Sword and Dagger Pommels Associated with the Crusades Part II: A Technical Study

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The upsurge in demand during the Middle Ages for ecclesiastical and secular metalwork initiated an intense period of creativity for goldsmiths and metalworkers who were constantly adopting, evolving, and commingling techniques and materials to fulfill their clients' variable desires. The group of lozenge- and scallop-shaped pommels in the collection of Laird and Kathleen Landmann and in the Arms and Armor Department at The Metropolitan Museum of Art are emblematic of this foment in that they exemplify the unique conjunction of two distinct technologies brought together to satisfy both decorative and functional requirements: champlevé enamel and the casting of hollow objects in the round by the lost-wax technique.

At the beginning of the twelfth century, metalworkers in Lower Saxony and northern Germany integrated into their technical repertoire the ability to cast hollow, three-dimensional objects in the round by the lost-wax process.[1] The technique had not been practiced in the West since antiquity, but it is possible that Early Christian, Byzantine, and Islamic objects served as models. The difficulties inherent in the technique limited its implementation during the medieval period to objects of significant value such as aquamaniles. It was, however, the ideal mechanism for creating the more modest hollow forms of pommels, being preservative of raw material and providing an efficient means of creating an object with sufficient physical integrity to withstand regular usage.

In simplified terms, the lost-wax casting of a hollow object modeled in the round involves the initial shaping of a core, the application of an overlaying wax layer that represents the form of the intended casting, and the application of a claylike investment, or outer layer, that envelops the wax and is keyed to the core by a series of core pins. Both core and investment were traditionally comprised of inorganic and organic components, with the particular mix depending on local supplies and traditions. The intent was to create a blend of materials that had sufficient cohesiveness and plasticity to allow easy modeling, that would retain its shape during subsequent working and heating, and that would provide an adequate refractory for casting.[2] Core material is preserved in many of the pommels, and where visually accessible it has a heterogeneous appearance consistent with the inclusion of powdered brick, sand, and inorganic materials (see Figure 31). The cores for both the lozenge-shaped pommels and the scalloped disks were modeled to mirror closely the intended final form of the casting. For the scalloped pommels, each lobe was articulated and in some instances a taper introduced in the core's depth along its vertical axis with the widest point abutting the grip. The degree of conformity is easily discerned in the X-radiographs (Figure 32), as is the occasional rounding of the shoulders of each lobe where they meet the central disc, thickening the casting in that area to ensure a sufficient depth of metal for further working after casting.

The similarity in the size and shape of the scalloped pommels suggests that the cores were produced in a replication process. One possible approach might have entailed creating an exact model of the required core and introducing extensions at either end of the vertical axis that approximated the dimensions of the tang at its point of entry and exit and served as core prints securing the core within its investment. Next, a simple clay bivalve mold of the completed model, each valve including a nearly equal volume of the central form and the two extensions, would have been formed and fired. The two halves could then have been

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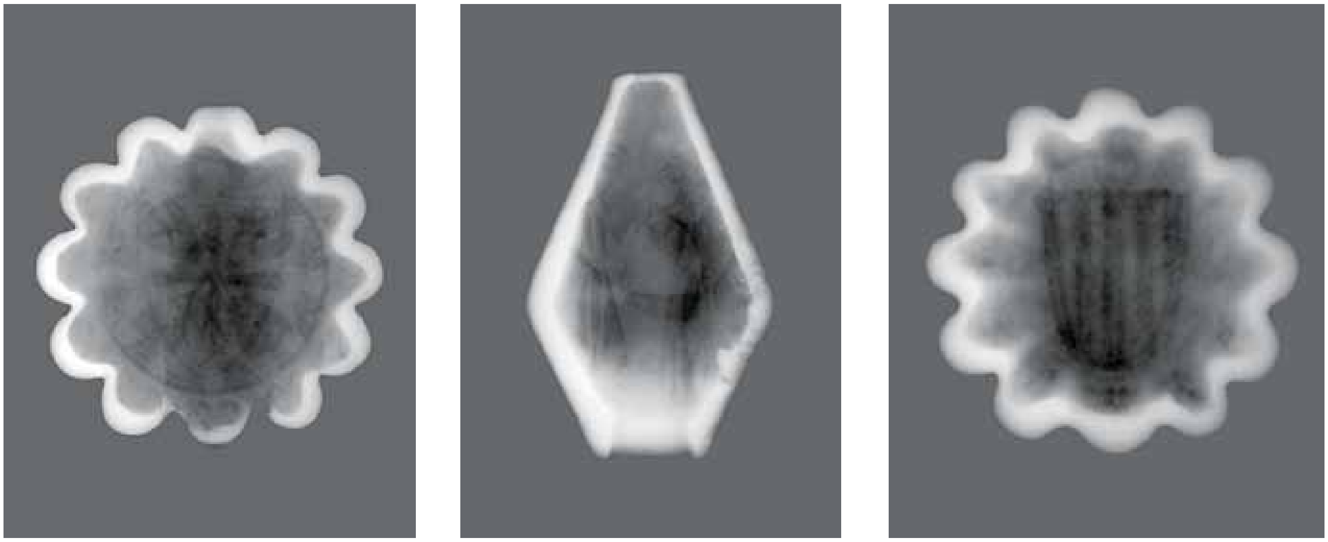
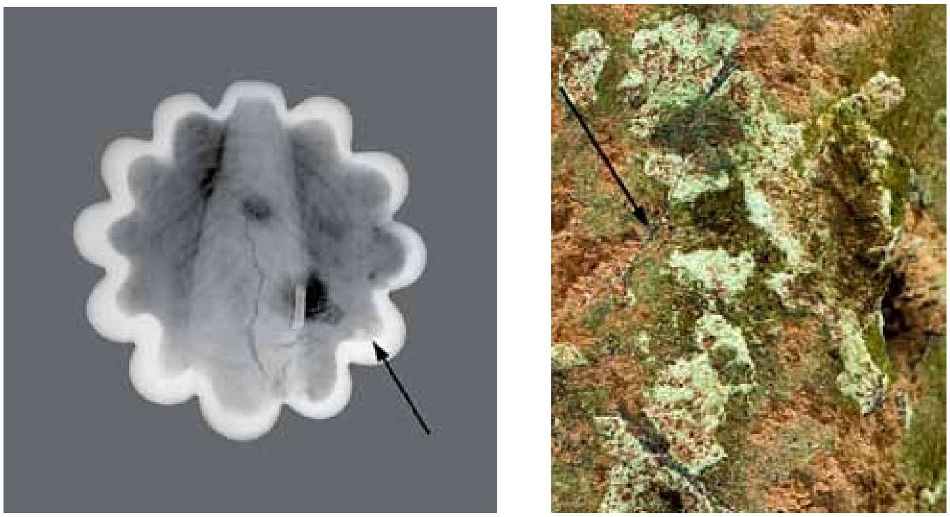
31. Detail of a cross-section of the core of L.2007.86.23 (see Figure 14). The detail of the core's cross-section illustrates its heterogeneous, porous composition, with large grains of quartz and other materials bound in a clay matrix. The high incidence of quartz would allow the channel for the tang to be readily cleared. The gray color of the core adjacent to the metal at the base of the image is indicative of the reducing atmosphere there, while the reddish color closer to the interior denotes an oxidizing environment. Photograph: Pete Dandridge

filled with core material, pressed together, and released to provide a copy of the original model and its core prints. Alternatively, a wooden strip similar in size and shape to the tang could have been set across the central cavity, to be embedded within the core material there while entirely filling the space at either end of the mold reserved for the core print. (For the solidly cast pommels, integrating a wooden model of the tang during casting would have been the most functional means of creating a central path for the insertion of the tang after casting.) Or a ball of core material could have been formed around a wooden model of the tang and the whole pressed between two boards to flatten and to impart the desired taper. The lobed profile would have been cut in by a metal former much like a cookie cutter, with the ends of the wooden model extending beyond the perimeter of the core. The use of the last option might explain why on some of the pommels the taper is not evenly aligned on both sides of the central axis, as it would have been easy to tilt one of the boards slightly to one side during compression.

Once air dried, the core was overlaid with beeswax, which in the final phase of casting was melted out and replaced by molten metal. A minimum depth of wax was required to allow for the unrestricted flow of the fluid metal into the evacuated space between the core and the investment and for the hardened metal to have sufficient mechanical strength to withstand finishing and use. Dipping the core into molten wax would have been an efficient means of achieving an even coating.[3] After the wax model had been refined, a series of core pins would have been inserted through the wax and into the core. A section of each pin



32. X-radiographs of, left: L.2007.86.7, center: L.2007.86.3, and right: L.2011.47 (see Figures 6, 25, 19). In these X-radiographs the thickest areas of metal appear the lightest. The greater depth of metal on the sides of these hollow pommels outlines the shapes of their conformal cores. In the pommel on the right, the fins of metal extending from the hollows of each lobe into the center indicate that the shoulders on either side of the lobes were rounded off in the core, thickening those areas in the casting. In the lozenge-shaped pommel in the center, a triangular core plug is visible in the lower right side, and a similarly shaped plug is apparent in the pommel on the left at 4 o'clock. Photographs: Pete Dandridge



33. X-radiograph (left) and detail of the exterior surface (right) of L.2007.86.8 (see Figure 7). The X-radiograph indicates the form of the core, the tapering shape of the retained section of tang, a rectangular fill adjacent to the lower right edge of the tang, and two core plugs, indicated by the arrow. The detail of the exterior surface of the pommel shows the peanutlike profile of the hammered-in plugs and a thin line of soft solder around their perimeter, indicated by the arrow. Photographs: Pete Dandridge

34. Detail of L.2007.86.10 (see Figure 23, right). The triangular cross-section of the V-shaped graver is apparent in the incised areas carved out to receive the enamel, as are the stepped jumps of the burin used to engrave the shallower, linear design elements toward the interior of the pommel. Photograph: Juan Trujillo, Photograph Studio, MMA

extended beyond the wax and was enveloped in the investment, effectively securing the register of core and investment during the melting out of the wax and the pouring in of the metal. In the instance of the pommels, the core prints at either end of the prefabricated cores, either the clay mixture or the wood, would have extended beyond the wax layer to be encapsulated within the investment, effectively anchoring core to investment and obviating the necessity of core pins. However, nearly half the pommels seem to have included a single core pin, evinced either by the presence of a core plug filling the space previously occupied by the pin or by a circular hole absent either pin or plug.[4] The extant plugs, usually discernible only in X-radiographs (see Figure 33), were carefully finished on the exterior and are presently covered with an archaeological surface of corrosion products and burial accretions.

Before the wax was covered with its investment, a series of wax rods were attached to provide a gating system that would allow the wax to be melted out and the metal poured in. The simplicity of the pommel's shape might have required only a single runner or central sprue with a wax model of a pouring basin at the top to receive the molten metal and direct it down into the areas previously occupied by the wax. A single riser at the base of the pommel would have provided an exit point for trapped air and the gases generated during the pour, as well as excess metal.

The application of the investment was generally a multistep process. The consistency of the initial layer was finer in order to pick up surface details articulated in the wax. When a sufficient thickness had been built up to provide an adequate refractory to absorb the thermal shock of the hot metal, the core, wax, and investment were placed near an oven to cure and to melt out the wax. The interlocked core and investment were then transferred to a furnace for firing and while still warm, removed from the kiln and buried in well-tamped soil. The resistance provided by the soil offset the pressures generated by the gases and steam released as the molten metal flowed into the interior of the mold and prevented the investment from breaking open and spoiling the casting. When the metal cooled,the investment and the core prints were broken away, the excess metal in the runners and risers was cut off, the core pin(s) were replaced with core plug(s), and the surfaces were finished and prepared for enameling. Microscopic examination of the pommels' exposed metal surfaces within enamel cells and incised designs reveals no trace of as-cast texture; the surfaces show only the tool marks associated with chisels, gravers, and punches, indicating that the cells and designs were carved in after casting (see Figure 34).

Retaining the core during engraving would have provided additional resist for the metal skin, but prior to enameling it would have been necessary to clear a channel for the insertion of the tang. The inclusion of a high proportion of sand would have resulted in a friable core that could be readily broken out. Similarly, a wooden stick that carbonized during casting would have been easily cleared. To secure the pommel in place it would have been inserted over the tang, against the grip, and the top of the tang then

35. Details of L.2011.47 and L.2007.86.8 (see Figures 19, 7). Triangular wedges have been used to expand the metal of these two pommels at the entry point of the tang, aiding their cohesion. An additional sheet of copper was also inserted between the tang and the pommel on L.2007.86.8. Photographs: Pete Dandridge

hammered flat to secure pommel, grip, and guard to the sword or dagger. If the opening at the base of the pommel was oversize relative to the tang, it would have been necessary to expand the metal of the pommel around the tang's point of entry; the resultant horizontal strikes, supplemented on occasion by an additional metal insert, are visible on the sides of some of the pommels (see Figure 35). Several of the pommels also exhibit on their sides, often on lobes not associated with the insertion of the tang, a series of vertical or horizontal marks parallel to one another that are more suggestive of assembly marks (see Figure 36).

The predominant copper alloy used for casting in the Middle Ages both in Europe and in the Islamic world was latten, with zinc the primary alloying agent and tin and lead present at concentrations greater than 1 percent.[5] For this study, the metal compositions of thirty pommels were analyzed (see Table 1). A review of the analyses shows that latten alloys do predominate; however, brass, leaded bronze and brass, copper, and alloys falling outside these characterizations were utilized as well. The compositional variations suggest that the pommels were produced not within a single, codified tradition but rather by multiple fabricators using their traditional alloys and integrating recycled material as well. What almost all the alloys share is a color resembling gold and a relatively high concentration of lead, commonly added to enhance the metal's casting properties and to ease its engraving.[6] Two of the pommels were formed from unalloyed copper; microscopic examination of the surfaces of both revealed traces of gold and surface analysis of one (38.60) confirmed the presence of gold and mercury, indicating that the surface was amalgam gilt.

Champlevé enameling, in which shallow depressions, or cells, in a metal substrate are filled with powdered glass and

36. Pommels exhibiting what look to be assembly marks on their sides. a: L.2011.47 (see Figure 19), b: L.2007.86.15 (Figure 21, center), c: L.2007.86.11 (Figure 21, left), d: L.2007.86.17 (Figure 22, left), e: L.2007.86.23 (Figure 14), f: L.2007.86.19 (Figure 22, right). Photographs a–d and f: Pete Dandridge; e: Juan Trujillo, Photograph Studio, MMA

TABLE 1. SEM-EDS ANALYSES OF METAL ALLOYS (WEIGHT %)

	Fe	Ni	Cu	Zn	As	Sn	Sb	Pb
L.2007.86.2	0.4	nd	74.8	11.3	0.3	3.2	nd	9.9
L.2007.86.3	0.4	nd	71.7	18.3	0.3	0.3	nd	8.9
L.2007.86.5	0.4	nd	75.0	10.9	0.4	2.9	nd	10.3
L.2007.86.6	0.3	nd	77.2	10.2	0.5	2.1	nd	9.6
L.2007.86.7	0.4	nd	82.2	14.7	0.7	0.5	0.2	1.2
L.2007.86.8	0.5	nd	81.6	15.4	0.6	0.4	nd	1.4
L.2007.86.9	0.8	nd	78.5	4.2	0.4	4.5	nd	11.5
L.2007.86.10	0.6	nd	78.3	3.5	0.6	8.0	nd	8.9
L.2007.86.11	0.5	nd	75.2	6.4	0.2	4.0	nd	13.7
L.2007.86.12	0.4	0.1	80.8	6.2	0.4	5.7	0.4	6.0
L.2007.86.13	0.2	nd	83.0	10.8	0.9	1.3	nd	3.7
L.2007.86.14	0.5	nd	79.2	4.3	0.4	7.8	nd	7.7
L.2007.86.15	0.3	nd	80.5	2.7	0.7	8.3	nd	7.4
L.2007.86.16	0.5	0.1	78.7	6.1	0.3	5.7	nd	8.4
L.2007.86.17	0.1	nd	85.8	0.7	0.4	5.4	nd	8.5
L.2007.86.18	0.8	nd	79.2	10.5	0.6	2.8	nd	6.0
L.2007.86.19	0.6	nd	79.9	6.0	0.5	3.6	nd	9.3
L.2007.86.20	0.8	nd	73.8	8.3	0.4	2.2	0.2	14.2
L.2007.86.21	0.3	nd	75.8	11.0	0.7	3.2	nd	8.9
L.2007.86.22	0.5	nd	73.7	10.8	0.2	0.2	1.1	13.4
L.2007.86.23	0.5	nd	74.4	6.6	0.5	3.3	0.3	14.3
L.2007.86.24	0.5	nd	79.8	9.8	0.5	2.0	0.4	6.9
L.2007.86.25	0.3	nd	65.8	17.4	0.3	nd	nd	16.1
L.2007.86.26	0.3	nd	79.5	3.7	0.4	3.7	nd	12.4
L.2011.47	0.7	nd	75.6	8.5	0.6	2.2	nd	12.3
29.158.680	0.3	nd	80.3	2.4	0.3	10.7	0.7	5.2
29.158.685	0.6	nd	77.6	11.3	0.6	4.2	nd	5.6
42.50.134	0.2	nd	91.5	6.8	0.2	0.9	nd	0.3
42.50.136	nd	nd	99.3	nd	0.4	nd	0.2	nd
38.60	nd	nd	97.8	0.1	0.7	nd	0.4	0.9

nd = not detected

Microsamples of the metals were taken from below the corrosion layers and analyzed by energy dispersive X-ray spectrometry in the scanning electron microscope (SEM-EDS). Weight percentages of the elements detected were calculated according to well-characterized reference metals and standards. Elements sought here included iron (Fe), nickel (Ni), copper (Cu), zinc (Zn), arsenic (As), tin (Sn), antimony (Sb), and lead (Pb). Minimum detection limits for most elements are estimated at 0.1 percent by weight, with antimony and lead somewhat higher at 0.2 and 0.3 percent respectively. Because of segregation of lead in copper alloys, the lead content in a leaded alloy may vary tremendously from spot to spot, and the analysis of a microsample from one area may not be entirely representative of the average composition of the piece as a whole. Partial mineralization of the metal from the sampled areas, and possible contamination of the metal microsamples with corrosion products, may also affect the apparent ratios of the elements. Surface analysis in the SEM was done of one additional piece (L.2007.86.4) that could not be safely sampled. This pommel appears to be formed of a leaded bronze alloy.

then fired in a kiln at high temperature to fuse the granules into a glassy state, was one of the decorative techniques that became more ubiquitous and refined during the Middle Ages. Because it is a subtractive process and requires a consequent depth of metal, the substrate is usually comprised of copper or copper alloy, a more robust and less expensive choice than silver or gold. Historically, champlevé enamel was incorporated into fibulae, horse trappings, and other utilitarian objects created in western Europe, Britain, and Ireland during the Gallo-Roman, Celtic, and Anglo-Saxon periods, from roughly the third to the eleventh century.[7] Within these cultures, the substrates were solid castings and the cells generally transferred from the model. This approach to champlevé enameling seems to have disappeared or fallen out of favor with the introduction in the Romanesque period, at the beginning of the twelfth century, of an entirely different methodology utilizing wrought copper or copper alloy as the substrate and with the cells carved in. The Meuse Valley, Cologne, and Limoges were the principal centers of enamel production and innovation at that time.[8] In engraving their cells and designs, the metalworkers who produced these pommels were following contemporary practices, but their use of a cast substrate on a hollow, three-dimensional object appears to be a distinct variant.

Analyses of medieval Limoges and Mosan enamels on copper have revealed at least some of the types of enamels in use at the time.[9] The overall composition of the vast majority of these enamels can be described as soda-lime-silica, that is, a glass based on silicon, with sodium as the main fluxing agent, and also containing a significant amount of calcium. The enamels from this period, with the exception of the reds, appear to fall into two types. Enamels used until about the end of the twelfth century contain relatively small amounts of magnesium and potassium oxides, generally less than 1 percent each, with relatively large amounts (about 2 percent or more) of aluminum oxide. These kinds of enamels are opacified with compounds of antimony: calcium antimonate white in the opaque white, blue, and turquoise colors, and lead antimonate yellow in the opaque yellows and greens. As indicated in some medieval manuscripts, and supported by analytical studies, this type of enamel was probably made from recycled Roman glass mosaic tesserae, which would have supplied a ready source of different colored glasses.

Starting about the end of the twelfth century a different type of enamel began to be used. These enamels contain larger amounts of both magnesium and potassium, with smaller amounts of aluminum. Instead of antimony compounds, the enamels are opacified with white crystalline tin oxide or, in the case of some yellows and greens, with lead-tin yellow. Associated with the tin oxide opacifier, and probably added with it, are significant amounts of lead oxide, while only small amounts of lead, if any, are found in the calcium antimonate opacified compositions. These later enamels appear to have been made from contemporary glass, rather than reused Roman material. Some Limoges objects dating from the late twelfth century to about the first quarter of the thirteenth century have both types of enamels, sometimes even mixed together in the same color. After about 1225 only the later type of enamels appear to have been used, possibly along with some reused Roman opaque yellows and greens.

The red enamels from medieval Limoges and the Meuse Valley do not really fit into either the early or the late type. Most of the reds contain relatively high levels of magnesium and potassium, as well as aluminum, and most also have small amounts of lead oxide. Unlike the other colors, which are opacified with antimony or tin compounds, the reds are opacified with reduced copper oxide. One Limoges red enamel and some Mosan red enamels were found to have potassium-based compositions quite different from the other soda-lime-silica–based enamels. These reds appear to have been made using contemporary European potash glass, best known from stained-glass windows.

Most of the pommels in the group at the Metropolitan are decorated with red and blue enamels, and six contain white enamel.[10] Samples of the enamels from twenty-five different pommels were analyzed to determine the overall compositions and identify the colorants and opacifying agents.[11] All of the enamels have soda-lime-silica compositions. The reds were all found to have relatively high levels of magnesium, aluminum, and potassium, with varying but generally small amounts of lead, and they are colored and opacified with reduced copper oxide. Most of the blue enamels have high-magnesium, high-potassium, low-aluminum compositions, with significant amounts of lead, and are opacified with tin oxide crystals. Nine of the blues, however, have low levels of magnesium and potassium and a high level of aluminum and are opacified with calcium antimonate.[12] All of the blue enamels are colored with cobalt oxide. The six examples of white enamel all have high-magnesium, high-potassium compositions with lead and tin oxide. The single green enamel in the group is a translucent green glass, also with high magnesium and potassium but no opacifier.

Based on studies of Limoges enamels, all of the enamels on the pommels appear to be consistent with a twelfth- to thirteenth-century date. The nine with blue enamel with low magnesium and potassium may date no later than the beginning of the thirteenth century, while the other pieces appear to date no earlier than the late twelfth century. One pommel (L.2007.86.3) has white enamel of the later type composition and blue enamel of the earlier type; again based on analyses of well-dated Limoges enamels, this would indicate that it dates somewhere from the late twelfth to the early thirteenth century.

These pommels represent a unique melding of technologies firmly rooted in the twelfth and thirteenth centuries that are chronologically aligned with their stylistic and historic dating. Where this distinctive approach originated is less clear. Metalworkers in both medieval Europe and the Islamic world had the capacity to cast hollow objects in the round by the lost-wax process, and in both cultures alloys similar to those found in the pommels were used. Champlevé enameling, however, was pervasive in western Europe, and the similarity between the compositions of the enamels on the pommels and those found on objects fabricated in the Meuse Valley and Limoges in the twelfth and thirteenth centuries strongly suggests a European origin. It is also possible that craftsmen familiar with western practices were working in Palestine and supplying the Crusaders resident there. What is certainly true is that the pommels offer yet more proof of the inventiveness, skill, and creativity of medieval metalworkers.

NOTES

1. For a discussion of the introduction of the casting of hollow objects in the round by the lost-wax process in medieval Europe and the techniques and materials utilized, see Dandridge 2006.
2. See the twelfth-century treatise by Theophilus on painting, glass-making, and metalwork (Theophilus 1979, p. 132) and the sixteenth-century treatise by Benvenuto Cellini on goldsmithing and sculpture (Cellini 1967, p. 113).
3. Depending on the shape of the core, sheet wax could be used as well. That process and the dipping of cores are documented in a DVD by Ubaldo Vitali and Pete Dandridge (2006).
4. L.2007.86.2–4, L.2007.86.6–8, L.2007.86.10, L.2007.86.16–18, L.2007.86.23, L.2011.47, 29.158.685, 42.50.134.
5. Latten was used in the Middle Ages to describe copper alloys and has been used in contemporary descriptions of quaternary alloys of copper containing zinc, tin, and lead in concentrations greater than 1 percent; see Oddy, La Niece, and Stratford 1986, p. 6. For a selection of analyses of medieval copper alloys, see Werner 1982; Brownsword and Pitt 1983; Craddock 1985; Newman 1991; Blades 1998; Heyworth 2002; and Brownsword 2004. For analyses of Islamic metalwork, see Allan 1979, pp. 23–65, 141–52; Atil, Chase, and Jett 1985, pp. 35–39; Craddock, La Niece, and Hook 1998; and Ponting 2003.
6. The original surfaces of the pommels are generally obscured by corrosion and burial accretions associated with their archaeological context, with the exception of 29.158.685 (Figure 10), which has a golden color indicative of the original patination.
7. The sophist Philostratus is recorded in the third century A.D. as remarking, “These pigments, it is said, the barbarians living by Oceanus compound of red-hot bronze, and they combine, and grow hard, and preserve what is painted with them” (Philostratus 1931, p. 109). See also Scull 1985, Craddock 1989, and Bayley and Butcher 2004, pp. 46–50.
8. For a description of the techniques utilized in Mosan and Cologne enamels, see Stratford 1993. For a similar discussion of Limoges enamels, see Biron, Dandridge, and Wypyski 1996.
9. See Biron, Dandridge, and Wypyski 1996 and also Freestone 1993.
10. The pommels with white enamel are L.2007.86.3, L.2007.86.6, L.2007.86.8, L.2007.86.25, 29.158.685, and 38.60.
11. SEM-EDS analysis was performed on microflakes of the enamels removed from subsurface areas with little or no weathering, which can drastically alter the composition of the glass. The samples taken were too small to prepare for accurate quantitative analysis but could provide semiquantitative results sufficient to characterize the compositions.
12. The nine pommels are L.2007.86.3, L.2007.86.9, L.2007.86.10, L.2007.86.12, L.2007.86.14–17, and L.2007.86.19.

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