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Casting cores used to craft large bronze masterpieces of the Florentine Renaissance and Mannerism

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ABSTRACT

We investigated the casting cores of twelve large bronze masterpieces of the Florentine Renaissance and Mannerism (artworks by Ghiberti, Donatello, Verrocchio, Rustici, and Danti). Materials were characterized in their mineralogical-petrographic features, chemical composition, organic content and fossil traces.

The results achieved provide information on the main recipes employed for manufacturing the casting cores, which largely agree with written sources of the time, and shed light on the art foundry processes between the 15th–16th centuries. The data collected point out a pronounced affinity of natural raw materials used in all the casting cores investigated, consisting in silty-sandy clays with a suitable natural fine-grained temper component. A large use of organic fibres and matters of both animal and vegetal origin and a minor use of gypsum in selected workshops (Rustici, Verrocchio) were highlighted. Textural analyses allowed gaining information on direct vs indirect methods of casting, while firing temperatures up to about 1000 °C were estimated from mineralogical and microstructural observations. Despite the strong similarities, significant differences among the various samples analysed were pointed out, providing some initial analytical clues that suggest different practices in separate workshops. Finally, the whole petrographic, geochemical and paleontological data gave information on the provenance of the clayey raw materials.

This work represents the first step of a systematic approach to the classification of the core materials used in Florentine foundries along the centuries and shows the significant contribution the petrographic analyses can provide to the interpretation of the execution processes of large bronzes.

1. Introduction

The lost-wax casting technique is the main method used for the production of bronze artefacts since antiquity. As well known, such practice requires the preparation of a wax model with refractory core (casting core) and investment (mantle), which constitute the mould of the object to be cast in bronze. For low and high reliefs one can conventionally define as core and mantle the investment of the front (sculptural surface) and rear sides, respectively. Remnants of these materials can often be found inside ancient and modern bronzes whereas material traces of the mantles are very rare. Before the wide-spread use of the modern gypsum-based cores, they usually consisted of a clayey base with a suitable natural and/or added content of sand/pebble acting as temper (i.e. as a component which limits shrinkage and improve the ability of the clay to withstand thermal shock) and, sometimes, other additions useful to give the mixture particular properties suitable for casting operations.

A usual practice in art foundries since antiquity has been to procure raw materials from their immediate vicinity. This assumption represents the starting base of scientific research on casting core remnants carried out in the last few decades, mostly concerning archaeological findings and addressed to provenance determination and dating (e.g. Lombardi, 2009 and references therein; Martini and Sibilia, 2003 and references therein).

Regarding Renaissance bronzes, information on the art foundry practices are reported in several treatises of the 16th century and in particular in those written by Biringuccio in 1540 (Smith and Gnudi, 1966), by Vasari in 1550 (Brown, 1960) and by Cellini in 1568 (Ashbee, 1967). These authors describe the preparation of clay-matrix casting cores through different phases including the selection of the raw earthy materials, their processing, and

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eventually a set of construction procedures (Ashbee, 1967, pp. 111–133; Brown, 1960, pp. 158–166; Smith and Gnudi, 1966, pp. 213–277). Fine grained clay-based materials with a significant non-plastic fraction are considered the most suitable in order to achieve a good workability and ensure a sufficient structural resistance during firing and casting operations. Biringuccio suggests collecting these materials from quarries, poorly fertilized landscapes, furnaces, or riverbanks, while Cellini prefers caves, mountains, or rivers.

The descriptions of the material processing in the three treatises underline the importance of sieving and careful mixing with water with the addition of organic fibres. For Biringuccio the latter are preferably wool cloths frayings: "… *also mix it with two-thirds of the whole quantity of wool-cloth clippings*" (Smith and Gnudi, 1966, p. 219), but also discards of wool-carding and hide-tanning, dung, washing ash, and vegetal fibres, like scutched flax, reed flowers and minced straw represent good alternatives. During this phase, Biringuccio also considers the possibility to mix different kinds of earthy materials in order to achieve the suitable temper content, followed by repeated drying, pounding, sieving, wetting, and beating operations. Vasari mentions horse dung and cloth frayings while wet ash should be directly applied on the waxes (investment). After preparing the earth adding cloth frayings ("… *then you mix it with cloth frayings, about half as much of the latter as you have clay*", Ashbee, 1967, p. 113) and other organic matter, Cellini lets the mixture macerating in water for at least four months, in order to make it pasty and soft like an unguent. He also suggests adding ground bones in the outer layers of the casting core in order to get a higher porosity at the contact with the metal.

Finally, the tradition provides detailed descriptions of several methods for building and firing the whole mould. Among these, the construction through application, drying, and mild firing of consecutive layers of earthy mixture is reported by both Cellini and Vasari, while a careful final firing is emphasised by all the three authors. In particular, Cellini recommends a gentle firing by avoiding charcoal and oak wood as fuel in order to prevent vitrification ("… *because all these fuse the clay and make it become like glass*", Ashbee, 1967, pp. 118–119) and consequent worsening of the mechanical properties of the mould.

All these recipes provide useful hints for suitably addressing the material analyses, although they are qualitative and sometimes aimed at outlining the artist's skill in selecting materials and optimizing processes according to his own experience and crafting needs, rather than at revealing all his technical secrets. Thus, only the systematic analytical characterization can reveal to which extent core materials can provide reliable keys of discrimination among different artists and historical periods, other than provenance information in the case of sculpture of unknown origin.

Despite the significant potential of modern petrographic techniques, the literature dealing with casting cores of Renaissance artworks is restricted to a few papers (Formigli and Schneider, 1993; Milam Weisman and Reedy, 2002; Reedy, 1991), although we can expect that other investigations on this topic were reported in local workshops proceedings, exhibition catalogues or monographs difficult to be found. Reedy (1991) illustrates a detailed petrographic study of casting cores aimed at provenance determination of Himalayan and Renaissance small bronzes, the last ones consisting in sixty-four artworks (among which many of certain or probable Italian provenance) from the Kunsthistorisches Museum of Vienna and the Getty Museum (complete data are reported in a previous technical report by Milam et al., 1988). Formigli and Schneider (1993) describe casting cores and investments of thirty-one large bronzes of various age and geographical location, among which ten Renaissance artworks. Milam Weisman and Reedy (2002) report a thorough technological investigation on fifty-two bronze sculptures preserved at the Kunsthistorisches Museum of Vienna, among which forty artworks containing casting cores object of the previous investigations (Milam et al., 1988; Reedy, 1991), and they compare their observations with the contents of the main Renaissance treatises on bronze casting techniques. The results reported in these papers are resumed and discussed in Section 5.1 for comparison purposes.

Recent restoration interventions carried out on Florentine Renaissance and Mannerism masterpieces at the Opificio delle Pietre Dure and the Museo Nazionale del Bargello (Florence, Italy) have provided a unique opportunity to carry out thorough metallurgical observations and collect samples of core materials to be characterized through laboratory investigations.

Petrographic, mineralogical, chemical, and paleontological analyses have been carried out, which allow sketching an early picture on the casting cores used in Florence between the 15th–16th centuries and in particular to answer open questions such as the following. Had the artists preferred sites around Florence from where they collected their raw materials? This is never mentioned in the technical treatises of 16th century. Furthermore, which features of the preparation processes they describe can objectively be confirmed through the material analyses? Which technological information on crafting procedures of large bronzes can be derived from the investigation of casting cores? Our study pointed out common features, which can be related to the historical information, whereas some particular differences we found can be useful for discriminating among the various Florentine workshops. Finally, the present results have a direct exploitability in authentication studies concerning the discrimination between original Renaissance and Mannerist artefacts and modern counterfeits.

2. Materials and analytical methods

We investigated twelve large bronze masterpieces covering a period of about two centuries (from 1401 to 1571) and crafted by some of the greatest artists of the Florentine Renaissance and Mannerism. The bronze sculptures investigated are listed in Table 1. General information on these celebrated artworks can easily be found elsewhere. Table 1 also lists the most recent books associated to their recent restoration works. Here, we focus on a particular feature of their execution, i.e. the preparation of cores used for casting these masterpieces and in particular on the earthy and organic components of the core structures.

After visual observation aimed at discriminating casting cores with respect to other materials, 1–3 samples (each of them constituted by several fragments and powder) were collected from the interior of each artwork (Table 2). In all the cases the samples were taken in proximity of the metal wall, apart from two exceptions, DD1 and BBB1, which were extracted from a hole in the throat of the David by Donatello and from the middle of the core structure of the Baptist by Danti, respectively. During the sampling we took note of orientation of the fragments and of their contact surface with the bronze wall. The sizes of the fragments taken from *LG-SI* and the panels of *LG-GP* were around several millimetres. For all the other sculptures, they always exceeded 1.5 cm (up to 5 cm in the cases of *GR-SB-P* and *VD-BB-S*) in all the three dimensions.

Preliminary observations on colours were carried out by means of a visual comparison with Munsell Soil Color Chart (USDA, Soil Conservation Service).

X-ray diffraction analyses (XRD) were carried out on powder specimens, using a Philips X'Pert PRO PW 3040 diffractometer (Bragg-Brentano geometry) with a CuKα source operating at 40 kV and 40 mA and equipped with a PW3015 X'Celerator detector.