THE "MYSTERY" OF THE POST-MEDIEVAL TRIANGULAR CRUCIBLES RECONSIDERED – A GLOBAL PERSPECTIVE

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1. BACKGROUND

In 1677, the *chymist* Robert Plot examined some English crucibles manufactured by John Dwight, long time potter, experimental *chymist* and entepreneur, and concluded that "he hath discovered also the mystery of the Hessian wares, and makes Vessels for reteining the penetrating Salts and Spirits of the Chymists, more serviceable than were ever made in England, or imported from Germany it self" (Plot 1677). This secrect arguably unveiled in Dwight's workshop was indeed a long standing enigma: since the Middle Ages, crucibles manufactured in Hesse (Germany) had been widely traded across the world, thus indicating their renowned quality.

More than three centuries after Plot's observation, in 1992, John Cotter recaptured this "mystery" to raise awareness of the "remarkably little attention paid to the subject of post-medieval crucibles" and, particularly, to the triangular type (Cotter 1992: 256). Based on historical documents, he contended that literally millions of these had been imported into Britain alone.

The triangular or laboratory crucible is made by simply pushing inwards the upper walls of a beaker-shaped vessel, thus creating three pouring spouts (fig. 1). This simple tool was used in fire assays as well as in copper and brass metallurgy, for gold and silver working, glassworking and even in experiments in the quest for the philosophers' stone. Increasing numbers of these are recorded in different archaeological contexts but, until quite recently, they received little attention beyond vague attributions to the "Hessian type", particularly when they are sand-tempered and triangular.

2. RESEARCH QUESTIONS, MATERIALS AND METHODOLOGIES

This paper is a brief summary, necessarily short of bibliographic references, of a wider research project aimed at obtaining a more

Figure 1. "Nest" of triangular crucibles recovered in Hesse (Photo S. Häpe, by courtesy of H-G. Stephan).

comprehensive picture of this scenario and establishing the technological, historical and archaeological implications of this vessel type (Martinón-Torres 2005). Three basic questions were posed: (1) what is the "mystery" that made these crucibles so highly esteemed? (2) does the standard appearance of the vessels respond to a standard manufacture? and (3) were these crucibles primarily traded or was the triangular shape simply adopted progressively in different regions?

Accordingly, our research concentrated on three overlapping aspects: (1) the formal and material properties, as well as the performance characteristics, of these vessels, with a special focus on the choices made during their manufacture, consumption and use; (2) their process of manufacture; and (3) fabric grouping and provenance of different types.

The sources of information consulted were historical and archaeological. The former group included early modern technical treatises as well as documents regarding pottery production and trade. The archaeological data were obtained from the comparative analytical study by optical microscopy and SEM/EDX (following standard protocols in Martinón-Torres and Rehren 2002) of a range of crucible samples and ordinary ceramics obtained from ten different sites in Germany, Britain, Portugal, Austria and Virginia (USA), together with a reconsideration of published examples.

This paper necessarily overlooks the potential of fine-grained chronological sequences and more detailed explorations into each case study (see Martinón-Torres 2005). However, it is hoped that it provides a general background where future finds and questions may be contextualised.

3. TRADITIONAL KNOWLEDGE: INFORMATION FROM TECHNICAL TREATISES

Cotter (1992) has provided a fine account of the best known written sources of information about the manufacture of triangular crucibles, namely the early modern century treatises and mining, metallurgy, alchemy and assaying. Using Cotter's sources, the resulting picture is that the best crucibles were made of light firing clay tempered with fine sand or crushed pebblestone and, occasionally, grog. The clay mixture could be shaped either on the potter's wheel or in brass moulds, and then fired in ordinary pottery kilns. Several provenances for the clay and/or the crucibles are cited, most of them in Central Europe. For example, there are references to the clays from Hildesheim and Waldenburg (Saxony), and to the crucibles from Ipps (Bohemia) and Vienna (Lower Austria) (cf. Cotter 1992). Occasionally, however, there are suggestions that crucibles could be produced outside this Central European focus, as is Biringuccio's mention of "Valencia clay" (Smith and Gnudi 1990: 72).

Remarkably, in the late 15th century, the alchemist Thomas Norton complained about the lack of suitable crucible makers "in any country of English grounde". Two hundred years later, Johann Glauber noted that "those [crucibles] of Hessia are still preferred before others, retaining better, metals and salts" (cf. Cotter 1992: 265-266).

Several technical qualities of the crucibles are appreciated. In some cases, their resistance to corrosion by hot metal oxides and fluxes seems to be the most important asset, as in Plot or Glauber's statements above. In other instances, a good refractoriness appears crucial (Sisco and Smith 1951: 180).

4. REVISED KNOWLEDGE: ARCHAEOMETRY AND WRITTEN DOCUMENTS

4.1. The light crucibles from Hesse

Contrary to widespread assumptions, neither all the triangular crucibles are Hessian, nor all the Hessian crucibles are triangular. It is true, however, that the triangular crucibles from Hesse played a major role in many sorts of early modern pyrotechnological workshops. The large scale production of crucibles in the region of Hesse in Central Europe, particularly in Groβalmerode and Epterode, has been addressed in detail (Stephan 1995). Since the Middle Ages, these vessels were usually made of clay heavily tempered with sand, and massively traded. Nevertheless, information was missing with regards to the extent of this trade (but see Cotter 1993 and Stephan 1995) and the specific material properties and performance characteristics of these vessels.

Detailed analyses of samples across the world and spanning from the 16th to the 18th century reveal an extraordinary degree of homogeneity in the pastes. Hessian crucibles were invariably made with a remarkably lean and refractory clay, with alumina levels above 36 wt% and the sum of the alkalis below 2 wt% (table 1). The only noticeable mineral inclusions are occasional occurrences of iron oxides. The clay was tempered with 30-40 vol% of subangular or spheroid quartz grains, moderately well sorted (although this varies from sample to sample). These minerals are normally surrounded by large expansion voids. In some specimens, some possible grog fragments were observed, although the high degree of vitrification hinders a definite identification. The crucibles were thrown on the wheel, sometimes stamped

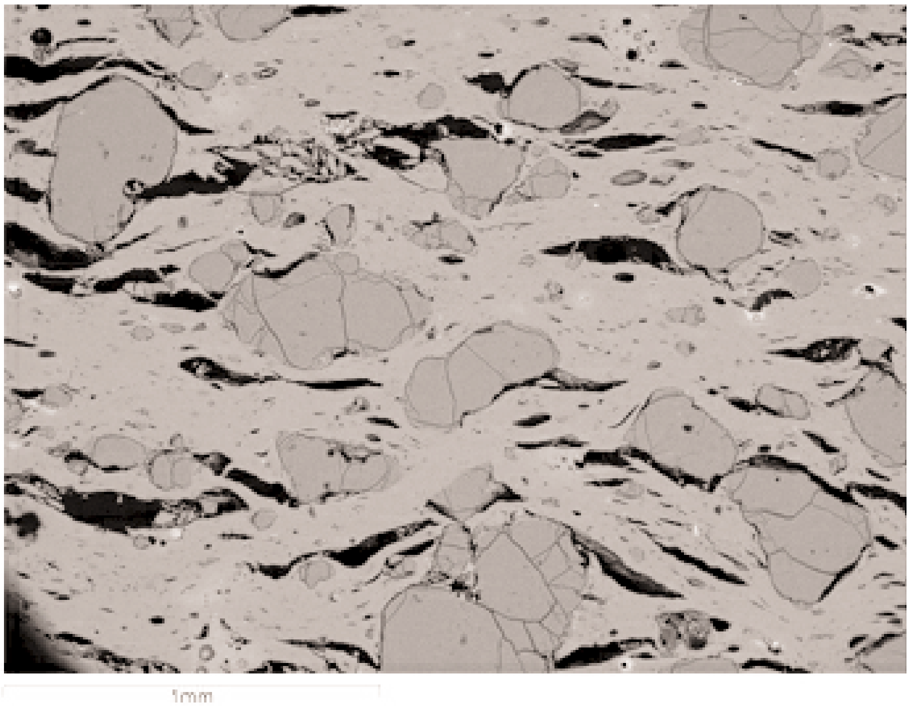

Figure 2. Backscattered electron image of a light Hessian crucible, showing sand temper shattered by thermal stress, expansion voids and a high degree of matrix vitrification.

in the base with a variety of motifs such as stars or initials, and fired to temperatures in excess of 1200 °C, as indicated by the fact that, despite the high refractoriness, the clay matrix shows complete vitrification (fig. 2).

The abundant quartz temper substantially enhanced the toughness and the thermal shock resistance of the vessels (Tite *et al* 2001). The high temperature of the original firing would improve the vessels resistance to subsequent firings, while the homogenous glassy matrix would have augmented their tensile strength when handled whilst holding considerable weights. Even though the iron oxide inclusions often melted and thus fluxed the surrounding ceramic area, they are relatively rare and small, and would normally not have challenged the vessel's stability. All in all, the "mystery" of the quality of the Hessian wares seems to have been the selection of very refractory clays, well refined and mixed with fine quartz sand, and subsequently very high fired.

	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	TiO_2	FeO
Light Hessian (n=12)	0.2	0.5	36.7	56.9	0.2	1.4	0.3	1.9	1.8
Dark Bavarian (n=2)	0.7	0.9	28.3	56.9	0.3	2.6	0.9	1.3	8.1
Dark Austrian(?) (n=6)	0.2	0.7	32.4	57.3	0.3	2.1	0.7	1.3	5.0

Table 1. Average chemical composition by SEM/EDX, normalised to 100 wt%, of the ceramic matrices of different crucible types. From top to bottom: Hessian crucibles found at different sites; dark crucibles found in Obernzell and Oxford; dark crucibles found in Oberstockstall.

Although used samples may appear light grey or even black depending on the conditions of use, unused crucibles are very consistent in their appearance: the highly vitrified matrix is grey, but the areas surrounding the quartz grains, particularly those erupting through the surface, show orange shades. In addition, the texture of the surfaces is particularly sandy and pimply. These features make it relatively easy to single out a crucible as "Hessian" even before analysing it, as would have been the case in the past. This grainy surface, however, in addition to the substantial expansion voids within the paste, would have been a detrimental performance factor, facilitating the penetration of corrosive substances into the crucible body, which seems paradoxal in the light of the historical remarks of these vessels' resistance to corrosion.

Within this study, by comparison to samples from production centres, and given the consistent characteristics of the pastes, Hessian crucibles were identified or confirmed in contexts relating to bronze and brass metallurgy in Burgsteinfurt (Germany), coin minting in Porto (Portugal), the chymical laboratory at the Old Ashmolean (Oxford, UK), goldsmithing in Cripplegate (London, UK), and ore assaying and bronze metallurgy in Jamestown

(Virginia, USA). In addition, the stamps in the crucibles from the Archbishop's Mint in Trondheim (Norway), as well as others from Colchester and London (UK), could also be adscribed to Hesse.

4.2. The dark crucibles from Bavaria

A somewhat surprising discovery in the course of this study was the existence of another large scale producer of high-quality crucibles in post-medieval Europe, which was startingly overlooked in 16th-century treatises as much as in present-day studies (with the exception of a few notes in Cotter 1992).

From local historical documents and archaeological finds, it is known that, at least since the Middle Ages, potters from Bavaria and neighbouring regions competed for the exploitation of certain clays, which they used for the production of black wares in general, and crucibles in particular. These clays were referred to as *Eisentachen* or "iron clay", probably due to their metallic appearance, as they were naturally very rich in graphite inclusions. The most famous crucible producers in the area during early modern times were the potters from Obernzell, in the archdiocese of Passau, where the largest deposits of graphite in Europe are to be found. Other clay deposits in Bohemia and Upper Austria were exploited as well (Bauer 1976; Bauer 1983).

Bavarian crucibles are consistently wheel-thrown and fired dark grey or black in a smoky kiln, altough used samples range from brown through purple to orange. The clay matrices are rich in alumina (around 30 wt%), although they also show moderately high iron oxide levels (≥5 wt%) (table 1). They were fired to relatively high temperatures, in the range 950-1050 ºC, as noticed in the initial to intermediate degree of vitrification, together with the presence of residual plagioclase and the unaltered state of feldspar inclusions in unused vessels. The most remarkable feature of these fabrics is normally the presence of graphite speckles, in concentrations ranging from 20 to 70 vol% (fig. 3). As discussed elsewhere (Martinón-Torres 2005), graphite brings an excellent technical asset for the crucibles, enhancing to the utmost not only the toughness and the thermal shock resistance, but also the refractoriness, the tensile strength, the thermal conductivity and even the corrosion resistance of the crucibles. Only repeated firings in strongly oxidising conditions would progressively lead to the burning away of graphite and the subsequent weakening of the vessels.

The fact that graphite brings about specific material properties in the ceramic paste does not imply that all of these qualities were noticed or valued in the early post-medieval period, not even that the good quality was directly associated to the presence of graphite. In fact, the assemblage from the laboratory in Oberstockstall (Austria) shows the presence of non-graphitic crucibles that were reduced fired and used as the graphitic ones (Martinón-

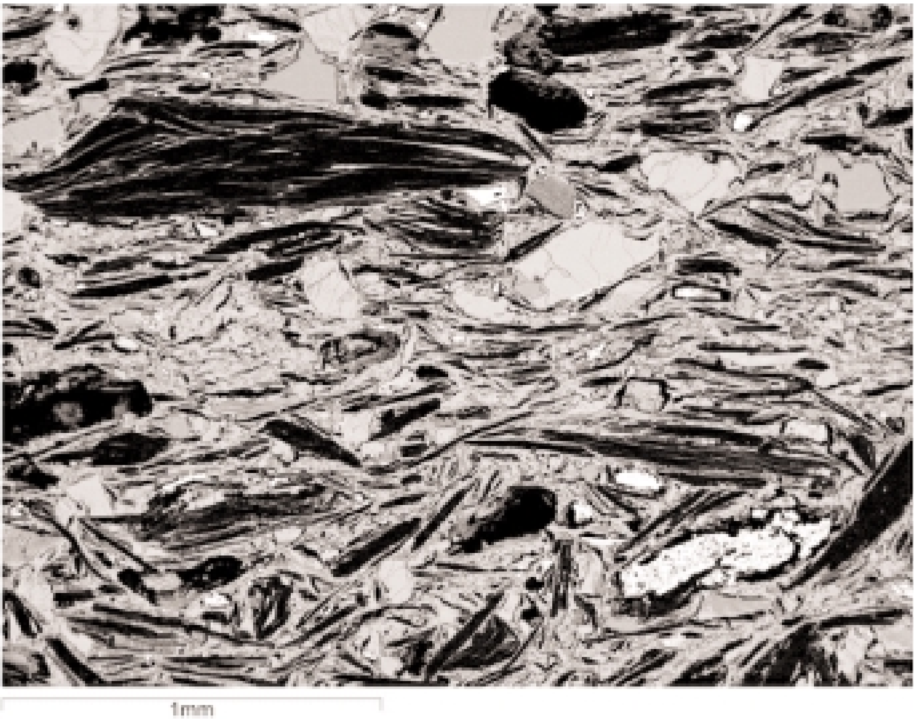

Figure 3. Backscattered electron image of a dark Bavarian crucible, showing abundant graphite speckles (black) as well as some silicate inclusions.

Torres *et al* 2003). Furthermore, graphite is not explicitly mentioned at all until the late 17th century (and even then it is referred to as *Wasserbley* or "liquid lead", still denoting an atypical understanding). In this sense, perhaps the better performance was originally related to the external quality, much more in line with the Renaissance mentality. Only by repeated experience, and through feedback between manufacturers and users, the link between graphite and good performance would have been fully realised. This would explain the concern with appearance, as all the crucibles produced in the region, graphitic or not, show a very smooth surface finish and black surface, resulting from a deliberately smoky firing.

Post-medieval dark crucibles, primarily graphitic, could be identified in the production centre of Obernzell, as well as in the laboratory in Oberstockstall (Lower Austria), the Ashmolean laboratory in Oxford (where, interestingly, Hessian ones are also present), some spot finds from London and Canterbury (UK), and the Imperial Mint in Rio de Janeiro (Brazil). Those produced in Obernzell sometimes show a compex stamp in the base, combining a symbol resembling a number 4, a cross and two initials inside an elongate cartouche. The vessels found in Oberstockstall show a distinct 'T' stamp, and slightly different microstructure and composition.

5. CONCLUSIONS AND FURTHER WORK

This brief outline provides a preliminary picture of the crucible production and distribution in the post-medieval world. It has been shown that not only Hessian, once "mysteriously good", crucibles were produced and exported in large quantities, but also the historically less documented black crucibles manufactured in Bavaria, Bohemia and Upper Austria. The latter had generally equivalent material properties and performance characteristics, in spite of the different design and appearance. Other productions, possibly local, are present in several sites, and these are normally less refractory.

It seems reasonable to assume that both the main types co-existed and competed with each other in the international market. In this sense, their contrasting appearance and texture (light-coloured and sandy *versus* dark-coloured and smooth) may be highlighted as foremost factors potentially leading to their identification in the market as "one of a kind". It should be noted that shape, colour and texture, together with other external qualities, and not the material properties, are the features conditioning the choice of one pottery type or another (cf. Sillar 1997; Cumberpatch 1997; Jones 2004). Furthermore, the peculiar perception and understanding of graphitic clays in early times stresses the danger of assuming that past societies appreciated the same formal and material properties as we do today.

Given the variety of archaeological contexts where these crucibles are found, it will be interesting to determine the reasons behind the choice of each type of crucibles in each particular case, which specific features were noticed and valued, and details of the crucibles' performance in specific circumstances. In addition, questions arise as to the channels of this large scale commerce, and as to whether the flow of crucibles amongst different spheres of technology was accompanied by skills and ideas. These are aspects of ongoing research.

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REFERENCES

Bauer I 1976. Zur Geschichte der Schmelztiegelherstellung in Obernzell, *Volkstümliche Keramik aus Europa. Zum Gedenken an Paul Stieber*, 13-37. Munich: Deutscher Kunstverlag.

Bauer I 1983. *Handbuch und Führer zum Keramikmuseum Schlo? Obernzell, Zweigmuseum des Bayerischen Nationalmuseums* (2nd rev. edn.; 1st edn. 1982). Munich: Bayerisches Nationalmuseum.

Cotter J P 1992. 'The Mystery of the Hessian Wares': Post-medieval triangular crucibles. In D Gaimster and M Redknap (eds) *Everyday and Exotic Pottery from Europe c. 650-1900. Studies in honour of John G. Hurst*, 256-272. Oxford: Oxbow.

Cumberpatch C G 1997. Towards a phenomenological approach to the study of medieval pottery. In C G Cumberpatch and P W Blinkhorn (eds) *Not so much a pot, more a way of life. Current approaches to artefact analysis in archaeology*, 125-151. Oxford: Oxbow.

Jones A 2004. Archaeometry and materiality: materials-based analysis in theory and practice, *Archaeometry* 46: 327-338.

Martinón-Torres M 2005. *Chymistry and Crucibles in the Renaissance Laboratory: an Archaeometric and Historical Approach.* PhD thesis. University of London.

Martinón-Torres M and Rehren Th 2002. Agricola and Zwickau: a study of the theory and practice of Renaissance brass production in SE Germany', *Historical Metallurgy* 36(2): 95-111.

Martinón-Torres M, Rehren Th and von Osten S 2003. A 16th-century lab in a 21st-century lab: archaeometric study of the laboratory equipment from Oberstockstall (Kirchberg am Wagram, Austria). *Antiquity* 77(298) [http://antiquity.ac.uk/ProjGall/martinon/martinon.html].

Plot R 1677. *The natural history of Oxford-shire: being an essay toward the natural history of England*. Oxford.

Sillar B 1997. Reputable pots and disreputable potters: Individual and community choice in present-day pottery production and exchange in the Andes, in C G Cumberpatch and P W Blinkhorn (eds) *Not so much a pot, more a way of life. Current approaches to artefact analysis in archaeology*, 1-20. Oxford: Oxbow.

Sisco A G and Smith C S 1951. *Lazarus Ercker's Treatise on Ores and Assaying, translated from the German Edition of 1580*. Chicago: The University of Chicago Press.

Smith C S and Gnudi M T 1990. *The Pirotechnia of Vannoccio Biringuccio: The Classic Sixteenth-Century Treatise on Metals and Metallurgy* (1st edn. 1959). New York: Dover.

Stephan H-G 1995. *Großalmerode: Ein europäisches Zentrum der Herstellung von technischer Keramik. Die Geschichte der keramischen Gewerbe in Großalmerode und Epterode und die Entwicklung ihrer Produktion vom 12. bis zum 19. Jahrhundert, Teil II: Technische und Baukeramik…* Großalmerode: Glas- und Keramikmuseum.

Tite M S, Kilikoglou V and Vekinis G 2001. Strength, toughness and thermal shock resistance of ancient ceramics, and their influence on technological choice. *Archaeometry* 43: 301-324.

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