Research Article

Stefania Martiniello, Antonella Capitanio, Claudia Sciuto, Stefano Legnaioli, Simona Raneri*

Synopsis of a Treasure. A Transdisciplinary Study of Medieval Gold Workings Biographies

https://doi.org/10.1515/opar-2022-0336
received January 10, 2023; accepted September 22, 2023

Abstract: The article aims to show how a transdisciplinary approach can contribute to a better understanding of the composite biography of a precious object. The study focuses on the Cintola del Duomo (Museum of the Opera del Duomo, Pisa), one of the most famous objects in the history of goldsmithing, both for its exceptional manufacturing quality and for its devotional value. For a long time, the Cintola was considered a fragment of a long garland – decorated with precious stones, enamel, and silver plates – that was displayed on the façade of the Cathedral on certain days of the liturgical calendar. Detailed historical studies suggested that the garland was lost in the early 1300s, while the object now in the museum is more likely to be a reconstruction, decorated with ancient and modern gems. *In situ* diagnostic campaigns were carried out on the garland using portable Raman spectroscopy (i-Raman, B&W Tek) and portable X-Ray fluorescnece (XRF) (Elio, Bruker) to reveal the identity of the gems and enamels preliminarily studied by gemmological analysis. The combination of analytical techniques made it possible to better outline the complex history of the artefacts. The analysis provided information on the identity of the gems, proposing an interesting question about their possible relationship with the crown of Henry VII of Luxembourg (in the same museum). The study includes aspects related to the materiality of the objects, revealing the socio-cultural context in which the object was produced and supporting its recontextualisation in the museum as a symbolic representation of the past.

Keywords: gems, Raman, XRF, enamels, silver

1 Introduction

The aim of this article is to show how an integrated approach, based on the framework of *chaîne opératoire*, can be valuable for outlining the biographical narrative of a precious art object. The theoretical reflection on the intersections between the concepts of object biographies, provenance, and *chaîne opératoire* has led to a

Special Issue on Reconsidering the *Chaîne Opératoire*: Towards a Multifaceted Approach to the Archaeology of Techniques, edited by Marie-Elise Porqueddu, Claudia Sciuto & Anaïs Lamesa.

*** Corresponding author: Simona Raneri,** CNR-ICCOM, National Research Council, Institute of Chemistry and Organo-Metallic Compounds, Via G. Moruzzi, 1, 56024, Pisa, Italy, e-mail: simona.raneri@pi.iccom.cnr.it
Stefania Martiniello: "La Sapienza" University in Rome, Piazzale Aldo Moro, 5, 00185, Roma, Italy
Antonella Capitanio, Claudia Sciuto: Department of Civilizations and Forms of Knowledge, University of Pisa, Pisa, Via dei Mille, 19, 56126, Italy
Stefano Legnaioli: CNR-ICCOM, National Research Council, Institute of Chemistry and Organo-Metallic Compounds, Via G. Moruzzi, 1, 56024, Pisa, Italy

transdisciplinary approach to the study of the Cintola del Duomo, a garland of precious stones, enamel, and silver plates exhibited in the Museum of the Opera del Duomo in Pisa (Italy).

The *chaîne opératoire* was first formulated as an anthropological concept but has certainly become famous for its wide application in archaeology, especially in prehistory, as a framework for outlining biographical narratives. The concept itself has a long history, crossing different archaeological theories and currents (Lewis & Arntz, 2020). The application of the syntax of *chaîne opératoire* to outline not only the creation but also the entire history of an object intersects with theorisations of the biographies of things (Gosden & Marshall, 1999; Kopytoff, 1986), conceived as a composite narrative of intertwined agencies in their cultural contexts. In the case of archaeological materials, the biographies of ancient art objects can be studied using a *chaîne opératoire* approach, not only to describe their production process but also to delineate all the material transformations of the object, as well as the symbolic role the object plays in different cultural contexts.

From this perspective, the *chaîne opératoire* framework used to outline an object's biography is also used to trace its provenance.

The term provenance can be used with different connotations in the context of archaeological or art historical research. In art history, the provenance of an object refers to the record of ownership and the passing of the object from one owner to the next (Baca & Harpring, 2022). The art historical idea of provenance is linked not only to the metamorphoses of the art market but also to the knots and trajectories of individual objects, as well as to the study of the intrinsic relationships underlying the valorisation of certain objects in certain cultural contexts. In this sense, provenance focuses in particular on the human agency associated with ownership and the "transformative power of possession" (Feigenbaum, Reist, & Reist, 2012, p. 1).

In archaeology, the term provenance has a different meaning, especially when contrasted with provenience (as discussed in the study by Sciuto, 2018a,b). Provenance is used to indicate the place where an artefact was found or the origin of the raw materials of an artefact (Malainey, 2010). Rosemary Joyce suggests a more inclusive idea of provenance, understood as the itinerary of objects that "consist primarily of raw materials and are continually altered, changing their properties and becoming other things" (Joyce, 2012, p. 124). Such a definition could be further developed to be even more inclusive, recognising the entangled agencies of people, places, and materials that co-occur in an object's biography.

As the concept of provenance can be seen as "ongoing" and open to the evolution of an object's life, the series of material transformations that the object undergoes over time can be characterised by applying the *chaîne opératoire* framework.

The transdisciplinary approach thus becomes a fundamental key to interpreting the material history of the artefact. The observation of the artefact's microscopic and macroscopic characteristics is equally necessary to describe the traces of the manufacturing process on the one hand and the nature of the components themselves on the other. In this study, we combine the practical gemmological study, carried out through macroscopic and microscopic observation of the objects, with an analytical approach to the identification of gemstones through Raman spectroscopy (Figure 1).

The objectives of the study are multiple: on the one hand, to show how art historical research can use a typically archaeological and anthropological theoretical approach to study the biography of a composite object. On the other hand, the combination of diagnostic analyses and gemmological observations allows new light to be shed on an object that is the bearer of a symbolic and traditional value.

2 The Cintola del Duomo

The *Cintola del Duomo* is a long red silk drape (16 cm × 291 cm) composed of six fragments stitched together, with a border of a cord, also made of silk, in red and gold. Eighty-seven open-worked and engraved settings for gems – made of a golden silver alloy, with sunburst motifs engraved by burin – are sewn onto the drape, of which five gems are missing (Figure 2). Alternating the gems, there are 12 Pisan silver embossed crosses (a typical cross shape related to the Republic of Pisa), 5 embossed and chiselled silver tiles with champlevé enamel (Noli me tangere; Farewell of Saints Peter and Paul; The Martyrdom of St. Paul; The Evangelist Luke;

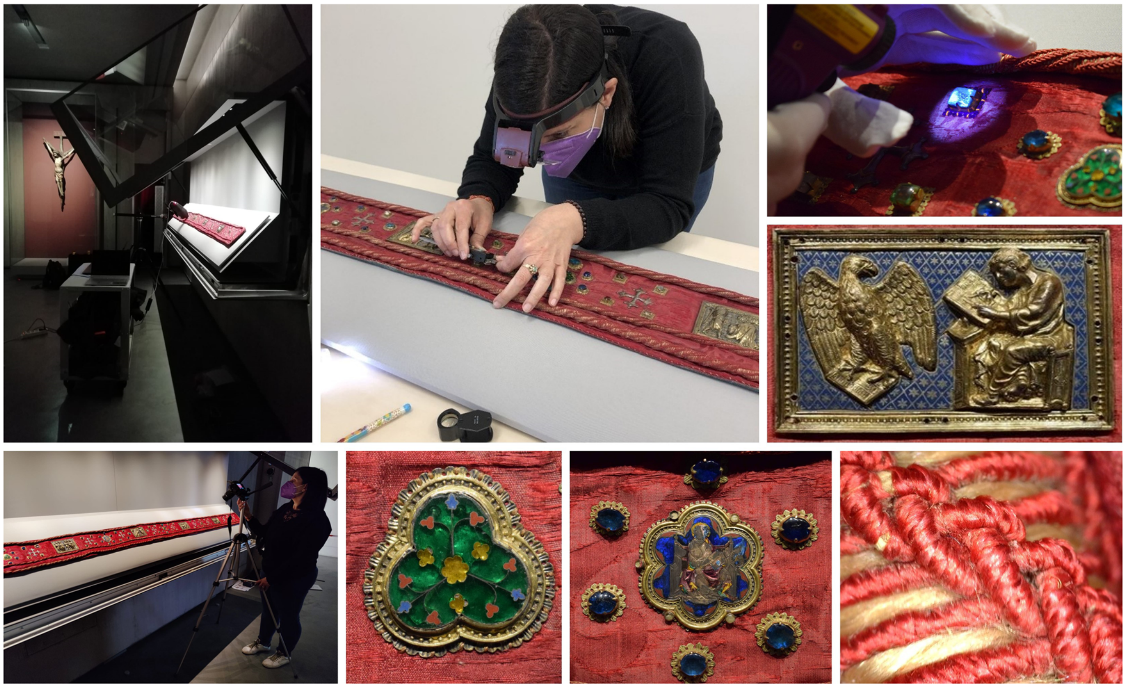

Figure 1: Analysis campaigns on the Cintola del Duomo.

and The Evangelist John), a translucent enamel tile with the figure of St Mark, and three trilobed plates decorated in *émaux de plique*.

Since 1906 (Bellini-Pietri, 1906, pp. 46–47), the object is mentioned in the literature as *Cintola del Duomo* and considered for a long time a fragment of the precious medieval garland adorning the Cathedral façade during religious festivities (namely, i.e. Epiphany 6th January, Pisan New Year 25th March, Easter, Pentecost, St. Ranieri patron saint of Pisa 16th June, Assumption 15th August, and Christmas 25th December) (Noferi, 2008).

Only recently have scholars begun to interpret the Cintola as a collection of unrelated objects that imitate the original medieval garland, as suggested by the individual analysis of the plates, precious stones, crosses, and silk. In fact, the width of the drapery seems too limited when compared to the magnificence of the Cathedral's façade; the silver plates – so finely crafted – are too small to be appreciated at a height of 4 m, and the precious stones placed on night-set bezels could not have shown their colours and transparencies from such a distance. It is more likely that we are dealing with a re-arrangement of an "enamel bundle" recorded in the inventory drown up by the Opera del Duomo in 1597, after the devastating and famous fire of 1595, which was made to list the surviving objects (Barsotti, 1959; Capitanio, 2023).

Reviewing the literature on this devotional object, Roberto Paolo Novello (Novello, 1995) informs us that the actual configuration of the *Cintola* was reassembled after 1723, when the object was reduced and the plaques were rearranged in a different order, according to the description given by Martini (1728) in his Appendix *ad Theatrum Basilicae Pisanae,* published in Rome in the same year.

Thus, the drape exhibited in the museum is currently interpreted as a re-arrangement, namely an object deliberately made in imitation of the legendary *Cintola*, reproduced for devotional and promotional reasons, credibly on the occasion of the Exhibition of Sacred Art in 1897 (Simoneschi, 1897). The object is characterised by an explicit heterogeneity since it is formed as an assemblage of fragments with different artistic and manufacturing trajectories. The historical and scientific analysis cannot, therefore, be separated from the study of the individual components, techniques, and materials used in the assembly of a suggestive transposition of the medieval garland.

The different origins of the components are reflected in the scattered chronology. In the museum's archives, the Cintola is mentioned as a damask drape dated to the seventeenth century; however, the chronology of the gems and silver crosses is not entirely consistent with this dating, as will be discussed below on the basis of

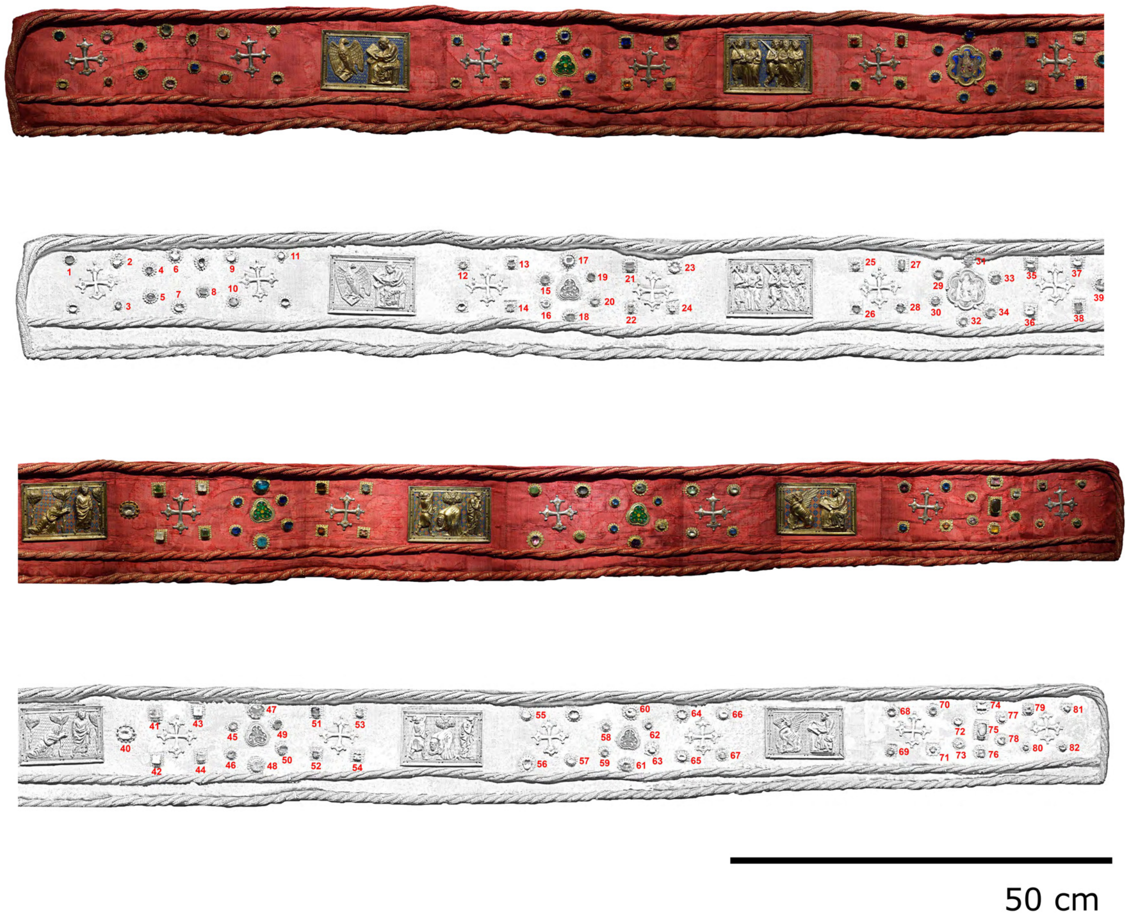

Figure 2: The Cintola del Duomo and its 82 studied gems.

gemmological analysis. There are no other descriptions in the literature, except for two short texts in the catalogues of the exhibitions of the Ancient Sacred Art in 1926 and of the Museum of the Opera del Duomo in 1996.

2.1 The Enamels

While the overall history of the garland remains to be defined, the enamels have been the subject of numerous studies, with a flourishing literature available since 1946 (Toesca, 1946). In his research carried out between 1946 and 1951 and revised in 1971, Toesca (1971) attributed the *champlevé* enamels to the artistic influence of Nicola Pisano. However, many scholars have questioned their authorship, attributing them to an unknown master from Convalle, to Pace di Valentino from Siena, or to Andrea di Jacopo di Ognibene from Pistoia. As far as dating is concerned, some studies place them in the last decade of the thirteenth century, attributing them to an unidentified artist who was clearly influenced by Nicola Pisano, Nicolas de Verdun, and the Rhenish goldsmiths of the twelfth and thirteenth centuries. However, its provenance is still disputed; some scholars suggest that it was originally part of the medieval garland, while others suggest that it came from the decoration of the Cathedral's high altar (Baracchini, 1986, p. 116).

Calderoni Masetti (2002) speculates that the enamels may come from the monumental Gospel and Epistle Books mentioned in the Cathedral's inventory of 1313. The enamel medallion depicting St Mark the Evangelist on the throne has been attributed to various artists; according to Pierluigi Leone De Castris (1983), it is linked to the workshops of Tondino di Guerrino and his groups. On the contrary, according to Elisabeth Taburet-Delahaye (1987, p. 28) and Cioni (1998), the enamel shows stylistic features that justify comparisons with the cross of Santa Vittoria in Matenano (Ascoli Piceno, Italy), whose authorship is still uncertain. However, the medallion depicting St Mark seems to be linked to the workshops of Duccio di Donato, Tondino di Guerrino, and Andrea Riguardi (Cioni, 1998). The three trilobed enamelled plaques were studied by Gauthier (1972) and Danielle Gaborit-Chopin on the occasion of the exhibition dedicated to Philippe the Fair and his sons (Gaborit Chopin & Avril, 1998). They are an interesting and exceptional example of *émaux de plique*, the attribution of which is not straightforward, prompting comparisons with the *Carandolet* antependium in Palermo, the six enamelled plaquettes preserved in the National Medieval Museum in Paris (Gaborit Chopin & Avril, 1998) and some other testimonies in the Naples area. In fact, in Paris, Guillaume Julien – royal goldsmith at the court of Philip IV – was known for the production of *émaux de plique*; however, it seems that he did not have the exclusive rights to produce them, and Paris was probably not the only centre where they were produced, as evidenced by the appearance of *émaux de plique* made in Naples and Palermo dating from the Angevin period.

3 Gemmological Analysis and Diagnostics

The composite nature of the object under study required the development of an integrated methodology that allowed different scales of investigation to be combined and complementary information to be gathered (Smith, 1999, 2005, 2006). Ideally, therefore, the garland was broken down into its constituent parts, and a detailed study of each part was then undertaken. This approach made it possible to work on the individual artistic and craftsmanship paths of the pieces and to better understand the dynamics of the assemblage and the overall history of the piece as a whole.

The gemmological studies carried out on ancient jewellery aim to not only identify the material analysed but also provide numerous elements for chronological attribution, for the detection of tampering, or for tracing provenance, all of which are indispensable elements for reconstructing the history of an object (Table S1). The purpose of gemmological analysis is to identify a gemstone by determining not only the type of material it is made of (natural or synthetic) but also whether it has been subjected to any kind of enhancement. Due to the nature of the material to be examined, the analyses must be non-invasive, and there are very few cases where micro-destructive techniques are used. In the case of analyses to be carried out on antique jewellery, the procedures are considerably more complicated. This is both because transporting the pieces to the laboratory can be difficult and sometimes dangerous for their conservation, and because there are limitations to the use of analytical techniques on mounted gems.

Each of the 82 gemstones on the garland was inspected both visually and using portable instruments. As a first step, the gems were examined visually (to determine shape and cut). The shape of a gemstone is defined by its perimeter, while the cut refers to its entire volume. Today, the choice of one type of cut over another is determined by the balance between two important factors such as beauty and weight (which determine the price). In the case of historical jewellery, the type of cut can give us a great deal of information about the chronology and manufacture, taking into account the development of techniques over the centuries (Prim, 2020).

UV fluorescence through a laser pointer was used to check the gemstones and the presence of any treatments in them. Finally, inclusions and other details useful for identification were observed and recorded. A Dino-Lite model AM4113ZT digital microscope equipped with eight white LEDs, with the possibility of working with the LEDs off or on, was used for the analyses carried out in this study. The microscope has a magnification of 10–70× and 200× and is equipped with an anti-reflection lens. It has a complementary metal-oxide semiconductor CMOS-type sensor and a resolution of 1.3 megapixels (1,280 × 1,024).

Mineral identity and gemstone composition have been determined directly *in situ* by mobile instrumentation without any sample preparation or artefact handling. The entire set of gemstones was analysed using the B&W Tek i-Raman portable Raman spectrometer, equipped with a 785 nm laser source and an optical probe working in contact with the object surface; prior to the experimental session, the equipment was calibrated using a silicon wafer; and spectra were collected with an integration time of 10 s and a laser power of less than 300 mW. This technique is widely and successfully used in the characterisation of jewels and jewellery collections for gemstone identification (Bersani & Lottici, 2016; Culka & Jehlička, 2018; Edwards, Vandenabeele, & Colomban, 2022; Gonthier et al., 2009a,b; Karampelas, Kiefert, Bersani, & Vandenabeele, 2020, p. 112; Raneri, Barone, Mazzoleni, & Bersani, 2020; Smith, Benbalagh, Gonthier, Ospitali, & Martinez-Arkarazo, 2009).

Table 1: Summary of analysed gems and attribution based on Raman analysis

Gem-ID	Raman modes (cm^{-1})	Identification based on Raman analysis	Chemical elements (p-XRF)
C1	Broad band	Quartz	
C4	No signal, only fluorescence	None	
C5	No signal, only fluorescence	None	
C6	118-197-456-1040	Quartz	
C7	456-1040	Quartz	
C8	Broad band	Glass	
C9	118-128-201-258-456-465-800	Quartz	
C10	218-465-480	Quartz	
C11	118-142-197-256-456-480	Quartz**	
C12	1367	Glass	
C13	118-197-456-1367	quartz + glass, doublet	
C14	1367-1853	Glass***	
C15	1370-1880	Glass	
C16	118-128-20-258-456-470	Quartz*	
C17	118-197-456	Quartz*	
C18	1376	Glass	
C19	1380	Glass	
C20	1376	Glass	
C21	Broad band	Glass	
C22	1367	Glass	
C23	197-456	Quartz	
C24	118-198-258-456-465-800	Quartz	
C25	456-1356	Quartz + glass, doublet	
C26	Broad band	Glass	Si, K, Ca, Ba, Mn, Fe, Cu, Sr, Ag
C27	1367-1853	Glass	
C28	Broad band	Glass	Si, K, Ca, Ba, Mn, Fe, Cu, Sr, Ag
C29	1367	Glass	
C30	1375	Glass	Si, K, Ca, Ba, Mn, Fe, Cu, Sr, Ag
C31	1370	Glass	
C32	1367	Glass	
C33	1371	Glass	Si, K, Ca, Ba, Mn, Fe, Cu, Zn, Pb, Sr, Ag
C34	1376	Glass	
C35	1376-1850	Glass	
C36	1375-1870	Glass	
C37	118-135-199-256-342- 456-472-800	Quartz	
C38	1375-1870	Glass	
C39	Broad band	Glass	
C40	1375	Glass	
C41	118-197-456	Quartz**	
C42	118-135-199-342-456-472	Quartz*	
C43	118-135-199-256-342-456-472-800	Quartz*	
C44	118-135-199-456-472-935-1154	Quartz**	
C45	1375-1870	Glass	
C46	1375-1870	Glass	
C47	Broad band	Glass	
C48	1376	Glass	
C49	1375-1870	Glass	
C50	1375-1870	Glass	
C51	Broad band	Glass	
C52	1370	Glass	
C53	1376-1856	Glass	
C54	1376-1856	Glass	
C55	118-135-199-456-472	Quartz**	

(Continued)

Table 1: *Continued*

Gem-ID	Raman modes (cm^{-1})	Identification based on Raman analysis	Chemical elements (p-XRF)
C56	118-135-199-456-472	Quartz	
C57	118-199-456	Quartz**	
C58	1376-1856	Glass	
C59	1376-1856	Glass	
C60	118-135-199-456-472	Quartz	
C61	118-135-199-456-472	Quartz	
C62	1376-1856	Glass	
C63	118-135-199-456-472	Quartz	
C64	1376-1856	Glass	
C65	1036-1376-1856	Glass	
C66	1376-1856	Glass	
C67	1376-1856	Glass	
C68	1376-1856	Glass	
C69	1376-1856	Glass	
C70	1376-1856	Glass	
C71	135-199-456-472-1375	Quartz + glass, triplet (based on gemmological observation**)	
C72	1376-1856	Glass	
C73	356-1376-1856	Glass	
C74	118-135-199-342-456-472	Quartz	
C75	118-199-456	Quartz	
C76	1376-1856	Glass	
C77	118-199-254-346-383-455-800-1152	Quartz	
C78	456	Quartz**	
C79	118-135-199-346-456-472-1371	Quartz + glass, triplet (based on gemmological observation**)	
C80	118-135-199-346-456-472-1375	Quartz + glass, triplet (based on gemmological observation**)	
C81	118-199-254-346-383-455-800	Quartz**	
C82	456	Quartz**	
C83		Enamel	S, Ba, Fe, Cu, Pb

Additional information on chemical elements detected by p-XRF – when available – are provided for some of the glass and enamel. *Gemmological analysis evidenced also the presence of glass underneath the quartz, thus the gem can be classified as a doublet. **Gemmological analysis evidenced the presence of three different layers constituting the gem, with the upper layer identified as quartz by Raman, thus the gem can be classified as a triplet.

A combined spectroscopic approach allowed us to improve the knowledge of blue glass imitations and to characterise the enamels, which were also studied by X-ray fluorescence using the Elio © Bruker spectrometer, operating at 40 keV and 80 μA.

The gems' settings were not analysed by spectroscopy, but only by visual observation, which made it possible to determine the engraving techniques of the decorative motifs.

The information obtained was systematised according to the object, including its formal and spectroscopic characteristics. Each object has been dated and, where possible, its provenance has been indicated.

4 Results

From all the data collected during the gemmological and spectroscopic analyses, we were able to group the 82 gemstones according to the raw materials used: mainly quartz and glass. Further distinctions could be made on the basis of the natural colours or the colouring agents of the glass pastes. Some colouring effects were achieved by the addition of metal leaf. Useful information about the manufacturing process and the dating were obtained by observing the cut of the gemstones, the shape, and, especially, the use of doublets and triplets (i.e. composite gemstones made of two or three layers of different materials).

Table 1 shows the main Raman bands detected, together with the chemical elements obtained by portable X-Ray fluorescence on blue glass and enamels, providing further information on glass receipts. Only in two cases (namely C4 and C5) the Raman analysis failed to identify the materials, giving only a strong fluorescence signal. For all the quartz gemstones, regardless of colour, the Raman signal is dominated by the intense band at 464–465 cm^{-1}, associated with weaker bands typical of the mineral; when used in combination with glass in composite gemstones, a broad band related to luminescence at about 1.350 cm^{-1} is also evident, associated with the typical Raman signal of glassy materials. Raman spectra collected on glass – regardless of colour – showed typical glassy broad and unstructured bands, sometimes with luminescence signals related to trace elements and/or colourants (Gaft, Reisfeld, & Panczer, 2015; Figure 3).

The gems were, therefore, divided into six different groups: (i) colourless quartz (hyaline) with coloured metal leaf, (ii) coloured quartz-glass composite gems (triplets), (iii) glass-glass and quartz-glass composite gems (doublets), (iv) glass pastes, (v) substituted gems, and (vi) a single natural gem without any treatment.

Quartz (hyaline quartz) is worked as a well-polished cabochon; gemstones are mounted through a binder (visibly dehydrated) on a silver foil coloured with pigment.

In the case of the doublets and triplets, the cuts, manufacturing technique, and finishing treatments could be compared with the composite gems adorning a reliquary cross and an ostensory from the Basel Cathedral Treasury, both dated around 1440 (Hänni, 1998); this evidence would suggest – at first glance – a date around the first half of the fifteenth century for the composite gems of the Cintola. The settings of the doublets and triplets were made of silver foil, openworked, and engraved with a sunburst pattern; all the bezels are of the "night" type (i.e. closed on the back) and have a gallery rile until the gems are gilded, thus concealing any enhancement treatments. The way in which the settings were made suggests that they were produced in large quantities to be pinned onto jewellery or sewn onto textiles with eyelets, as a semi-finished product.

The triplets have a hyaline quartz top, a coloured paste middle, and a glass bottom. Glass-glass doublets have a coloured glass top and a silver leaf bottom, while quartz-glass doublets have a hyaline quartz top and a coloured glass bottom. In some doublets and triplets, the glue is oxidised and dehydrated around the perimeter of the gemstone, remaining cohesive only in the central part, which also determines a change in the final colour and appearance of the gems.

The vitreous pastes are of excellent quality. They are light green and deep blue in colour, the latter being obtained from a mixture of silicon, potassium, calcium, barium, manganese, iron, copper and strontium, with occasional traces of zinc and lead.

Scholars have suggested that the "original/non-replaced" quartz and glass were taken from the Gospel and Epistle books listed first among the sacristy items in the 1313 Cathedral inventory (Calderoni Masetti, 2002)

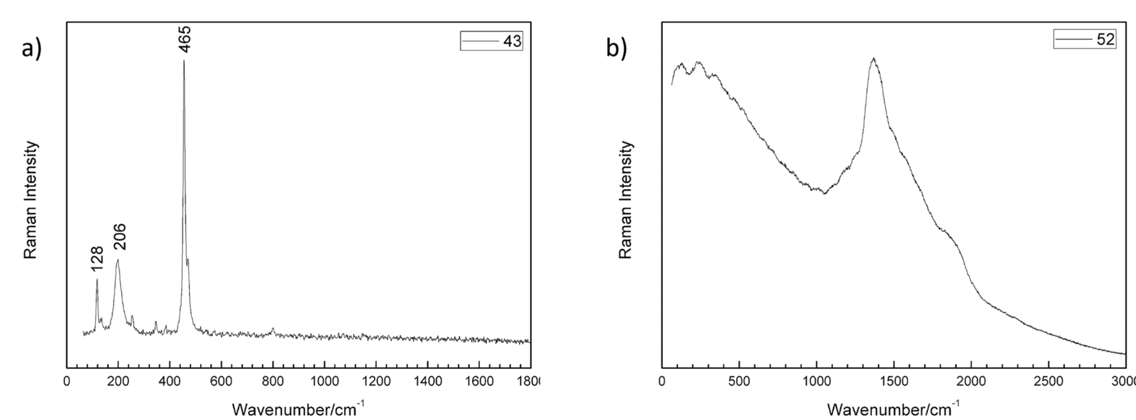

Figure 3: Raman spectra collected on (a) quartz and (b) glass gems, as an example.

along with some *champlevé* enamel plaques. Microscopic analysis of both the settings of the gemstones and enamel plaques, however, suggests that they came from textile support; In fact, the holes interpreted by Calderoni Masetti (2002) as nails for attaching the gems and the enamels to the gospels are more likely to be eyelets. We can, therefore, assume that the gems for which no clear signs of replacement are visible can be considered contemporary with their settings. In this case, the materials and their workmanship also provide some additional information about the biography of the assemblage.

Some other quartz and glass can be interpreted as later substitutions and can be dated between the seventeenth and eighteenth centuries (Table S1). In quartz, the late date is indicated by the type of cut, while in glass, it is suggested by both the cut and the quality of the highly transparent material with a high refractive index, which is impossible to find in glass dated before this period (Anderson, 1981). In addition, the shape of these gems is quite different from their settings, suggesting later substitution. The provenance of the individual replaced gemstones is unclear, but the settings can be traced back a few centuries before the assembly of the Cintola.

The presence of a unique natural and unworked amethyst among the 82 gems would indicate a common origin with the other original gemstones, perhaps from a sacred vestment on which enamels and gems were sown thanks to the eyelets. In fact, in ancient times, the belief that amethyst protected against drunkenness (as noted by Di Rennes in his *Lapidarium* written around 1093 (Di Rennes, 2006)) made it an indispensable amulet for celebrants who drank wine during festivities.

The analysis campaigns on the Cintola del Duomo have provided an opportunity to study another interesting object preserved in the Museo dell'Opera del Duomo, namely the crown of the Emperor Henry VII, whose gems and settings have very strong formal and compositional similarities with the Cintola, raising interesting questions about the dating of the gems. The crown, made of simple gilded silver foil, is part of Henry VII's burial goods, recovered in May 2014 during a campaign to explore the emperor's tomb (Mallegni, 2015, p. 14). Henry VII was crowned emperor in Aachen on 6 January 1309 and died in the summer of 1313 at Buonconvento, near Siena, during his campaign in Italy. The crown consists of a metal band closed at the back with riveted pins and decorated with four gilded metal foil lilies, each set with two gems. Four further gems are set along the band, all held in prong settings.

A comparative analysis of the gems mounted on the *Cintola del Duomo* and the Crown of Henry VII revealed great similarities in the setting of the doublets (Figure 4). These features suggest a common production in the same workshop, probably specialised in premounted gems, ready to be sewn onto textile ornaments or nailed onto metal objects. The practice of doublets and triplets was quite common in late medieval and modern goldsmithing and is documented in jewellery from the late first half of the fifteenth century (Hänni, 1998), although the first descriptions of the manufacturing technique are only found in texts and treatises from the sixteenth century (e.g. see references in Cellini's volumes, 1568 (Cellini, 1852)).

Given this gap in the literature, the use of these techniques earlier than this *terminus ante quem* might seem doubtful; however, the doublets on the crown of Henry VII can be dated to around 1313, the date of the emperor's funeral.

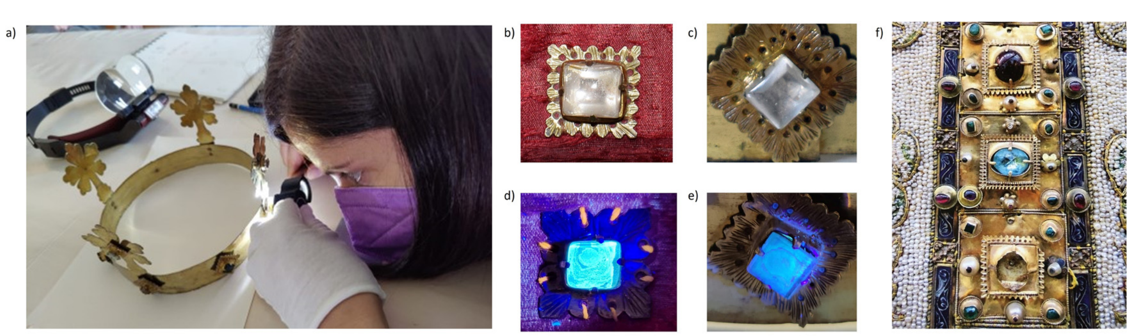

Figure 4: (a) Analysis campaign of the crown. (b and c) Visible and (d and e) UV light pictures of doublets mounted on the Cintola (b–d) and the crown (c–e). (f) Picture of the Amalfi Mitra for comparison.

Thus, if a common provenance of the jewels adorning both the Cintola and the crown is confirmed (by ongoing further analysis), this evidence would bring forward the dating of the doublets and triplets mounted on the silk garland to around 1313. This would date them to the first quarter of the fourteenth century, contrary to what was originally proposed on the basis of comparisons with the Basel Treasure, which represents to the best of our knowledge the oldest documented composite gems. In support of this backdating hypothesis, a parallel could be found with the gem settings of the Amalfi Mitre – the most valuable medieval religious grab (D'Avanzo, 2014) – which was made in the first quarter of the fourteenth century by an Angevin workshop (Distefano, 2021) (Figure 4).

4.1 The Overlapping Temporalities of a Composite *Chaîne Opératoire*

The large amount of data collected during the survey campaign on the artefact suggests a scattered and fragmented trajectory for the Cintola del Duomo. The direct observation of the traces of workmanship and the formal characteristics of the individual parts, combined with spectroscopic analysis and the collection of processed data, allow us to outline a multi-temporal *chaîne opératoire* articulated on different scales of observation.

The Cintola as a whole is the result of the fragmentation and re-aggregation of several objects. The traces of work on the individual parts allow us to read the dynamics of this "secondary" assemblage, tracing some details of the individual *chaîne opératoire*. In their specificity, the pieces reflect different production and economic contexts, belonging to different temporalities. The reassembly of the pieces takes place around a strong symbolic value, that of the Cintola, which characterises the secondary assemblage.

We can then attempt to reconstruct the multitemporality and multiscalarity of the object itself by making explicit the provenance and authorship of the individual parts (Figure 5 and Table S1):

- The silk drape entails six fragments sewn together, edged with a red and gold silk cord. The silk stole is mentioned in the Museum's most recent catalogues as a seventeenth-century damask (De Angelis D'Ossat, 1986; Garzella & Collareta, 2023).
- Sets of settings with unsubstituted/original gems present formal characteristics that suggest their production in a workshop dedicated to the creation of gold jewellery ornaments. Their dating remains to be confirmed, but could date back to the early fourteenth century.
- A group of bezels with material and stylistic characteristics similar to those of the first group but modified by the substitution of gems, dated between the seventeenth and eighteenth centuries, based on the characteristics of the cuts of the gems themselves.
- The embossed tiles with champlevé enamel can be dated by stylistic comparison to the second half of the thirteenth century. Scholars have argued that the tiles come from the covers of epistolary or evangelical volumes; however, given the characteristics of the holes for fixing them, it is more likely that they were placed on textiles, as in the famous *Paliotti*, e.g. in the *Carandolet antependium* (Gaborit Chopin & Avril, 1998).
- Cloisonné enamels (*émaux de plique*), of which only a few other examples are known from the Paris, Palermo, and Naples area, can be dated from the end of the thirteenth century to the beginning of the fourteenth century.
- The chronology and provenance of the Pisan crosses and embossed silver foil are difficult to determine; they can probably be considered contemporary with the bezels, on the basis of stylistic observations.

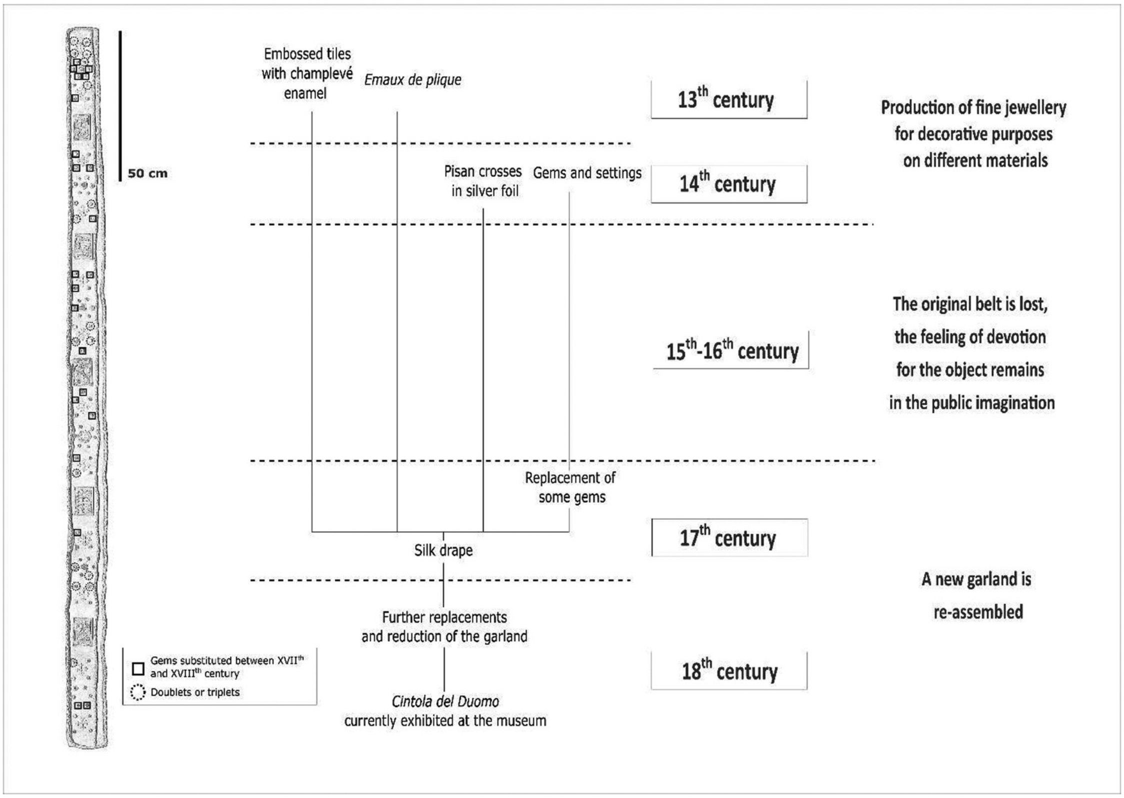

Figure 5: Chronological scheme for the making of the Cintola.

5 Conclusions

The transdisciplinary research carried out on the *Cintola del Duomo* shows how a holistic approach can contribute to understanding the historical dynamics linked to the object itself. Based on the documentary sources on the Cintola (which marks a *terminus post quem* around the eighteenth century) and the dating of the silk drape (which marks a *terminus ante quem* around the seventeenth century), the object was probably assembled between the seventeenth and eighteenth centuries using older settings and gems, replacing gems where they had been lost. The composition has no formal coherence but brings together a series of extremely valuable decorated plates.

The symbolic value of the object is linked to the sacredness of the Cathedral itself and the liturgical traditions associated with it. The prestige of the replica garland lies not so much in the authenticity of its dimensions as in the prestige of the gold work on it. At the same time, the *Cintola* tells us about the transmission of artistic techniques for the production of enamel and the stylistic influences passed on from workshop to workshop. Above all, the analysis of the gems and their settings allows us to understand certain dynamics linked to the production and trade of these specific objects, the study of which is often limited to formal analysis without taking into account the materiality and technical aspects.

As is often the case, the study opens up new and interesting research perspectives that are related not only to the object itself but also to the study of production systems in late medieval goldsmithing. The similarities between the settings of the *Cintola* and the *Crown of Henry VII* further support the idea that some of the gems mounted on the *Cintola* del Duomo can indeed be dated to the very early fourteenth century. A more in-depth scientific analysis of the glues is forthcoming to confirm the proposed hypothesis, which would recognise in these gems some of the first analysed and documented examples – known to date – of doublets and triplets on ancient jewellery objects.

It is, therefore, the technical considerations, combined with the work of the craftsmen in their workshops, that allow us to outline a biography of the artefact while also recognising the ritual and symbolic value that the object has had over the centuries and still has today in a museum setting. The fragmented and multi-temporal *chaîne opératoire* outlined in this article aims not only to highlight the technical steps necessary for the composition of the assemblage but also to show how the art object transcends the technological system (Ingold, 2001).

Acknowledgements: The authors acknowledge the Opera del Duomo Museum restorers and curator for the access to the Museum and Opera del Duomo for authorising the study of the *Cintola del Duomo* and the *Crown of Henry VII*. Some reflections on the concept of provenance in art history were formulated following the fruitful debates during the Ancient Itinerary Institute, established by the Getty Foundation in 2018–2019.

Author contributions: S. Martiniello wrote paragraphs 2 and 2.1. C. Sciuto wrote paragraphs 1, 4.1, and 5. S. Martiniello and S. Raneri co-authored paragraphs 3 and 4. S. Legnaioli carried out part of the analysis and data processing. A. Capitanio provided supervision for the project.

Conflict of interest: All authors declare that they have no conflicts of interest.

Data availability statement: All data generated or analysed during this study are included in this published article and its supplementary information file.

References

Anderson, J. B. (1981). *History of Jewels*. New York: Park Lane.

Baca, M., & Harpring, P. (2022). *Categories for the description of works of art*. Los Angeles: Getty Research Institute. https://www.getty.edu/research/publications/electronic_publications/cdwa/.

Baracchini, C. (1986). Il tesoro e le argenterie. In De G. Angelis d'Ossat (Ed.), *Il Museo dell'Opera del Duomo a Pisa*. Cinisello Balsamo (Mi): Silvana Editoriale.

Barsotti, R. (1959). *Gli antichi inventari della Cattedrale di Pisa* (p. 105). Pisa: Vallecchi.

Bellini Pietri, A. (1906). *Catalogo del Museo Civico di Pisa*. Pisa: Tipografia Municipale.

Bersani, D., & Lottici, P. P. (2016). Raman spectroscopy of minerals and mineral pigments in archaeometry. *Journal of Raman Spectroscopy*, *47*(5), 499–530. doi: 10.1002/jrs.4914.

Calderoni Masetti, A. R. (2002). Smalti traslucidi italiani: Ieri, oggi, domani. *Annali della Scuola Normale Superiore di Pisa, Classe di lettere e Filosofia, IV Serie – Quaderni, Quaderno 9/10, Programmi delle giornate di studio in ricordo di Giovanni Previtali, XI-XII*, 157–163.

Capitanio, A. (2023). L'Oreficeria. In M. Collareta & G. Garzella (Eds.), *Il Museo dell'Opera del Duomo*. Pisa: Pacini Editore.

Cioni, E. (1998). *Scultura e Smalto nell'Oreficeria Senese dei secoli XIII e XIV*. Firenze: S.P.E.S.

Cellini, B. (1852). In G. Silvestri (Ed.), *Due trattati uno intorno alle otto principali arti dell'oreficeria l'altro dell'arte della scultura dove si ragiona del lavorare le figure di marmo e gettarle in bronzo (1568)*. Milano: Tipografia Silvestri.

Culka, A., & Jehlička, J. (2018). A database of Raman spectra of precious gemstones and minerals used as cut gems obtained using portable sequentially shifted excitation Raman spectrometer. *Journal of Raman Spectroscopy*, *50*(2), 262–280. doi: 10.1002/jrs.5504.

D'Avanzo, G. (2014). *Mitra, in ori, argenti, gemme e smalti della Napoli angioina 1266-1381*. In P. L. De Castris (Ed.), *Catalogo della mostra, Napoli, Cappella e Museo del Tesoro di San Gennaro, 11 ottobre–31 dicembre 2014* (pp. 138–142). Napoli: Arte'm.

De Angelis D'Ossat, G. (1986). *Il Museo dell'Opera del Duomo di Pisa*. Cinisello Balsamo (MI): Silvana Edeitoriale.

De Castris, P. (1983). Trasformazione e continuità. In A. R. Calderoni Masetti (Ed.), *Atti della prima Giornata di Studio sugli smalti traslucidi italiani* (p. 545). Pisa: Scuola Normale Superiore.

Di Rennes, M. (2006), In B. Basile (Ed.), *Lapidari. La magia delle pietre preziose. Testo latino a fronte*. Roma: Carocci.

Distefano, G. (2021) *Esmaltis viridibus. Lo smalto de plique tra XIII e XIV secolo*. Savigliano: L'Artistica Editrice.

Edwards, H. G., Vandenabeele, P., & Colomban, P. (2022). Jewellery and Gemstones. In *Raman Spectroscopy in Cultural Heritage Preservation* (pp. 125–154). Basel: Springer International Publishing.

Feigenbaum, G., Reist, I., & Reist, I. J. (2012). *Provenance: An alternate history of art*. Los Angeles: Getty Publications.

Gaft, M., Reisfeld, R., & Panczer, G. (2015). *Modern luminescence spectroscopy of minerals and materials*. Basel: Springer International Publishing.

Garzella G., & Collareta, M. (2023). *Il Museo dell'Opera del Duomo di Pisa*. Pisa: Pacini Editore.

Gauthier, M. (1972). *Emaux du moyen age occidental*. Fribourg: Office du Livre.

Gonthier, E., David, C. S., Zivkovic, A., Billard, K., Reyjal, I., Romain, O., … Fourcault, J. M. (2009a). Bijoux moghols: Histoire de techniques joaillières avec vérifications Raman de leurs gemmes. In M. H. Moncel & F. Fröhlich (Eds.), *L'Homme et le précieux, Matières minérales précieuses de la Préhistoire à aujourd'hui* (pp. 257–284). Oxford: British Archaeological Reports.

Gonthier E., de-Noblet T., Sage-Fresnay J. P., Romain O., Smith D. C., & Benbalagh N. (2009b). Un harnachement mameluk du Musée de l'Armée, et le symbolisme des gemmes archéologiques colorées. In M. H. Moncel & F. Fröhlich (Eds.), *L'Homme et le précieux, Matières minérales précieuses de la Préhistoire à aujourd'hui* (pp. 285–304). Oxford: British Archaeological Reports.

Gaborit Chopin, D., & Avril, F. (Eds.). (1998). *L'art au temps des rois maudits: Philippe le Bel et ses fils, 1285-1328, Catalogues d'exposition, Galeries nationales du Grand Palais*. Paris: Réunion des Musées Nationaux.

Gosden, C., & Marshall, Y. (1999). The cultural biography of objects. *World Archaeology*, *31*(2), 169–178.

Hänni, H. (1998). Raman investigation on two historical objects from Basel Cathedral: The reliquary cross and Dorothy monstrance. *Gems and Gemmology*, *34*(2), 102–125.

Ingold, T. (2001). Beyond art and technology: The anthropology of skill. In M. B. Schiffer (Ed.), *Anthropological perspectives on technology* (pp. 17–31). Albuquerque: University of New Mexico Press.

Joyce, R. A. (2012). Life with things: Archaeology and materiality. In D. Shankland (Ed.), *Archaeology and anthropology: Past, present and future* (pp. 119–132). London: Routledge.

Karampelas, S., Kiefert, L., Bersani, D., & Vandenabeele, P. (2020). *Gems and Gemmology: An Introduction for Archaeologists, Art-Historians and Conservators*. Basel: Springer Nature.

Kopytoff, I. (1986). The cultural biography of things: Commoditization as process. *The Social Life of Things: Commodities in Cultural Perspective*, *68*, 70–73.

Lewis, M., & Arntz, M. (2020). The Chaine Operatoire: Past, Present and Future. *Archaeological Review from Cambridge*, *35*(1), 6–16. doi: 10.17863/CAM.65457.

Malainey, M. E. (2010). *A consumer's guide to archaeological science: Analytical techniques*. Berlin: Springer Science & Business Media.

Mallegni, F. (2015). *Enrico VII di Lussemburgo tra biologia, storia e tradizioni. Archivio per l'Antropologia e la Etnologia, Società Italiana di Etnologia e Antropologia, Firenze, Vol. CXLV* (pp. 7–54).

Martini, G. (1728). *Theatrum Basilicae Pisanae, in quo praecipuae illius partes enarrationibus, iconibusque ostenduntur*. Roma: Antonio de Rossi.

Novello, R. (1995). Il Duomo di Pisa. In A. Peroni (Ed.), *Mirabilia Italiae Vol. III* (pp. 636–638). Modena: Franco Cosimo Panini.

Noferi, M. (2008). *La cintola del Duomo di Pisa*. Pisa: Pierucci Editore.

Prim, K. J. (2020). *The Secret Teachings of Gemcutting 50 Classic Gemstone Designs*. Magus Gems.

Raneri, S., Barone, G., Mazzoleni, P., & Bersani, D. (2020). Non-destructive spectroscopic methods for gem analysis: A short review. *IMEKO TC-4 International Conference on Metrology for Archaeology and Cultural Heritage, MetroArchaeo 2020 Trento* (pp. 501–506). https://www.imeko.org/publications/tc4-Archaeo-2020/.

Sciuto, C. (2018a). *Carved mountains and moving stones: Applications of near infrared spectroscopy for mineral characterisation in provenance studies*. Umeå: Umeå University Press.

Sciuto, C. (2018b). Recording invisible proofs to compose stone narratives. Applications of Near Infrared Spectroscopy in provenance studies. In A. Foka, A. Chapman, & J. Westin (Eds.), *Technology in the Study of the Past, Digital Humanities Quarterly Special Issue*, *12*(3).

Simoneschi, L. (1897). *Mostra di Arte Sacra Antica*. Pisa: Tipografia Mariotti.

Smith, D. C. (1999). Letting loose a laser: MRM (Mobile Raman Microscopy) for Archæometry and Ethnomineralogy in the next millennium. *Mineralogical Society Bulletin*, *125*, 3–8.

Smith, D. C. (2005). Jewellery and precious stones. In H. G. M. Edwards & J. Chalmers, (Eds.) *Raman spectrometry in archaeology and art history* (pp. 335–378). London: The Royal Society of Chemistry.

Smith, D. C. (2006). A review of the non-destructive identification of diverse geomaterials in the cultural heritage using different configurations of Raman spectroscopy. *Geological Society, London, Special Publications*, 257(1), 9–32.

Smith, D.C., Benbalagh, N., Gonthier, E., Ospitali, F., & Martinez-Arkarazo, I. (2009). Les plateaux de tables florentines en marqueterie de pierres dures du XVIème au XVIIème s.: Une approche spectrométrique Raman. In M. H. Moncel & F. Fröhlich (Eds.), *L'Homme et le précieux, Matières minérales précieuses de la Préhistoire à aujourd'hui* (pp. 243–256). Oxford: British Archaeological Reports.

Taburet-Delahaye, E. (1987). Il San Galgano del museo di Cluny e il calice dell'abbazia di San Michele di Siena: Proposte per il "Maestro Frosini". In L. Morozzi (Ed.), *Bollettino d'arte supplemento, Oreficerie e smalti traslucidi nei secoli XIV e XV* (pp. 17–29). Roma: Istituto Poligrafico e Zecca dello Stato.

Toesca, P. (1946). Oreficerie della scuola di Nicola Pisano. In *Arti Figurative Vol. II* (pp. 34–36). Roma: Danesi.

Toesca, P. (1971). *Il Trecento*. Torino: UTET.