Casting Experiments and Microstructure of Archaeologically Relevant Bronzes

The book presents results of an archaeological experiment, the aim of which was the creation of a reference collection of bronzes which can be used for determination of prehistoric production methods.

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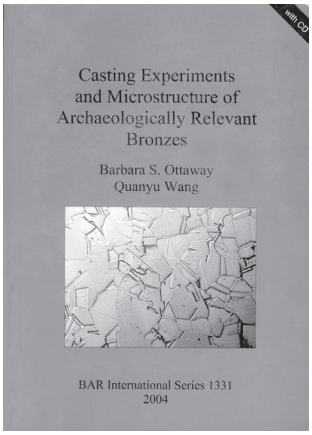

Quanyu Wang and Barbara S. Ottaway, have published the results of a sound archaeological experiment in a mainstream archaeological series, which happens all too rarely. This publication will further not only the understanding of the microstructures of cast bronzes, but also the importance of experimental archaeology as a methodology in mainstream academic archaeology.

The main aim of the authors was the creation of a reference collection of archaeologically relevant bronzes, cast in different mould materials, with controlled variables such as composition, pre-heating of the moulds and subsequent quenching. The reference collection of the recorded microstructures can then be used for determination of prehistoric production methods, when compared to microstructures from prehistoric objects.

After a consideration and summary of previous work carried out on the experimental casting and microstructural analysis of bronzes, the compositions, mould materials, and methodology are introduced. The authors emphasise the importance of not repeating work which has been carried out already, and give this as one of the reasons for their selection of alloys, moulding materials and cooling regimes. Although a substantial part of experimentation should include repeat experiments by different experimenters, the authors in this case wanted to tread new ground.

The moulding materials used were sand, clay and bronze and the methodology and results are described in the central chapters of the book. For each mould material, the mould making, casting, grain size, dendritic arm spacing and micro-hardness are summarised. A further three chapters deal with the comparison of the microstructure and the malleability of the metals cast in the three different moulding materials, and the behaviour of the alloying elements tin and lead, during melting and casting.

The same object (a flat axe) was cast throughout the experiments, in order to obtain comparability of results and standardisation. All the experiments were carried out in a modern foundry using a clay graphite crucible and an induction furnace. For health and safety reasons, it was not possible to carry out the experiments actualisticly in the open air. However, a similar experiment, published in German in 2002, (*Jochum Zimmermann, Kunzler-Wagner and Kunnert 2002*, 292) which is not referred to in the present volume reviewed, has shown that the only difference between the microstructure of objects cast under modern conditions and 'prehistoric' conditions, is the increased occurrence of gaseous inclusions and porosity.

The pattern used to make all the moulds, was made from pine and was varnished to avoid shrinkage. The first mould material used was sand, in this case floor sand and Mansfield sand, which have added petroleum based oils. An alternative would be to add linseed oil to the mixture (*Jochum Zimmermann, Kunzler-Wagner and Kunnert 2002*, 292), which might be more authentic but unlikely to have been used in prehistory, due to the probable value of oil (*Jochum Zimmermann, Kunzler-Wagner and Kunnert 2002*, 292). The effect of the type of sand on the microstructure was not addressed in either study. Other variables like the clay and water content as well as the compactness of the sand were identified and controlled. A modern cope and drag box was used to hold the sand.

Clay was the second mould material used. High silica industrial fire-clay was used, with 20% saw dust. However it is unclear if the clay was weighed dry or wet when the proportion of saw dust was added. The clay moulds were fired at 700° C, and different pre-heating regimes and cooling regimes were used.

The third mould material was bronze. There is still a lot of debate regarding the exact function of bronze moulds found in the archaeological record. They are sometimes interpreted as having been used for casting wax or lead models, and sometimes as having been used for casting the actual bronze objects. In this experiment the exact function is less important as the aim is to create a reference collection of bronzes cast in different mould materials.

In total 84 flat axes were cast in sand, clay and bronze moulds. Twelve different alloyed compositions were used, as well as different pre-and post-treatments (preheated, un-preheated, air-cooled and water-quenched). This large number of variables meant that even with a comparatively large sample size, there are no two axes treated in the same way, which makes it difficult to come to any firm conclusions. It is a well known problem in experimental archaeology, that the sample size is often inadequate due to time and cost constraints. Sometimes it might be better to reduce the variables, in order to obtain results which might be more statistically significant.

A series of experiments similar to the one under review here (Wang and Ottaway 2004), has also a sample size which is too small for statistical analysis. Despite these problems, both experiments show common trends, which they also share with other casting experiments. The cooling down happens much faster in the bronze moulds, and the clay moulds are the slowest to cool down. The cooling times for sand and stone moulds (for the latter see *Jochum Zimmermann, Kunzler-Wagner and Kunnert 2002*) lie between the bronze and clay moulds. The speed of cooling does have an effect on the microstructure, as the dendritic arm spacing in the objects cast in the bronze moulds is much smaller than that seen in the objects cast in the sand and clay moulds.

The present study also looked at the difference in workabil-

ity between the different samples, as well as the behaviour of tin and lead during melting and casting. Water-quenched bronzes can generally be further reduced in thickness than air-cooled bronzes, and objects cast in sand can withstand more cold working than objects cast in clay or bronze. There was a loss of both tin and lead in the melting and casting process, with more tin and lead being lost from casting into clay and bronze moulds, than from casting in the sand moulds. The volume also contains a CD-ROM containing the colour photographs of the microstructures of all samples. This is a great resource for future work, as it makes it easy to compare results.

The authors end the publication with a justified call for more work into extending the reference collection, as well as analysing archaeological material to see whether different mould materials and cooling regimes have been used in prehistory, depending on the end product wanted. Despite some problems, this is an excellent example of experimental archaeology, and together with the experiments carried out by 'Experiment A' (*Jochum Zimmermann, Kunzler-Wagner and Kunnert 2002*), builds a great start for a reference collection of archaeologically relevant bronzes. With more research, we might one day be able to understand the casting technology and mould material used and the choices people made, simply by looking at the microstructure of the objects.

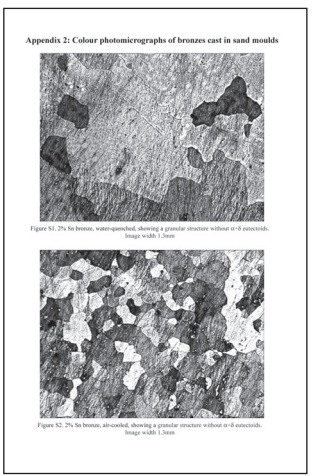
Appendix 2: Colour photomicrographs of bronzes cast in sand moulds

Figure S1. 2% Sn bronze, water-quenched, showing a granular structure without α+δ eutectoids. Image width 1.3mm

Figure S2. 2% Sn bronze, air-cooled, showing a granular structure without α+δ eutectoids. Image width 1.3mm

Casting Experiments and Microstructure of Archaeologically Relevant Bronzes

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Bibliography

Zimmermann, E.J., Künzler-Wagner, N. and Kunnert, U. 2002: Zurück zur Gussform! Zum Einfluss des Gussformmaterials auf die Mikrostruktur eines gegossenen Bronzeobjektes. In M. Fansa (ed) Experimentelle Archäologie in Europa, Bilanz 2002. Oldenburg: Isensee Verlag. 79-82. (Back to the mould – the impact of the mould material on the microstructure of the cast bronze object)

Summary

Die Autoren veröffentlichen die Resultate eines archäologischen Experiments, das der Herstellung archäologisch relevanter Bronzen diente, die in verschiedenen Gussformen angefertigt wurden, wobei mehrere Variablen wie die Materialzusammensetzung der Gussformen, das Vorheizen der Gussformen und das Ablöschen derselben berücksichtigt wurden. Bei den zur Herstellung der Gussformen verwendeten Materialien handelte es sich um Sand, Ton und Bronze. Ein gleichartiges Objekt, ein Flachbeil, wurde bei den Experimenten auf verschiedene Weisen hergestellt, um eine Vergleichbarkeit und eine Standardisierung der Ergebnisse zu gewährleisten. Die daraus entstandene Vergleichssammlung kann mit seinen dokumentierten Mikrostrukturen nun zur Analyse prähistorischer Produktionsweisen dienen.

Les auteurs publient les résultats d'une expérimentation archéologique effectuée dans le but de créer un ensemble de bronzes, pertinent du point de vue de l'archéologie, coulés dans des moules en différents matériaux. Parmi les variables contrôlé, il y avait la composition de l'alliage, le préchauffage des moules et le refroidissement. Pour fabriquer les moules, on a utilisé du sable, de l'argile et du bronze. On a moulé à chaque fois le même objet - hache plate afin d'obtenir des résultats susceptibles d'être comparés. La collection de référence des microstructures enregistrées peut servir à déterminer les techniques préhistoriques.