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Archaeometric Study of Two Tanagra Type Statuettes of Unknown Provenance to Support Forensic Study

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Abstract: This paper is concerned with a morphological-stylistic and archaeometric study of two small pottery statues, confiscated by the Cosenza Carabinieri Unit for the Protection of Cultural Heritage and Anti-Counterfeiting (Calabria, Italy). The research aimed to establish the authenticity of the artworks and to verify a possible origin from the same workshop manufacturing, by providing indications about the textural features and raw materials used for their production. For these purposes, the analytical approach involved the use of minero-petrographic and physical analysis, as follows: petrographic analysis (OM), X-ray diffraction (XRD) and thermoluminescence tests (TL). The preliminary observation, which highlights differences in the stylistic features of the two statuettes as well as in the color, morphology and distribution of the white-greyish patina, is further confirmed by the TL investigations. The TL test revealed an ancient production only for one of the analyzed finds and the investigations on the raw materials allowed to relate this to a possible local historical-artistic context. The second statuette, on the other hand, is attributable to a modern production as confirmed by TL measurement.

Keywords: authentication; cultural heritage; illicit traffic; pottery; votive coroplastic; Tanagra type

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1. Introduction

In the context of forensic investigations and in the field of cultural heritage, the multidisciplinary approach is very important to collect data and valuable information on historical and archaeological finds. Such investigations take on particular value when artifacts come from clandestine archaeological excavation contexts or are the result of investigations addressed to the fight against illicit trafficking of cultural goods of unknown origin. The large number of seized objects of significant cultural value and the global reach of the networks involved in such illicit trafficking (103 countries) provide tangible evidence of a global illicit trade that is growing [1]. In the context of the illicit trafficking of cultural goods and in clandestine excavations, the phenomena of archaeological falsification are very common. Through consolidated techniques, for centuries, the forgers have been able to cheat buyers, collectors, investigators, etc. The skilled forgers place the fake goods in real archaeological contexts so that they can take on the characteristics of the archaeological deposit and over time be exchanged for real artifacts, deceiving the inexperienced. Entering the cycle of illicit routes, the ancient objects often become part of museum collections. In principle, an artifact is defined as false or authentic based on various elements and features to be investigated, allowing for an analysis of the object as a whole, i.e., from a chemical, physical, structural, morphological and stylistic point of view. When archaeologists or art historians analyze artifacts from unknown contexts, they face many difficulties, such as decontextualization, and consequently, the almost total lack of information on the find itself, such as information about production techniques, place of production, style and so on. In this case, identifying a finding as false or authentic is only possible through the contribution of multi-analytical scientific research. The benefits of forensic investigations, in the context presented, are manifold and occur only when the quality of the data is guaranteed and the results can be used as forensic evidence in court [2,3]. A multidisciplinary approach, therefore, is required to obtain valuable results and information when unknown artifacts are brought to light, allowing: (1) to support investigations; (2) to obtain historical-scientific information on the artifact. Specifically, raw materials used, minero-petrographic, chemical and physical features, can provide information about possible workshops of production, but also cultural and commercial routes [4] or, as in the case of votive statues, the religious traditions. The investigations on the raw materials through archaeometric analyses allow in fact to increase the possibility of obtaining important compositional and technical data, also relating them to possible historical-artistic and archaeological contexts, considering the stylistic connotations of the artifacts.

In the present paper, a morphological-stylistic and archaeometric study of two small pottery statues, seized by the Cosenza Carabinieri Unit for the Protection of Cultural Heritage and Anti-Counterfeiting (Calabria, Italy), was conducted. The study aims to establish the authenticity of the artworks and to verify a possible origin from the same workshop production manufacturing, by providing indications about the textural features and raw materials used for their production.

The two objects depict two standing female figures, wearing a *chitone*, tight at the waist and surrounded by *himation*, rich in drapery. The iconography is close to the representation of the *tanagrine* statuettes, produced in Tanagra, today's Boeotia (Greece), made starting from the end of the 4th century B.C. [5–7]. The *tanagrine* figures do not have particular features and were produced to represent the human sphere in general, but usually, they depict female figures wearing a tunic, called *chiton*, and a mantle, the *himation:* A study of the pose, of stylistic and bodily traits and the way of wearing both the *chiton* and *himation* can be preliminary evidence to get information about the origin of the statuettes.

Tanagra terracotta was first discovered around the end of the 19th century by grave robbers [6]. The figurines dated to the Hellenistic period were much appreciated over the last few decades among the 19th century middle-class for representing the reality of life in Greek antiquity. Within a few years, Tanagra had become a generic term to name a draped young lady [7]. Moreover, the so-called Tanagras do not come only from Tanagra but Tanagra-like small figurines were created all over the Mediterranean area. The Tanagra and Tanagra-like market quickly became a place of speculation and also great institutions, such as the Louvre Museum or the British Museum, and private collectors bought several statuettes. This great interest and the high market demand led to the production of fakes ascribable to three main typologies: (i) the inventions of the 19th century, made by contemporary artists, were figurines with a style distinct from the antique figurines, with a multiplication of the folds and draping; (ii) Tanagra obtained by using antique or modern molds; (iii) pastiches where pieces from various genuine figurines are put together to create a modern piece. All this has made it difficult to identify genuine Hellenistic products from fake products [7].

Elements for a preliminary and qualitative distinction in the recognition of authentic terracotta could be the representation of the fabric of the drapery, the way it rests on the body and the number of folds, often excessive for an original Hellenistic production, and the conservation state of pictorial layers still visible on the ceramic surface.

Starting from a first stylistic and morphological analysis and to objectively verify the authenticity of the two statuettes studied here or, on the contrary, bring them back to the modern production of this type of votive coroplasty widely spread at the end of the 19th century, an analytical approach was applied involving the use of minero-petrographic and physical analysis, as follows: petrographic analysis (OM), X-ray diffraction (XRD) and thermoluminescence (TL) measurements.

2. Stylistic Analysis and Iconography of the Statuettes

The analyzed artifacts consist of two decontextualized votive statuettes (Figurine A and Figurine B; Figure 1) confiscated by the Cosenza Carabinieri Unit for the Protection of Cultural Heritage and Anti-Counterfeiting (Calabria, Italy). Specifically, the two statuettes belong to the figurative type of ceramics and to the iconography of votive coroplastics.

(**a**) (**b**)

Figure 1. (**a**) Figurine A; (**b**) Figurine B.

The votive coroplastic is a type of production dating back to the end of 4th century B.C., at first only in the territories of Greece and later also in the colonies. This type of pottery, mostly depicting female figures, is called *korai* and it is made by a double matrix technique. Such a technique consists of making first the front side of the artwork and then the rear; the two pieces are then connected at a later time. A peculiar characteristic of votive statuettes, among other things observed in both figures analyzed in this work, is the presence of a more or less large hole on the back, near the head or back, which has a vent function. Among other functions, the hole was used to hang statuettes on trees in sacred places such as sanctuaries, as evidenced by several findings in excavations carried out in worship places.

The production of figurative pottery in the archaic period is connected with the votive offering. In this period, as already pointed out, the production of *korai* was very widespread, for the understanding of faithful/divine communication [8,9]. These figures display different and complementary aspects of the archaic world, as well as of the dynamics of votive practices and expressions of popular religiosity [10–13]. The local production of coroplastic, widespread in the territories of Sicily, ancient Apulia, Lucania and the colony of Locri Epizephiri, was inspired by the Greek-Oriental model. This production also included the class of votive coroplastic made up of the *tanagrine* figures, manufactured starting from the end of the 4th century B.C. in Tanagra, in today′s *Boeotia.* [10–17].

It is in this context that the two analyzed statuettes stylistically inserted (Figure 1) and represent two standing female figures, both wearing a long chiton enriched with draperies and tightened at the waist, surmounted by a himation that covers both the head and the arms, showing a glimpse of the right foot on which the weight of the body rests. They show a height of about 30 centimeters and a maximum width of 11 centimeters. Both are hollow with a diameter of five to six centimeters, also presenting a hole on the back no more than 2 cm wide. They are represented frontally and resting on a not very high circular base. Statuette A is intact, while Statuette B has a fracture on the back of the base of which part of the same is missing.

From an iconographic point of view, the two statuettes seem similar. Both show a curled hairstyle that stops behind the ears following the *Tanagrian* iconographic tradition of *melonen frisur*, where the hair is pinned into a knot at the nape of the neck (*chignon*), and divided into "parallel segments". In addition, the tanagrine statuettes are often enriched with polychrome decorations or with gold foils [10], elements not found in the statuettes analyzed here. Both have a rounded face, with the hair pinned behind the ears embellished with earrings to the lobes. The right hand of both is resting on the hip that moves the *himation*. The *himation* draperies have wider bands, while the *chiton* drapes are thinner. Then, from an iconographic and stylistic evaluation, the two statuettes would seem similar to widespread production of votive coroplastic of the central Mediterranean and of the Magna Grecia territories, as well as to the aforementioned *tanagrina coroplastic*.

Small differences can be recognized between the two finds; for example, Figurine A (Figure 1a) appears to be made of a darker ceramic paste than Figurine B (Figure 1b). Both statuettes have an uneven white-grey layer, probably natural or artificial encrustations and traces of a typical engobe, a clay coating belonging to the kaolin-type, characteristic of this type of figurine. Figurine A also shows brownish encrustations on the left shoulder, left hip and right foot, and in general, these layers are thinner and more uniform than the patina of Figurine B. Finally, again from a macroscopic point of view, important differences are observed between the two figurines in the volumes of the face (flatter for the statuette A) and along the edges of the draperies: for example, note the absence of the incisions that mark the folds of the himation in the external profile of the left arm of Figurine A.

3. Sampling and Analytical Methods

The two ceramic artworks were studied by laboratory investigations after having taken some micro-fragments of the material to be analyzed.

Sampling of pottery fragments and powders (Figure 2) was performed under the supervision of the Cosenza Carabinieri Unit for the Protection of Cultural Heritage and Anti-Counterfeiting. Specifically, to conduct minero-petrographic investigations (OM, XRD), two micro-fragments (ST_R; ST_I) having sizes smaller than ~5 mm^2, were chipped off from the backside of the artifacts, using suitable stainless-steel tools (lancets and small chisels). Moreover, to conduct investigations in TL, small amounts of powdered (Figure 2) material were sampled from the two statuettes (ST_Rp; ST_Ip) by means of a micromotor, set at low revolutions to avoid overheating of the ceramic matrix and the possible consequent loss of the TL signal [18,19].

(a)

(b)

Figure 2. (**a**) Figurine A; (**b**) Figurine B: sampling of the powders for TL test from the base of the objects.

As far as minero-petrographic analyses are concerned, they have been carried out to define the mineralogical and textural characteristics of the ceramic findings, in order to establish similarities or differences in the composition of the raw clay, in the mineralogical phases, also evaluating the firing temperature. In particular, thin section observations by Optical Microscopy (OM) and X-ray diffraction (XRD) were made. Thin-section observations were carried out through a Zeiss Axioskop 40 polarizing microscope, equipped with a digital camera. The observations allowed the definition of textural and compositional features of the two ceramic pastes.

X-ray Powder Diffraction (XRPD) was performed using a Bruker D8 Advance X-Ray diffractometer (Bruker, Karlsruhe, Germany), Bragg-Brentano geometry, with a copper sealed tube X-ray source producing Cu kα radiation (wavelength of 1.5406 Å) from a generator operating at 40 kV and 40 mA. The diffracted X-rays are recorded on a scintillation counter detector located behind a set of long Soller slits/parallel foils. Scans were collected in the range of 3–65° 2θ, using a step size of 0.014° 2θ and a step counting time of 0.2 s. EVA software (DIFFRACplus EVA version 11.0. rev. 0) was used to identify mineral phases by comparing experimental patterns with 2005 PDF2 reference patterns.

Thermoluminescence (TL) analyses [20–23] have been carried out in order to verify the compatibility of the archaeological dating hypothesized on stylistic aspects of two votive potteries with the total absorbed dose, which indicates a more or less long exposure of the sample to ionizing radiation from natural radioactive sources. The ionizing radiation dose is measured in Gray (Gy), the derived unit in the International System of Units (SI), and 1 Gy is equal to an absorbed dose of 1 Joule/kilogram. The TL dating of materials that contain quartz and feldspar crystals in the pottery matrix is applicable only to those objects that have undergone strong thermal stress [24,25]; in fact, for materials that have never been heated to high temperatures, the luminescence emitted is linked to the total dose absorbed by the crystal since its geological formation. In the case of ceramic finds, this thermal stress is represented by the firing of the artifact, which takes place at temperatures above 500 °C [20,21]. The firing resets the luminescent clock of the crystals, deleting the information relating to the dose accumulated during the geological time and starting a new exposure to natural radioactive sources, until new heating corresponds to the reading of the TL signal: the age obtained is, therefore, the period of time that elapses between the last heating, identified as instant zero, and the measurement in the laboratory

The TL dating principle in fact is that ceramics contain some crystalline minerals capable of accumulating energy when they receive ionizing radiation from the radioactive impurities contained in the same ceramic matrix and in the surrounding environment. This energy can be returned in the form of light emission when heated to temperatures above 500 °C. The visible emission measurement related to the total absorbed dose (accumulated since the last heating) and, if the value of annual dose value is known, the TL test allow to obtain the age of the analyzed ceramic sample according to the ratio:

$$\frac{total\ absorbed\ dose\ (Gy)}{annual\ dose\ (Gy/a)} = archaeological\ age$$

The total absorbed dose represents the energy released to the product by ionizing radiation (internal and environmental) from the last firing of the ceramic object to TL measurement, indicating a more or less long exposure of the sample to ionizing radiation from natural radioactive sources. The annual dose is the alpha +beta + gamma dose that each item accumulates per year due to natural radiation.

In the case of finds deprived of their discovery context, the thermoluminescence (TL) technique does not allow to verify the absolute dating due to the lack of data on the value of the annual dose absorbed by the analyzed matrix [20–22]. However, even in these conditions, the TL can still be fundamental, as it allows to verify the authenticity of ceramics of unknown origin for which we have doubts regarding whether they are ancient ceramics or imitations of recent production [7,24,25].

Therefore, starting from the absence of environmental information of the context of the excavation, and therefore, the impossibility of giving an absolute dating, the TL measurements on the two statuettes had the only purpose of verifying their authenticity on the basis of the compatibility of the total dose measured with the value expected for the hypothesized historical period. To proceed with these measurements, a minimum amount of powder (<10 mg) was sampled from the base of the object, to minimize the aesthetic damage on the two finds.

The evaluation of the total absorbed dose for the two analyzed samples was obtained according to the fine-grain technique and the added dose method was used.

A list of all examined samples and the techniques employed are summarized in Table 1.

Table 1. Investigated samples and relative employed techniques for minero-petrographic characterization (OM and XRD) and authentication tests (TL).

Sample ID	Type	Employed Techniques
ST_R	micro-fragment from Figurine B	OM, XRD
ST_I	micro-fragment from Figurine A	OM, XRD
ST_Rp	powder from Figurine B	TL
ST_Ip	powder from Figurine A	TL

4. Results

4.1. X-ray Diffraction (XRD) and Optical Microscopy (OM)

As for observations by OM, both micro-fragments were subjected to thin sectioning for a petrographic study, which focused on the composition of fabrics characterizing the types, amounts, size ranges, roundness and sorting of non-plastic inclusions and accessory minerals. The microstructure of the clay matrices was also observed, evaluating the shape, orientation and size of voids, as well the distribution of inclusions within the fabric. Parameters were defined according to the guidelines proposed by Whitbread [26].

Specifically, sample ST_R is a fragment with a quite homogeneous groundmass, characterized by medium-high optical activity and brown-reddish color in plane polar light (PPL). The microstructure shows rare micro pores of planar void types with sizes reaching 200 µm in diameter. The inclusions, with shapes that vary from sub-rounded to angular, are well sorted and mainly represented by monocrystalline quartz granules and polycrystalline ones, followed by feldspars, calcite, micas and iron oxides with sizes up to 400 µm. Few fragments of metamorphic and volcanic rocks were also observed. Crystals′ preferential orientations are not visible. Finally, amorphous concentration features (Acfs), mainly given by pure nodules and impregnant portions occur as grains of opaque material.

Sample ST_I display a quite homogeneous groundmass where the microstructure is characterized by pores, ranging from planar voids type to vesicles, the latter ones show slightly regular shapes and smooth surfaces; their size falls into the micro-pores range, with diameters up to 400 µm. The groundmass also presents a medium-low optical activity and a reddish color in PPL. As for the inclusions, they are moderately sorted and mainly fine-grained (up to 500 µm), characterized by dominant mono- and polycrystalline quartz, mainly rounded and sub-rounded in shape, along with feldspar, calcite, micas and iron-oxides. Acfs, mainly given by pure nodules, are also present.

Moreover, according to Whitbread [26], a semi-quantitative estimation of the coarse fraction/fine fraction/porosity (i.e., c/f/v ratio (%) or groundmass/aggregate/pore ratio) was performed by a visual valuation for each sample and corresponds to 50/45/5 for sample ST_R and 60/30/10 for sample ST_I.

Representative photomicrographs are displayed in Figure 3.

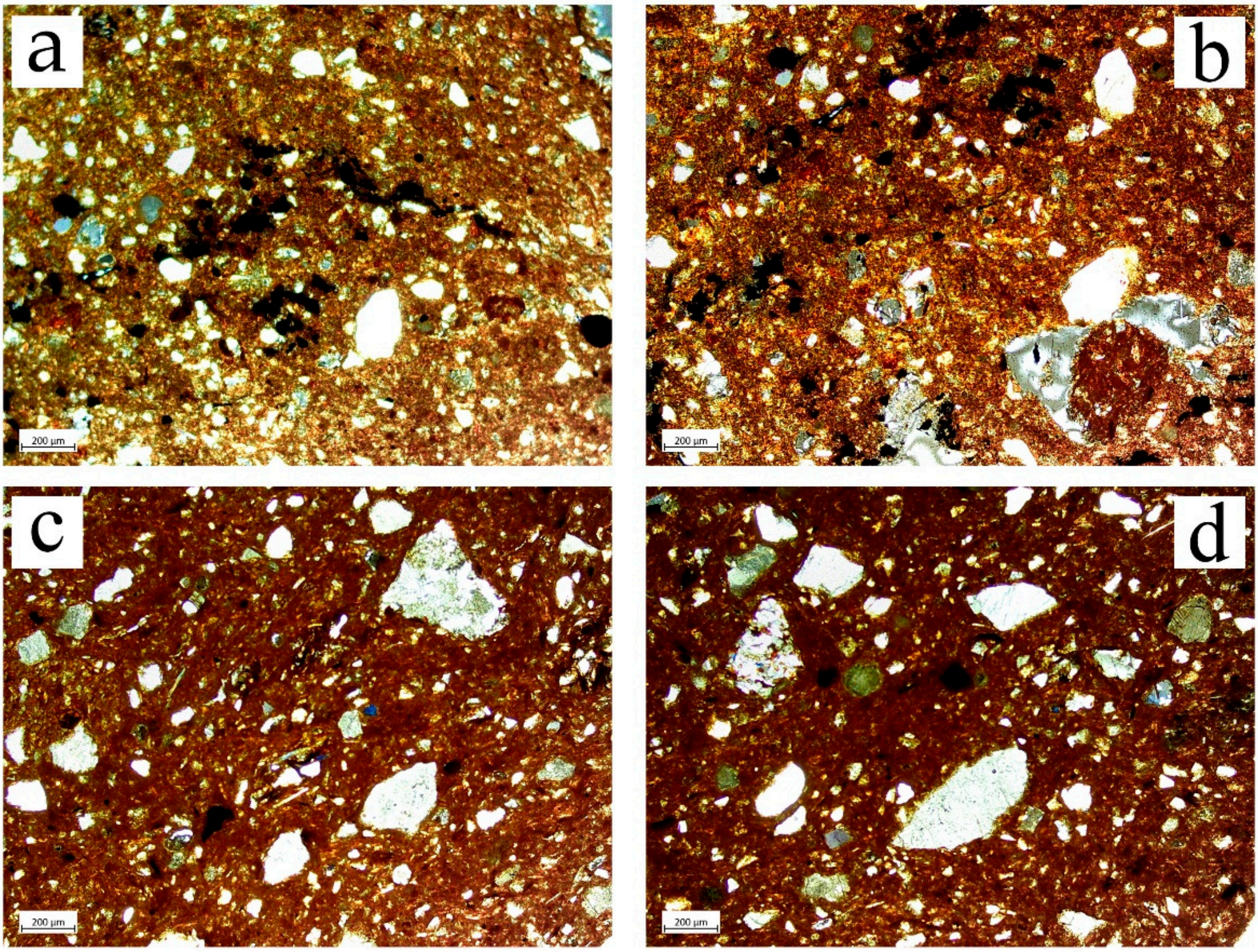

Figure 3. Representative photomicrographs showing textural features of two pottery fragments: (**a**,**b**) ST_R and (**c**,**d**) ST_I.

Results of optical microscopy observations were confirmed by XRD analysis (Figure 4). Quartz is the most abundant mineralogical phase in both the samples, followed by smaller amounts of plagioclase, feldspars, calcite, micas and clay minerals. The latter (micas and clay minerals) were identified only in the sample ST_R. Their presence is probably linked to that of fragments of metamorphic and volcanic rocks as well as to a clayey raw material more micaceous than that of the sample ST_I. Traces of gehlenite were also identified, whose presence is probably connected to mineralogical and structural transformations occurring at high temperatures, which are principally affected by the composition of the raw clay, its grain-size distribution along with kiln temperature and atmosphere (i.e., oxidizing or reducing) [27–31]. Although still in traces, the presence of gehlenite would seem greater in the ST_I sample.

4.2. Thermoluminescence (TL) Tests

The TL authenticity tests on the two samples gave the following results: the total absorbed dose measured for the ST_Rp finding is compatible with an archaeological production with a Paleodose value equal to 7.2 ± 1.0 Gy [22,24]; on the contrary, the effective dose measured for the finding ST_Ip have a value equal to 1.2 ± 0.7 Gy, much lower than that of the first finding and not compatible with an archaeological manufacturing period but in line with a production no older than the end 19th century–early 20th century [7].

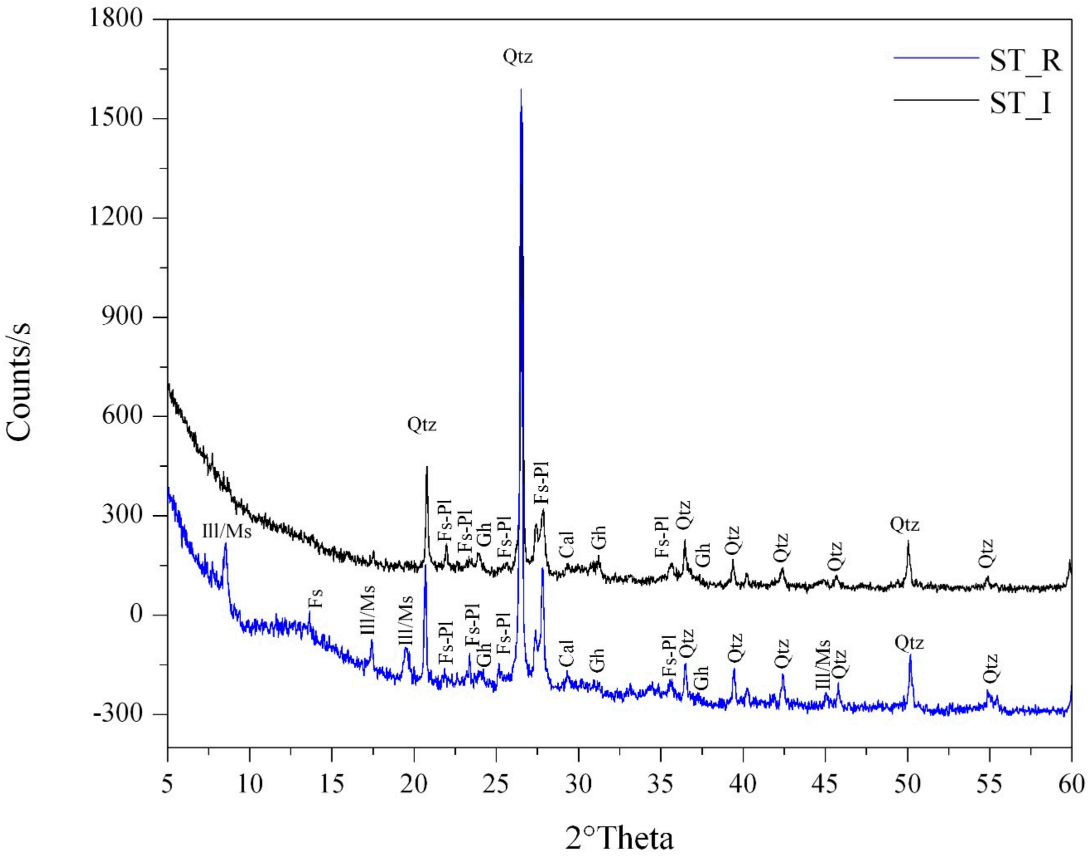

Figure 4. XRD pattern of the two fragments: Qtz = quartz; Fs = feldspar; Pl = plagioclase; Cal = calcite; Gh = gehlenite; Ill/Ms = Illite/Muscovite.

5. Discussion

The compared evaluation of the results obtained by the different and complementary methodologies provided important information on the two ceramic figurines of unknown origin (Figurine A; Figurine B) by analyzing the iconographic style, the textural features and raw materials used for their production and investigating a possible origin from the same manufacturing workshop.

From the iconographic and stylistic point of view, the two statuettes would seem similar and linked to the production of votive coroplastic of the central Mediterranean and of the Magna Grecia territories [5–9]. The two figurines differ only in some aspects, such as the color of the past, which is slightly darker in Figurine A, or the presence of encrustations, which appear thinner and more uniform in Figurine A.

According to the guidelines proposed by Whitbread [26], optical microscopy observations suggest how samples show different textural features, although the aggregate is quite similar. Specifically, the ST_I sample has a coarser paste, a greater presence of porosity and a lower density of the aggregate fraction than the ST_R sample. In both the samples, quartz, feldspar, calcite, micas and iron-oxides are detected, while they differ in the presence of metamorphic and volcanic rocks fragments, as they are present only in ST_R. The presence of micas and clays in ST_R is probably attributable to the rock fragments identified under the optical microscopy as well as to a clayey raw material more micaceous than that of the sample ST_I [4,27–31]. These differences could be attributable to the use of different clayey materials.

The XRD analysis confirmed observation under optical microscopy and allowed to estimate the high firing temperature reached by the ceramics. The occurrence of gehlenite as neoformation phase is greater in ST_I than ST_R and suggests that the original raw clay was fired at temperatures higher than 850 °C [22–26].

Finally, the TL tests on the two powdered samples showed a higher Paleodose value in ST_Rp, compatible with an archaeological production [20–24]. The Paleodose value of the ST_Ip, on the other hand, refers to production not prior to the end of the 19th century–the beginning of the 20th century. This evidence allowed to identify Figurine A as one of the large number of fakes made at the end of 19th century due to the great interest in the Tanagra type figurine [7]. This result is a further reason to date the origin of Figurine A later than Figurine B.

6. Conclusions

In this work, two pottery statuettes seized by the Cosenza Carabinieri Unit for the Protection of Cultural Heritage and Anti-Counterfeiting (Calabria, Italy) were studied in order to evaluate their authenticity and to identify minero-petrographic characteristics by a micro-destructive analytical approach.

The ceramic fragments subjected to authenticity tests through thermoluminescence made it possible to confirm the compatibility with an archaeological period of realization only for one of the two statuettes, stylistically referable to the Tanagra type, which spread throughout the Mediterranean from the end of the 4th century B.C.

Even if the two statuettes at a preliminary macroscopic observation appeared similar, many differences in terms of executive details and morphology, distribution and state of conservation of the patina had been highlighted already in the initial phase of the study.

The results of the TL texts confirmed a very low Paleodose value for one of the statuettes (Figurine A), verifying that this is attributable to the large production of forgeries that developed at the end of the 19th century to respond to the great market demand for these archaeological finds following the discovery of the archaeological site of Tanagra, in present-day Boeotia (Greece). POM and XRD analyses also confirmed, albeit minimal, differences in the type of accessory minerals, giving further evidence of different raw materials and providing a preliminary hypothesis for the local production for the authentic one (Figurine B).

The research carried out demonstrates once again that a systematic archaeometric study [2–4,28–32] can provide objective and certain answers in the context of forensic investigations, supporting the opinions of archaeologists and art historians in identifying authentic or fake artworks. The investigations on the two case studies made it possible to obtain valuable information and to answer the questions posed by the institutions for the resolution of various doubts on cases concerning the seizure and recovery of ancient objects of cultural interest.

In the specific context of this study, the importance of specific analytical and diagnostic protocols when examining objects recovered from seizures is highlighted. Only in this way can scientists working in the cultural heritage field answer questions posed by institutions regarding the authenticity of artifacts that could be lost as a result of crimes committed against Cultural Heritage.

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