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Glass and metal analyses of gold leaf tesserae from 1st to 9th century mosaics. A contribution to technological and chronological knowledge

Elisabetta Neri [a,*], Marco Verità [b]

[a] Labex RESMED, UMR 8167, Université Paris IV-La Sorbonne, Paris, France
[b] Laboratorio Analisi Materiali Antichi, Sistema dei Laboratori, IUAV University, Palazzo Badoer, San Polo 2468/B, 30125 Venice, Italy

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ABSTRACT

An archaeometric study was carried out on 40 gold leaf tesserae from mosaics in Italy dated 1st to the 9th century AD. Glass layers and gold leaf were both analysed by X-ray microanalysis. The main aim was the identification of the composition of the glass and of the gold leaf, in order to assess the variations in composition and nature of the tesserae in the examined period.

The analytical results show that the tesserae were obtained with natron type glass; three compositional groups were identified, each characterized by a specific colour. The coexistence of colourless (antimony-manganese as decolourizer) and naturally coloured (manganese as decolourizer) glass in each mosaic suggests the simultaneous use of the two materials, probably related to aesthetic choices.

The analyses of the gold leaves indicate the use of pure gold or of gold-silver alloys. The good matches between the compositions of the gold leaves and the analyses of contemporary gold coins in the late antique and byzantine samples (3rd–9th c.) suggest that the leaves were made by beating circulating gold coins. This, in some cases, can help the dating of the tesserae and a more precise information on the type of glass used in this period.

1. Introduction

Gold leaf tesserae are composite materials made of a thin gold leaf hot sandwiched between two glass layers. This is first specified in the *Manoscritto di Lucca* (217r, 30 ch. *De inoratione musiborum*), a late 8th century manuscript of Greek tradition (Hedfors, 1932).

The tesserae were obtained by cutting cakes consisting of three hot fixed layers: a layer of poured glass (the support, less than 10 mm thick), a thin beaten gold leaf (less than 1 μm thick) and a thin layer of blown glass (less than 1 mm thick), the *cartellina*, protecting the gold leaf and increasing its brilliance (Verità, 2000, 2006). The making of these cakes requires a complex procedure whose variations in time are not yet fully understood (Neri and Verità, 2013a,b).

The earliest examples of their use date back to the 1st c. A.D. in Rome, in the *Nymphaeum* of *Lucullus* (Bartoli et al., 2013) and the *Domus Aurea* (Lavagne, 1970; Sear, 1977). From the end of the 2nd c., sporadic occurrences of gold tesserae are found (Boschetti, 2011; Scheibelreiter, 2009); their use for large backgrounds in mosaics is supposed, according to the sources, to begin in the Constantinian age (early 4th c.) and they spread widely in the 5th–6th c. (Brenk, 1972; Guidobaldi and Pedone, in press).

1.1. The glass

Between the 1st and 9th centuries AD, both the *cartellina* and the support were made with transparent colourless or naturally weakly coloured glass. The chemical composition of the support and *cartellina* was similar (Silvestri et al., 2011; Conventi et al., 2012), corresponding to a soda–lime–silica glass characterized by low potassium, magnesium and phosphorous contents (natron type glass). Their composition, similar to that of other glass artefacts of the same period (Wypyski, 2005), did not change substantially until the 8th–9th centuries, when a new type of soda–lime–silica glass with higher potassium, magnesium and phosphorous content, produced using soda–lime plant ashes as a flux, was introduced beside conventional natron glass (Verità and Rapisarda, 2008; Silvestri et al., 2011).

Dating the tesserae is complicated by the fact that natron type glass technology included two phases. Melting of the raw materials

* Corresponding author. INHA, 2 rue Vivienne, 75002 Paris, France. Tel.: +33 6 25 99 83 15.
E-mail addresses: elisabetta.neri@unicatt.it, betsneri@yahoo.it (E. Neri), mverita@libero.it (M. Verità).

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took place in a few specialized centres (now identified on the Syro-Palestinian coast and in Egypt)[1]; subsequently, the raw glass (primary glass) was transported to a large number of secondary workshops, where it was remelted and shaped (Nenna, 2007; Freestone, 2005).

This fact implies that:

1. Only a few compositions can be distinguished, which remain substantially unchanged over long periods of time;
2. The chemical composition is not specific to the production workshop of the glass artefact, but rather to the primary workshop producing the raw glass.

The differentiation of some compositional groups was proposed, but the time range is rather wide and the characteristics cannot always be distinguished (Freestone, 2005; Freestone et al., 2005).

On the other hand, the knowledge of late antique and early medieval glass technology for mosaics is limited, so that some scholars suggest that the glass tesserae from mosaics later than the 4th–5th c. could have been recovered from the dismantling of older mosaics (re-use) (Freestone, 1993; DeLaine, 1997; Wypyski, 2005).

1.2. The gold

Some scholars suggested that native gold to which silver was added to lower the melting point, or electrum (a natural gold–silver alloy) was used (Colomban et al., 2005). Ancient recipes to produce the leaves provide interesting information. Pliny (*Naturalis Historia*, XXXIII, XI) writes that from one ounce of pure gold, 750 leaves with a four-inch side length could be obtained for marble, wood and copper gilding. The *Manoscritto di Lucca* (124r, 7) reports that gold leaves were obtained by beating gold between two copper sheets. The source refers to interaction between mints and leaves production: the provenance of gold from Byzantium, the indication of weight and the manufacturing process similar to minting. Medieval and Renaissance recipes specify that the leaves are made from gold coins or mint gold. The *Libro dell'arte* (ch. 39) by Cennino Cennini (late 14th century) reports that gold coins (Venetian *ducati*) were beaten for this purpose. Likewise, 13th century (second half) documents report the use of gold florins and ducats to make gold foils (Travaini, 2005). The use of circulating gold coins to obtain gold leaves also during Late Antique and Byzantine period (from late 3rd to 9th c.) cannot be excluded. This hypothesis is supported by the fact that the circulation of gold was strictly controlled, in particular between 325 and 610, when the institution of *sacrae largitiones* controlled the operations from extraction to mint and circulation. There was no free commerce of raw gold and *sacrae largitiones* also controlled the major transactions of gold coins (including taxes) and gold not minted (e.g. the activity of the palace goldsmith) (Carlà, 2009; Guest, 2005; Johns, 2011).[2] Further support to this hypothesis arises from late antique and Byzantine sources explaining that jewellery may also have been made from coins (Ross, 1962[2]; Oddy and La Niece, 1986; Gosonovà and Kondoleon, 1994; Yeroulanou, 1999; Carlà, 2009; Giostra, 2011).

It is known that the composition of circulating gold coins varied in time and sometimes also according to the mint of coinage (Morrisson et al., 1985). The control over the purity of minted gold was exerted in Byzantine age too, also when debasement phenomena occurred in the provincial mints, especially from the end of the 7th c. onwards (Oddy, 1988; Morrisson, 2002). Coins are amenable to close dating, even if the time of coin circulation varies according to the period: an estimation of about 30 years during the 3rd–5th c. (Depeyrot, 1988; Arslan, 1994; Callu, 2010), but up to a hundred years in the 6th c. was made (Morrisson, 2002).

The aim of this paper is to improve present knowledge on the materials used to produce gold leaf tesserae by means of X-ray microanalysis on the glass and metal leaves of tesserae from mosaics from the 1st to the 9th centuries AD. Any correspondence between the composition of gold leaves and that of circulating gold coins published in the literature has been also verified in order to improve the dating of the tesserae and of glass decolouration techniques and to tell between new and reused materials, or restoration inlays.

2. Experimental

2.1. Samples

About forty gold leaf tesserae from mosaics in Italy, dated to between the 1st and 9th centuries A.D., were analysed (gold leaf, on 31 samples). The date range begins with the first evidence of gold tesserae, to see the variation or the continuity in this period with respect to the Late Roman period, and it ends when there is a change in the technology of glass and coins gold content is no longer stable. The tesserae were sampled during restoration of in situ mosaics, well dated by archaeological and historical records (paleochristian curch from Rome and Ravenna) or found during archaeological excavations in the layer of building demolition (Rome, Villa dei Quintili; Ostia; Milan) or belonging to a collection (Aquileia). A description of the analysed samples is summarized in Table 1.[3] The samples were either whole tesserae, for which the support, gold leaf and *cartellina* were analysed separately (samples indicated as (sc)), or tesserae for which only the support (s) or *cartellina* (c) with remains of the gold leaf adhering to them were available. About 2 mm thick sections (including support, gold leaf and *cartellina*) were cut perpendicularly to the surface from the tesserae with a thin diamond wheel. Samples were embedded in cross-section in an acrylic resin, ground and polished with diamond pastes down to 3 μm grain size. Samples were carbon coated before analysis.

2.2. Analytical methods

2.2.1. Glass

The quantitative composition of the glass was determined by wavelength-dispersive X-ray microanalysis with a microprobe

[1] Despite the archaeological evidences of primary glass production in the Levant and in Egypt, the production of primary glass by melting natron and silica-lime sand in other places and specifically in Europe, as proposed by some scholars (Brehms et al., 2012; Wedepohl and Baumann, 2000) cannot be excluded. This hypothesis is also supported by the description of Pliny in the *Naturalis Historia* (Pliny the Elder, *Naturalis Historia*, 36, 66) about the use of sands from the mouth of the Volturno river (north of Naples, Italy) and by the archaeometric investigation on this subjects (Vallotto and Verità, 2002; Silvestri et al., 2006).

[2] The vignette of *Notitia dignitatum* (5th c.) includes gold and silver foils among the products controlled by *sacrae largitiones*. The purity of gold was tightly controlled through mandatory melting before minting from the reform of Valentinian in 368. Since then, the acronym OB (abbreviation of *obryza* = purified) is marked on coins. In this historical background, unless we suppose a state-run industry, the use of native gold to produce gold leaves is less probable than the use of mint gold (coins or ingots) or re-molten treasures and jewellery, which represent an easily accessible source of gold.

[3] See the references in Table 1 for more precise indications about the provenance of mosaics. See also Andaloro 2006, with references for the dating of Rome's paleochristian mosaics, frequently dated by the patron's name in epigraphic evidence on the mosaic; and Arena 2005 for numismatic dating of the mosaic at Ostia, Porta Marina. Historical and iconographic elements date the mosaic at St. Apollinare Nuovo (Urbano, 2005) and St. Vitale (Angiolini Martinelli, 1997) in Ravenna. The archaeological layers associated to the building phase date the villa of the Quintilii (unpublished data) and the tesserae from the wall mosaics of the baptistery of Milan. The archaeometric data of St. Lorenzo suggest the dating for mosaics (Neri and Verità, 2013a,b).