CASE REPORT

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Provenance and Authenticity of Roman Sculptures by Petrographic Techniques

REFERENCE: Lazzarini, L. and Lombardi, G., **"Provenance and Authenticity of Roman Sculptures by Petrographic Techniques,"** *Journal of Forensic Sciences*, JFSCA, Vol. 40, No. 6, November 1995, pp. 1090–1096.

ABSTRACT: Forensic petrographic methods—such as microscopy, X-ray diffraction and thin section examination—applied to materials of archaeological interest—provided reliable answers to questions related to their provenance. It could be demonstrated that the patina on a Roman marble statue had been faked and that the genetic history of earthy incrustations on the sculptures and on a fragment of marble from an illegal excavation site was the same, therefore indicating a common provenance. Moreover, the same techniques proved that a terracotta fragment found in the belts of an excavator was from the same area as the illegal excavation site.

KEYWORDS: forensic science, criminalistics, provenance, authentication, petrography, marbles, forensic geology

Italy holds an extremely large and diversified artistic heritage, which can only in part be adequately protected against thefts. In 1993 over 30,000 pieces of archaeological interest were stolen, most of which were later recovered. There is a special group of Carabinieri (Comando Carabinieri Tutela Patrimonio Artistico) consisting of approximately 150 men, who are assigned to the protection and recovery of stolen works of art. Several external professionals, such as art experts, archaeologists, restorers etc., are involved in the proceedings against this type of crime.

Forensic geology has often given a substantial contribution to investigators in this field. The paper reports a case where typical petrographic techniques were successfully applied to tracing of the place of origin of some Roman marble sculptures and to the assessment of their authenticity.

The Case

Italy has a very rich underground market of objects of art illegally dug out by the so-called "tombaroli" (tomb robbers). Besides ordinary investigations and intelligence work among antique dealers, frequent helicopter flights by the Carabinieri monitor the sites in the surroundings of Rome where archaeologists are aware of potentially interesting excavations.

During a routine flight, the shining of a digging tool at the margins of an extensive, isolated, abandoned olive grove caught a pilot's eye. Upon landing, it appeared that an approximate 100 × 50 m hillside had been plowed by an excavator and the ground was covered by fragments of floors, of frescoed walls and of marble artifacts. The area was the site of a large villa of the first century A.D., unknown in the literature and discovered by illegal diggers. It was rich of very precious sculptures, such as the Triade Capitolina (Fig. 1), recovered shortly after the completion of this study.

After this discovery, during a search in the home of a suspect, the Carabinieri forfeited three marble torsos, fragments of a sarcophagus and other sculptures. In the belts of an excavator kept in a property of the suspect, they also found a fragment of "terra sigillata" ceramic. The suspect denied that he was connected with the illegal excavation, declared that the sculptures were false, but could not offer an acceptable explanation about their provenance.

G.L., with an over 20-year experience in forensic geology, and L.L., a specialist in petrography of monumental stones used in antiquity, were called in by the Court to investigate whether the forfeited sculptures were copies or originals and whether they could be related to the illegal excavation site. A field survey was carried out and samples of the soil covering the ruins of the villa and fragments of marble and terracotta lying on the ground were collected as reference samples.

The case is a recent one which has not yet been brought before the Court; therefore, names and details were intentionally omitted or masked, though analytical data and results are genuine.

Samples and Methods

This study only reports the results obtained on the following most significant samples:

1 two marble torsos (Torso 1 and Torso 2), 36 and 31 cm high respectively;
2 one decorated sarcophagus fragment (approx. 30 × 20 × 3 cm);
3 one ceramic fragment (approx. 13 × 8 × 1 cm) from excavator belts;
5 one marble fragment (approx. 15 × 10 × 3 cm) from the excavation site;

Received for publication 7 Feb. 1995; revised manuscript received 24 March 1995; accepted for publication 27 March 1995.

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FIG. 1—*The magnificent Triade Capitolina, a 2nd century A.D. marble sculpture valued at over 30 million dollars, illegally unearthed from the ruins of a villa close to Rome. This picture was taken a few days after its recovery and before restoration.*

6 three samples of the soil from the excavation site.

Sampling on the torsos and on the sarcophagus fragment was conditioned by the fact that no visible damage could be done to the surfaces of the forfeited material. Therefore, only a few milligrams of material were collected by careful scratching with a blade. Attention was paid to the patinae that covered part of the surfaces whose analysis might have indicated whether they were natural or artificially added by forgers. Very thin, reddish, earthy incrustations were observed on some sheltered part of the sculptures and thicker ones on the terracotta fragment; their composition was compared with the type of soils from the excavation site.

Analysis of the patinae consisted in the examination of all samples, as collected, under a stereomicroscope and a polarizing microscope. This examination was repeated after etching with 3N HCl and carried out by microchemical spot tests. All samples underwent X-ray diffractometry (CuKα/Ni at 40 kV, 20 mA) to identify their main crystalline phases. In addition to the described investigations, thin sections were prepared from the earthy incrustations and the soil samples after embedding of the samples in epoxy resin under vacuum, according to standard practice [*1*]. The sections were then studied under a polarizing microscope.

The marble of the objects was carefully inspected with a magnifying lens and its grain size was evaluated. This parameter as well as the M.G.S. (Maximum Grain Size) [2]—where possible, thin section determined—play a crucial role in identification of marbles used in antiquity. The findings were compared with the data in the literature (Fig. 2) [*3*].

The Questions Asked

Three were the questions asked by the Court:

i) Are the marble sculptures originals or fakes?
ii) If originals, do they originate from the illegal excavation site?
iii) May the fragments of ceramic from the excavator belts be related to the illegal excavation site?

Originality (and provenance) of a sculpture may be assessed by combining the findings of experts reports by historians with the analysis of the stone and of its patinae, if any. In our case, the archaeologists of the Museo Nazionale Romano reported that the style and technical details of all three sculptures were consistent with the period (first century A.D.) when the villa was built.

Determination of the provenance of the marble of an ancient work of art and study of its patina are generally regarded as substantial evidence [*4,5*]. Two very famous cases can be quoted regarding two important Greek sculptures, the so-called "Boston relief" [*6*] and the "Getty Kouros" [*7*], where the authenticity issue was solved by scientists.

Type of Marble

Torso 1 was 36 cm high, with no head or arms, the left leg cut above the knee and the right one missing. Taking advantage of a

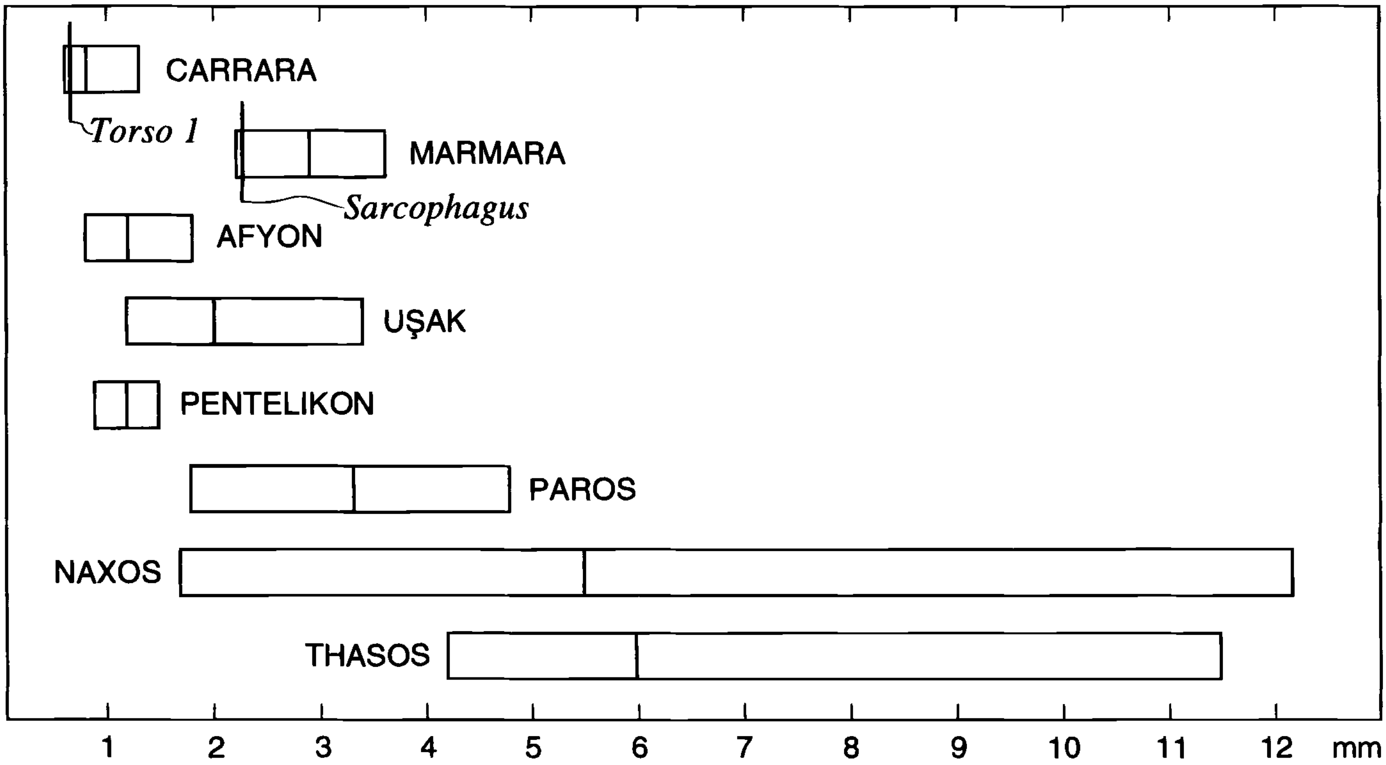

FIG. 2—*Among other key parameters, such as rock texture and composition, white marbles from different geologic formations and areas may be characterized by the different Maximum Grain Size (M.G.S.) of their calcite crystals. This is a plot showing the range of calcite crystal diameters and* (vertical lines) *their medians for the marbles coming from the most important quarry districts in the Mediterranean area (Moens, et al., 1988). The M.G.S. of two sculptures examined in this study were from Carrara (Central Italy) and Proconnesos (Marmara, Turkey).*

surface failure (probably occurred during excavations), a few mm fragment of the white marble was chipped away from Torso 1 and a thin section obtained. The rock had a crystalloblastic texture typical of metamorphic rocks; it was composed of calcite associated with very minor quantities of partly reabsorbed quartz. The grain size of the calcite crystals (which helps to identify the origin of antique marbles) was homogeneous and close to 0.5 mm. The M.G.S. was equal to 0.7 mm and the overall characteristics of the marble, among which the polygonal fabric, were typical of "Statuario," a variety of Carrara marble (Tuscany, Italy).

Torso 2 was 32 cm high, the legs cut above the knees, the right arm missing and the left one slightly bent and with a drape cut below the elbow. It was sculpted from a piece of light-gray marble with large grains of calcite (over 3 mm diameter). Though only macroscopic characteristics could be observed, its peculiar large grains of calcite suggested origin from the island of Naxos (Cyclades, Greece).

The *sarcophagus fragment* was irregularly shaped, approx. 25 × 3 × 9 cm, with a bas relief of a female face preserved in part. Its marble was white, with average calcite crystals (M.G.S. = 2.3 mm); upon striking it produced a smell of H_2S, typical of marbles from the island of Proconnesos in Asia Minor (the present day Marmara). A few mm chip in thin section confirmed its crystalloblastic texture, the dominance of calcite, the presence of minor quantities of other minerals such as quartz and sericite.

It may be concluded that the three sculptures are made of three different types of marble, all from quarries which were very active in antiquity, also in the period when the excavated villa was built. Therefore, style and type of marble indicate that the sculptures may be originals and not fakes.

The Patinae

Natural patinae on buried Roman sculptures are deposited by circulating mineralized solutions during their long underground life. In the Roman area, waters are normally rich in calcium bicarbonate; therefore, the main component of the patinae is calcite. In other cases, patinae may consist of other components, such as Ca-oxalates (for example, if the marble was exposed to the action of certain microorganisms [*8*]) or of gypsum, when soils are rich in this mineral as in Mesopotamia and Egypt [*9*].

In the three sculptures two different types of patinae were identified.

The Torso 1 patina was yellowish with calcite dominant and the single constituent revealed by XRD. Under the microscope, calcite appeared to be both in fine-grained micritic aggregates and, occasionally, in larger-sized grains, which were crystals from the Carrara marble of the Torso, removed from its surface during sampling. Quartz was associated with calcite, in angular fragments, together with fine-grained, reddish, earthy fine-grained aggregates and rare pyroxene with the habit of a volcanic mineral. Most interesting, both patinae showed few, fine metal chips, 0.8 to 1.2 mm long, as those obtained through the lathing of iron (Fig. 3).

After attack by a 3N hydrochloric acid solution, the following components have been observed:

i) optically isotropic, extremely fine-grained (<0.005 mm) particles, resembling micronized silica;
ii) fine, reddish, weakly birefringent particles, whose nature was not discernible under the microscope, but which strongly resembled those of clay minerals;

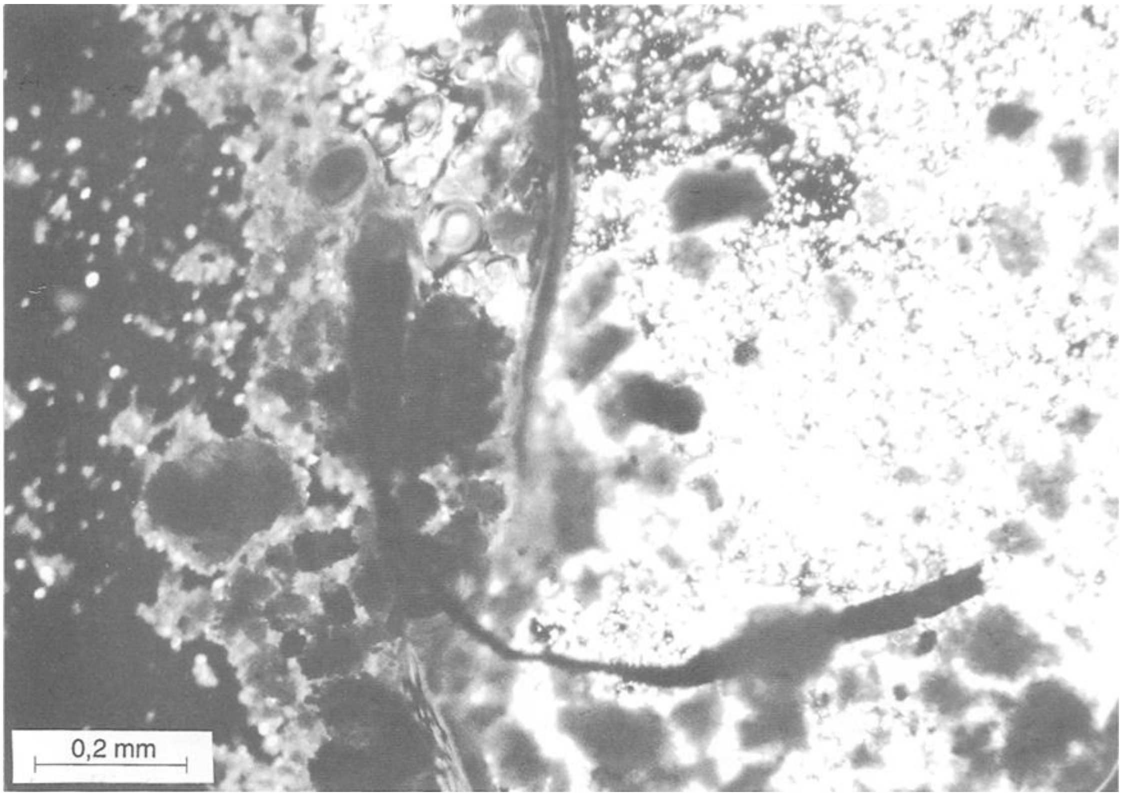

FIG. 3—*The patina of Torso 1 under the microscope. It is composed of a mixture of whitish micronized silica, calcium carbonate, small amounts of volcanic material and metal chips, the latter two components added by forgers in order to darken the patina.*

iii) porous, subrounded, purple-orange volcanic scoriae;
iv) rare quartz clasts.

A barium chloride test showed that no sulphates were present.

An acetone dissolution test carried out under the microscope, in reflected light, after evaporation of the solvent uncovered a colorless, transparent, residue resembling an organic resin or glue.

An ethyl alcohol test carried out as above to check the presence of natural resins yielded no results.

The overall composition of these patinae indicated that they were not natural; they were presumably prepared from a mixture of calcium hydroxide (which by reacting with atmospheric CO_2, rapidly turns into calcite $CaCO_3$), micronized silica and a small amount of earthy volcanic material and iron fragments to give a slightly orange-colored appearance. A synthetic, acetone-soluble resin (such as PVA) was added to them to improve their bond to the marble surface.

Such practice is frequently used in forged sculptures from blocks of Greek or Carrara marbles. The style of the Torso and its details seemed to be genuine. As a result two hypotheses remained standing: i) the Torso was a good fake and the patina components were used to age it; ii) the Torso was an original, whose incrustations and bad-looking patinae had been completely (and badly) removed and then covered with an artificial patina to improve its appearance.

The Torso 2 and the sarcophagus fragment patinae had very similar characteristics. They were composed of dominant calcite associated with quartz and occasional reddish, earthy aggregates. Some dark vegetal fibres were also found. XRD analysis disclosed the presence of calcite and quartz only.

Their characteristics were consistent with origin from the natural, slow deposition of calcite by circulating waters during the burial period of the Torso. The vegetal fibres and the earthy aggregates were incorporated in the patinae during their growth.

The Incrustations

Based on analysis of the patinae, Torso 2 and the sarcophagus fragment seemed originals. Both had very small amounts of thin reddish incrustations, preserved in the inner part of folds of the arms and of the legs of the torso and in the details of the bas-relief of the sarcophagus. Two 10 to 20 mg samples of very fine-grained material could be carefully scratched from these surfaces. After microscopic examination, a thin section was prepared from the >0.062 mm fraction and studied at the polarizing microscope; the <0.062 mm fraction was analyzed by XRD. The same analyses were conducted on the more abundant, similar, earthy incrustations on the terracotta fragment from the excavator belt and on the soil samples from the excavation site and results were compared.

The incrustations adhering to the Torso 2, to the sarcophagus fragment and to the terracotta appeared to have the same overall composition. The dominant constituents were the following fragments of different types of rocks and minerals, the latter originally part of the rocks themselves.

Sedimentary Rocks—Limestones, with different textures, Sandstones with calcitic cement, Chert.

Volcanic Rocks—Leucitic lavas, Scoriae and pumices, Iron-oxide-rich aggregates.

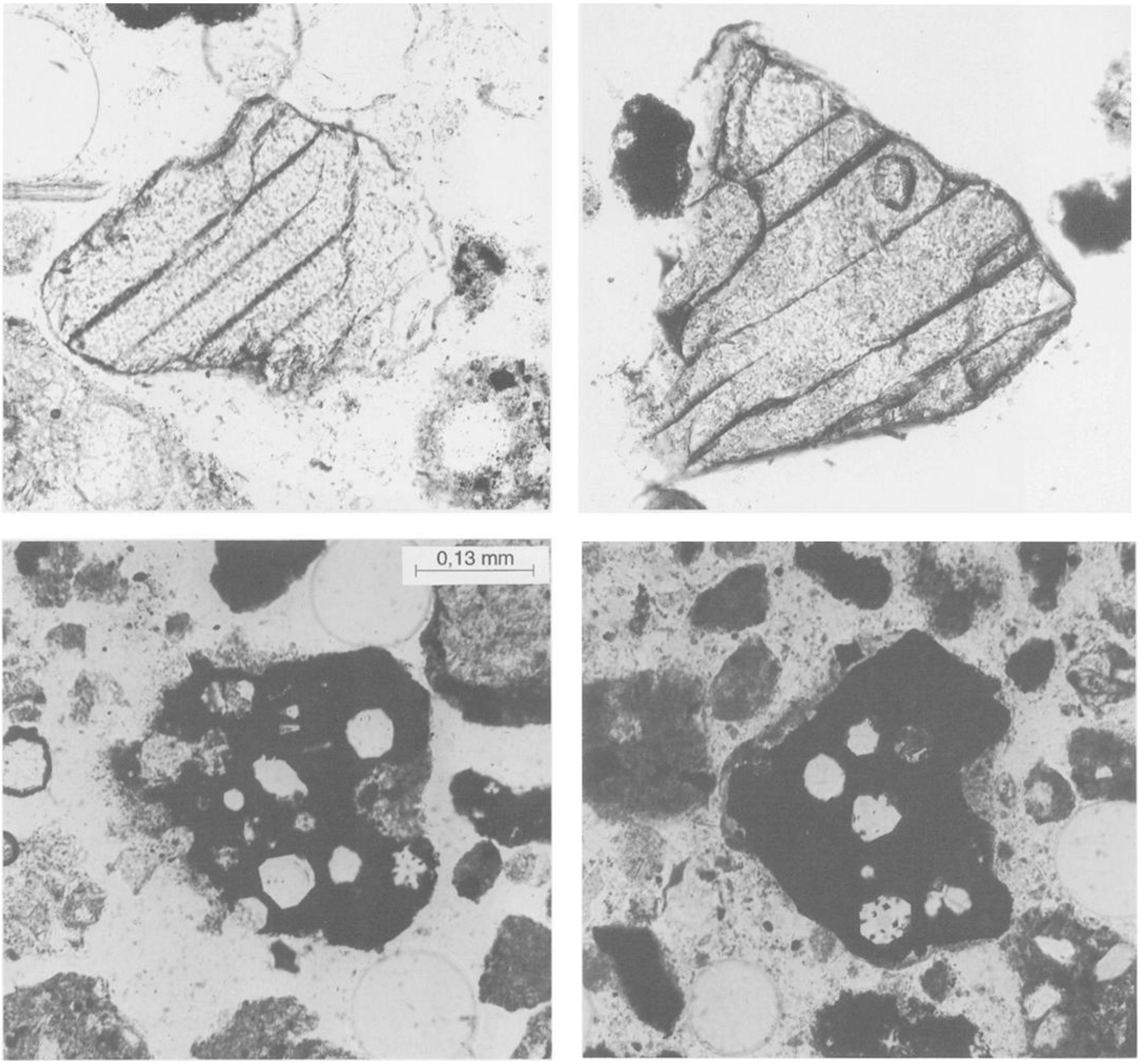

FIG. 4—*Under the polarizing microscope, in thin section.* Upper left: *crystal of the volcanic mineral pyroxene in the soil of the illegal excavation site.* Upper right: *same species of pyroxene in the earthy incrustations of Torso 2.* Lower left: *volcanic scoria with icositetrahedral leucite crystals in the soil of the illegal excavation site.* Lower right: *very similar scoria in the earthy incrustation of the sarcophagus fragment.*

Minerals—Quarts, Calcite, Sanidine, Plagioclase, Monoclinic pyroxene, Biotite, Leucite, Analcime.

Both rock fragments and single minerals were in part cemented by a red-clay matrix, giving rise to aggregates with a clastic texture composed of sedimentary and volcanic components. They derived from in-situ cementation of loose fragments of rocks and minerals deposited over the villa ruins by running waters. The incrustations from the three samples had the same texture; they only differed by the relative ratios of similar components.

The Soil Samples

The composition of soils differs substantially from larger to smaller grain sizes. The incrustations of the Torso 2, of the sarcophagus and of the terracotta were very fine-grained; consequently, in the field, sampling of the less than 2 to 3 mm fraction of the soils was preferred.

The three soil samples picked at the excavation site were very similar. They were loose, brownish, very heterogeneous and part of a detritus cover which was accumulated at the hill bottom, entirely covering the ruins of the villa. The dominant fraction was made up of fragments of rocks and minerals very similar to those found in the sculpture incrustations. The observed differences were due to a larger amount of carbonate fragments and of calcite, a higher number of pyroclastic rocks and a larger clay mineral (kaolinite, illite and smectite) fraction in the soils.

The soil samples also had yellowish and brownish vegetal fibres and animal residues, associated with the inorganic material, such

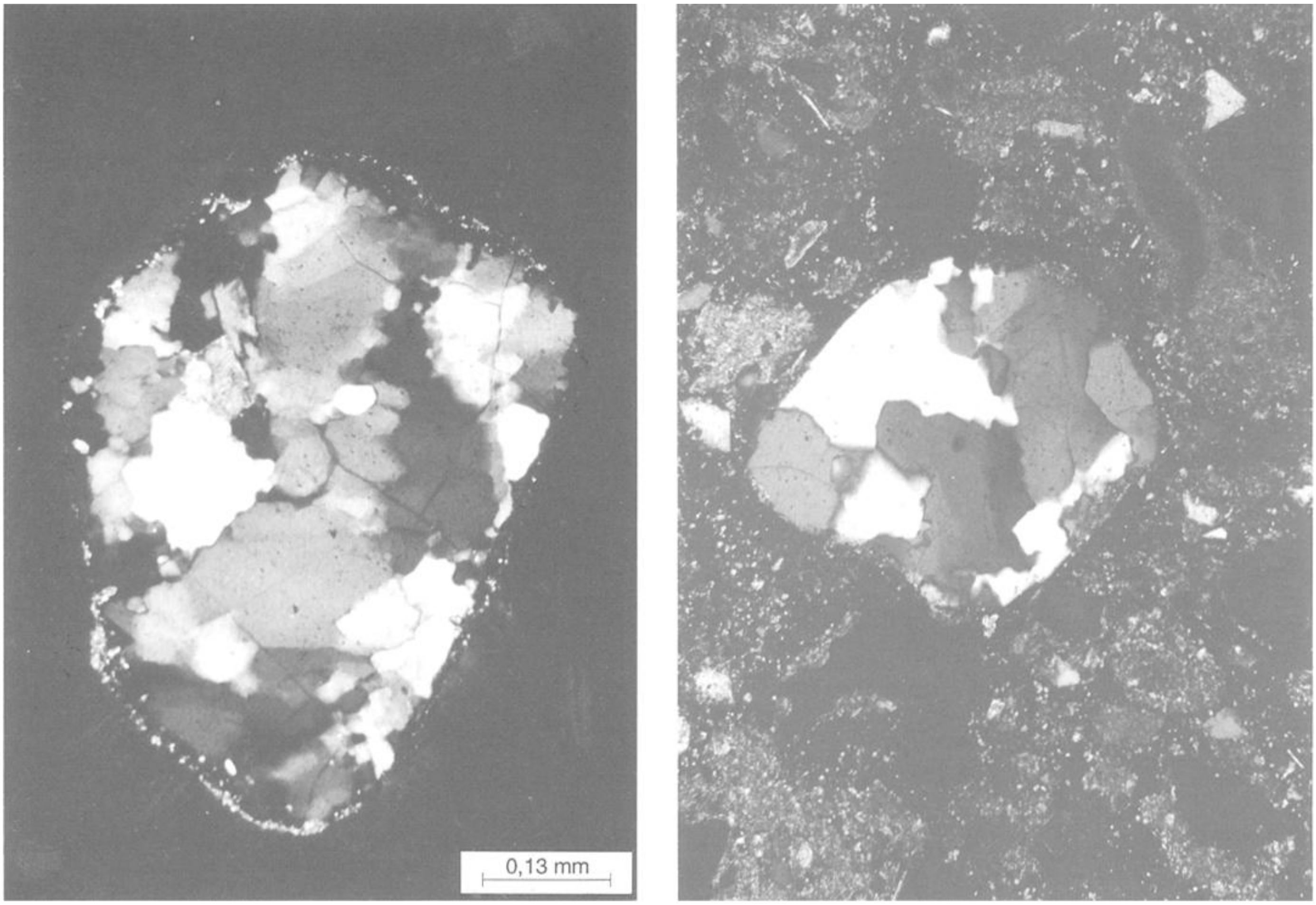

FIG. 5—*Under the microscope, in thin section.* Left: *fragment of polycrystalline quartzite from the sedimentary constituents of the soil at the illegal excavation site.* Right: *same type of fragment from the earthy incrustation of Torso 2.*

as: fragments of shells of bivalves, gastropods and of insects and other small organisms. Mixed with the other components were numerous fragments of white-grayish mortar, clearly coming from the ruins of the villa.

In conclusion, the dominant constituents of both the incrustations adhering to the Torso 2 and the soil samples were fragments of different types of rocks and minerals, the latter mainly derived from the breaking-up of the same rocks (Figs. 4 and 5).

The sedimentary components originated from the local Pliopleistocenic marine formations; the characteristics of the volcanic components clearly indicated their provenance from the perpotassic Quaternary Latian Volcano.

Relevant for investigations were the incrustations on a piece of Greek marble found in the area of the excavation site. These incrustations were very similar to those found on Torso 2 in their macroscopic appearance and overall composition. In thin section, both displayed marble grains in which the incrustations penetrated along the cleavage traces of the calcite with an extremely similar pattern (Fig. 6).

Therefore, a two-stage genesis of the incrustations which developed in the same way was reconstructed. In the first stage, circulating waters partially corroded the calcite of the marble, preferentially penetrating along the weaker lines, for example, the cleavage traces of the mineral. In the second stage, by slowly covering the ruins, the detritus penetrated along the cleavage traces, adhered to the external surface and was then cemented during the later burial stage.

The compositional analogy between the incrustations on the marble of Torso 2, forfeited in the home of the suspect, and those on the surface of a fragment of marble of the same type, picked up at the excavation site, indicated that they were compatible with a common provenance. The analogy of the two-stage process which led to the peculiar type of incrustation penetrating into the calcite of the marble inferred that their genetic history was the same. In other terms, not only the type, but also the timing and mode of adhesion of the incrustation was the same.

The compositional analogy between the soil samples and the incrustations on the fragment of terracotta from the excavator belt demonstrated that it had been on the site of the illegal excavation.

Conclusions

On three marble sculptures, two had an original patina. The other one had an artificial patina, applied either to cover some defects occurred during cleaning of the Torso or applied to age a modern fake.

The earthy incrustations observed on some protected parts of one Torso and of the sarcophagus fragment had the same texture and numerous similar constituents of the fine fraction of soils from the illegal excavation site.

Incrustations penetrating into the cleavage planes of the marble calcite were detected in both the marble of the sculptures and in a marble of the same type collected at the excavation site. They

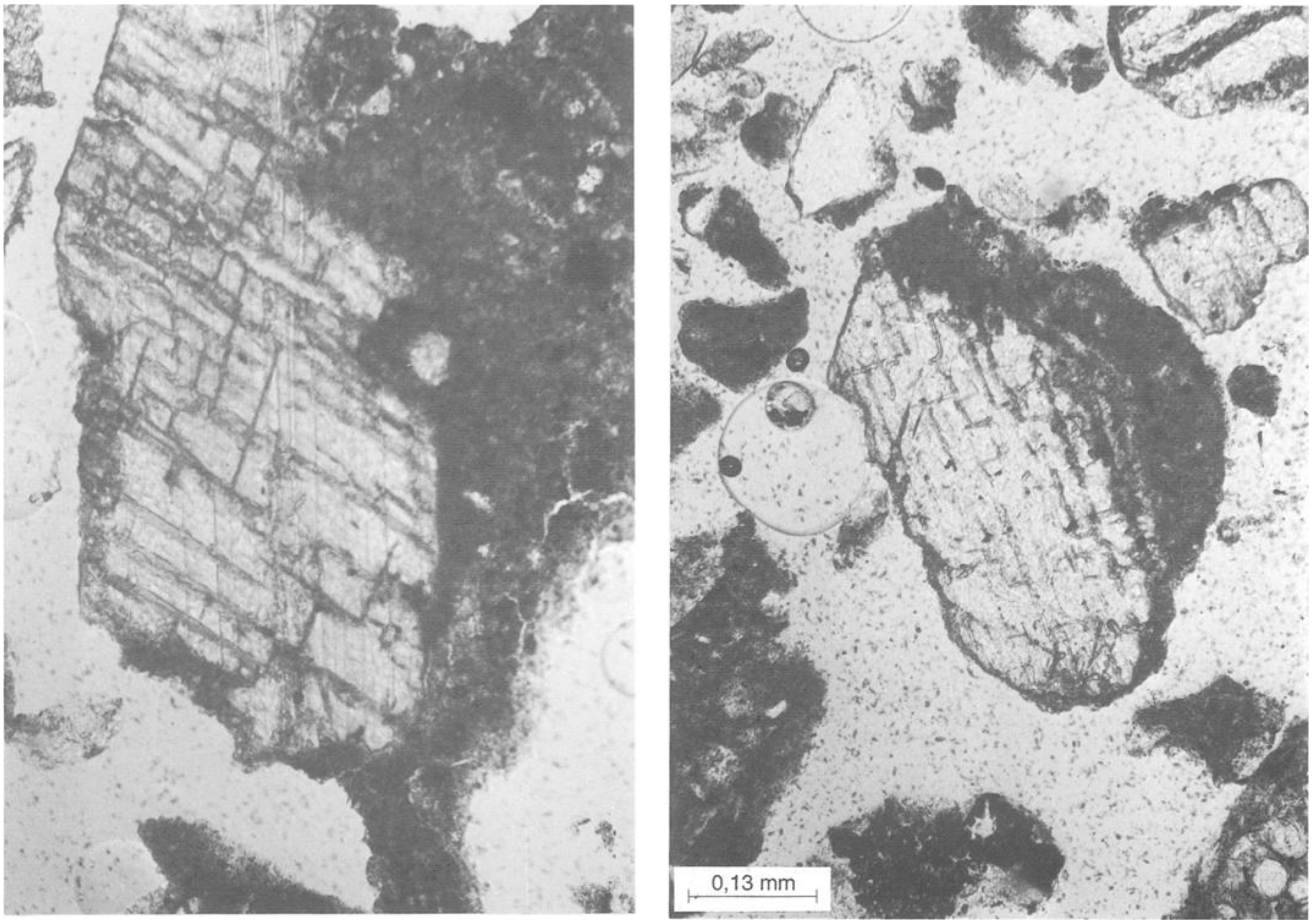

FIG. 6—*Under the polarizing microscope, in thin section.* Left: *small fragment of Proconnesian white marble from Torso 2; on its external surfaces, earthy incrustations which penetrate to the cleavages of the corroded calcite crystals.* Right: *same process of corrosion and penetration of earthy incrustations into the marble calcite crystals in a fragment of marble found at the illegal excavation site.*

demonstrated that the adhesion process developed in the same way and, presumably, in the same period of time, corroborating provenance of the sculptures from the illegal excavation site.

In this case, petrographic techniques normally applied to the study of soil samples from clothes, shoes, vehicles were vital in ascertaining provenance of the Roman sculptures, with the involvement of a suspect in the illegal excavation, and in the recovery of important works of art belonging to the national heritage.

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