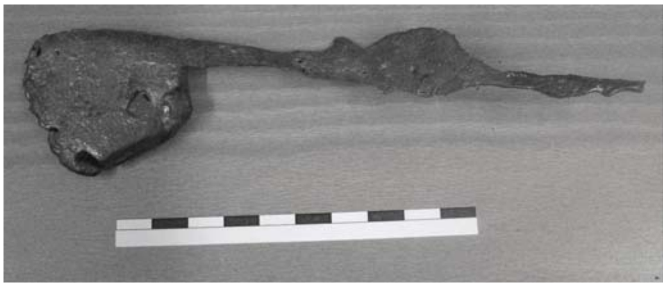

Figure 6. The cast from session 3

After the third casting session my material had run out and I realised that if I wanted to carry out statistically meaningful experiments with a large enough sample size, I would have to find an alternative way to melt and cast copper. The three casts will be sampled and I fully intend to carry out metallography, to compare the microstructure to other experimentally cast axes as well as archaeological ones. It is important to know for example if the microstructure of actualistically cast axes varies from axes cast in a modern furnace. I am now about to start a series of experiments using a gas furnace and the remaining copper. However the actualistic experiments were very valuable indeed. It made me realise and understand the processes which are necessary to melt and cast these enigmatic and large objects. It also illustrated how ephemeral these activities can be, which might explain why not a single casting site is known from archaeological contexts. These early furnaces can easily be misinterpreted as hearths. A further observation was the importance of seeing metallurgy as a composite technology, with many other technologies involved. We should study metallurgy in a more organic way, taking into account the invisible processes as well as the visible metallic remains.

I would like to thank the Historical Metallurgy Society for helping me carry out my pre-experiments through the Coghlan bequest, without which I would not have been able to buy all the materials necessary. I would also like to thank the group 'Experiment A' and A. Young for helping me on the way to become a practical metallurgist, and last but not least all my 'bellower's', Tine Schenck, Via Baker, Genevieve Hill and Sophie Thorogood.

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C O N F E R E N C E   R E V I E W

HMS Spring Meeting 2008
19th-century Ferrous Metallurgy
Sheffield, 18th April 2008

The spring workshop provided a forum to discuss recent and ongoing investigations into 19th-century ironmaking. The meeting was organised by Anna Badcock in Sheffield and was well attended by field archaeologists, historians and metallurgists.

The recent redevelopment of brownfield sites (that is ones which had previously had industrial uses) in many of our city centres has provided archaeologists with many opportunities to investigate iron and steelmaking sites of the 19th century. At the spring meeting we heard about recent excavations on the sites known to have had blast furnaces, puddling furnaces, cementation furnaces and foundries. Curatorial staff, archaeological contractors and metallurgical specialists provided informative and candid assessments of their experiences.

Some people still question the need for any archaeological research into such a recent period but many speakers illustrated the ways in which archaeology can enrich historical accounts. Christine Ball's excellent presentation went even further and illustrated how the historical record could contain errors; it was created by individuals who could be biased, lazy or even malicious.

The archaeological investigation of many of these brownfield sites is certainly a challenge for many of the people involved. Helen Gomersall recalled how until recently everyone thought the archaeology of 19th-century ironworks was a lost cause and that most archaeologists were not keen to excavate such sites because of their nature and scale. These sites often cover several hectares, may be covered in several metres of rubble and could even be contaminated with hazardous chemicals. Ben Reeves described how some of his colleagues thought that his site "wasn't real archaeology" and his excavation team had virtually no experience of 19th-century industrial sites. Nevertheless, many speakers illustrated how far the archaeological excavation of such sites has progressed in such a short period of time.

Due to a technical problem it was not possible to see David Cranstone's slides on the day, however, the images and text are available to download from the HMS website: http://www.hist-met.org/cranstone.pdf