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RESEARCH ARTICLE

Pompeii's Wall Paintings and the Art Criticism

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Abstract

Significant progress has been made in understanding Pompeian painting techniques through the chemical analysis of paint layers. The results are innovative, and the new findings call for a methodological update of studies on ancient painting. This update is necessary to determine the precise painting techniques used, which will inform conservation and restoration and renew the knowledge required for valorization. Chemistry plays a crucial role in art criticism, particularly in understanding the materials and techniques used in art. By analyzing the paintings' chemical composition, it becomes possible to reconstruct the creative processes and methods employed by artists. Here, we examined fragments of Pompeian painting, focusing on analyzing the pictorial layer. The interpretation of chemical data suggests that the samples analyzed were painted using a tempera technique. This finding has significant implications for art criticism, reinforcing the usefulness of this technique for understanding the cultural context of Pompeian painters and their patrons as well as those of the Vesuvius areas.

Keywords: Pompeian Wall Paintings, Organic Binders, Cultural Heritage, Art Criticism.

1. Introduction

1.1 Research Objective and Main Findings

Studies on the composition of the pigments in Roman paintings over many decades have yielded numerous publications. These studies were performed in situ and laboratories using several chemical and spectroscopic procedures (Augusti, S. 1967; Bearat and Fuchs, 1996; Meggiolaro et al., 1997; Pye, E. 2000; Siddall, R. 2006; Piovesan et al., 2011; Pagano et al., 2022; Grimaldi, M., 2022; Pagano et al., 2023). This allowed more accurate comparisons among different paintings and helped us to better understand the development of Pompeian paintings over time. However, there is also difficulty in placing the paintings within the society that produced them and the lack of knowledge about the unknown artists who created them (Grimaldi, M., 2022). There is still a lack of in-depth qualitative and quantitative characterization of the pictorial layer components. Further research in this area would be valuable as it could help to shed light on the painting techniques used by Pompeian artists and the materials that were available to them.

Pliny the Elder (1st century BC), and Marcus Vitruvius Pollio (1st century BC) in De Architectura, accentuated the art and the popularity of Roman paintings, particularly the wall paintings in Roman decorations. Vitruvius (Volume VII), talks about private buildings, their typology, and wall decorations. It is here that Vitruvius describes for the first time colors applied on humid walls and therefore not subject to discoloration, but remain permanently permeated. He also referred to a secco painting without specifying the kind of binder used. With Charles of Bourbon, the first underground searches of Pompeii began with the antiquary Marcello Venuti, who directed

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the excavations up until 1740, and subsequently by Roque Joaquin de Alcubierre, in which numerous wall paintings were brought to light. Thanks to the treatise of Vitruvius, the archaeological research begun by Charles of Bourbon, and the conservation of the finds that were classified by the archaeologist August Mau in four styles, subsequently used to characterize all the art before 79 AD. Mora and Philippot proposed a "theory of the fresco". According to this theory, artists were able to realize a fresco on large (about 9 m^2) of fresh lime (pontate), thus avoiding the need to divide the wall surface in painting days (giornate). The experiment carried out by Barbet, A. (Barbet, A., 2002) was to paint a surface equivalent to a pontata (including the joints of the plaster) with the cooperation of eight painters. Four days later, the work was not completed. Barbet's result showed that the pontata could not have been painted in one day and thus would not have been painted in fresco.

There was no consensus on whether paintings were created using the fresco technique, in which pigments are applied to wet plaster, or the secco technique, in which pigments are applied to dry plaster (Evershed, R.P., 2008; Domenéch-Carbò, M.T., 2008; Duran et al., 2010). These procedures were generally executed most likely by ancient artists' workshops formed by a certain number of workers around a master or workshop leader who negotiated with the clients, agreeing with each of them the terms, costs, and deadlines for the delivery of the works to be carried out (Bragantini, I., 2004). Under this regard, of great archaeological importance was the organization of the work on the construction site that has been well documented from the excavation conducted in the House of Painters at Work "la Casa del Pittore" (Esposito, D., 2011), the House of the Iliac Sacellum "la Casa del Sacello Iliaco" (Esposito, D., 2011) and nearby buildings as well as the context discovered in room I of the first lower level of the "Villa dei Papiri in Herculaneum", which was also under restoration and redecoration at the time of the eruption (Guidobaldi and Esposito, 2009). Also important are the studies regarding intervention, the practice adopted in the application of plasters and pigments, aspects concerning maintenance, such as those reported in recent works "Insula 10, Regio IX" (Zuchtriegel et al, 2024), "the ancient graffiti (Tituli Picti)" (Ruffolo et al., 2020), and "Le Botteghe del Regio VII" (Pellecchi, S., 2018).

Analysis of archaeological mural paintings is a complex task that requires knowledge of scientific disciplines, as well as historical and conservation skills (Pérez-Diez et al., 2023; Kastenmeier et al., 2010; De Caro, S., 2015; D'Alconzo, P., 2017; Eskici and Eryurt, 2022). The intersection of chemistry and art has been pivotal in preserving and understanding artistic heritage, especially in Pompeii, where environmental factors and time have taken a toll on ancient works. By applying advanced chemical analysis, conservators can better understand the original materials, techniques, and compositions used by ancient artists, shedding light on the cultural and aesthetic priorities of their time. For instance, identifying pigments and binders enables us to reconstruct not only the physical aspects of a piece but also the symbolic choices that the artist made, as these materials often carried specific cultural significance. In Pompeii, where frescoes serve as both artistic expressions and historical records, scientific analysis of paint layers, mineral content, and degradation patterns has helped preserve their integrity.

Art critics and historians also play an essential role here, as seen in the work of Messina and Pascariello (2016). Their studies emphasize that Pompeian art prefigured later developments in perspective by suggesting spatial depth within architectural scenes, even before formal perspective rules were codified during the Renaissance. The figurative canons they reference, using intuitive depth and architectural representation, demonstrate an early form of perspective that hints at an understanding of spatial realism. This approach allowed Roman artists to create immersive scenes, situating viewers within a three-dimensional space on a two-dimensional surface, long before perspective was formally defined. Thus, by combining chemical analysis with art historical critique, we gain a holistic view of Pompeian paintings, understanding not only their material makeup but also their conceptual contributions to art history. This integrated approach is invaluable for preserving and appreciating the artistic heritage of Pompeii and similar sites (Messina and Pascariello, 2016; Petrillo, J., 2016; Spinelli, A., 2022).

To this purpose, we carried out various chemical studies on Pompeian mural paintings with the idea of updating the relationship between insiders and works to be valued. The studies revealed so far that the samples analyzed were not frescoes, but likely tempera paints or other dry painting techniques. Fresco uses a lime-based binder applied to fresh plaster. As it dries, the lime binds the pigments to the surface, creating a

stable, long-lasting coloration (Baraldi et al., 2019). In contrast, tempera relies on a water-soluble binder that mixes with pigments to create paint. This method sits on the surface, rather than bonding deeply with a lime layer, allowing for a different range of colors and textures. The use of organic binders in wall paintings introduces unique challenges for conservation and demands a distinct approach compared to traditional fresco restoration since it creates a stable, durable pictorial layer based on lime carbonate. In contrast, tempera or other dry painting techniques make the artwork more susceptible to environmental degradation, as organic materials are more sensitive to humidity, temperature changes, and biological growth. The use of tempera techniques in Pompeian works suggests that Pompeian painters were capable of creating highly sophisticated and nuanced works of art. They were not merely copying reality but were skilled at using their medium to convey complex ideas, moods, and intricate compositions "pictores imaginarii" (Bragantini, I., 2004).

Since these findings challenge the traditional classification of Pompeian paintings as "frescoes," the term "wall paintings" might be a more accurate descriptor, covering a broader range of techniques. Such an update would also align with a more nuanced view of these works, acknowledging the technical variety and artistic choices available to Roman painters. These arguments, which enter the category of artistic techniques, are certainly also matter of competence of art criticism, even if this science has not completely solved its epistemological problems. Ancient art historians and critics have not yet produced a diagnosis, in other words, a narration of Pompeian paintings that goes beyond their nature as archaeological finds (Brandi, C., 2022). In the case of Pompeian painting, this would mean providing new and qualified work tools for cultural operators, including guides. Knowing the pictorial techniques, the chromatics, the client, the cultural significance in that specific Domus, the meanings of the pictorial representation and its composition, and the connections with the client's religious, political, and cultural world would be undoubtedly of interest to visitors.

1.2 Studies on Pompeian Wall Paintings

To date, research performed on Roman and Pompeian mural paintings has highlighted the need to efficiently extract the organic binders used for the preparation, together with the pigments of the paints. This difficulty is made even more challenging by the in-depth knowledge of the walls on which the works were executed, thus posing the question that the chemical analyses performed did not provide significant results for the identification of the pictorial means used. Some studies on ancient paintings showed that the absence of an organic binder was not due to their execution as fresco, but to the difficulty of identifying the origin of pictorial medium (Jiménez-Desmond et al., 2024). Furthermore, the fresco technique in paintings was also controversial because of the lack of the technical characteristics of the fresco, such as the absence of large monochromatic pictorial surfaces, and the use of pigments not suitable for fresco. These aspects have suggested a pictorial technique that involved the use of organic material to bind the pigments (Casoli and Santoro, 2012; Casoli, A., 2021; Pérez-Diez et al., 2023). In this context, the focus is on the pictorial layer of the paintings (the layer of color that defines the artistic work). The analysis of the pictorial layer allows researchers to uncover detailed information about the techniques used, independent of the type of wall support or plaster beneath it (Colombini e Modugno, 2009; Bonaduce et al., 2016).

A comparative analysis between different studies on Pompeian paintings highlighted the heterogeneity of data consistent within various research groups and considerably different among different groups. The inconsistency of these results was most likely related to the complexity of the extraction of the pictorial binders, the environmental circumstances, and the possible microbiological contamination of the reports. All this led to uncertainty about the composition of the paints, and therefore, to the employment of adequate treatments aimed at conservation and valorization. Therefore, there is a need to develop efficient procedures for the extraction of the organic binders and the evaluation of the influence of biological contamination on the organic material (Cunì, J. 2016). From this point of view, the analysis of the composition of ancient Pompeian paintings represents a very stimulating mission that requires skills in analytical techniques mainly finalized to the choice of suitable valorization and conservation interventions (Domenéch-Carbò et al., 2012; Perez et al., 2013; Amadori et al., 2015). However, besides the millennial age and the effects of atmospheric and external chemical and biological agents, it is almost impossible to know the exact original composition of the original Roman wall painting mixtures (Maggiolaro et al., 1996). Thus, improvement of the micro-analytical chemical

procedure to increase the extraction efficiency of the organic and inorganic components of the paint layers is necessary. In our experimental research, we observed that the quantitation of paint components of ancient Pompeian mural painting, by scraping a tiny amount of paint from the sample surface, is always hampered by the contamination of calcite during sample collection. Scraped solid paint powder might be compared to particles formed by a matrix water-resistant covered by porous organic compounds. Therefore, improvement of the extraction process could be achieved by mechanical pulverization of the painting powder (Pawliszyn, J., 1993), thus the fine reduction of particle size might promote the subsequent solubilization process (Favretto et al., 2011).

Within this framework, chemical analyses were conducted on selected wall painting fragments from the *Villa Imperiale*, the *House of Marcus Fabius Rufus*, and the *House of the Golden Bracelet* in Pompeii's *Insula Occidentalis*. The archaeometric investigations, detailed in the Supplementary Information, consistently identified organic components in all samples. These substances were most likely employed by the pictores imaginarii as binding media in the preparation of pigment colored mixtures (e.g., palettes) (Bragantini, 2004).

1.3 Critical Analyses for Valorization

Briefly, the goal of art criticism in analyzing Pompeian paintings is to uncover new dimensions of their cultural and artistic value through a systematic, scientific approach that enhances their appeal to a broader audience (Argan, G.C., 1975). This approach advocates moving away from traditional methods, chronological, perceptual, historical-biographical, and philological, and instead embracing a multi-layered critical discipline. This new discipline would integrate chemical-physical, informative, literary, historiographical, philosophical, and journalistic perspectives to address the unique needs of ancient art, particularly Pompeian art (Berenson, B., 1948). In this framework, art criticism would act as a mediator, bridging the gap between creators and audiences by illuminating the hidden values embedded in these artworks. Through such valorization, Pompeian paintings would be recognized not merely as historical artifacts but as part of a coherent "Pompeian art," reflecting the distinct culture of the Vesuvius area. Significant progress has already been made, as Pompeian art has gained international recognition, highlighting its unique cultural value. The next step is to deepen research into the complexity of these works and continue exploring new values within this rich cultural heritage (Wollner, J.L., 2013).

2. Conclusions

Our analysis of selected Pompeian wall-painting samples indicates that Pompeian artists likely used a tempera or secco technique, blending pigments with organic binders of animal or plant origin. To address challenges in extracting and analyzing these paint components, we applied a novel method that combines two pre-analytical steps: pulverizing the paint sample and using chemical and spectroscopic quantification. This approach has improved our ability to recover organic components compared to previous methods, suggesting that further refinement could yield even deeper insights into the complex techniques of ancient painting. Such advancements could not only enhance conservation and valorization efforts but also inspire a fresh perspective in art criticism, recognizing the sophistication of these ancient artworks.

Supplementary Informations

1. First Investigations on Pompeian Wall Paintings from *Villa Imperiale*

Two fragments from Villa Imperiale (ca. 1st century AD, ~3 × 2 cm) were obtained with the collaboration of the archaeologist Dr. De Carolis (Fig. S1A), dating back to approximately the 1st century AD. Samples measured around 3 × 2 cm and appeared to be relatively well preserved. Due to limited *in situ* sampling, only a few sporadic samples were studied. Paint powder was scraped and extracted with polar and non-polar solvents, following the Standard Metabolic Reporting Structures SMRS method (Lindon et al., 2005).

As shown in Fig. S1B, analyses via spectroscopy, GC, and MS showed amino acids (28.91 mg/kg) with a cereal-like profile (possibly wheat flour) (Bonaduce et al., 2007) and significant sugars, mainly arabinose, xylose, and glucose, comprising over 85% of the total (excluding myo-inositol, likely from microbial contamination). High arabinose and glucose levels suggest natural gums from fruit trees or tragacanth.

In the non-polar fraction, various fatty acids were identified, potentially originating from a mixture of vegetable oils, such as palm oil, olive oil, and others (Kurata et al., 2005). However, some of these fatty acid profiles could also result from the degradation of the paint layer due to environmental exposure (Regert et al., 2001).

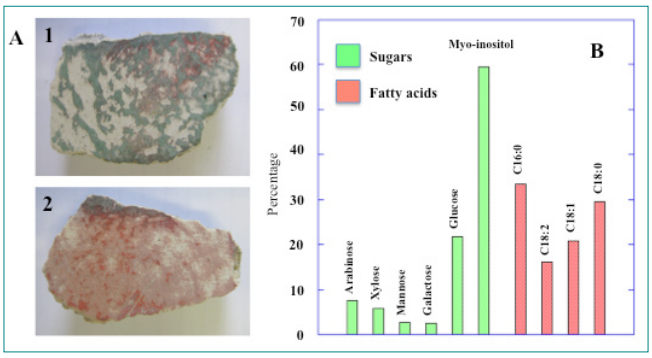

Fig. S1. *A. Sporadic wall painting samples (1 and 2) from Villa Imperiale. B. Percentage of sugars and fatty acids detected in the polar and non-polar paint powders fraction.*

2. Binder Analysis in Pompeian Wall Paintings from the *House of Marcus Fabius Rufus*

A study of binders in Pompeian wall paintings, spanning the 1st–4th decorative styles (ca. 200 BC-79 AD), was conducted under Dr. Mario Grimaldi's studies (Grimaldi M, 2006, 2007, 2008a, 2008b). Samples from the garden of the *House of Marcus Fabius Rufus* and the terrace above the *Villa Imperiale* were classified by decorative style to trace stylistic and material changes (Gelzo et al., 2014). After the 62 AD earthquake, earlier decorative fragments were reused as fill in the Villa garden, preserving 1st-4th style plasters, some from late Republican layers, beneath volcanic deposits. Recent excavations in this garden (2007-2008) even reached the late Republican layers (4.5 meters deep), where large plaster fragments from the first style were found (Grimaldi, M., 2008a, and 2008b). The samples recovered from this garden area, having been buried, likely avoided deterioration during the 79 AD eruption of Vesuvius and thus retained much of their original composition. These well-preserved fragments, free from modern restoration waxes (Croisille, J.M., 1985; Duran et al., 2010), were suitable for comparative binder studies. The samples, classified according to the four distinct Pompeian decorative styles (Grimaldi, M., 2006-2008), provide insight into stylistic and material evolution over time (Fig. S2A). Paint powders (~50 mg) were extracted for polar and non-polar compounds analyses.

Polar fraction analysis showed abundant glutamic acid, glutamine, valine, proline, alanine, serine, and glycine, resembling cereal proteins (Corso et al., 2012). Amino acid concentrations were lower in older (1st–2nd style) samples than in later (3rd–4th style) ones, suggesting shifts in binder composition over time, possibly due to changing materials, techniques, or artistic preferences.

Monosaccharides detected in all samples included arabinose, fucose, xylose, galactose, glucose, galacturonic acid, and myo-inositol, with xylose dominating (~64%). Myo-inositol levels declined with decorative style age, from ~5% in the 1st style to <0.1% in the 4th, possibly reflecting preservation state or original binder composition. The absence of rhamnose excluded gum Arabic (Hough L., 1959) while the presence of fucose indicated tragacanth gum (Lluveras-Tenorio et al., 2012). Therefore, based on the classification of Reido (Riedo et al., 2010), these data suggested the hypothesis that tragacanth gum had been used in paint mixtures. However, contamination over time cannot be ruled out as a factor affecting the detected protein and amino acid contents in the samples.

Non-polar fraction analysis identified palmitoleic (C16:1), palmitic (C16:0), linoleic (C18:2), oleic (C18:1), and stearic (C18:0) acids, with palmitic and stearic each contributing ~42-44% of lipids. The profile suggests mixed vegetable oils (e.g., olive) with no beeswax (no hydrocarbons > C20:0) (Regert et al., 2001) (Fig. S2B).

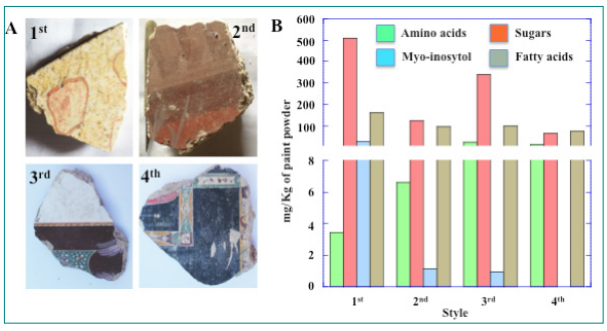

Fig. S2. *A. Selected wall painting samples of the 1st, 2nd, 3rd, and 4th styles from the House of Marcus Fabius Rufus. B. Amount of organic panting components (amino acids, sugars, myo-inositol, and fatty acids) detected in the specimens.*

3. Refined Extraction and Analysis Procedure Applied to Samples from the *House of the Golden Bracelet*

In a follow-up study, five samples from the House of the Golden Bracelet (collaborating with Dr. Stefania Giudice) were deemed suitable for further investigations to address concerns regarding the efficiency of extraction procedures for organic compounds in ancient paints (Ciardiello, 2012; Gelzo et al., 2019) (Fig. S3A). Responding to critiques about prior extraction methods (Cunì, J., 2016), a novel approach involving the fine mechanical pulverization of mural paint scraped from both the sample's surface and the calcite layer immediately beneath it was developed. This technique enabled a more precise quantification of the actual paint by using a calibration curve based on the Fourier Transform Infrared (FT-IR) peak area of calcite at 2510 cm^{-1}, which helped distinguish between the scraped paint powder and the underlying calcite layer (Fig. S3B).

Five samples were re-examined using a novel approach that scraped both surface paint and underlying calcite, quantified via FT-IR (2510 cm^{-1}). This yielded higher free amino acid concentrations (1764-7592 mg/kg) than previous analyses (5.13-28.91 mg/kg). Glycine dominated in samples C1 and C5 (43.6% and 38.5%), suggesting collagen or animal glue binders (Mills and White, 1994). In C2–C4, ornithine was most abundant (20.4-27.8%), likely from animal/plant substances or arginine degradation over time. In contrast, ornithine, a non-proteinogenic amino acid was most abundant in samples C2–C4 (20.4-27.8%), which could derive from animal/plant substances or from the degradation of arginine over time (Weber and Miller, 1981) or result from the breakdown and conversion of arginine over time (Corso et al., 1993) (Fig. S3C).

The findings indicate varied binder compositions in Pompeian paints, pointing to differences in materials or preparation methods. Collagen-based glue and ornithine suggest choices influenced by availability, style, or function, offering insights into ancient practices and informing conservation strategies.

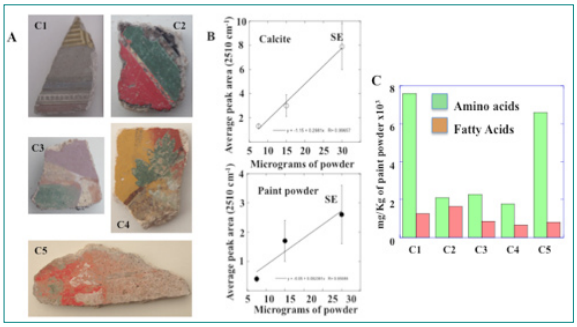

Fig. S3. *A. Selected wall painting samples from the House of Golden Brachalet. B. Paint powder calibration curve performed by FT-IR spectroscopy. Increasing amounts of paint powder and the corresponding below calcite powder were scraped from the sample surface and analyzed by FT-IR at 2510 cm-1. For each sample analyzed, four spectra were collected and the average peak area, SE (standard error), and curve equation were calculated. C. Total amount of amino acids and fatty acids.*

The analysis of non-polar fractions identified nine fatty acids, with palmitic (C16:0), oleic (cis-C18:1), and stearic (C18:0) dominating the profiles (Fig. S3C). Total fatty acid concentrations (649-1630 mg/kg) were much higher than in past studies, reflecting improved extraction and quantification methods. The C16:0/C18:0 ratios (>1) suggest animal fats, possibly mixed with vegetable oils (Buckley et al., 2004). Variations between samples indicate diverse sources, including cereals, fruit tree gums, and vegetable oils. The enhanced method improved amino acid detection by one order of magnitude and lipids by two.

Calcium oxalates, whewellite (Petrov and Soptrajanov, 1975), and weddellite (Bralia et al., 1989) that indicate bio-deterioration or environmental alteration of the paint layers, were neasured via FT-IR peak area at 780 cm^{-1}.

Using this enhanced approach, it was possible to estimate approximately the percentages of true paint components contained in the painting mixture (Table 1).

Table 1. *The average amount of calcite and paint components evaluated by FT-IR in samples from the Golden Brachalet's House**

	weighted powder (µg/spot) 7.5	15	30	True Paint (%)	Calcite (%)	Oxalate (780 cm^{-1}) area/µg	OM (AA + FA) (%)	Pigments + other OM + DC (%)
	Calcite in the paint (µg)							
Average	4.9	8.68	59.06	40.94	59,06	0.57	0.506	40.42
SD	1.14	1.66	2.19	2.19	2.19	0.099	0.28	2.25
CV%	23.25	19.18	3,70	5.34	3.70	17.31	55.69	5.57

**Gelzo et al., 2019. FT-IR Analyses were performed on 7.5, 15, and 30 µg/spot of scraped paint powder. AA, amino acids; FA, fatty acids; OM, organic material; DC, decay compound; SD, standard deviation; CV, coefficient of variability*

These chemical insights contribute valuable information about the complex mixtures of organic materials used by Pompeian artists, supporting the notion of a sophisticated approach to paint formulation that varied over time. This knowledge could be crucial for conservation efforts, as it allows restorers to choose methods and materials compatible with the original compositions of these ancient paintings (De Caro, S., 2015).

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Authors' Contributions

CP was involved in art criticism. OA was involved in bibliographic research. GC and PA made substantial contributions to the drafting and revision of the manuscript. All authors read and approved the final manuscript.

Competing Interests

The authors declare that they have no competing interests.

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