

# Idiomatic and Mainstream: The Technical Vocabulary of a Late Roman Crossbow Fibula

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THE METROPOLITAN MUSEUM of Art recently acquired a Late Roman–Early Christian crossbow fibula (acc. no. 1995.97)—the traditional clasp used to pin the fabric of a chlamys where it is gathered at the shoulder (Figures 1, 2). The object is immediately impressive for the elegant proportions of its multiple forms, the richness of the gold surfaces, and the quality of the light as it plays across the broad, unadorned planes of the bow and the elaborately ornamented foot. The latter, also called a catch (the elongated container in which the pin is safely encased), is elaborately incised and punched to create an openwork design in a technique known as *opus interrasile*. That the fibula is a visual tour de force is hardly surprising; such works are thought to have been commissioned by the emperor, members of the court, or civil servants of high rank.<sup>1</sup> Given these imperial associations, such fibulae testify to the prowess of those who must have been the period's finest goldsmiths.<sup>2</sup>

This study will focus on the identification of the specific techniques and materials utilized to create the fibula's numerous components and unifying structure, and it will end with a brief consideration of fibulae in different media. Not only can the articulation of the work's technical details characterize the working practices of an individual goldsmith, but quite possibly, it may provide another means of elucidating provenance as well as the object's relationship to other fibulae of similar typology.

The workshop practices of Late Roman and Early Christian goldsmiths were distilled from traditions active since ancient times, which would remain substantially unchanged until the early Middle Ages. Such homogeneity of tools and techniques in the period notwithstanding, a complex object, such as the Metropolitan's fibula, can reveal an individual or local approach to the fabrication of a particular element or to the resolution of a specific structural problem. If such idiosyncrasies of technique exist, they should be

useful in evaluating the fibula's relationship to the small group of extant gold and silver crossbow fibulae that also have rectangular feet, either ornamented with *opus interrasile* or adorned with S- or C- shaped volutes. Similarly, it may be possible technically to associate the fibula with other kinds of jewelry in precious metal, bracelets for instance, which incorporate comparable elements, such as the screw mechanism or *opus interrasile* panels.<sup>3</sup> Of equal interest is the relationship between those who fabricated objects in precious metal and those who produced stylistically related pieces in baser materials.

Previous technical studies of these objects either have discussed the fabrication of specific crossbow fibulae, produced in copper or its alloys, or have described the physical aspects of a distinct element of a fibula produced either in precious or in base metal.<sup>4</sup> Replication experiments have reproduced the tools and the exact sequence of steps used to create the *opus interrasile* work found on a specific object, and descriptions of *opus interrasile* have either documented the associated tool marks or advanced a probable sequence of steps and tools.<sup>5</sup> While these efforts have substantially broadened our understanding of fabrication techniques, no systematic and complete technical study of an individual gold crossbow fibula has been undertaken that might be used for comparative purposes. It is my hope, in the pages to follow, that this description—first structural and formal, and then material—will provide an account that could prove useful in the identification and understanding of other works both more and less obviously related.

## FORM AND STRUCTURE

The Metropolitan's gold fibula is one of eight, displaying similar forms and decorative techniques, that have been grouped together stylistically.<sup>6</sup> Each has a rectangular foot or catch, either triangular or semi-circular in section, the top plate of which is decorated in *opus interrasile* (Figure 3). One end of the foot is

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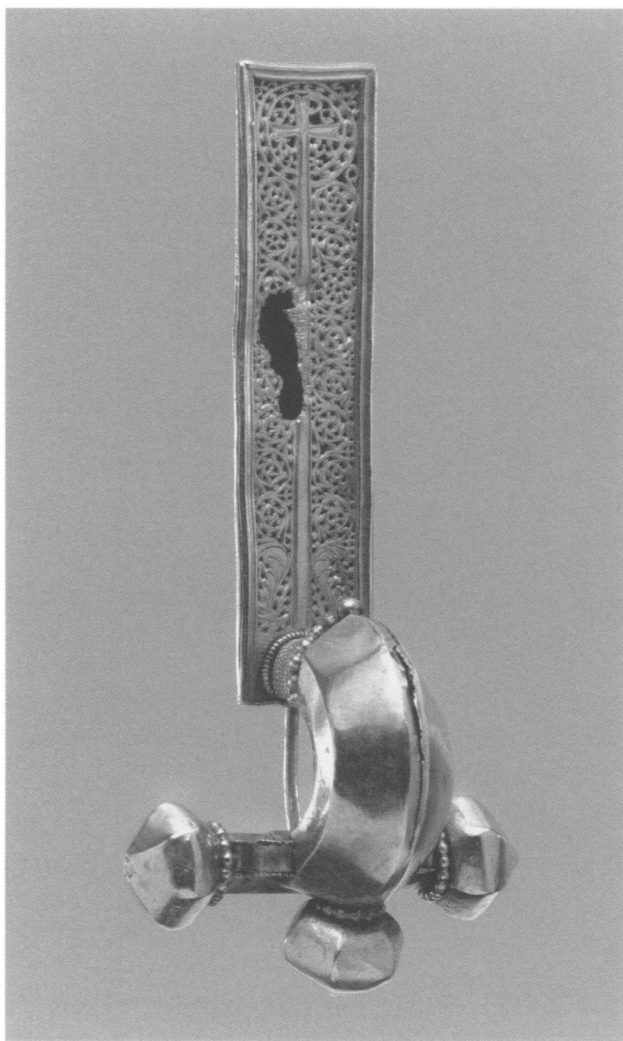


Figure 1. Crossbow fibula, ca. A.D. 450–ca. 558. Gold, L. 11.9 cm. The Metropolitan Museum of Art, Purchase, Lila Acheson Wallace Gift, 1995 (1995.97). See also Colorplate 1

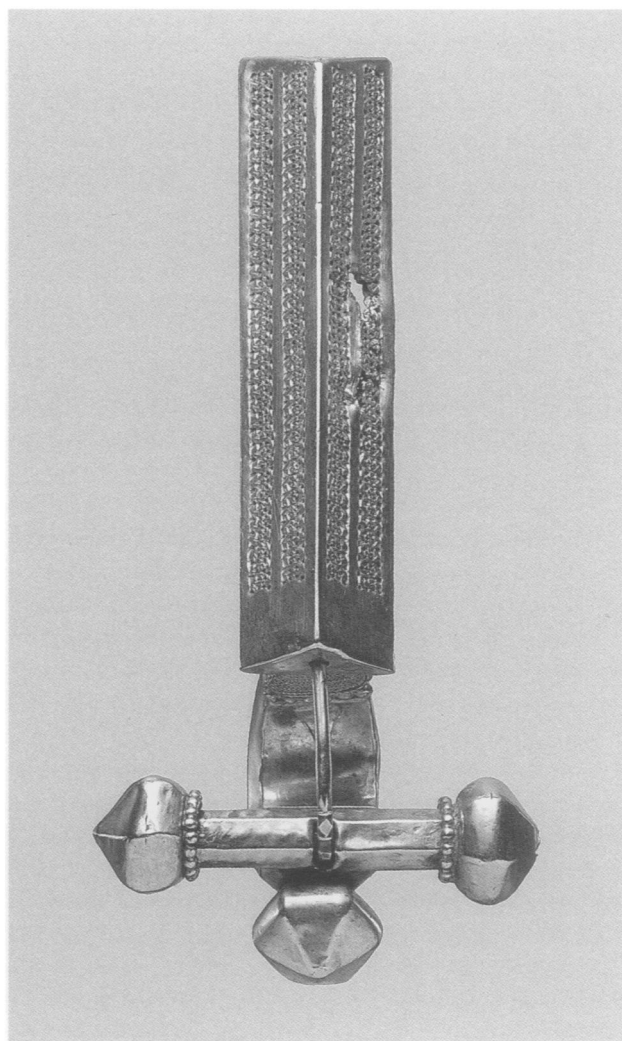


Figure 2. Back of the fibula in Figure 1

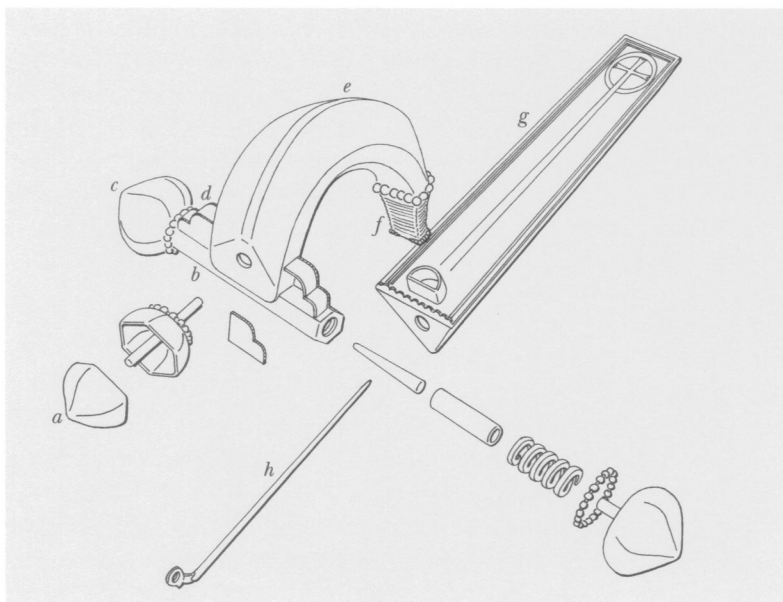


Figure 3. Drawing of the Metropolitan's gold fibula, with exploded views of the screw mechanism, head knob, and appliqué. Dimensions of the fibula: foot, L. 8.23 cm, W. 1.95 cm, D. 1.10 cm; crossbar, L. 5.53 cm (to the end of the knobs), W. 0.73 cm; knobs, H. 1.23 cm, W. 1.45 cm; screw mechanism (finial, threading, tip), L. 4.07 cm; pin, L. 9.83 cm, D. 0.19 cm (drawing: Daniel Kershaw). Parts of a fibula: (a) head knob or finial, (b) crossbar, (c) knob or finial, (d) appliqué, (e) bow, (f) filigree collar, (g) foot or catch, (h) pin

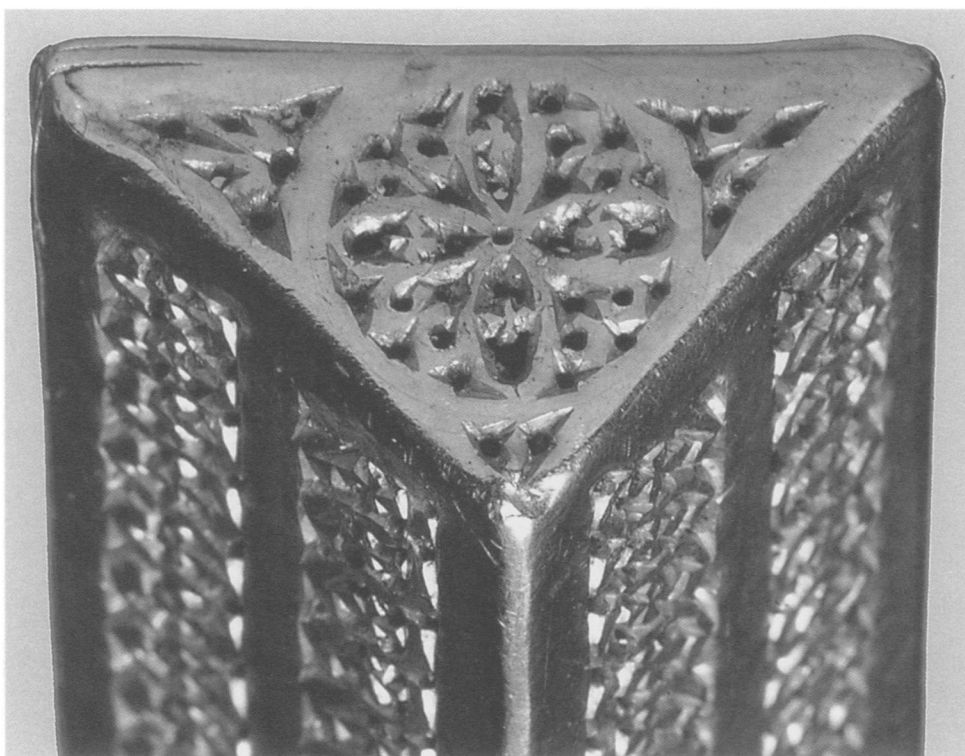


Figure 4. Detail of the end of the catch; the solder lines clarify the placement of the triangular cap with the sides, subsequently overlaid by the top plate and its molding. Scribed compass lines are apparent in the reserved border of the circular design

attached to a hollow bow, pentagonal in section. The opposite end of the bow—the head end—is soldered to a hollow, transverse crossbar. Onion-shaped knobs are attached to either end of the crossbar, with a third where it is joined to the bow; crossbar and finials are hexagonal in section. A length of beading encircles the base of each knob, while beading, beaded wire, granules, and strip-twisted wire is used selectively at the junction of bow and foot. Overlaying the top facet of the crossbar, on either side of the bow, are appliqués.

To function, the fibula's pin was pushed through a gather of cloth with the pointed end inserted into a hole at the end of the catch. The head of the pin rested in a slot cut out of the center of the crossbar (Figure 2). The pin was then secured by a screw mechanism attached to one of the lateral finials, which threads into the transverse arm and through the loop at the head of the pin.

The triangularly sectioned foot of the Metropolitan's fibula is fabricated from several elements of gold sheet soldered together. The side panels are shaped from a single piece bent along its previously incised, longitudinal axis. The foot or catch is capped at either end by a triangular piece inserted between the side panels at the bow end but both over and between those same panels at the opposite end (Figure 4). The top is a single sheet that overlays the edges of both side and end panels. Lengths of shaped molding, mitered at the corners, encircle three sides of the top plate. The end behind the bow, however, is surmounted by a

rectangular strip whose top edge has been serrated to create a beaded profile.

Prior to assembly, the foot's top, side, and front panels were all decorated with *opus interrasile* designs. The method by which these designs were executed—the tools used, their shape, and the exact sequence of the steps—has been reconstructed from microscopic examination of the tool marks and replication in silver blanks of the technique by the author. In several instances, the individual steps described here parallel those postulated in earlier studies. For example, the separate elements of sheet gold were fixed to a yielding layer of waxlike material rolled out over a more solid support.<sup>7</sup> The design was then scribed lightly into the gold using both a rule and a compass. Indeed, the marks of the compass are still apparent in the center of the whorls along each side of the top plate. Traces of the scribed lines are visible in scattered locations on all the panels (Figure 5). Following this procedure, an awl, a round-sectioned tool tapering to a point, was used both to mark each of the spots where the design would pierce the sheet and to initiate the perforation of the gold.<sup>8</sup> The very fine taper of these holes suggests the awl was struck with a mallet, since hand pressure alone would rock the tool slightly, broadening the circumference of the hole. A tapered, triangular-sectioned tool—a graver, such as that described by Ogden and Schmidt in their replication experiments—articulated the incised lines radiating out from the

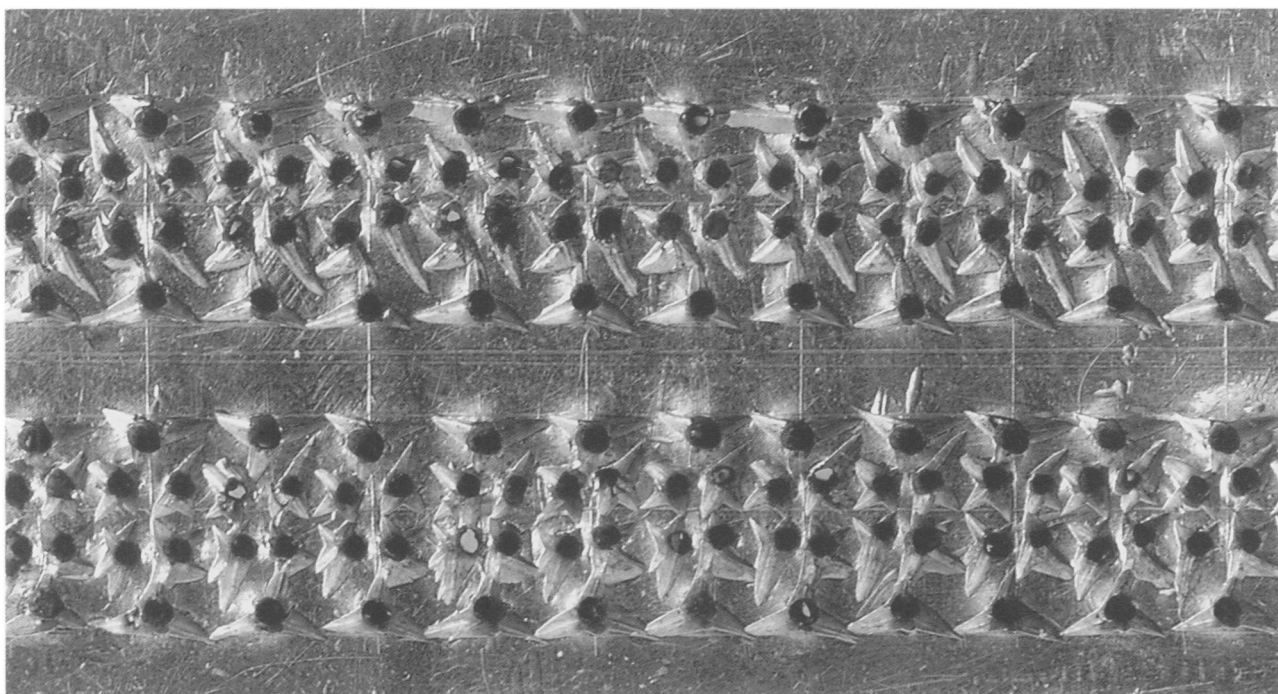


Figure 5. Detail of the *opus interrasile* decoration on the side of the foot. The scribed lines block out the pattern, with punched holes and engraved lines articulating the design

perimeter of the punched holes (Figures 5, 6).<sup>9</sup> The graver was held at an acute angle to the surface and pushed across the lip of the punched hole. The natural resistance of the gold to the cutting action of the graver was reduced substantially by the apogee of the cut occurring within the void of the punched hole.<sup>10</sup> The curls of metal, pushed up in front of the tool, were released as the point of the graver passed over the edge of the punched hole. The substantial negative space in the openwork design in the triangular plate (enclosing the end of the foot away from the bow) and around the pendant Greek letters on the cross on the top plate required successive cuts to enlarge the initial opening (Figure 6). (For the significance of these letters, see Deppert-Lippitz, on the *crux monogrammatica*, page 41 in this volume.) However, the more systematic, less complex designs on the side panels and the top may have been executed with a single pass of the graver.

Before removing the sheets from their support, the awl was used again. This additional step served several purposes. It removed any curls of metal still lodged in the initial punched hole; it confirmed that the hole pierced the entire depth of the sheet; and it allowed the goldsmith to clarify or add additional weight to the negative space of the design.<sup>11</sup> An occasional mis-stroke occurred during the second punching, and the initial mark can be seen immediately adjacent to it,

not always having pierced the sheet (Figures 5–7). The largely vertical orientation of the awl, as it moved through the plaque, displaced metal both in advance of its point and perpendicular to its shaft. As the gold was pushed out, parallel to the surface of the sheet, it formed burrs, still present and visible under the microscope, along the front edges of the planes defining the V-shaped channels radiating out from the holes.

The top sheet also exhibits a more traditional use of the graver. The veins of the two acanthus leaves at the base of the cross (Figure 1) have been accentuated by rocking the head of the tool as it was pushed through the metal. The faceted quality of the stepped line creates a textural variant to help distinguish the form and enliven the surface (Figure 7).

The pressures exerted on the thin gold sheet during the engraving and punching process resulted in substantial distortions in the horizontal plane of the metal, further exacerbated by its attachment to a forging surface. With each strike of the awl that pierced the depth of the plaque, a cone-shaped projection with ragged edges was produced on the reverse encircling each hole. When the panels were removed from the wax, the goldsmith was able to reduce such distortions and flatten the sheet by applying moderate force across the backs of the plates with a burnisher or similar



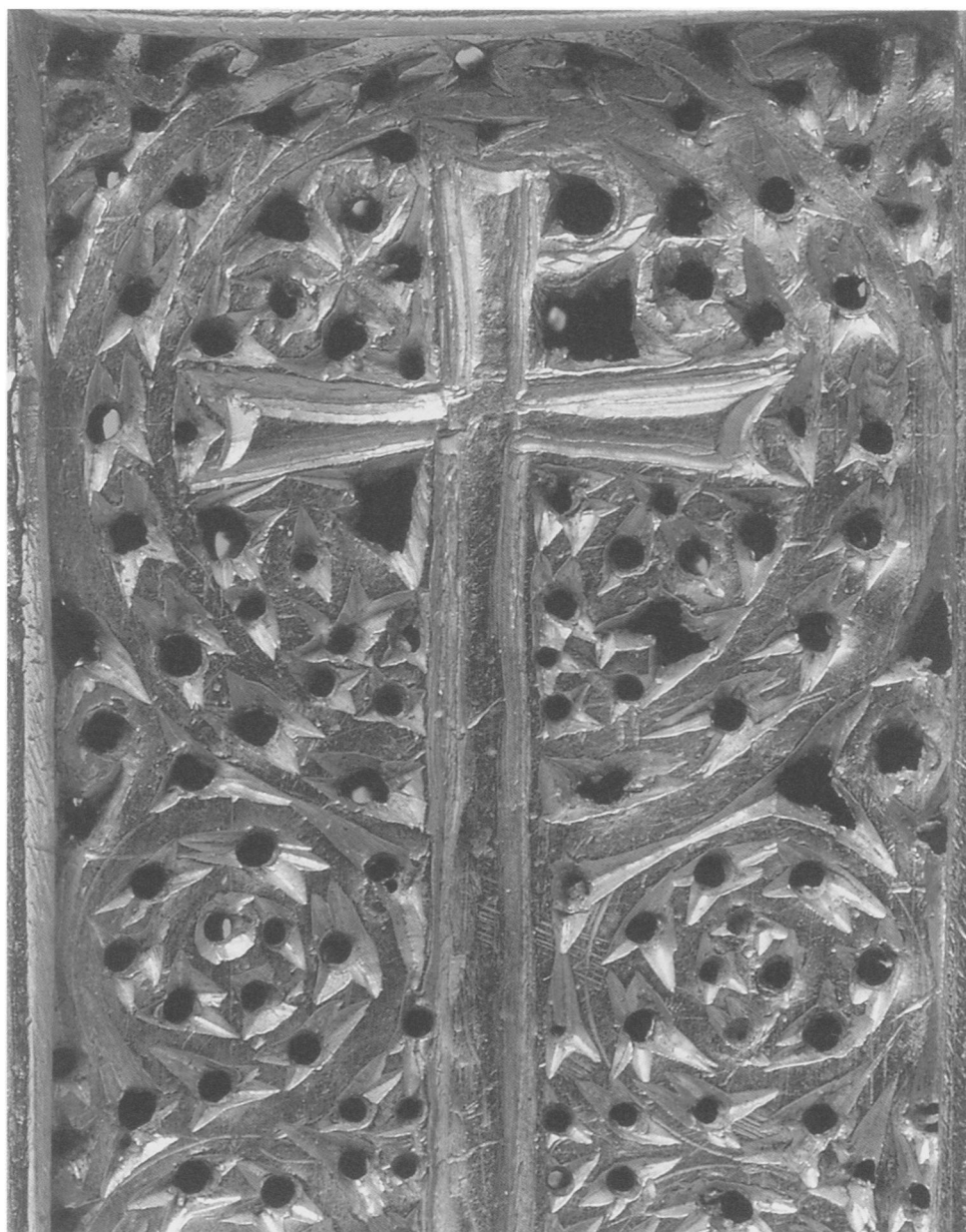


Figure 6. Detail of the *opus interrasile* decoration on the top face of the foot, with enlarged openings on either side of the crossarms; burrs along the front edges of the V-shaped channels radiating out from the punched holes; and occasional misstrikes between the first and second stage of punch work

smooth-surfaced tool.<sup>12</sup> The raised metal of the cones would be compressed into a flat-surfaced annulus and the jagged edges reduced. The burnishing action also reduced the diameter of the holes, occasionally closing them entirely, and pushed fragments of the torn edge back into the base of the circular opening. There is no evidence indicating that the fronts of the panels were burnished.

The transition from the foot to the head of the fibula is made by the bow, whose broad forms have been shaped from three sheets of thin gold joined with

solder. Two of the sheets were seamed along the top ridge and then worked to form the top angled faces and the perpendicular sides. The strip forming the underside of the bow constitutes the third element. The use of thin sheet allowed the goldsmith both to shape the forms more easily and to be conservative in his use of precious material; however, the lightness of the construction meant that the bow needed to be reinforced to withstand compressive and shear forces. To that end, the goldsmith introduced a filling material into the interior of the bow. A triangular opening



Figure 7. Detail of the *opus interrasile* decoration at the bow end of the foot, with the engraved rocking line articulating the acanthus leaves visible in the bottom quarter of the detail, the scattered misstrikes, and the burrs of metal along the front edges of the V-channels

on the underside (visible in Figure 8) allowed powdered sulfur to be poured into the interior of the form, which when warmed would adhere to the metal and form a solid mass.<sup>13</sup> Since the melting point of sulfur is well below that of solder, the filling of the bow would have been one of the last steps in the fibula's overall manufacture.

Where the bow intersects the catch, its profile was stepped back, and its shape, in cross section, changed from pentagonal to semicircular (Figure 9). The narrowed end fits, sleeve-like, over a collar of sheet gold, nearly identical in outline (see Figure 3), soldered to the top of the foot at the base of the acanthus leaves. The additional surface provided by the collar creates a large area of contact for the solder joint, substantially increasing its strength.<sup>14</sup> The top edge of the step-back in the bow was worked further to create a semicircular channel, into which three lengths of beaded wire were set.<sup>15</sup> Individual granules were placed in each corner, with the large granule in the front serving a decorative function and those in

the corners maintaining the rhythmic pattern of the beaded wire while filling a slightly constricted space; one of the granules is now lost. By recessing the wire, its projection above the surrounding surfaces was minimized, and thus susceptibility to dislocation was reduced. Another length of beaded wire of smaller diameter was set around the semicircular section at the base of the bow, where it attaches to the foot, with the ends of the wire cut into thin tapers and tucked into the narrow space between the back of the bow and the serrated strip of molding. The area between the beaded wires was wrapped with two lengths of strip-twisted wire, oriented to one another to form a herringbone pattern.<sup>16</sup> Because the top edge of the step-back was not parallel to the surface of the foot, the goldsmith threaded the upper strands of the wire in and out of the underlying sheet to accommodate the variable height of the space. One end of a length of wire is visible in the X-rays above the top of the recess where it was stitched into the interior of the bow (Figure 10).

Figure 8. Detail of the underside of the bow and the triangular opening for the insertion of the sulfur packing

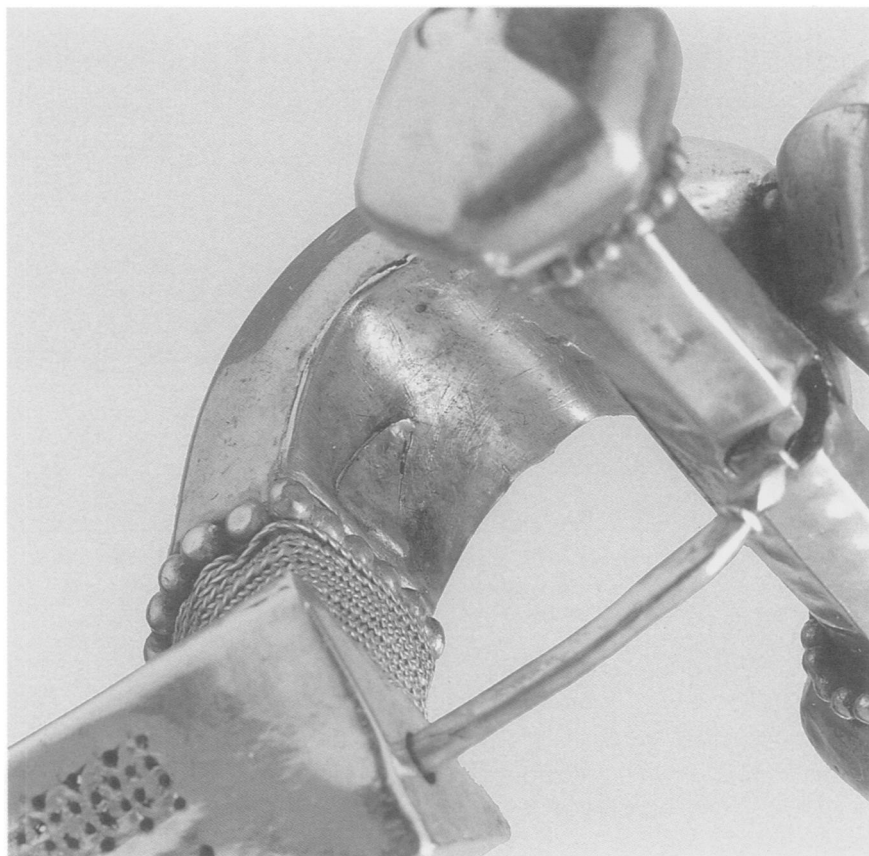


Figure 9. Detail of the foot end of the bow, with beaded wire around the top and bottom of the recess and lengths of strip-twisted wire in a herringbone pattern filling the space in between. The upper strands of wire are stitched into the interior of the bow



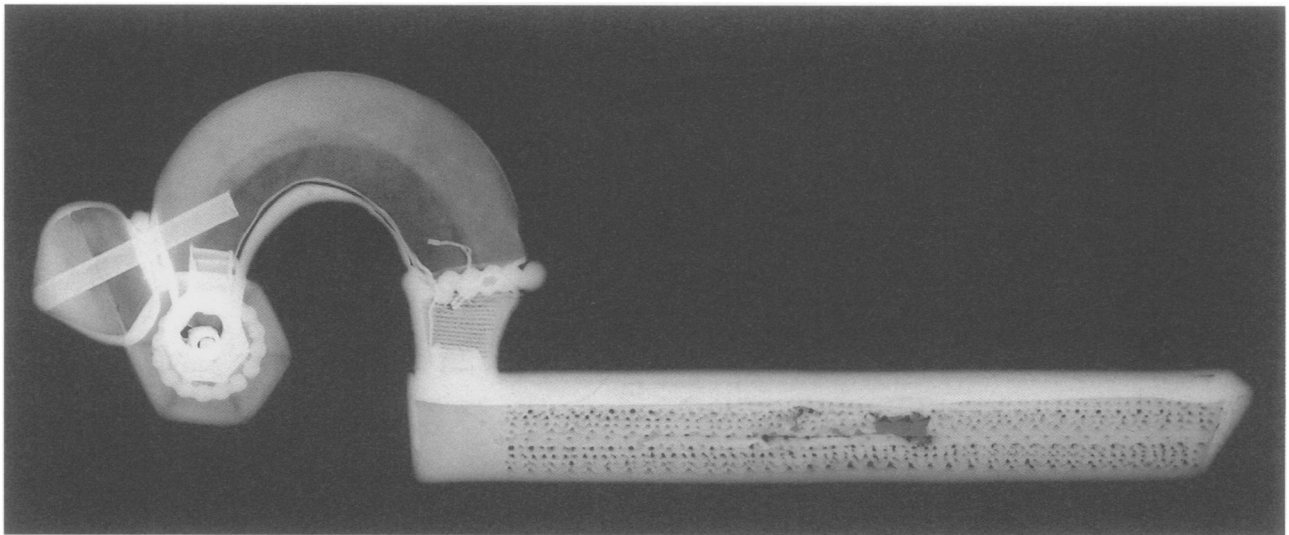


Figure 10. Radiograph revealing the supporting tube in the interior of the head finial, the horizontal solder seam around the finial, the collar at the head end of the foot (over which the bow is set), and a length of the strip-twisted wire stitched into the interior of the bow (radiograph: P. Dandridge)

At a right angle to the head of the bow is the transverse crossbar shaped from a single sheet of gold and worked into hexagonal form, with the overlapping ends soldered together. The end of the bow was then cut and shaped so as to intersect with the crossbar and to provide maximum surface contact for the solder join. The edges of the bow's two parallel, flat sides were set across and perpendicular to the upper facet of the crossbar, while the flattened top and the underside of the bow covered each adjoining face, straddling the bar. Stepped appliquéés were now attached to the upper facet of the crossbar on either side of the bow; these appliquéés were made up from four pieces of sheet—two sides and two curved strips each defining a step. The open end and base of the appliquéés were set against the side of the bow and on the top of the crossbar, respectively (as shown in Figure 3). The sides of the appliquéés projected above the top of the steps and were shaped with a chisel to form a beaded pattern. The chisel marks carried over onto the top strip in a manner that indicates the pattern was cut in after assembly. These appliquéés served several functions: they covered the lap join on the top facet of the crossbar, gave additional strength and rigidity to the juncture of crossbar and bow, and disguised the pattern of the screw threads that would show through the thin sheet of the crossbar.

Each end of the crossbar terminates with an onion-shaped finial faceted on six sides. An identical finial was placed just above the point where the bow joins with the crossbar, effectively hiding the flattened section of the bow made to accommodate its junction with

the transverse arm. The base of each finial is encircled by a length of beaded wire slightly smaller in diameter than that decorating the catch end of the bow. The triangular, tripodlike arrangement of the finials provides a stable base for the fibula when it is at rest across the collarbone of the wearer, allowing it to maintain its vertical orientation.

Microscopic examination and X-rays show that each finial was fabricated from two domes formed from thin sheet and soldered together along a horizontal seam. The close correspondence in the dimensions of all the finials suggests they were made with a matrix or a die.<sup>17</sup> While it appears that both halves were formed in a similar fashion, the bottom half was subsequently reshaped. In order to create a flatter surface for attachment, cuts were made from its tip down along the ridges of each side with the flaps then bent inward, perpendicular to the sides; the resultant overlapping metal was then cut away. To mitigate against the potential compressive forces placed on the finials, a tube of thin gold sheet, lap joined, was inserted through a hole in the bottom of each finial and pushed up until it came to rest against the top. The tube was soldered in position at its juncture with the top and with the base.<sup>18</sup> The distance the tube extended beyond the base of the finial varied depending on its position. The head knob bore the greatest shear stress, and in an attempt to counteract those forces, the tube continues well into the body of the bow (Figure 10) and thus was anchored in the sulfur filling. The proper right finial was soldered directly to the end of the crossbar with the tube extending just beyond the join.<sup>19</sup>



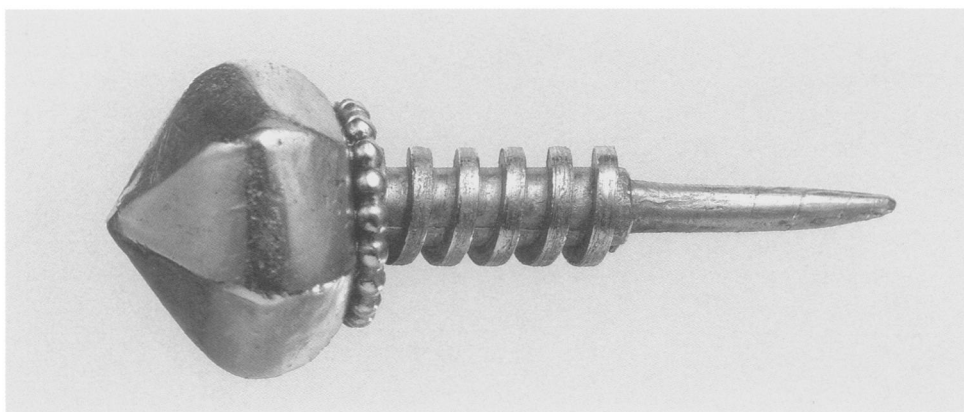


Figure 11. Detail of the screw mechanism—finial, beaded wire, threading, hollow shaft, and tip. Note the spiral groove along the tip that was scratched into the surface by a sharp edge or point within the head loop of the pin. Dimensions: finial, H. 1.23 cm, W. 1.45 cm; beading, D. 0.15 cm; threading, L. 1.50 cm; tip, L. 1.41 cm

The third finial, at the opposite end of the transverse bar, was not attached directly to the crossbar but, rather, was soldered to the shaft of an elaborate screw mechanism that served both to secure the finial to the transverse bar and to lock the pin within the crossbar (Figure 11). These different functions required that the various elements making up the whole have different physical properties, and in its fabrication the goldsmith created the fibula's most complex component. The tip of the screw mechanism is a solid piece of gold tapered to a dull point that would ease through the loop in the head of the pin as it sat in a slot cut in the underside of the crossbar (Figure 8). The weight of the fabric pulling against the pin required that the loop be held securely by a strong piece of solid gold. The opposite end of the screw tip is blunt and is inserted into a hollow shaft of equal length to the tip (Figure 12). The wall of this cylindrical shaft is of substantial thickness—greater than that of the supporting tubes for the finials—and was butt joined along its longitudinal axis with hard solder. To create the male and female threads for the screw, and to assure their alignment, two identical pieces of wire, square in section, were wrapped spirally around the shaft in six convolutions.<sup>20</sup> By wrapping both threads around the screw shaft simultaneously,

and then removing the length to be soldered to the interior of the crossbar, the accuracy of the pitch was secured. The tip of the male thread was cut at an angle to ease its entry into the female-threaded crossbar and was soldered in position along the hollow shaft. The female thread was cut down in length to two and one-half convolutions and was soldered into the interior of the crossbar.<sup>21</sup> The modest number of convolutions of the female, or nut, thread inside the bar made soldering easier; it also allowed for some play in the mechanism, facilitating the movement of the screw tip through the head of the pin. The male thread and its supporting hollow shaft were soldered to the base of the finial with the tube in the interior of the knob sleeved into the end of the screw shaft.<sup>22</sup> By using a hollow shaft for the center of the screw, as a cylindrical bridge or collar uniting extremities, the goldsmith was conservative in his use of metal and provided a clever means of structurally linking all three elements of the mechanism—tip, shaft, and finial.<sup>23</sup>

The most straightforward element for the goldsmith to produce, finally, was the fibula's pin. A thick, rectangular strip of gold was cut from a sheet, twisted, rolled smooth between two flat surfaces, and shaved down with a scraper along its length to refine the shape

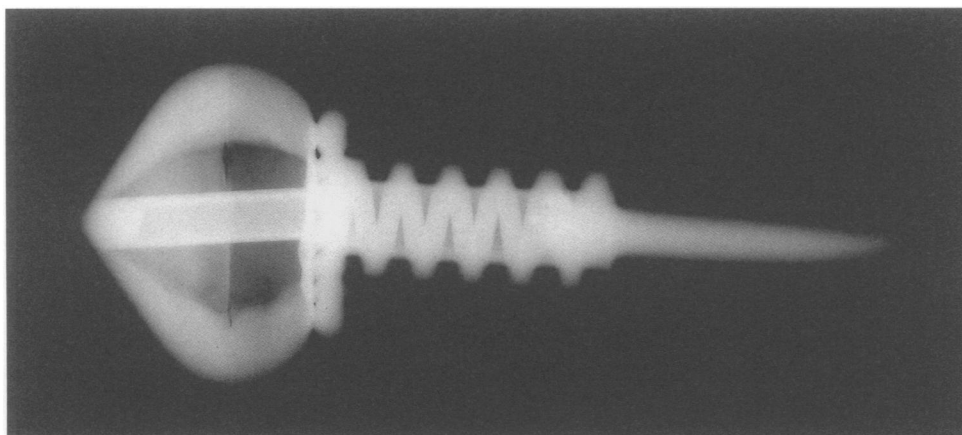


Figure 12. Radiograph of the screw showing the interior tube in the finial and the hollow shaft encircled by the spiral threading (radiograph: P. Dandridge)



Figure 13. Detail of the top of the pin, with the helical creases and the parallel, longitudinal lines along the shaft left by the scraper

and add the taper (Figure 13). The two helical creases indicative of block-twisted wire and the parallel marks of the scraper are visible to the naked eye and under the microscope. The absence of a solder seam at the head of the pin suggests that it was formed by heating the end of the pin to form a globule which was hammered flat and shaped and faceted to fix into the slot in the crossbar. The tip of the screw mechanism would have marked the position of the hole.<sup>24</sup>

#### MATERIAL ANALYSIS

Various gold coins—the solidus, semissis, and tremissis—have been suggested as the raw material for the fabrication of gold crossbow fibulae during the time they were in fashion, between the fourth and sixth centuries A.D.<sup>25</sup> Supplies of gold were strictly controlled during all stages of its extraction, refining, and minting, and it is unlikely that a goldsmith would have had either the access or the means to accumulate such a valuable resource. Such constraints were easily overcome and controlled if those who commissioned the work also supplied gold of a known weight and purity.

The primary sources of gold during this period were placer deposits, with inclusions of platinoid grains a diagnostic feature of this alluvial gold.<sup>26</sup> These gray-white alloys of the platinum-group metals are insoluble in gold at its usual melting point and were ordinarily retained with the gold during its refining and working. It would not be surprising, therefore, to find platinoid inclusions in jewelry produced from coins or other secondary sources,<sup>27</sup> and, in fact, platinoid grains are apparent in the triangular plate that encloses the end of the fibula's foot, as well as near the head of its pin. The clustering of inclusions is not unusual, given that platinoid grains have a higher specific gravity than gold

and would collect at the bottom of a crucible during melting, with the segregation continuing throughout the pour and subsequent working.<sup>28</sup> The inclusion in the pin was analyzed using energy-dispersive X-ray spectroscopy (EDS) and was found to be Osmiridium, the cubic form of the osmium-iridium-platinum alloy.<sup>29</sup>

In the east, the solidus and the other gold coins were an integral element of the circulating currency. While less common in the west, substantial supplies of solidi existed there as well, though primarily in the form of tribute paid out by the emperors to protect the borders of the empire. Undoubtedly, the recipients of this largesse were among those who were the goldsmith's patrons.<sup>30</sup> Analyses of gold coins dating from the period of the fibula's fabrication indicate that their composition remained extremely consistent, with a purity of between 96% and 97%.<sup>31</sup> Studies of gold jewelry of the same general date show that if goldsmiths were using coins as their source, they generally debased their supply by adding variable amounts of silver and copper as a way of adjusting the physical properties of their alloy.<sup>32</sup>

Analyses by EDS of multiple points on the fibula's surface, as well as on extracted samples, indicate two different alloys were used to fabricate the various elements. The data may be seen in Table 1. In evaluating the results of these analyses, several variants need to be kept in mind. Surface analyses of gold alloys can be affected by preferential corrosion and leaching away of the less noble elements—silver and copper—that can occur naturally during burial or in post-excavation treatment. Such an enriched surface would have a greater percentage of gold than a similarly analyzed sample of the original bulk metal. Even in the analyses of the samples, instrumental variabilities can introduce discrepancies in the reported values of the elements. With these provisos in mind, it appears that the analyses sort themselves into three different composi-

TABLE 1. EDS ANALYSES OF THE GOLD CROSSBOW FIBULA (MMA 1995.97)

Sample analyses are given in roman type, surface analyses in *italics*

Group	I									II		III		IV
Weight %	Foot			Crossbar	Screw Mechanism					Bow		Pin		Solder
	Side	Top	Side		Finial		Thread		Shaft			Head	Shaft	
Gold (Au)	89.2	87.9	87.2	87.0	88.5	90.3	89.0	87.0	84.8	80.0	80.6	81.5	81.8	61.2
Silver (Ag)	9.7	9.8	10.7	10.2	9.2	8.3	8.6	11.2	13.1	18.1	18.4	15.2	15.8	35.1
Copper (Cu)	0.7	2.0	1.9	1.2	1.9	1.3	2.0	0.8	0.8	1.5	0.8	0.8	2.0	1.2
Iron (Fe)	0.4	0.2	0.2	1.6	0.3	0.1	0.5	1.1	1.3	0.5	0.1	2.2	0.4	2.6

tional groups, segregated by their silver content—of roughly 9%, 18%, and 36%, respectively—with the most debased alloy being the solder. The three different compositional groups are identified in Table 1 as I, II, and IV. The copper content remains consistent at 1.5%. The variation in the percentage of silver among the three groups implies that the goldsmith was adjusting the alloy incrementally; it also shows that if coins were the goldsmith's raw material, then silver was the sole debasing agent.

Since pure gold is extremely soft, the very fineness of gold coinage in the Late Roman period made it impractical for use in those elements of jewelry subject to stress or wear. By increasing the amount of silver and/or copper alloyed with the gold, the mechanical properties of the metal could be altered so as to become successively harder, better able to withstand stress without deforming, and more elastic, that is, able to reconfigure itself after stressing.<sup>33</sup> These inherent characteristics can be amplified further during the fabrication process by cold-working the metal; however, a significant portion of this increase in mechanical strength will be negated by the application of heat during soldering or annealing.

The artisan responsible for the Museum's fibula was aware of the advantages to be gained in altering the purity of his primary gold source and in varying his methodology. In the group of components alloyed with 9% silver—the top and sides of the foot, the transverse crossbar, the finials, and the screw mechanism (Group I in Table 1)—different working methods have been used to affect its properties in other ways. For example, softening the metal to the extent the alloy permits would have facilitated the extensive engraving required for the creation of the *opus interrasile* design on the panels of the foot. To that end, the gold would have been fully annealed before incising in order to minimize the influence of the initial hammering, when the sheet was reduced to its requisite

thickness. Conversely, the other elements in the group would have benefited from the residual effects of work-hardening, and to that end the goldsmith may have minimized their exposure to heat after their shaping.

For the creation of the bow, the choice of alloy and technique would follow the same principles described above. In the main, stresses placed on the foot or the crossbar would have been transferred to their points of attachment with the bow. The ability of the bow to absorb these forces without distorting or tearing was reinforced by strengthening its attachment to the foot with a collar and using an elaborate lap joint at the crossbar and by doubling the amount of silver in the alloy (Table 1, Group II). The tensile strength and hardness were substantially improved by increasing the silver content in the alloy, and even though successive solderings were required to join the elements of the bow to itself and the other components of the fibula, some residual benefit was retained from its cold-working. Aesthetic consideration may have played a part in the choice of alloy for the bow as well. With the addition of more silver, the color would have been made cooler, or less yellow, and would enhance the contrast of form and texture between the bow and the foot.

Data from the surface analyses of the pin do not fall within either of the two alloy groups (Table 1, Group III). Whether the compositional variation in these results represents a separate melt or is the effect of the vagaries of surface analysis is unclear. Given the stresses placed on the pin, it would seem logical that the goldsmith would have tried to maximize the strength of the pin and to fabricate it from the same alloy used for the bow.

The most significant debasement occurs in the composition of the solder, where 36% silver was added to the gold (Table 1, Group IV). For a hard solder to be efficient, it is necessary that it have a liquidus temperature, or melting point, below that of the elements being joined, yet close enough to their melting point



Figure 14. Crossbow fibula, 5th century A.D. Gilt-copper alloy, L. 6.82 cm. The Metropolitan Museum of Art, Gift of J. Pierpont Morgan, 1917 (17.191.189)

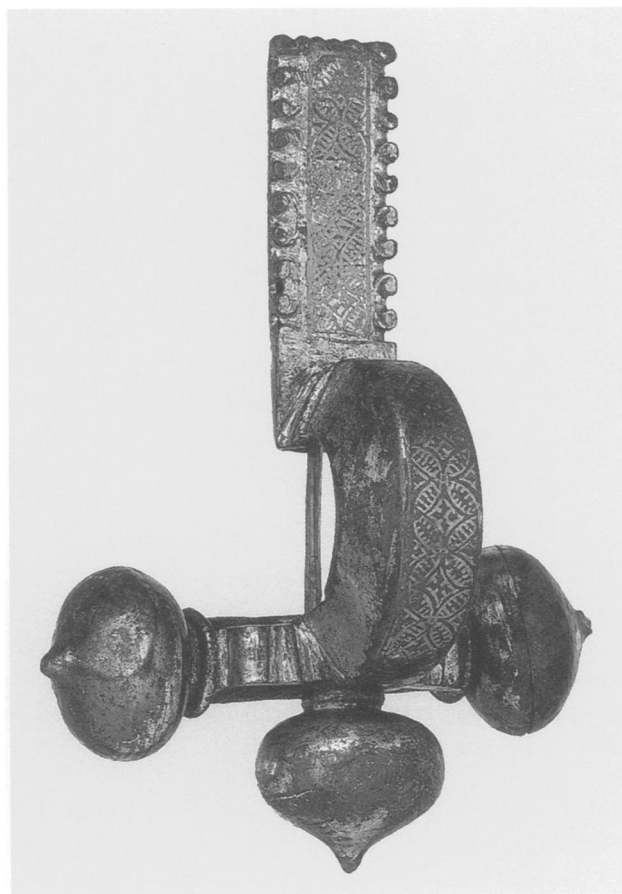


Figure 15. Crossbow fibula, 5th century A.D. Gilt copper and niello, L. 8.79 cm. The Metropolitan Museum of Art, Rogers Fund, 1999 (1999.42)

for the solder to effectively flow and wet their surfaces. The melting points for the two alloy groups are approximately 1045° and 1035° Celsius for the least and most debased, respectively, while the melting point for the solder is around 1015° Celsius.<sup>34</sup> An effective difference of 20° represents a very fine margin of error and is a further indication of the goldsmith's control and skill.

#### COMPARATIVE STUDIES

Since most of our understanding of the workshop practices of Late Roman and Early Christian goldsmiths is derived from information extrapolated from their creations, any systematic technical study may have potential benefits. Once objects of similar typology and materials are analyzed and compared, then the possibility exists of discovering if a particular object, such as the Metropolitan's fibula, represents a largely idiomatic and local solution to a range of technical problems. This would be in contrast to the possibility

that the goldsmith's methodology reflects a technical approach growing out of an undifferentiated tradition of artisanal procedures. If an idiosyncratic method can be identified, it could be useful in isolating a group of objects as belonging to a specific craftsman or workshop. While such complete specificity is not possible, here, a close "reading" of our object and of kindred objects does create a basis for useful future extrapolations.

The possibility of associating objects of a related typology but of dissimilar materials may prove difficult; indeed, it may not be possible without the benefit of archaeological evidence. The economics associated with the supply of and demand for copper, gold, and silver, as well as the variations in their working properties, meant that copper and its alloys were used less conservatively and with less facility, thus limiting our ability to make one-to-one comparisons. For instance, the signature elements of the gold fibulae under discussion (in this essay and that of Barbara Deppert-Lippitz)—the screw mechanisms and the *opus interrasile* panels—cannot be used to establish a correspondence. The screw





Figure 16. Detail of niello decoration across the ridge of the gilt-copper fibula in Figure 15

mechanisms, as they occur in copper or copper-alloy fibulae, are made in part or in whole in a subtractive process, by means of engraving and/or filing, and not in the additive process common to gold examples;<sup>35</sup> and *opus interrasile*, as a technique, did not translate into the baser medium. However, other technical features found in the Metropolitan's gold fibula are commonly encountered in fibulae created in base metal and, in some instances, exhibit a technical mastery and decora-

tive sophistication commensurate with the nobler examples. The identification of these common patterns in technique may not provide enough evidence, by itself, to establish a specific relationship among fibulae in different media; however, it might provide some insight into the connection between those artisans working in copper and those working in precious metals.

Two gilt-copper fibulae in the Metropolitan's collection, somewhat earlier in date than the gold fibula, incorporate forms and technical approaches common to the gold fibulae.<sup>36</sup> The fibula from the Morgan collection is characterized by a series of tightly formed C-shaped volutes visible along either side of the catch (Figure 14).<sup>37</sup> A recently acquired example is detailed with similar volutes along its foot (Figure 15); however, it is distinguished by an elaborate pattern of circles and lozenges engraved across the top of the bow and over the foot and inlaid with niello (Figure 16).<sup>38</sup> Each was made entirely from sheet with its multiple elements soldered to one another.<sup>39</sup> The bows are pentagonal with the profiles of the foot ends cut back and articulated with a single length of wire applied around the top edge of the semicircular indentation. At the head end, the bows are attached to their transverse crossbars by means of elaborate lap joints. The finials are hollow, formed from two domes joined horizontally and soldered in position. Only the head finial on the recently acquired fibula is extant, possibly due to the additional security of a rivet (Figure 17) inserted through its tip and out the opposite side of the bow. The rivet serves the same function as the interior tube in the head finial of the Museum's gold fibula.<sup>40</sup> On both copper fibulae, along the sides of the catches' top plates are C-volutes that emulate the delicacy of *opus interrasile*. In the case of the Morgan fibula, the volutes are engraved separately and soldered in position, while

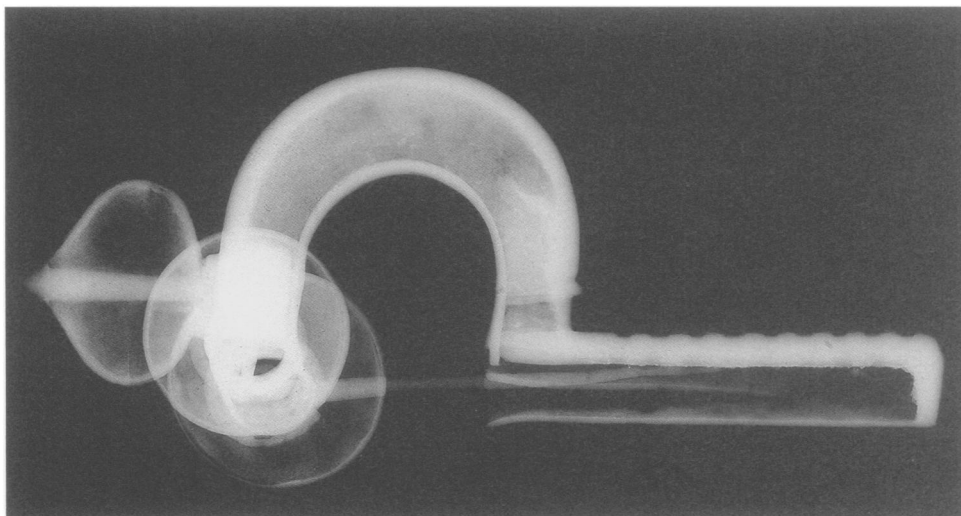


Figure 17. Radiograph of gilt-copper and niello fibula (MMA 1999.42), featuring many of the same characteristics as the Metropolitan's gold fibula (MMA 1995.97)—hollow bow, hollow finials formed from two domes joined along a horizontal seam, head finial secured with a rivet through its length and the width of the bow (radiograph: P. Dandridge)

those on the recently acquired fibula are carved out of the sheets defining the foot.<sup>41</sup> Both fibulae were mercury gilt.

Although the condition of the gilt-copper fibulae has deteriorated, it is still possible to imagine them with their surfaces intact and thus imbued with a striking visual presence. While they are accomplished pieces, compared to other copper fibulae of their type, they are neither remarkable nor unusual examples. They were intended to supply the needs of a less elevated clientele than those receiving or commissioning gold fibulae, and so were made with baser materials; however, in an attempt to achieve visual parity, they were enhanced with gilding, niello, and applied decorations. Interestingly, it is only in the respective value of their materials that the copper-alloy fibulae are wanting, for the time and skills required for their creation are identical to those needed to execute the gold fibulae. From a technical point of view, there is no reason to believe that the same individual could not have fabricated both types. Perhaps the term goldsmith should not have a strictly material connotation but should apply to those who created works of beauty and technical sophistication in gold, silver, and copper.

## ACKNOWLEDGMENTS

I would like to thank Catherine Metzger of the Département des Antiquités grecques, étrusques et romaines, Musée du Louvre, for allowing me access to the Louvre's gold crossbow fibula; and Barbara Deppert-Lippitz, for her collaboration. My thanks, as well, to colleagues at The Metropolitan Museum of Art: Katharine Brown, Department of Medieval Art, for editorial comments; Anna-Marie Kellen, Photograph Studio, for all the photographic images; Daniel Kershaw, Design Department, for the exploded drawing; and, in the Sherman Fairchild Center for Objects Conservation, Mark Wypyski for the SEM analyses, and, especially, James H. Frantz and Richard Stone for their expertise and editorial assistance.

## NOTES

1. For a thorough discussion of the stylistic evolution of the crossbow fibula and its place in the Late Roman world, see Barbara Deppert-Lippitz, "A Late Antique Crossbow Fibula in The Metropolitan Museum of Art," in this volume, pp. 39–70.
2. Claude Lepage, "Les Bracelets de luxe romains et byzantins du II au VI siècle: Étude de la forme et de la structure," *Cahiers*

- Archéologiques* 21 (1971), pp. 1–23; Barbara Deppert-Lippitz, "A Group of Late Antique Jewelry in the Getty Museum," *Studia Varia from the J. Paul Getty Museum* 1 (1993), p. 136; Barbara Deppert-Lippitz, "Goldener Schmuck der Spätantike," in *Die Schraube zwischen Macht und Pracht: Das Gewinde in der Antike*, exh. cat., Museum Würth and Archäologisches Landesmuseum Baden-Württemberg (Sigmaringen: Jan Thorbecke Verlag, 1995), p. 113; Barbara Deppert-Lippitz, "Late Roman Splendor: Jewelry from the Age of Constantine," *Cleveland Studies in the History of Art* 1 (1996), pp. 59–60.
3. Numerous authors have used stylistic comparisons to relate the different types of jewelry incorporating either the screw mechanism or *opus interrasile*. See, for instance, Katharine Brown, "The Morgan Bracelets Reconsidered: A propos of the Screw Mechanism as Used in the Production of Early Christian Bracelets, 400–600 A.D.," in *Outils et ateliers d'orfèvres des temps anciens*, Antiquités Nationales, Mémoire 2, Musées des Antiquités Nationales et du Château de Saint-Germain-en-Laye (Saint-Germain-en-Laye, 1993), pp. 85–92; David Buckton, "The Beauty of Holiness: *Opus interrasile* from a Late Antique Workshop," *Jewellery Studies* 1 (1983–84), pp. 15–19; Catherine Metzger, "Un Bracelet byzantin en or au Louvre," *La Revue du Louvre et des Musées de France* 1 (1990), pp. 7–11; Deppert-Lippitz, "A Group of Late Antique Jewelry," pp. 107–40; Deppert-Lippitz, "Late Roman Splendor," pp. 30–71.
4. Hans von Drescher, "Ein Beitrag zur Technik römischer Zwiebelknopffibeln," *Germania* 37 (1959), pp. 170–79; Aldo Candussio, "Considerazioni sulla tecnica di fabbricazione delle fibule a balestra nel IV secolo," *Memorie Storiche Forogiuliasi* 65 (1985), pp. 23–26. Drescher also discusses the techniques used to create a gold crossbow fibula in the same article; however, some of his conclusions may need to be reevaluated, for instance, that the bow and foot are cast in one piece (pp. 177–78). Aspects of the manufacture of various gold, copper, and copper-alloy screws have been addressed, but most of these descriptions are limited to how the threads were applied or cut in, the number of convolutions of the threads, and the direction of the screws' threading; Hugo Mötefindt, "Zur Geschichte der Löttechnik in vor- und frühgeschichtlicher Zeit," *Bonner Jahrbücher* 123 (1916), pp. 151–57; Hugo Mötefindt, "Zur Geschichte der Schraube," in *Studien zur Vorgeschichtlichen Archäologie* (Leipzig, 1925), pp. 199–206; and, generally, *Die Schraube zwischen Macht und Pracht* (see note 2, above).
5. Buckton, "The Beauty of Holiness," p. 17; Barbara Deppert-Lippitz, "L'*opus interrasile* des orfèvres romains," in *Outils et ateliers*, pp. 69–72; Deppert-Lippitz, "A Group of Late Antique Jewelry," p. 111; Deppert-Lippitz, "Late Roman Splendor," pp. 34–35, 45; Anton Kisa, "Römische Ausgrabungen an der Luxemburgerstrasse in Köln," *Bonner Jahrbücher* 99 (1896), p. 47; Barbara Niemeyer, "A Byzantine Gold Collar from Assiūt: A Technical Study," *Jewellery Studies* 8 (1998), pp. 87–96; B. Niemeyer, "Der lunulaförmige Halsschmuck aus Assiūt in der Berliner Antikensammlung: Eine goldschmiedetechnische Untersuchung," *Jahrbuch der Berliner Museen* 39 (1997), pp. 191–206; Jack M. Ogden, *Jewellery of the Ancient World* (New York: Rizzoli, 1982), pp. 43–44; Jack M. Ogden and Simon Schmidt, "Late Antique Jewellery: Pierced Work and Hollow Bead Wire," *Jewellery Studies* 4 (1990), pp. 5–12; R. Zahn, review in *Amtliche Berichte aus den Königlichen Kunstsammlungen* 38, no. 1 (1916), p. 15.
6. For a formal description of each of the eight, see, in this volume, Deppert-Lippitz, "A Late-Antique Crossbow Fibula."

7. Ogden and Schmidt, "Late Antique Jewellery," p. 6.
  8. Drills have been suggested as a means of opening the initial hole; Kisa, "Römische Ausgrabungen," p. 47; Ogden, *Jewellery*, p. 43; Deppert-Lippitz, "A Group of Late Antique Jewelry," p. 111. Zahn, in his review of the techniques postulated for the working of *opus interrasile*, thought the use of a drill unlikely; I also found the technique to be time-consuming and awkward compared with the use of a punch or awl; Zahn, in *Amtliche Berichte*, p. 15.
  9. Ogden and Schmidt, "Late Antique Jewellery," pp. 6–8. Chisels and files have been suggested as the tools used to open out the design after the initial punching; Buckton, "The Beauty of Holiness," p. 17; Kisa, "Römische Ausgrabungen," p. 47; Ogden, *Jewellery*, p. 43; Deppert-Lippitz, "L'opus interrasile," p. 70; Zahn, in *Amtliche Berichte*, p. 15. It has been suggested the chisel was used more commonly in the third and fourth centuries A.D. with thin gold sheet, while the graver became the standard later when designs were more intricate and the gold sheet thicker; Ogden and Schmidt, "Late Antique Jewellery," p. 6.
  10. Ogden and Schmidt, "Late Antique Jewellery," p. 7.
  11. In the *opus interrasile* decoration, on the side panels of the catch, the quatrefoils are bordered on either side by a cable pattern whose negative spaces are of a consistently larger diameter than those defining the quatrefoils.
  12. A scraper has been suggested as the tool used to remove the burrs on the underside of the objects worked in thin gold sheet or on those objects that would be in contact with the wearer; Ogden and Schmidt, "Late Antique Jewellery," p. 7.
  13. The sulfur is still retained in the interior of the bow, a small amount of which was extracted through an opening in the solder join along the ridge and analyzed using the Debye-Scherrer camera with a Phillips 1840 X-ray generator and a copper tube at 37Kv and 20Ma for two hours. Patterns were identified with the Fein-Marcourt Search-Match Program using a PDSM database. The extent to which hollow elements on gold crossbow fibulae were filled is unclear, but photographic evidence indicates that the head knob on the fibula from Apahida (Muzeul Național de Istorie a României, Bucharest, inv. no. MNIR 54256) has a triangular opening on its underside that could have served only as a point of access for filling; *Die Schraube*, p. 117. Certainly, any filling material would preclude comparisons made of the weights of the fibulae and those of contemporary gold coinage.
- Sources for sulfur are known to have existed south of the Alps, and its usage is reported to have been common during the Roman period; Birgit Arrhenius, *Merovingian Garnet Jewellery: Emergence and Social Implications* (Stockholm: Almqvist & Wiksell International, 1985), p. 88. Sulfur has been documented in the Late Roman Thetford Treasure both as a backing paste in settings and as a filling material for a hollow ring hoop (M. R. Cowell, Susan La Niece, and Nigel D. Meeks, "The Scientific Investigation of the Thetford Treasure," *The Thetford Treasure: Roman Jewellery and Silver*, ed. Catherine Johns and Timothy Porter [London: British Museum Publications, 1983], p. 60); in an earring from Roman Britain in the British Museum (Catherine Johns, "Some Unpublished Jewellery from Roman Britain," *Jewellery Studies* 5 [1991], p. 55); in the terminals on the sixth- or seventh-century A.D. Byzantine torque in the British Museum (reg. no. M&LA 1984, 5-2, 1) thought to be from the southeastern Mediterranean (Marilyn Hockey, "The Composition and Structure of a Byzantine Torc," *Jewellery Studies* 3 [1989], p. 36); and in the saddle mounts from Apahida II, in Arrhenius, *Merovingian Garnet Jewellery*, p. 36.
14. The vulnerability of this particular join is apparent, for example, in the condition of the crossbow fibula from Vienna, where the bow has separated cleanly along the point of attachment from the now-lost foot (Kunsthistorisches Museum, Vienna, inv. no. VII B 299; illustrated in Mötefindt, "Zur Geschichte der Löttechnik," p. 154, fig. 16).
  15. For a thorough discussion of the forming and shaping of wire, see Niamh Whitfield, "The Manufacture of Ancient Beaded Wire: Experiments and Observations," *Jewellery Studies* 8 (1998), pp. 57–86.
  16. Initially, in the backward-turned feet of European P-shaped fibulae, the wrapping served as a structural element. See, for instance, Richard Hattatt, *Iron Age and Roman Brooches* (Oxford: Oxbow Books, 1985), p. 126, no. 487; however, as it appears on crossbow fibulae, the wrapping is purely decorative.
  17. The widths of the finials are all 1.45 cm.
  18. The X-ray of the screw mechanism (Figure 12) shows an opaque material with a meniscus at the top of the tube within the finial which can be interpreted as solder.
  19. Without X-rays, it can be difficult to determine whether there is any structural support in the interior of the finials; however, many of the finials exhibit stress-tearing at their tips, with a circular outline possibly induced by a rigid tube beneath the surface of the gold. See, for instance, the head knob on the fibula from Vienna referred to in note 14 above. A gap on the underside of the head knob on the gold crossbow fibula in the Louvre (inv. no. Bj 947) allowed for the identification of a hollow tube in the finial's interior extending upward only a third of its height.
  20. Rüdiger Krause, "Das Gewinde in der Antike," in *Die Schraube*, p. 48.
  21. Outer diameter of nut thread is 0.65 cm; inner diameter of nut thread, 0.43 cm.
  22. The screw is a left-hand thread. The dimensions for the screw are: threads, 0.11 cm square; the flute width is 0.13 cm; the diameter of thread, 0.61 cm; the diameter of shaft, 0.38 cm.
  23. The loss of tips from a number of different screws for various gold crossbow fibulae suggests that tubular shafts were used. While a tip and shaft shaped from a single piece of gold would be unlikely to shear, the join between a hollow shaft and a solid tip would be susceptible to separation. See illustrations of the screws from the following fibulae: Apahida (Muzeul Național de Istorie a României, inv. no. MNIR 54256), in Mötefindt, "Zur Geschichte der Schraube," p. 200, fig. 1; Degoj (Kunsthistorisches Museum, Vienna, inv. no. VII B 299), in *Die Schraube*, p. 155, fig. 116; Desana (Museo d'Arte Antica, Turin, inv. no. 12/ORI), in *Die Schraube*, p. 82, fig. 54, pp. 153–54, fig. 115; Indiana (Indiana University Art Museum, Bloomington, inv. no. BYB 76.75.23), in *Die Schraube*, p. 26, fig. 3; Palatine (Museo dell'Alto Medioevo, Rome), in *Die Schraube*, pp. 81, 152, figs. 53, 113; Reggio Emilia (Museo Chierici di Paleontologia), in Brown, "The Morgan Bracelets," p. 85, fig. 2.
  24. Suggested by Robert Baines of the Royal Melbourne Institute of Technology in an oral communication.
  25. The relationship between coinage and jewelry both within and outside the empire is discussed in Jan Iluk, "The Export of Gold from the Roman Empire to Barbarian Countries from the 4th to the 6th Centuries," *Münstersche Beiträge zur antiken Handelsgeschichte* 4, no. 1 (1985), p. 99; Andrew Oddy and Susan La Niece, "Byzantine Gold Coins and Jewellery: A Study of Gold Contents," *Gold Bulletin* 19, no. 1 (1986), pp. 19–27.

26. Nigel D. Meeks and M. S. Tite, "The Analysis of Platinum-Group Element Inclusions in Gold Antiquities," *Journal of Archaeological Science* 7 (1980), pp. 267–75; Jack M. Ogden, "Platinum Group Metal Inclusions in Ancient Gold Artifacts," *Journal of the Historical Metallurgical Society* 11 (1977), pp. 53–72.
27. Ogden, "Platinum Group," p. 53.
28. Ibid.
29. Osmiridium has been reported as frequently occurring in ancient gold work; Ogden, "Platinum Group," p. 57. In situ elemental analysis was carried out using a Kevex Delta IV energy-dispersive X-ray spectrometer coupled to a modified Amray 1100 scanning electron microscope. The data was quantified using MAGIC IV ZAF corrections:
- | weight % of | osmium<br>(Os) | iridium<br>(Ir) | platinum<br>(Pt) | gold<br>(Au) |
|-------------|----------------|-----------------|------------------|--------------|
|             | 33.3           | 55.7            | 7.3              | 3.7          |
30. Philip Grierson and Mark Blackburn, *Medieval European Coinage* (Cambridge: Cambridge University Press, 1986), vol. 1, pp. 6–16; Iluk, "The Export of Gold," pp. 79–103; see also Joachim Werner, "Zu den auf Öland und Gotland gefundenen byzantinischen Goldmünzen," *Fornvännen* 44 (1949), pp. 257–86.
31. E. R. Caley, "Fineness of Gold Coins of the Roman Empire," *The Numismatist* 63, ser. 2 (1950), pp. 66–70; Cowell, La Niece, and Meeks, "The Scientific Investigation," p. 59; Grierson and Blackburn, *Medieval European Coinage*, vol. 1, pp. 422, 430, 432, 436, 438, 441; D. M. Metcalf, "Metal Contents of Medieval Coins," *Methods of Chemical and Metallurgical Investigation of Ancient Coinage*, ed. E. T. Hall and D. M. Metcalf, RNS Special Publications 8 (London, 1972), p. 429; Andrew Oddy and F. Schweizer, "A Comparative Analysis of Some Gold Coins," *Methods of Chemical and Metallurgical Investigation*, pp. 171–82; Andrew Oddy, "The Analysis of Four Hoards of Merovingian Gold Coins," *Methods of Chemical and Metallurgical Investigation*, p. 116; Oddy and La Niece, "Byzantine Gold Coins," p. 20.
32. Donald Bailey, "Some Classical Gold Finger-Rings in the British Museum," *Jewellery Studies* 5 (1991), pp. 33–41; Lawrence Becker, Deborah Schorsch, Jane L. Williams, and Mark T. Wypyski, "Technical Entries" and "Appendix 1—Technical and Material Studies: Gold Jewelry," *Art of Late Rome and Byzantium in the Virginia Museum of Fine Arts*, ed. A. Gonosová and C. Kondoleon (Richmond, 1994), pp. 406–9; Cowell, La Niece, and Meeks, "The Scientific Examination," pp. 56–59; Hockey, "The Composition and Structure," pp. 33–39; Iluk, "The Export of Gold," p. 99; Bruno Vorstz, "Analytische Untersuchungen archäologischer Goldfunde," in Ilona Kovrig, "Das Diadem von Csorna," *Folia Archaeologica* 36 (1985), pp. 146–47; Johns, "Some Unpublished Jewellery," pp. 55–64; Metzger, "Un Bracelet," p. 11 n. 3; Oddy and La Niece, "Byzantine Gold," pp. 19–20; Niemeyer, "A Byzantine Gold Collar," p. 90.
33. When the gold has been debased with 20% silver and/or copper, the increase in tensile strength and hardness thereby achieved

begins to level off and then to decrease. For a discussion of the mechanical properties of gold and its alloys, see *Precious Metals: Science and Technology*, ed. Dr. Linda S. Benner, Dr. T. Suzuki, Dr. K. Meguro, and S. Tanaka (Allentown, Pa.: International Precious Metals Institute, 1991), pp. 430–38.

34. Melting points were extrapolated from the phase diagrams for the binary alloys of gold-silver and gold-copper reproduced in David A. Scott, *Metallography and Microstructure of Ancient and Historic Metals* (Marina del Rey: Getty Conservation Institute in association with Archetype Books, 1991), pp. 127, 134.
35. Krause, "Das Gewinde," p. 50. The screw mechanisms—finial, threading, and tip—in copper and its alloys appear both as homogeneous elements, carved from a single blank of metal, and as composite objects, where the screw—threading and tip—is soldered to the finial, and the finial itself is assembled from two domes soldered together (as seen in many of the gold examples).
36. MMA 17.191.189, Gift of J. Pierpont Morgan, 1917; MMA 1999.42, Rogers Fund, 1999.
37. A nearly identical fibula (from a private collection) with all its finials intact is illustrated in *Rom und Byzanz: Archäologische Kostbarkeiten aus Bayern* (Munich: Himmer Verlag, 1998), p. 175, no. 231.
38. A sample of the niello was identified as chalcocite, a copper sulfide, by X-ray diffraction (under conditions identical to those outlined in note 13). Copper sulfides have also been identified by La Niece on Roman metalwork fabricated from copper and its alloys; Susan La Niece, "Niello before the Romans," *Jewellery Studies* 8 (1998), p. 50. The identical design in an expanded form appears on the bow and foot of a gilt-copper-alloy crossbow fibula in the collection of the Rheinische Landesmuseum Bonn, inv. no. 72.315, illustrated in Dorothea Haupt, "Spät Römisches Grab mit Waffenbeigabe aus Bonn," *Archéologie en Historie* (Brunsting-Festschrift, 1973), pp. 315–26.
39. EDS analysis of several points on the Morgan fibula indicate that it was formed from a brass with only minor amounts of tin and lead, while the recently acquired fibula was shaped from nearly pure copper. These analyses were performed under the same conditions outlined in note 29. Nd = not detected.
- | weight % of    | iron<br>(Fe) | nickel<br>(Ni) | copper<br>(Cu) | zinc<br>(Zn) | arsenic<br>(As) | tin<br>(Sn) | lead<br>(Pb) |
|----------------|--------------|----------------|----------------|--------------|-----------------|-------------|--------------|
| MMA 17.191.189 |              |                |                |              |                 |             |              |
| crossbar       | 0.3          | nd             | 91.7           | 6.8          | nd              | 0.5         | 0.7          |
| bow            | 0.4          | nd             | 91.8           | 6.7          | nd              | 0.3         | 0.8          |
| foot           | 0.4          | nd             | 91.4           | 6.9          | nd              | 0.4         | 0.8          |
| MMA 1999.42    |              |                |                |              |                 |             |              |
| crossbar       | 0.4          | nd             | 98.1           | nd           | 0.7             | 0.5         | nd           |
| foot           | 0.2          | nd             | 97.7           | 0.4          | 0.7             | 0.7         | 0.7          |
40. The use of a rivet to secure either a solid or a hollow composite head finial is not uncommon on crossbow fibulae in precious and base metal.
41. The volutes bear a close resemblance to those on the gold crossbow fibula from Desana (Museo d'Arte Antica, Turin, inv. no. 12/ORI), in *Die Schraube*, p. 82, fig. 54, pp. 154–54, fig. 115.