Copper Alloy Viking-Era Keys

Table of Contents

Item Description:

Simple Viking-Era turn-lock keys, an early style as found in Helgö, Birka, and Gotland.

Material:

The copper alloy composition is copper and zinc (90% copper, 10% tin). This makes the material consistent with bronze. I mixed the alloy used for all the castings present, including the keys.

Method:

A. The Metal: I created the metal alloy for both keys by inserting a small amount of tin into a graphite crucible, and then filling the crucible with copper ingots. I then used a propane smelting furnace to achieve a heat of around 1900-2000 degrees. Then, a chesnut-stick was used to mix the melt to insure a proper bronze alloy. Renaissance-Italian metal-smith Vannoccio Biringuccio suggested the use of a chesunut stick as a stirring device in *Pirotechnia.*[1]

B. The Clay Mould:

a. The method of casting was lost-wax, in clay moulds. Based upon research of metal-workshops from the Viking-Era, casting in the Viking Era moulds consisted of clay, mixed with quartz-sand and some kind of biological material (such as hair or manure). Historical sources differ on the exact consistency of the mixture, though archaeologist Michelle Smith provided a break-down of the composition that worked during her experimentation that was useful for this work.[2] Using Smith's analysis and that of historian Anders Söderberg and Renaissance-Era master-craftsman Vannoccio Biringuccio, along with a great deal of trial and error, the mixture of clay, sand and hair that seemed to work the best was 40% sand (which provides a refractory quality) and 10% hair, (which carbonizes as metal is poured in, allowing gasses to escape).[3]

b. The clay, when mixed, was wrapped around a wax model, with a large-enough opening left for pouring the melt in at an angle. This also allowed air to escape as the was metal poured in.

c. The moulds were then left to slowly dry for three days (allowing for shrinkage to set in). Slip was used to fill cracks that may have formed during the drying process, and then the mould was heated for four hours in a six hundred to eight hundred degree charcoal fire. The heat was suggested by Smith in her experimentation.[4] The mould was then set upside-down, the wax melted out, and the cavity was left to be filled with the melt.

---

[1] Gnudi, Martha Teach., Vannoccio Biringuccio, and Cyril Stanley. Smith. The Pirotechnia of Vannoccio Biringuccio: The Classic Sixteenth Century: Treatise on Metals and Metallurgy. Estados Unidos: Dover Publications, 1990. Pg. 296.

[2] Bork, Robert Odell. De Re Metallica: The Uses of Metal in the Middle Ages. Aldershot, Hants, England: Ashgate, 2005. Pgs 88-89.

[3] Ibid, Pg 90. Also Söderberg, Anders. "Viking Metal Casting." Viking Metal Casting. April 30, 1999. Accessed January 21, 2017. http://web.comhem.se/vikingbronze/casting.htm. Also Gnudi, Pg. 219.

[4] Bork, pgs 90-91.

Fig 1: Initial heating of the moulds. More charcoal will be added around the moulds after an hour.
Refer to the Figures in the text

Fig 2: Taking the melt. If the mould is hot enough, the melt should pour in safely.

C. The Wax: The beeswax used for this project was obtained from Master Hrodnavar Hakonsson, who maintains beehives in his backyard. It was lightly heated, shaped by hand, files, and knives, and candle flame was used to heat up parts of the wax for "glue," to attach joints and extraneous parts.

Inspiration/Use:

Keys are not uncommon in Viking-Era archeological sites.[5] Their utility and possible symbolism were apparently an important part of the 8th-10th century Scandinavian world. These seem to have been fairly common items that were either simple and utilitarian, or highly decorative. As I have never before worked with high-temperature copper alloy, wax, or clay moulds, I decided to try these out making keys. Happily, the process has granted some experience useable for more casting in the near future!

Both key styles featured here were found at Helgö and Birka, among other sites. Examples can be seen in the Swedish National Museum on display and in their digital archives (refer to the figures below). Apparently, both Helgö and Birka were once manufacturing sites for both locks and keys in the 9th and 10th centuries.[6]

The use of these items is suspected to be two-fold. The obvious use is that of opening locks.[7] Another, some archeologists suspect, had to do with status. Steele suggests that women oversaw the home and the farm and therefore were the guardian of the keys. This is to say that possessing and even displaying one's keys was symbolic of a woman's status in local society.[8] Such an analysis rings true, especially since in Scandinavia, women were typically left in charge of the home and farm when their husbands were away, and could inherit land from fathers or husbands.[9]

---

[5] Steele, Ramona S. "Viking Age Keys and Locks: Symbolism in Life and Death." Gotland Archaeological Field School, Papers from the 2013 Expedition. 2013. Accessed March 21, 2017. http://www.gotland-fieldschool.com/field-courses.html. Pg. 6.
[6] Ibid. Pg 5.
[7] Ibid.
[8] Ibid.
[9] Ibid.

The symbolism of the key is accounted for in the *Poetic Edda*, when Thor disguises himself as Freya and goes to wed Thrym so that Thrym will return Mjolnir (Thor's hammer):

> "Busk we Thór then in bridal linen, and buckle on him the Brísings' necklace. Let a housewife's door keys dangle about him. Let him bear on his breast bridal jewels, a hood on his head, as behooves a bride."[10]

By wearing keys on her chains, a bride, in this case, was showing her status.

Key #1: Simple loop turn-key:

Fig 3: Historiska Museet.[11]

Fig. 4: Historiska Museet[12]

Key #2: Simple Loop Turn-Key with Cross Hatch:

Fig 5: Historical Museet[13]

[10] Ibid.

[11] Historical Museet Image archive location: (http://mis.historiska.se/mis/sok/fid.asp?fid=479265&g=1)

[12] Historical Museet Image archive location: (http://mis.historiska.se/mis/sok/fid.asp?fid=452491&g=1)

[13] Historical Museet Image archive location: (http://mis.historiska.se/mis/sok/fid.asp?fid=107668&g=1)

Rationale:

Background: The inspiration for this project came about while I was travelling through Scandinavia on a trip to Gotalnd, Birka, and Hathabu. The museum exhibits at the Danish National Museum and the Hathabu historical site, along with the re-enactment village-center of Hathabu, are extremely exciting to see first hand. Although I have dabbled in pewter arts, this higher-temperature metal casting was something new, and therefore I really wanted to give it a shot. The hardest part is that I've never worked with brass or bronze. Similarly, I have never before worked with wax. Therefore, I chose a fairly simple design for this project: keys presumed to be once owned by female Scandinavian women.[14]

Material Rationale: Most of the materials used for this project are as close to the original as possible: copper, beeswax, clay, sand, wool, and heat. For the keys in this display, the zinc to make proper Viking-Era brass was replaced by tin, which effectively made bronze. This was specifically for the safety of the melt: zinc is dangerous to breathe, and safety respirators were not handy on the one non-rainy day I had to make this mixture. Please note that in the display, there are examples of "Classical Brass," of the sort the Viking-Era casters may have worked with.[15] This makes a somewhat more gold-like color compared to bronze, which is interesting, because Classical Brass (also known as Roman Brass) was reported to be gold in color and highly valued by those wishing to sport gold ornamentation, but who could not afford actual gold.[16]

Heating Rationale: My goal was to create a 2000 degree fire using methods as close to period as possible. To attempt this, I first tried a Viking-Era style furnace at Huntington Beach, using stone, sand, clay, and hardwood charcoal. The air was supplied by a double-action hand-pump through a *tuyre.*[17] Although this did result in a slightly melted alloy, this method simply did not heat the metal up enough to pour [Fig. 6-8]. I eventually used a proper charcoal fire in a sand fire pit to heat the moulds (contained for safety in an old smoker), heating the metal with a propane smelting furnace. While I have a long-term goal to completely recreate a full Viking-Era workshop with a mud/clay furnace and bellow, for obvious reasons I could not achieve the desired results on my condo carport!

Process Rationale: As far as is known, Viking-Era casters used two piece Direct-Matrix casting (pressing and removing a "tool" model or already extant piece into the clay to make a mould cavity), and, *based upon the quality of many period archeological finds*, also used lot-wax casting in a single mould. The

---

[14] Steele, Ramona S. "Viking Age Keys and Locks: Symbolism in Life and Death." Gotland Archaeological Field School, Papers from the 2013 Expedition. 2013. Accessed March 21, 2017. http://www.gotland-fieldschool.com/field-courses.html. *Additional note from this source:* While keys have been found in graves of both men and women, more keys are currently found in female graves. Interestingly, the evidence also suggests that women typically possessed simple keys (such as those in this entry), whereas men had more decorative keys, often displaying animals and various forms of knotwork.

[15] Söderberg, Anders. "Viking Metal Casting." Viking Metal Casting. April 30, 1999. Accessed January 21, 2017. http://web.comhem.se/vikingbronze/casting.htm. Extant finds show that bronze was not the most common copper alloy used by the Viking-Era Scandinavian metal casters. Söderberg notes that a correct English terminology for Viking-era alloys, would be "gunmetal (brass + Sn) leaded brass (brass + Pb), and leaded gunmetal (gunmetal + Pb)."

[16] Martinón-Torres, Marcos, and Thilo Rehren. "Agricola and Zwickau: theory and practice of Renaissance brass production in SE Germany." HM 36 (2002). Pg 102.

[17] Most bellows have a plastic, metal, leather or wood tip. This tip in most cases cannot withstand the heat inside of a furnace. Therefore, common practice (even in the Viking-Era) was to use a clay tube (a tuyre), made the same way a mould or crucible was, to funnel air from the bellows into the furnace. This protects the bellows from damage.

reason for the "based upon" statement above is that the process of making lost-wax moulds destroys the evidence of the wax. Therefore, there is limited evidence of beeswax lost-wax casting, though caked-wax stores have been found, which presumably was specifically for casting.[18] The one issue for which archaeologists agree is that the lost-wax method was most certainly used, as the quality of direct-matrix casting does not always result in extremely crisp detail that higher-quality Viking-Era work is famous for.[19] Smith suggests that perhaps a soft layer of clay mixed with charcoal dust may be the best way to preserve intricate detail in a direct-matrix mould.[20] This process will soon be tried!

Fig 6.

Fig 7.

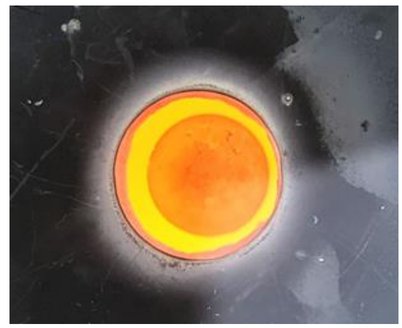

Fig 8.

Figures 6 & 7 show the melt in a sand & clay furnace at Huntington Beach. The melt was not able to be heated quite enough for a good pour. More forced air will be needed. Figure 8 shows the melt as it should be, as melted in a propane furnace.

Fig. 9: Sigurd Fafnesbane with tools and bellows. From the Sigurd Runic carving, Sweden. This carving gives credence to the use of double-bellows in the Viking-Era for metal-working. A similar set-up is currently in use at the Hathabu historic village.

[18] Gustafsson, Ny Bjorn. "Beeswax in metalworking in Viking Period Gotland." Fornvannen 111 (2016), pg. 4-5.
[19] Bork, Robert Odell. De Re Metallica: The Uses of Metal in the Middle Ages. Aldershot, Hants, England: Ashgate, 2005. Pgs 91.
[20] Ibid.

Lessons Learned:

As can be seen in the display, there were plenty of teachable moments along the way, both with the items entered and the casting process in general.

1. Specifically with the keys, while extant simple keys pictured in this documentation are not necessarily intricate works of art, arguably they are more refined than at least the cross-hatch key I put on display. The most glaring issue is that one outside loop did not fully cast, and the key prongs themselves are not as refined as I would have liked.
2. Casting in clay is more art than science. Where no one agrees is how much of each component (sand, clay, hair or wool, etc) should be used. Even the type of clay is unspecified in the research! This then is left up the caster to find out through the laborious process of trial and error. Red clay tended to dry very brittle and with a lot of shrinkage, thereby destroying the mould in the process. Moulds that took a good hour to make thereby destroyed themselves in what came to be a predictable fashion. It was eventually suggested to give white clay a try, and that, along with the added components went much better. There is still a 10%-20% loss rate, but that is better by far than a 100% loss rate!
3. Making brass is an interesting process that creates a green-yellowish fire during the melt, whereas the bronze fire is orange, and the copper fire is red. This is only to introduce the idea that there is a fire color that shows when the brass is coming together. The first thing I learned in trying to mix zinc into copper for the display pieces on the table, (just to see what it looks like), is that zinc cannot really be added after the melt is heated up. The zinc simply evaporates, leaving the original copper unchanged. The trick is to put the zinc into the crucible first, then tightly pack the copper ingots on top, and then start the fire. This way, the zinc evaporates into the copper, as the copper is beginning to melt.
4. Making bronze is easier, in that the tin can be added before or after the copper is heated up (I recommend before). As can be seen on the table, if one adds a bit too much tin, then the melt becomes…pewter!
5. For the partially cast items, quite a lot was learned. Firstly, the casting hole must be large enough to allow air to escape while the melt is being poured in. Otherwise a full cast cannot be attained. An alternative process in two part moulds that has been suggested (I have not tried it yet), is to allow for an imperfect mating of the two mould halves, so that small holes will allow air to escape. The melt will come out of the holes, but only until it begins to cool and plugs the hole. The problem with this method is that there will be a lot of wasted melt that has to be extracted and returned to the crucible.

Fig 10: Brass: The fire glows yellow!

Fig 11: Bronze: The fire burns bright orange!

APPENDIX

About the Turtle Brooch Display, and the process of Direct Matrix Casting (also known as: how did Viking Era casters quickly replicate already made items which they may or may not have originally made themselves):

Although the entry for this round of Pentathlon is two simple keys, the process of getting to the point where I could actually cast these keys is worth mentioning. While it is understood that lost wax casting, the method used for the keys, was most certainly used by Viking-era casters, the method of casting for which evidence survives points to direct matrix casting.

Direct matrix casting is really a form of plagiarism, at its best. It rarely results in high-quality casts, but rather "acceptable" casts. Furthermore, archeological studies have shown that Viking-Age metalsmiths absolutely plagiarized off each other. This is to say that after a set of brooches was made, for example, another metalsmith at another site might desire to copy that item, but from an existing piece. This results in a slightly less-detailed item, since it was not made with the original tool. Archaeologists have been able to trace the path several styles went by looking at what seems to be items all based on one original style, but in decreasing levels of detail over time.[21]

Following tradition, I decided that for my first attempt at direct-matrix casting, I would need an existing brooch to "copy." An excellent artisan, Master Raymond, was able to provide me with one of his replicas of a fairly complex turtle-brooch, designed after a Birka find. Brooches like Master Raymond's are the pinnacle of basic direct-matrix casting, as they are generally difficult to make well, from the creation of the original "tool" being copied, to the complex layout of the mould (which is why I suspect he smartly uses a sand-casting method for his brooches). A lot of time was spent on these in between the recent Southern California winter rains, before swapping to lost-wax casting for the Pentathlon entry. What this means is that the best example of direct-matrix mould making and metal alloys I have been able to re-create so far exist in the various turtle-brooches on display.

[21] Bork: 85

About the Moulds for Direct-Matrix Casting:

Both Smith and Söderberg have published their experimentation with two part moulds, fragments of which are extremely common archaeological finds at Viking Age furnace sites. What is specifically needed for a direct-maxtrix two-part mould are two slabs of clay mixed with quartz sand and organic material, a tool (which is the item being copied, such as a model or existing object), and some fine slip.[22] The fine clay slip is placed along the facing side of the mould, which will capture details of the item being copied clearly (remember that the mould will be fairly course, due to sand and organic materials). Then, the tool is pressed into the facing side and allowed to dry. If the tool is being copied exactly (such as a wood, bone, clay or original exact copy), the other back-facing slab is pressed over the tool and moulded to the sides of the facing piece. An added task is to carve into the moulds "keys" along the edges of the mould halves, so that when they dry they can be reassembled exactly, and "Sprues," which is the one or more funnels into the mould in which the metal will be poured. Once complete, the mould halves will be allowed to dry. Next, the two pieces are separated, the tool removed and then a knife can be used to insert pin-mounts if required. Then, the two halves are placed back together and the whole assembly is covered in a shell of mixed clay to seal it. Once completely dry, the mould will be slowly fired up to around 800 degrees and the metal poured slowly in.

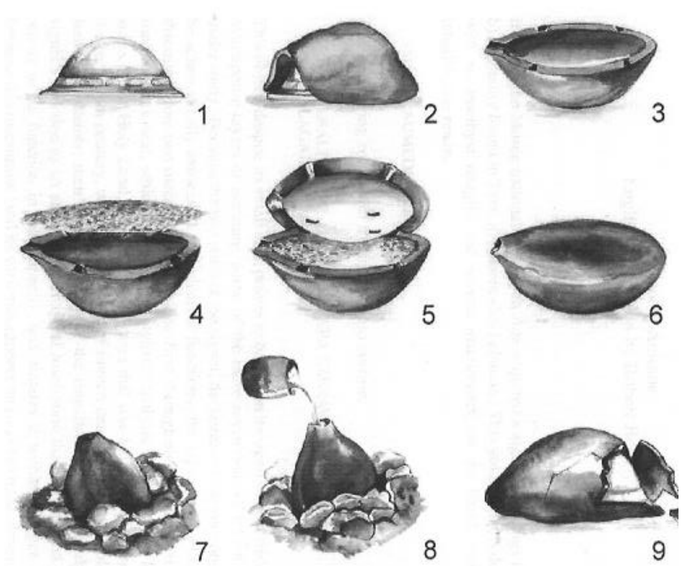

Fig 12: Diagram of an oval "turtle" brooch mould.[23]

[22] This tool, or master copy, can be made of any hard substance, including wood, bone, metal and stone.

[23] Bork, Pg. 8

Note that for oval brooches, there is an additional step, which includes leaving a piece of wool inside the back piece of the mould. So many oval brooch moulds have been found with the marks from the wool cloth that Smith wanted to figure out why it was there. It should be noted that of all the academics who have written about Viking Age oval brooches, Michele Smith is the only person to try to figure out what the wool cloth was for. Other archaeologists supposed it was just put there as a tradition, but never stated why.

What Smith found with her experimentation (replicated by myself) is that the thick wool cloth provided two functions. One, in the case that there is only a master tool with no back (like a block with a facing impression on it, but no back, etc), the inserted wool cloth provided an item thickness for which to press the back mould piece onto. The other use of the wool cloth, which was left in the mould after the two halves here assembled together, was to provide a sacrificial carbonizer, meaning that as the molten metal flows into the mould, the wool instantly carbonizes and uses up oxygen in the mould. The one thing all hot-metal casters know is that oxygen is an enemy of high-temperature casting, because it acts as a block to the gasses and metal being poured into the mould.[24]

Fig 13: Back of extant brooch with wool fabric pattern embedded, courtesy of the Royal Museum of Scotland.[25]

Below are some of the attempts at turtle-brooch mould making:

[24] Gnudi, Martha Teach., Pg. 92

[25] Bork, Pg. 97

Fig 14: The mould back, with the wool and the pin-mounts.

Fig 15: A completed cast. Note the low level of detail. This is somewhat common with direct-matrix casts.

Fig. 16: Back of cast #1: while the casting was far too thick, the vaporized wool cloth is visible, similar to Smith's findings, and that of extant period pieces.

Fig 17: Cast #2: a more successful cast, though the pin-mounds did not fully cast. The wool markings are still present.

About the Metal:

Although bronze was already an ancient metal alloy by the Viking Era, extant finds show that bronze was not the most common copper alloy used by the Viking-Era Scandinavian metal casters.[26] The rationale for why brass was more common seems to involve hypothesis that tin was either difficult to obtain in Scandinavia during the Viking-Era, or tin was simply more expensive at the time.[27] According to Anders Söderberg, zinc-based alloys were the most common consistency of metal in archeological finds in Scandinavia between 500-900 CE.[28] Pare's analysis of the metallurgy of 520 Bronze-Age graves North of the Alps shows that over 200 copper alloy finds had no tin at all, only 8% had more than 1% tin, and less than 5% had more than 4% tin.[29] Furthermore, Dungworth and Nicolas assert that throughout the Viking Age and into the 14th century, most "bronze" objects in Europe were actually a leaded antimony copper, often with little or no tin added at all.[30] Finally, Söderberg notes that a correct English terminology for Viking-era alloys, would be gunmetal (brass + Sn) leaded brass (brass + Pb), and leaded gunmetal (gunmetal + Pb)."[31]

More Lessons Learned:

As it turns out, making turtle brooches in a historic fashion is rather difficult! On display are several examples of fully cast (but not finished) or partially cast brooches, all copied by one sand-cast brooch provided for this experiment from Master Raymond (of Raymond's Quiet Press). The super thick items on display are such because the moulds either broke from the inside and ruined the casting, or the moulds were made (by myself, an inexperienced caster) to allow the brooch to be too thick. This occurred with both direct-matrix and lost-wax brooch casting. The next step, besides making my own original brooch (now that I have had a little experience with clay and wax) is to try to make such items thinner. The other issue is the metal melt. I learned very quickly that to make brass or bronze takes a

---

[26] Söderberg, Anders. "Viking Metal Casting." Viking Metal Casting. April 30, 1999. Accessed January 21, 2017.

[27] Lewis, G. R. The Stannaries: a study of the medieval tin miners, by Lewis. Harvard University: D. Bradford Barton, 1908. 26.

[28] Söderberg, Anders. "Scandinavian Iron Age and Early Medieval Ceramic moulds – Lost Wax or Not or Both?" Scandinavian Iron Age and Early Medieval Ceramic moulds. (2012).

[29] Pare, C. F. E. Metals Make the World Go Round: The Supply and Circulation of Metals in Bronze Age Europe. (Oxford: Oxbow, 2000). Pg: 18.

[30] Dungworth, David, and Matthew Nicholas. "Caldarium? An Antimony Bronze Used for Medieval and Post-medieval Cast Domestic Vessels." In Historical Metallurgy, 24-34. Vol. 38. (Harmondsworth, Middlesex: Historic Metallurgy Society, 2004).

[31] Söderberg, Anders. "Viking Metal Casting." Viking Metal Casting. April 30, 1999. Accessed January 21, 2017.

very small amount zinc or tin, respectively. Add just a little too much, and the metal is either very brittle, or it becomes a completely different alloy (such as pewter).

I am very excited to continue the process of bronze and brass casting, and am looking forward to the hopefully more stable warm-weather season to come!

Bibliography

Bencard, Mogens, ed. *Ribe excavations 1970-76*. Jutland Archaeological Society, 1984.

Bencard, Mogens, Lise Bender Jørgensen, Helge Brinch Madsen, and Aino Kann Rasmussen. *Ribe excavations 1970-76*. Jutland Archaeological Society, 2004.

Blair, John, and Nigel Ramsay. English Medieval Industries: Craftsmen, Techniques, Products. London: Hambledon Press, 1991.

Bork, Robert Odell. De Re Metallica: The Uses of Metal in the Middle Ages. Aldershot, Hants, England: Ashgate, 2005.

Dungworth, David, and Matthew Nicholas. "Caldarium? An Antimony Bronze Used for Medieval and Post-medieval Cast Domestic Vessels." In Historical Metallurgy, 24-34. Vol. 38. Harmondsworth, Middlesex: Historical Metallurgy Society, 2004.

Gnudi, Martha Teach., Vannoccio Biringuccio, and Cyril Stanley. Smith. The Pirotechnia of Vannoccio Biringuccio: The Classic Sixteenth Century: Treatise on Metals and Metallurgy. Estados Unidos: Dover Publications, 1990.

Gustafsson, Ny Bjorn. "Beeswax in metalworking in Viking Period Gotland." Fornvannen 111 (2016)

Hedegaard, Ken R. " Bronze Molds Craft in Late Germanic and early Viking Age in Scandinavia." *Archäologie in Schleswig* 2, 1992.

Lewis, G. R. The stannaries: a study of the medieval tin miners, by Lewis. Harvard University: D. Bradford Barton, 1908.

Martinón-Torres, Marcos, and Thilo Rehren. "Agricola and Zwickau: theory and practice of Renaissance brass production in SE Germany." HM 36 (2002).

Meeks, Nigel, Caroline Tulp, and Anders Söderberg. "Precision lost wax casting." *Experimental and Educational aspects of Bronze Metallurgy*, 2001.

Pare, C. F. E. Metals Make the World Go Round: The Supply and Circulation of Metals in Bronze Age Europe. Oxford: Oxbow, 2000.

Söderberg, Anders. "Scandinavian Iron Age and Early Medieval Ceramic Moulds - Lost Wax or Not or Both?" Scandinavian Iron Age and Early Medieval Ceramic Moulds - Lost Wax or Not or Both? | EXARC - Journal. 2013. Accessed January 21, 2017. http://journal.exarc.net/issue-2012-3/ea/scandinavian-iron-age-and-early-medieval-ceramic-moulds-lost-wax-or-not-or-both.

Söderberg, Anders. "Viking Metal Casting." Viking Metal Casting. April 30, 1999. Accessed January 21, 2017. http://web.comhem.se/vikingbronze/casting.htm.

Steele, Ramona S. "Viking Age Keys and Locks: Symbolism in Life and Death." Gotland Archaeological Field School, Papers from the 2013 Expedition. 2013. Accessed March 21, 2017. http://www.gotland-fieldschool.com/field-courses.html.

Images other than the author's:

Figure 4: Historical Museet Image archive location:
(http://mis.historiska.se/mis/sok/fid.asp?fid=479265&g=1)
Figure 5: Historical Museet Image archive location:
(http://mis.historiska.se/mis/sok/fid.asp?fid=452491&g=1)
Figure 6: Historical Museet Image archive location:
(http://mis.historiska.se/mis/sok/fid.asp?fid=107668&g=1)
Fig. 9: Image from Söderberg, Anders. "Viking Metal Casting." Viking Metal Casting. April 30, 1999. Accessed January 21, 2017. http://web.comhem.se/vikingbronze/casting.htm.
Figure 15: Bork, Robert Odell. De Re Metallica: The Uses of Metal in the Middle Ages. Aldershot, Hants, England: Ashgate, 2005.
Figure 16: Bork, Robert Odell. De Re Metallica: The Uses of Metal in the Middle Ages. Aldershot, Hants, England: Ashgate, 2005.