ASPECTS OF CASTING PRACTICE IN PREHISPANIC PERU

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The author has long marveled at the skill and ingenuity evident in the design and fabrication of metal artifacts from Peru; yet he has often wondered the reason for certain features. Why was it done thus when (by our standards) another solution would seem more appropriate? Investigating such intriguing matters gives further insight into Peruvian metals technology, and to the culture of which this technology was a part. The Peabody Museum of Archaeology and Ethnology at Harvard University is fortunate in having an extensive collection of Peruvian artifacts acquired by S. K. Lothrop circa 1940. The author recently examined artifacts in this collection and selected a sample of two object types that displayed features pertinent to this study.

1) Bola Weights

Three bola weights were reportedly found in a cave site on Puma Orqo, a hill at Paquari Tampu, Department of Cuzco. They were identified as belonging to the Inca period. The bola weights were oblate spheroids about 20 mm. in diameter weighing approximately 30 grams each. Each bola weight was fitted with a single opening within which an internal transverse bar could be seen (Figure 1).* Two of the weights were coated with dark green corrosion product, but the third had been cleaned to present a smooth, yellowish, metal surface. The third weight displayed three rectangular inlays of reddish metal arranged symmetrically about its opening; the other two weights, after partial removal of corrosion product, proved to be devoid of decoration. The author judged on the basis of appearance that all three weights were cast of bronze. Qualitative x-ray fluorescence analysis of one weight supported this view by indicating an alloy of copper containing about 15% tin and a small amount of lead. The decorative inlays had the appearance of oxidized copper.

Bolas were used for hunting and fighting by the natives of Peru. These devices consisted of two weights attached to the ends of a sturdy cord or rope. A hunter, on approaching his quarry, would hold one weight over his head and whirl the other about it in a nearly horizontal plane. He next released the hand-held weight simultaneously casting the device at his prey. If his aim was good, the angular momentum of the whirling weights would serve to wrap the cord tightly around the animal and prevent its escape. Bolas were also employed in combat for the purpose of entangling an opponent and impeding his movements so that he might be more readily dispatched with other weapons.

The author elected to investigate and record the device for attaching these bola weights to their respective cords because it: (1) appears unique to the Peruvian culture, (2) indicates sophisticated metallurgical skill, and (3) presents an interesting question of choice. Sectioning one bola weight disclosed an eye-shaped passage through the cast metal (Figure 1). A cord (no doubt smaller in

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* Figures follow text, beginning on page 137.

diameter than the external opening) was apparently introduced, coaxed around the looping passage, teased out of the opening, and then pulled through the loop to the desired extent.

The presence of the loop inside the casting indicates that a core of some refractory material (e.g., clay) was positioned within the mold that was to be invested with molten metal. The craftsman must have removed the core from the finished casting in order to open the internal passageway (possibly by using a wire). A friable core material would have facilitated removal. It has been reported that a mix of clay and powdered charcoal was used in Colombia, probably for this reason (Plazas and de Saenz 1979:16). Cores were commonly used elsewhere in Meso-America, Central America, and northwestern South America to make hollow castings, mostly in order to conserve precious metal (Easby 1966:77).

Metallographic examination of the sectioned bola weight after etching with potassium dichromate solution revealed a coarse dendritic microstructure with coring and shrinkage porosity in the interior of the casting, which cooled more slowly (Figure 2). This microstructure gradually changed to one of fine, equiaxed grains with many annealing twins at the exterior, which cooled more rapidly from contact with the mold (Figure 3).

There was some question whether the bola weights were cast in two-piece molds or in lost-wax investment molds. The author inclines to the latter process, at least in the instance of the decorated weight, because it seemed probable that inlaying was accomplished using undercut rectangular recesses carved into the surface of the wax model and reproduced in the casting itself. Presumably, these recesses were filling with matching pieces of copper which were hammered to expand them into the undercut and lock them tightly in place. Examination of the inlays at low magnification revealed excellent conformity. Since the melting point of copper exceeds that of bronze by roughly 300 C, it is conceivable that copper preforms were positioned in a two-piece mold (together with the eye-shaped core) prior to pouring the casting (Easby 1966:77). However, this alternate procedure would seem quite difficult. The rarity and excellent preservation of the inlaid bola weight precluded destructive examination to determine which possibility is correct.

The study of these weights has raised questions as regards purpose and design. They seem too small to have been used for warfare. Rigoberto Paredes (1918:148) has indicated that Peruvian military bolas had metal spheres about 30 mm. in diameter, which would have weighed more than three times those examined in this study. However, the purpose of the weights was not to impact the target, but rather to provide the circular momentum necessary to wrap the bola cord tightly around it. Therefore, the criterion was strength of cord: not as a single strand, but as a wrapping of several strands. The Peruvians were adept in the use of various natural fibers and were able to make cords that were quite strong, even in diameters commensurate with the openings of these small weights. It seems probable that smaller bolas, such as those examined in this study, were used by the elite for hunting, as of vicuñas. (During Inca times this animal was reserved for royalty [Dorst 1967:202]. Great hunts were organized in which thousands of loyal subjects drove the vicuñas within range of the royal party.)

The design of the bola weights is interesting because the internal passage is not only a unique means for cord attachment; it is more difficult to produce than several alternative means. A circumferential groove, an axial hole throughout, or an external eye (like a jug handle) would have enabled attachment as effectively. Failing to recognize a technical justification for the chosen method, the author can only suggest clean, elegant design as the basis for selection: it was a matter of style intended to please those who could afford (or demand) it.

2) Spindle Whorls

A string of nineteen "copper beads" from Pachacamac, situated in the Lurin Valley on the central coast of Peru, was chosen for analysis. The beads proved to be spindle whorls, i.e., small weights used to steady the motion of spindles used for hand-spinning yarn and thread.

The natives of Peru developed truly remarkable skills in spinning a variety of plant and animal fibers over the span of three millennia prior to the Spanish Conquest (Murra 1962:710). Cotton was used as early as 2000 B.C. in coastal Peru. The llama, principal source of wool for highland weavers, was domesticated by 1000 B.C., if not earlier. Although their looms were primitive in design, Peruvian weavers produced a range of textile products from simple cloths to complex tapestries, brocades, and embroideries.

The prestige that spinning and weaving acquired in Peruvian societies is difficult to comprehend without careful study of such historical records as are available. Clothes, necessary for warmth in the highlands, were valued for comfort, beauty, and indications of status throughout Peru; but cloth itself assumed a number of other important functions. Cloth became "the main ceremonial good and the preferred gift highlighting all crisis points in the life cycle" of the individual: christening, puberty, marriage, and death (Murra 1962:712). Cloth was also deemed an eminently suitable offering for religious sacrifices.

As weaving assumed such importance, the weaver's tools acquired prestige and were valued beyond their normal worth. Spindles were used to spin thread (or yarn) and retain it wound (much as on a spool) for the weaving process. Coarse fibers, such as llama wool, required a larger spindle with a disc-shaped whorl. The whorl acted much as a flywheel to maintain rotational momentum and promote further twisting of the thread beyond that already imparted by the spinner's fingers. However, on spindles for fine threads, such as threads of cotton fibers, the whorl was not used to prolong spindle rotation but rather to steady spindle motion and act as a barrier to retain the winding of thread on the spindle. Peruvian spindles for spinning cotton were needles of palm wood some 20-30 cm. in length. Some whorls consisted of wooden carvings integral with the spindle itself; more commonly, whorls were fashioned separately from baked clay, stone, or (rarely) metal. The separate whorls were made in various shapes of rotation coaxial with the spindle (Figure 4). Some were decorated with engraved designs filled with colored pigments.

Only a few of the metal whorls which the author examined possessed surface decorations. These were free-form designs, not sharply defined, which appear

to have been made by inscribing the model around which the ceramic mold was constructed (Figure 5). The author believes that a wax model would have enabled more precise replication of engravings on its surface. This is consistent with the observation that many Peruvian castings, although skillful and complex, "do not have the detail and delicacy that can be achieved with beeswax (models)" (Bird 1979:51). It has been proposed that models were fashioned from "some other unknown substance that could be melted or burned out of molds" (Ibid). The majority of these metal whorls, however, were in the as-cast (unpolished) condition and without decoration. Typically these whorls were 12-14 mm. in diameter and weighed about 7 grams each.

While examining the metal whorls under a binocular microscope with good illumination, the author observed that a number of these small castings were hollow and that the internal passage varied in size and was at points greater in diameter than the external openings. Since the purpose for this was not apparent, he prepared axial sections of two representative whorls in order to study their interiors. X-ray fluorescence analysis of the sectioned whorls revealed only copper and several percent of arsenic, indicating that the metal was arsenical bronze. The sections immediately disclosed that the whorls were of more complex design than their plain exteriors had suggested (Figure 6). Staining these sections with potassium dichromate served to reveal a mottled cast structure, which was equiaxed (i.e., nondirectional) except in portions which had been deformed subsequent to casting (Figures 7 and 8). Deformation served to elongate the grain of the metal producing a banded appearance in the stained macrostructure. By study of this macrostructure some insight into forming operations was gained, and reconstruction of the as-cast shape became possible (Figure 9). The macrostructure of these whorls indicated to the author a sequence of operations the purpose of which was to lock the whorl firmly on the spindle shaft. The internal rib served to stiffen the hollow casting and determine the points at which flexure would occur as the edges of the end openings were forced inward to grip the spindle. It would seem that the whorls could have been attached to their spindles much more easily (e.g., by a resin adhesive). The inseparable nature of the pressure bond may reflect the high value of the metal whorls.

The internal contours of bronze spindle whorl castings must have been imparted by cores of a refractory material, probably clay. These cores may have served as axles upon which wax (or a substitute) was deposited and shaped by rotation preparatory to fashioning an investment mold.

The author believes that this combination of investment molding and use of cores is consistent with the level of metallurgical expertise that developed in Peru during the Late Intermediate Period.

The bronze whorls represent investments in materials and labor far beyond those necessary to accomplish their nominal purpose; simple whorls of baked clay serve the same function (and, indeed, were used, presumably by the less affluent). Beyond the value of metal painstakingly extracted, consolidated, and alloyed, investment casting of bronze spindle whorls required an impressive sequence of operations demanding both technical knowledge and expert craftsmanship. This level of effort expended to fashion spindle whorls of bronze confirms the importance which Peruvian society attached to weaving and to the tools of this exalted craft.

Conclusion

Both the bronze bola weights and the spindle whorls revealed a propensity for innovative core design that deserves recognition as a new dimension to modern knowledge of the casting technology of Peru and possibly the hemisphere. Although cores were used contemporaneously in Meso-America, Central America, and certain other parts of South America, the apparent objective of craftsmen in those regions was to make hollow castings that conserved metal and did not weigh as much. Peruvian metalworkers discovered that the inside of a casting could be shaped to perform functions that aided or complemented its principal purpose. Features which, if external, might have detracted from the casting's appearance could, by clever design, be hidden within (as in the case of the bola weight's cord attachment device). Internal features could be used to modify mechanical behavior of the casting (just as the rib inside the bronze spindle whorl helped to control deformation needed to clamp the whorl upon its wooden shaft). Interior space could therefore be utilized advantageously, to meet functional requirements and enhance formal design of cast metal objects.

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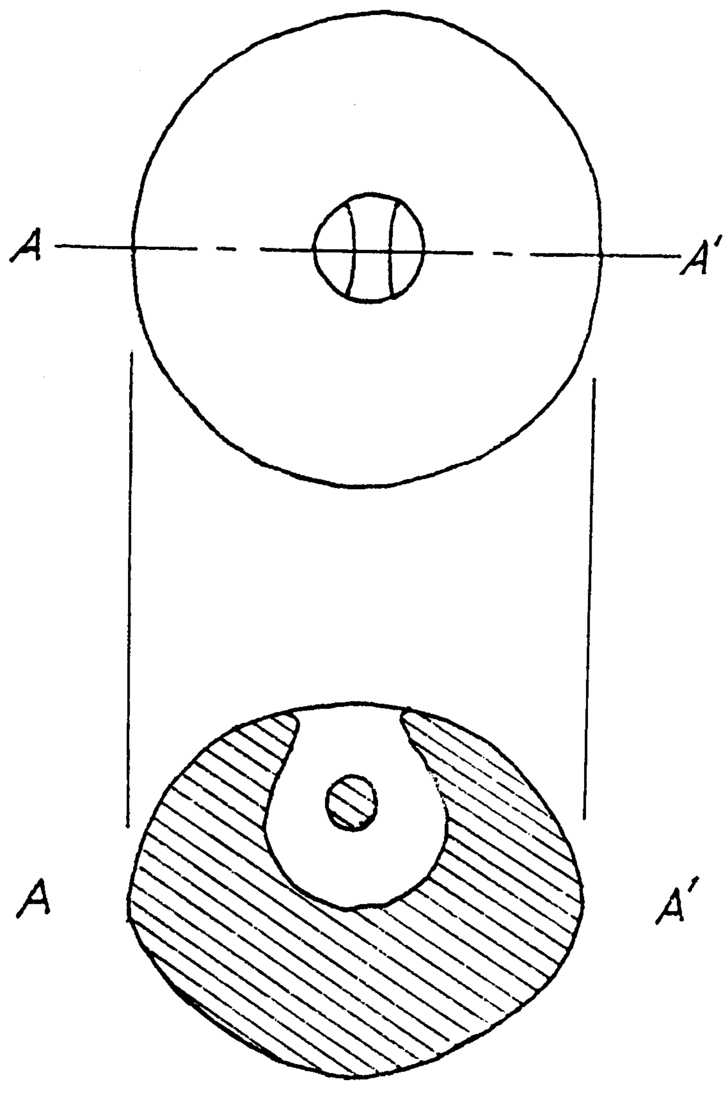
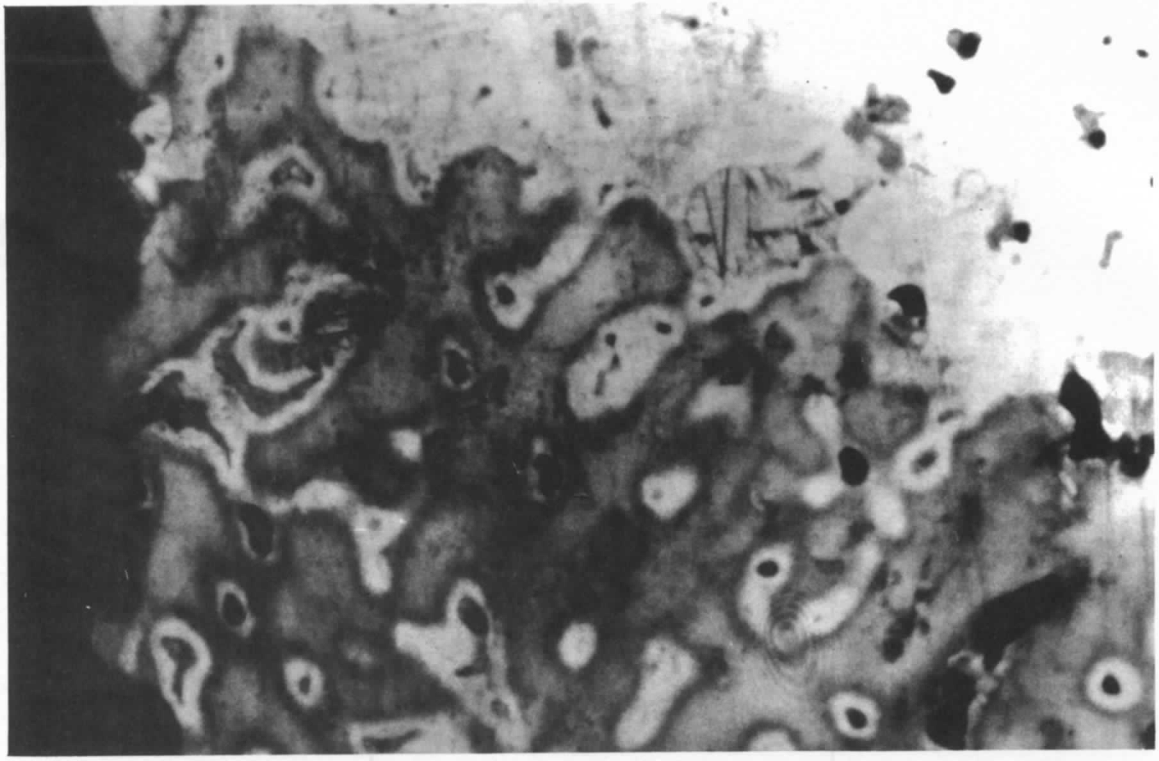


Figure 1. Bola weight, top view, showing single opening with internal transverse bar. Sectional view, below, shows eye-shaped passage through the cast metal.



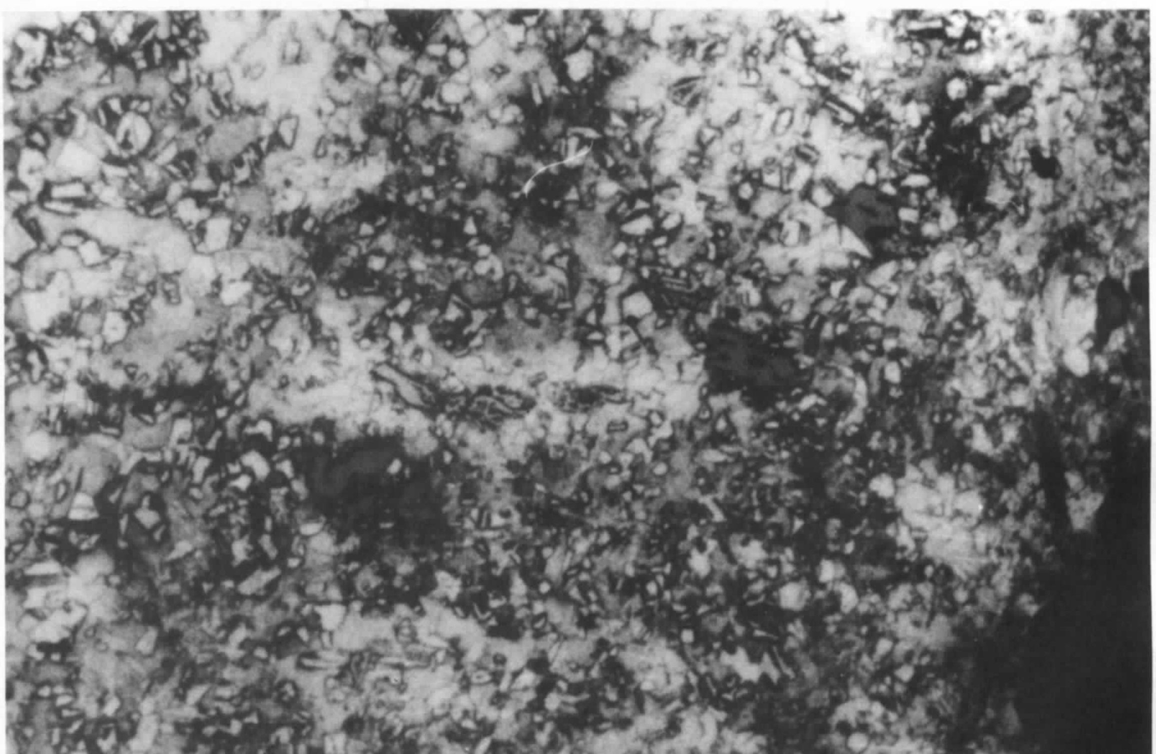


Figure 2. Top. Coarse microstructure near internal passage of bola weight, left, shows dendrites, coring, shrinkage porosity, and twinning. 200x.

Figure 3. Bottom. Fine microstructure near exterior surface of bola weight shows equiaxed grains and annealing twins. 200x.

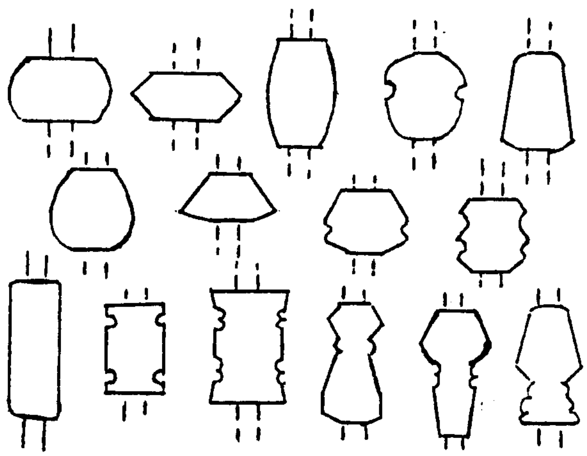


Figure 4. Shapes of some Peruvian spindle whorls (copied from Hirtzel 1928:17).

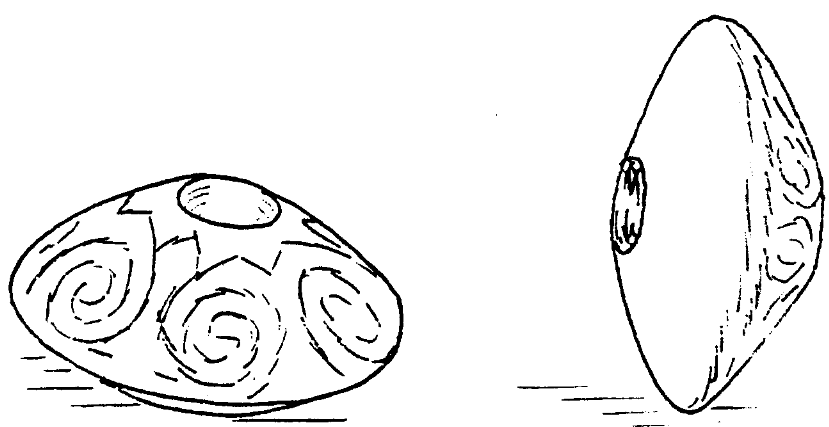


Figure 5. Drawing of lenticular bronze spindle whorl decorated on one surface only.

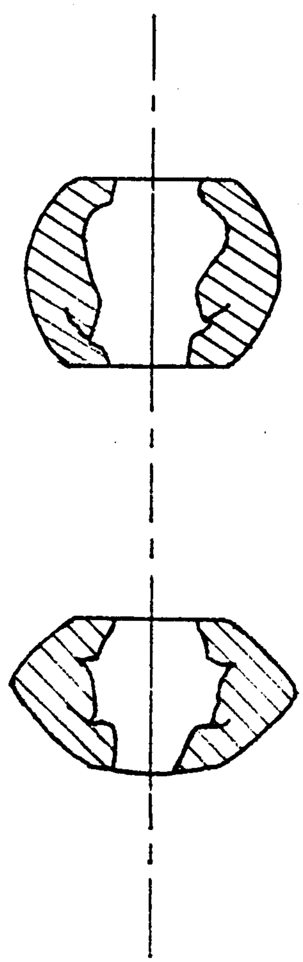
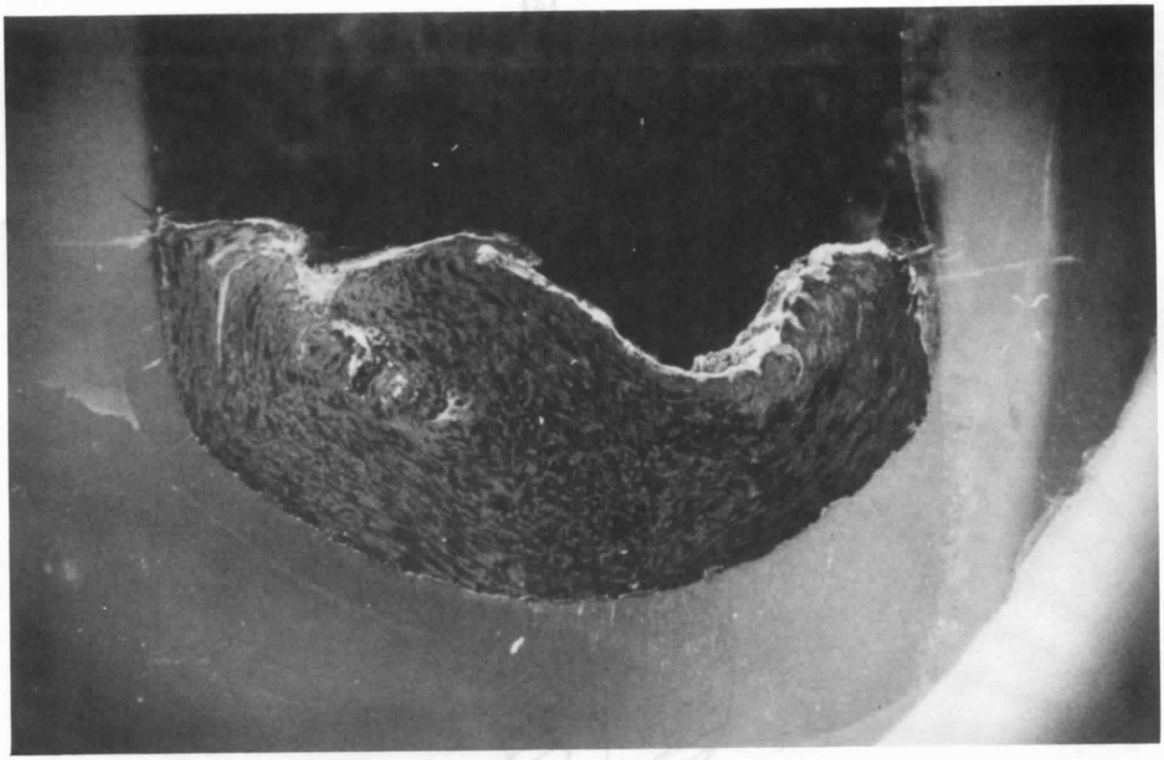


Figure 6. Drawing of cross-sections of two bronze spindle whorls.



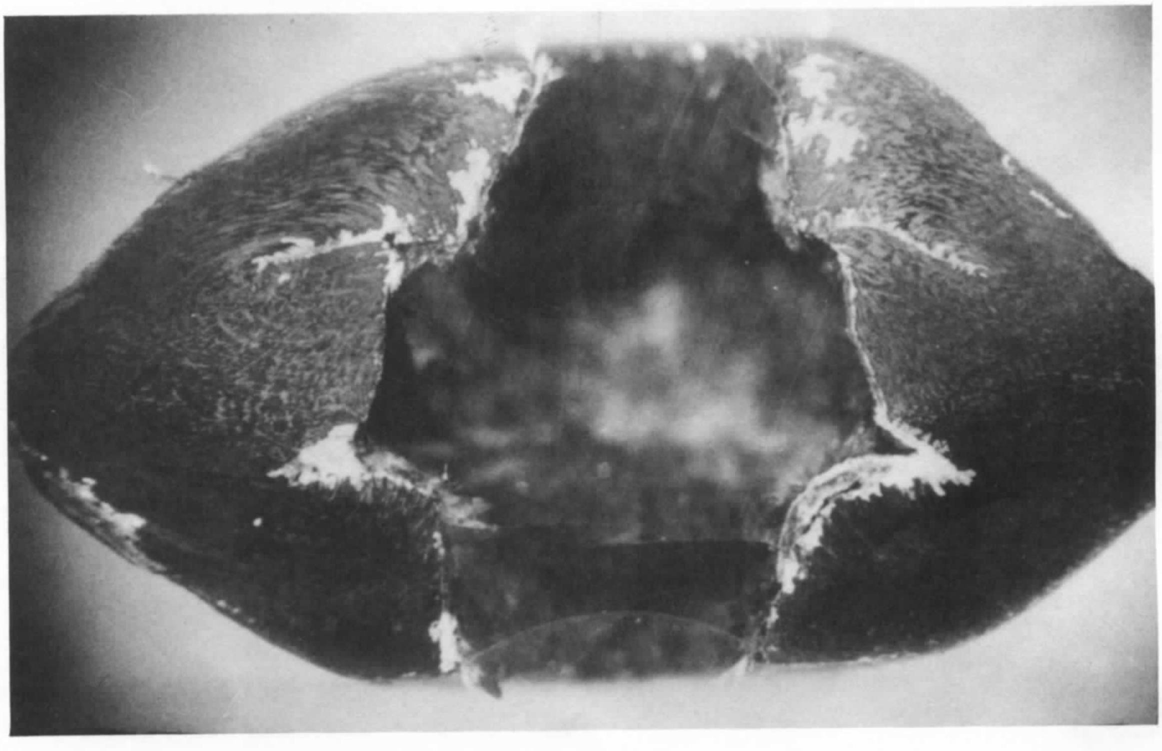
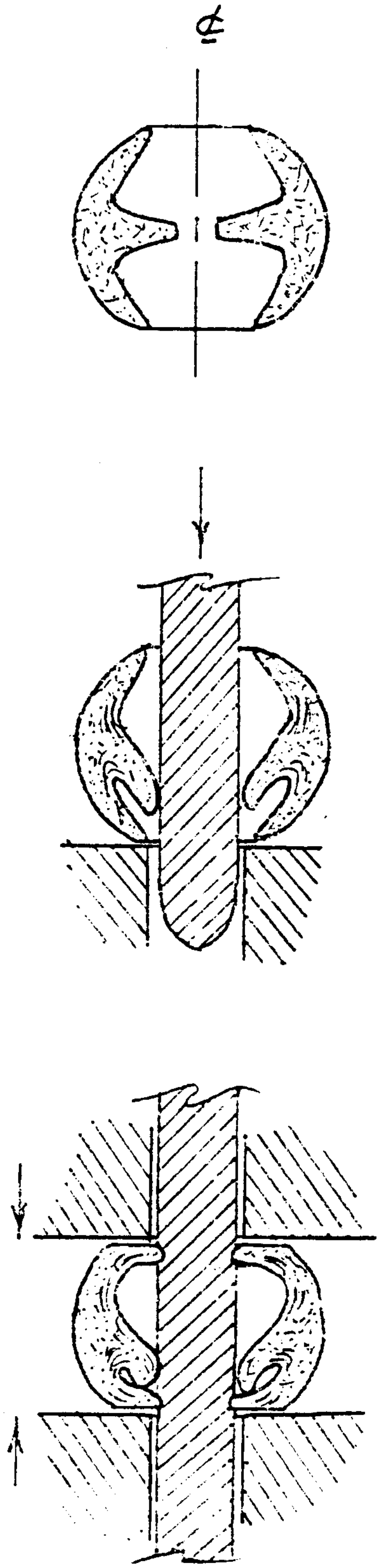


Figure 7. Top. Half of axial section of bronze spindle whorl stained with $K_2Cr_2O_7$ solution to show macrostructure. 15x.

Figure 8. Bottom. Axial section of bronze spindle whorl stained with $K_2Cr_2O_7$ solution to show macrostructure. 15x.



(a) Whorl, as-cast (note equiaxed macrostructure).

(b) Wooden spindle is forced through central orifice or whorl (note deformation of macrostructure at points of flexure).

(c) Ends of whorl are forced inwards by pressing or hammering. Whorl is clamped firmly on spindle.

Figure 9. Drawing showing reconstructed shape of as-cast whorl (a) and subsequent deformation during spindle attachment (b and c).