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The organic content of the bronze vases of the *heroon* of Paestum: new data for a new interpretation*

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Abstract: The famous hypogaeum of the Greek city of Poseidonia (Paestum), excavated in 1954 and dated from the end of the 6th c. BCE, has been interpreted as a *heroon* based on the archaeological material retrieved. It encompassed five iron rods (*obeloi*) wrapped in a thick wool cloth, deposited on a wood table (*trapeza*) in the center, of eight bronze vases (six hydriai; two amphoras) and of an Attic amphora with black figures, set along the north and south walls of the structure. The walls and the bottom of the bronze hydria and amphora revealed a thick and paste-like yellow-brown organic substance. Many researchers still interpret this substance as honey or the remains of honeycombs, which would have been offered as part of a heroic cult to the founder of the city. Yet, the different sets of analyses performed during the 1950s and 1980s, although they could not identify the nature of the fatty substance, had allowed to reject the honey hypothesis. New analyses took place recently within a research program led by the Jean Bérard Centre in Napoli. The pollen analysis and organic analysis by GC-MS have brought concordant data. The chemical analyses did not reveal any wax or animal fat, nor oleoresin or plant pitch, but rather the markers of a siccative oil. The extracted pollen was dominantly that of Cannabaceae (eg. *Cannabis/Humulus* type). The interpretation of these intriguing findings is discussed.
Keywords: Paestum, organic residue analyses, pollen, *Cannabis*, oil.

Résumé: Le célèbre hypogée de la cité grecque de Poseidonia (Paestum), fouillé en 1954 et datant de la fin du VIe s. av. J.-C., a été interprété comme un *heroon* en fonction du matériel qui y a été mis au jour. Celui-ci était constitué de cinq tiges de fer (*obeloi*) enveloppées dans un épais tissu en laine et déposées sur une table en bois (*trapeza*) au centre, de huit vases en bronze (six hydries; deux amphores) et d'une amphore attique à figures noires disposés le long des murs nord et sud de la structure. Les hydries et les amphores en bronze contenaient (sur les parois et dans le fond) une substance organique épaisse et pâteuse de couleur jaune-brun. Nombre de chercheurs interprètent toujours cette substance comme du miel (ou les restes de rayons de ruche), qui aurait été offert dans le cadre d'un culte

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héroïque rendu en l'honneur du fondateur de la cité. Pourtant, si elles n'ont pu identifier la nature de cette substance grasse, les différentes analyses faites entre les années 1950 et 1980 ont permis de rejeter l'hypothèse de miel. De nouvelles analyses ont eu lieu récemment dans le cadre d'un programme de recherche piloté par le Centre Jean Bérard de Naples. Une étude pollinique et une analyse chimique (GC-MS) ont apporté chacune des données concordantes. Les analyses chimiques n'ont révélé ni cire ou graisse animale, ni oléorésine ou goudron végétal, mais les marqueurs d'une huile siccative tandis que l'assemblage pollinique mis en évidence est nettement dominé par des grains de pollen de Cannabaceae (*Cannabis-Humulus* type). En fonction de ces résultats, peut-être proposée comme hypothèse une huile de graines de chanvre qui aurait été versée dans les vases en métal et qui se serait oxydée au cours du temps.
Mots-clés: Paestum, analyses de résidus organiques, grains de pollen, *Cannabis*, huile.

Introduction

The MAGI (*Manger, boire, offrir pour l'éternité en Gaule et en Italie préromaines*, 2013-2017) program funded by the ANR (French National Agency for Research) and directed by the Southern Brittany University, the Centre Jean Bérard in Napoli and the École Française de Rome was a program dedicated to the archaeology of biological products in funerary contexts. It has allowed to investigate, using both biochemical and palynological analyses, the biological contents of the vases of the Paestum so called *heroon*.

Poseidonia was founded around 600 BCE as a secondary colony by Greeks from the Sybaris *polis* – Francavilla Marittima – in the south of the Tarente Gulf. The famous Paestum (Poseidonia) *sacellum*, entirely closed and devoid of any human decease, was discovered in 1954 by Pellegrino Claudio Sestieri. Dated to the end of the 6th c. BCE, it was diversely interpreted as a Nymph sanctuary, the cenotaph of Is, founder of Sybaris, or a Chthonian sanctuary (Rolley 1982 with relevant literature). The finds are coming from a context and a period for which we do not have much contemporary literature, thus where the organic analyses are a primary source of knowledge to document the functions of the vases and the associated rituals.

The small subterranean structure is located in the area north of the Forum and south-west of the Athenaion, close to the Agora. The materials retrieved are exceptional, marking an elite special place with some rare elements: five iron rods interpreted after restoration as *obeloi*, the traces of a cloth bearing a net-type interlace décor, initially thought to be metal, some wood pieces, four big rectangular blocks, eight bronze vases (six hydriai and two amphorae) and one black-figured Attic amphora set along the north and south walls of the structure. A reconstitution of the interior of the structure can be found in the seminal article of Maria Bertarelli Sestieri (1985: 686, fig. 2). The walls and the bottom of the bronze hydria and amphorae revealed at the time of the excavation a thick and paste-like yellow-brown organic substance. The interlaced décor with part of the cloth being completely oxidized (Bertarelli Sestieri 1985: 687, fig. 4), the central element was interpreted at the time as a sacred bed supporting the idea of an *oikos* for a *hierogamos* or a symbolic *heroon*-cenotaph by

Pellegrino Claudio Sestieri, the archaeologist in charge who calls it either a '*sacello-heroon*', or in the text a '*sacello ipogeico*' (SESTIERI 1955: 53). This hypothesis was also supported, without any analysis, by the alleged contents of the vases, which most probably due to their yellow color and concrete form, were interpreted as honey e.g., a token of immortality (Figs. 1-2).

In 1985, Maria Bertarelli Sestieri has initiated a set of comprehensive analyses, which renewed the interpretation of the finds. This was a remarkable thorough work although limited since at the time the analytical techniques and references especially for organic analyses were still in infancy and did not allow to push the results very far. Nevertheless, she managed to produce a whole set of interesting results (BERTARELLI SESTIERI 1985: 647-691). The cloth was identified as a large wool cloth, the wood as possibly cypress; the interlaced décor was determined as originally vegetal for which the «*a pannocchia del tipo falsa Spiga*» [imprint of inflorescences in panicle of the false-spike type] suggested to the author the use of flax or hemp material (BERTARELLI SESTIERI 1985: 657). In the contents of the vases, she identified the presence of spores of fungi and hyphae and in the sediment after filtration, filaments of plants, insect casing and small wood fragments plus rare well conserved pollens from several plants, an assemblage which was interpreted as airborne.

For the analyses of the contents, three different laboratories were involved. One laboratory ruled out the possibility of honey based on the pollen count. The second laboratory performed after heating (130°C) a chloroform extraction and hydrolysis, which allowed then to propose a content of fatty acids and alcohols, and a saponification, which led the laboratory to rule out of fat, wax, or resin. The third laboratory performed a simple Gas Chromatography on the contents of the amphora, by which they identified a content of fatty acids with a dominance of palmitic acid (77,4%), an ubiquitous fatty acid, plus oleic, stearic, linoleic, arachidic and heptadecanoic (margaric) acids. These finds have allowed Maria Bertarelli Sestieri to propose a renewed interpretation with a wood offering stand (*trapeza*) for the *obeloi* placed in the center of the *oikos*, wrapped in a wool cloth ornated with laces of vegetal fibers, hand interlaced, which cross each other in the form of a net. The fungi and the hyphae spores were interpreted as coming from a later process of molding. For the contents of the offerings: «*le tre relazioni escludono concordemente che il prodotto contenuto nei vasi sia miele, asseriscono che non si tratta di un'unica sostanza allo stato naturale e ammettono che nel tempo si sia verificata una metabolizzazione, specie dei gliceridi che, data la componente di acido palmitico, quasi certamente erano contenuti nel prodotto*» (BERTARELLI SESTIERI 1985: 660).

MATERIAL AND METHODS

The material contained in Hydriai A and B had been stored since the time of excavation in the Museum in plastic boxes. It appeared as a yellow solid waxy amorphous material, with thin black layers. The thin black layers were interpreted as most probably coming from the contact with the metal, and the observed blue-green crystals as copper salts being the result of a saponification by the contact with the bronze of the vases. Five samples were taken.

Figures 3 and 4 show the five sampling zones selected to minimize the influence of the bronze container on the organic content. Samples A1 and B2 presented an even yellow colour; sample B1 was taken from the black part of the paste and samples B3 and A2 were a mix of yellow and darkish paste.

Chemical analysis

Lipid extractions were performed using established protocols described in detail in earlier publications (DUDD, EVERSHED 1998; GARNIER, VALAMOTI 2016). Briefly, samples (c. 20 mg) were extracted by ultrasonication (dichloromethane/methanol, 2:1 v/v, 4 mL, 30 min). After filtration through silica gel, the solvent was evaporated to dryness under a gentle flow of nitrogen to obtain the first lipid extract (1LE). An aliquot was derivatized with BSTFA (*N*,*O*-bistrimethylsilyl trifluoroacetamide)/pyridine (10:1 v/v, 50 μL, 80°C, 30 min), evaporated to dryness, dissolved in cyclohexane (500 μL) and submitted to GC-HRMS analysis.

Palynological analysis

Only 0.5 g of the sample A1 was analysed. To make the pollen and spores identifiable under the light microscope, the samples were chemically treated simply by adding acetone (C^3H^6O) which allowed the yellow substance to dissolve completely. Using palynological keys and atlases (REILLE 1992, 1995, 1998; BEUG 2015), pollen and spores were identified and counted under the light microscope (Olympus BX41) at a magnification of 400 X or, occasionally, 1,000 X.

THE RESULTS

The strong smell of coconut perceived upon sampling and analyzing characterizes an oxidized oil (CHAPMAN, PLENDERLEITH 1926). No residue of honeycomb was visible.

The chromatograms of the five samples are globally identical, consisting only in fatty acids, mainly palmitic (16:0) and stearic (18:0) acids. Samples B1, B2, and A1 are more concentrated, which allow to detect minor compounds such as short chain-diacids (6:0-dioic to 10:0-dioic) dominated by azelaic acid (9:0-dioic), a distribution characteristic of a degraded unsaturated plant oil. 9,10-Dihydroxy stearic acid (9,10-$(OH)_2$-18:0) is also an oxidative marker of unsaturated fatty acids, mainly oleic acid. Low amounts of oleic acid (18:0) and different regioisomers of linoleic (18:2) acids are identified. The dark colour of sample B1 comes from an oxidation process between oxygen from air and the residue (mainly unsaturated fatty acids giving short chain diacids), generating a series of oxidoreduction reactions catalysed by the Cu^{2+} ion from the copper alloy forming the sides on the hydria as it is observed in easel paintings when copper-based or lead-based pigments interact with siccative oils and resins used as medium, giving highly oxidized fatty acids and creating fatty

acid soaps (GUNN *et alii* 2002). Very minute traces of sitosterol have been identified in sample B1, pointing to a plant oil source. The presence of the 18:2 acids together with the absence of squalene or of the olive triterpenoids allowed to rule out the olive oil. Moreover, the absence of sterols and triterpenoids shows that the oil has incurred some modification process although no marker of cooking has been identified. A second set of analyses on the fatty acids using the DMDS protocol aimed at obtaining a better identification of unsaturated fatty acids did not yield any supplementary result. Triacylglycerids, native biomarkers of oils and fats have been researched through an ESI-MS/MS analysis (GARNIER *et alii* 2009), but they were absent, being totally hydrolyzed into their constitutive fatty acids.

The palynological analyses confirmed the presence of pollen in the contents of the vases, a find already identified by Maria Bertarelli Sestieri in the sediment after centrifugation of the contents, although the author in the publication does not provide the details of the pollen found but simply refer them to «*granuli di polline di varie piante* (…) *portati dal vento*» [pollen grains of various plants (…) airborne] (BERTARELLI SESTIERI 1985: 658). The total count of our study was established at 212 for 0.5 g of analyzed yellow substance, among which 15 Poaceae (Gramineae), 7 Cichorieae, 1 Asteraceae, 2 ribworts (*Plantago lanceolata* L.), 1 Ranunculaceae, 2 sorrel (*Rumex* sp.), 8 oak (*Quercus* sp.), 1 beech (*Fagus* sp.), 3 hazel trees (*Corylus* sp.), 4 birch (*Betula* sp.), 4 *Cerealia*-type, 1 Rosaceae. This environment-type assemblage could indeed be mostly airborne as was hypothesized by the previous analyses; however, the total count does not allow to properly hypothesize the environment. In fact, the overly dominant taxon (163 pollen grains) was of a Cannabaceae type. Many Fossil Pollen Studies (FPSs) assign pollen of either *Cannabis* or *Humulus* to a collective name (C–H, e.g. *Cannabis/Humulus* or Cannabaceae) due to the similarity of the two pollen; some criteria based on pollen diameter and pore protrusion have been developed, which allow to try to discriminate *Cannabis* pollen from *Humulus* pollen in light microscope (MOORE *et alii* 1991; FLEMMING, CLARKE 1998: 81-83, fig. 1; MERCURI *et alii* 2002). According to these criteriums of size as defined by MERCURI *et alii* (2002), 85% of Cannabaceae pollen grains detected in the analyzed substance could be referred to the *Cannabis* type (>28μm), 9% to the *Cannabis-Humulus* type (25< >28μm) and 6% to the *Humulus* type (<25 μm). Knowing that some authors (PUNT 1984) indicate a size of grain comprised 21 μm and 30 μm for the *Cannabis* type with an average size of 26 μm, it is possible that the percentage of the *Cannabis* type retained in this study is underestimated and that all the grains observed belong to the *Cannabis* genus. Thus, the newly defined microscopic criteria allowed a positive identification as *Cannabis sativa* L. (*sensu lato*) pollen (Fig. 6) in the assemblage. Minute plant fibers were also detected in the samples as also iron-oxide type bacteria sheaths probably from a metal residue.

Discussion

In science, negative results are often overlooked, yet interesting. The organic analyses allowed us to rule out elite contents: honey, wine, olive oil, perfume, but also resin or pitch, milk, and most probably animal fat. These results are very surprising for two main reasons: for one, in the more than 200 analyses performed during the MAGI program funded by the National French Research Agency, we have analyzed several funerary contexts in Southern and Central Italy of the same period and the results obtained for the hypogeum of Paestum are significantly set apart. The analyses in the area for the same period in vases of funerary contexts have revealed olive oil (although not frequently), animal-based fats often mixed with plant fatty acids, traces of wine or a fermented grape-based product, resin, or pitch, whether used for flavor or proofing and, in a few cases, the addition of plants although not all aromatic (Pouzadoux *et alii* 2021).

The presence of *Cannabis* in the pollen assemblage is equally surprising, even more so since the chemical fingerprint of the oil could be compatible with a hemp oil (18:1, 20:0, 22:0; Montserrat-de la Paz *et alii* 2014) and since it is one of the possible plants identified in 1985 for the vegetal entrelac décor. However, the pollen assemblage could also be coming from a vegetal environment with hemp as a component, whether at the time of the processing (that is if indeed the oil is of *Cannabis*), at the time of the deposition of the vases and the closing of the structure since *Cannabis* pollen is numerous, ammenophilous, e.g. air-borne and can be carried in large amounts over significant distances or after the discovery as a pollution occurring along the various manipulations of the contents (excavations, storage…). The hypothesis of deposition upon oil processing is somewhat unlikely since the oil would have been produced from the seeds of the female plants, *Cannabis* being mostly a dioicous plant, whereas the pollen is essentially coming from the male plants, which tend to flower earlier than the female ones. However, if male plants were involved in some part of the deposits like for instance the cloth décor, some pollen could have been trapped in the room. Indeed, the male plants are the preferred parts sourced for fibers. The hypothesis of an environmental contamination coming from a cultivation area is possible, although the results coming from a limited total count do not allow to confirm scientifically.

The *Cannabis* finds in early history of Europe have been the subject of comprehensive studies recently (Mercuri *et alii* 2002; McPartland, Hegman 2018 for Italy; Boulen, Zech-Matterne 2012 for France). McPartland and Hegman (2018) emphasize the multiple debates around the taxonomic status, center of origin and history of domestication of *Cannabis* sp., with an analysis based mostly on primary literature. They concluded their review with the fact that there is a lack of robust evidence for the claims of Neolithic hemp usage, with robust evidence only starting from the Bronze Age. In France, Boulen and Zech-Matterne (2012) showed, based on archaeobotanical results, the ambiguity of the evidence for documenting hemp uses and history. In Italy, the archaeobotanical literature tends to interpret hemp as a native from ancient periods, possibly as an adventitia of the Neolithic

package introduction, with *Cannabis* pollen grains being positively identified as early as the Neolithic. The authors document an increase around 3000 BP, and a peak in the 1st c. BCE (MERCURI *et alii* 2002). They currently interpret the data as a development through cultivation by the Romans. However, a few finds of fibers, some of them associated to metal, testify that hemp was used in pre-Roman times. Hemp was identified in the tabby of a metal weapon of the Final Eneolithic-Early Bronze Age at tomb 6, Gricignano d'Aversa (BAZZANELLA 2012: 210); as a small rope fragment on a 6th or 5th c. BCE iron object from Colle Madore (TERRANOVA, LO CAMPO 1999), as the fiber of a tabby, found in a 5th BCE burial at Himera (DI SCLAFANI *et alii* 2005), and on cordages of a shipwreck context at Pisa San Rossore, dating from Etruscan-Roman times (LENTINI, SCALA 2002, 2005).

In the literature, *Cannabis* finds are very often interpreted through the lens of their psychotropic usage even when the nature of the finds tends to point to less mundane functions. Such a use can be ruled out in the case of Paestum. Indeed, the use of psychotropic hemp in an archaeological context can be detected through positive chemical markers residues of cannabinoids such as Δ^9-tetrahydrocannabinol (THC), cannabidiol (CBD) and cannabinol (CBN). These markers have been identified so far in Northern China in Xinjiang, in a Yanghai tomb dated 2500 BP (RUSSO *et alii* 2008; JIANG *et alii* 2006; MUKHERJEE *et alii* 2008) and in other tombs of the same cemetery (REN *et alii* 2019); the markers have also been recovered recently in Israel on an 8th BCE altar in Arad (ARIE *et alii* 2020) and in two contexts in Europe, one in Spain in a Neolithic/Chalcolithic context (GARNIER *et alii* 2022) and one in France in a pre-Roman period (Garnier, pers. com.). No such finding is documented for Italy yet and the contents analyzed for Paestum did not yield the relevant markers for a psychotropic usage, which can, thus, be ruled out.

Indeed, as shown above, the finds documented so far in Italy tend to point to a utilitarian technical use for pre-Roman contexts, which is confirmed by the Latin agronomists (Varro *rust.*; Colum. 1.2, cap. 10), who classify it also among '*legumina*'. Hemp is later cited by Pliny the Elder (Plin. *nat.* XIX, 273-274), and Dioscorides (Diosc. III, 149.1) for some medicinal uses, both also mentioning the use as ropes (Plin. *nat.* XX, 259), but is absent from several major authors of the period as shown in Butrica (2002: 53-54; see also FABRE 2006 for a review). Thus, if not an environmental contamination, the finds of the *Cannabis* pollen should most probably be interpreted as linked to some of the artefacts deposited.

There is one instance where fibers or textile from *Cannabis* in an Etruscan early context may be associated to some epic mythology. This is a representation on a bucchero *olpe* found in Cerveteri (Tomb n. 2) dated to the second half of the 7th c. BCE and interpreted as representing the Argonauts. Among the three Etruscan legends, the word *kanna* is inscribed on an object carried over by six young men (RIZZO, MARTELLI 1988-1989). The word is considered as an Etruscan transliteration of the Greek world *kannabis* (BELELLI 2002-2003) although this interpretation is not entirely accepted (RIX 2002-2003). The object is diversely interpreted to represent the sail of Argo (BELELLI 2002-2003; BENELLI 2006: 114) which

would be in hemp, the dress brought back by the Argonauts from Lemnos (RIZZO, MARTELLI 1988-1989), or a luxury cloth to reward the fighters of the *pygmatia* represented on the vase (GRAN-AYMERICH 1999: 390, fig. 4 with an analysis of the various interpretations). This could represent an occurrence associating hemp – that is if we accept the equivalence *kanna-kannabis* – to some sort of heroic setting, but the interpretation of the vase has been and is still very much discussed. Thus, the evidence is overall too scarce to hypothesise the precise role of hemp in Paestum, a contamination from the ropes or décor, an environmental contamination, whether historic or contemporary or a symbolic use.

CONCLUSION

This work has allowed to confirm and build upon with more data the previous work of M. Bertarelli Sestieri. Our results confirm that the contents of the precious vases do not fit into the main Mediterranean ritual organic matters (honey, olive oil, wine…). Thus, the nature of the contents cannot be used to sustain the hypothesis of a heroic cult for the place. Nevertheless, the deposition of a pure highly unsaturated oil in such luxurious vessels is intriguing. The highly unsaturated oil has undergone some sort of treatment, but without intense heating (e.g., it has not been cooked) and the analyses have not allowed to identify the nature of the treatment. The contents are solid – an element that gave ground to the interpretation of honey in the early discovery phase. The solid state could be explained by two reactions: (i) the natural oxidation of the unsaturated oil by oxygen, giving a complex mixture or polyhydroxylated fatty acids that are solid at room temperature. They also explain the yellow color and the rancid and fruity smell of the residue; (ii) the interaction between fatty acids and the metallic container, giving copper and other metallic salts as observed in painting when copper- or lead-based pigments are mixed with plant oil as binder. The metallic ions also assist the oxidation of the unsaturations by ionic catalysis (COCCATO *et alii* 2017).

This is still a work in progress and additional analyses would be required to go further, especially to try to elucidate the oil signature by experimental organic analyses aging *Cannabis* oil in order to identify its archaeological signature versus other siccative oils. Indeed, the specific signatures of the siccative oils in archaeological residue analyses are still poorly understood, a fact which does not allow to interpret properly the results.

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Fig. 1: One of the amphoras retrieved from the *heroon* (courtesy of the Museum of Paestum).

Fig. 2: Hydria A, retrieved in the *heroon* (courtesy of the Museum of Paestum).

Fig. 3: Sampling zones Hydria A.

Fig. 4: Sampling zones Hydria B.

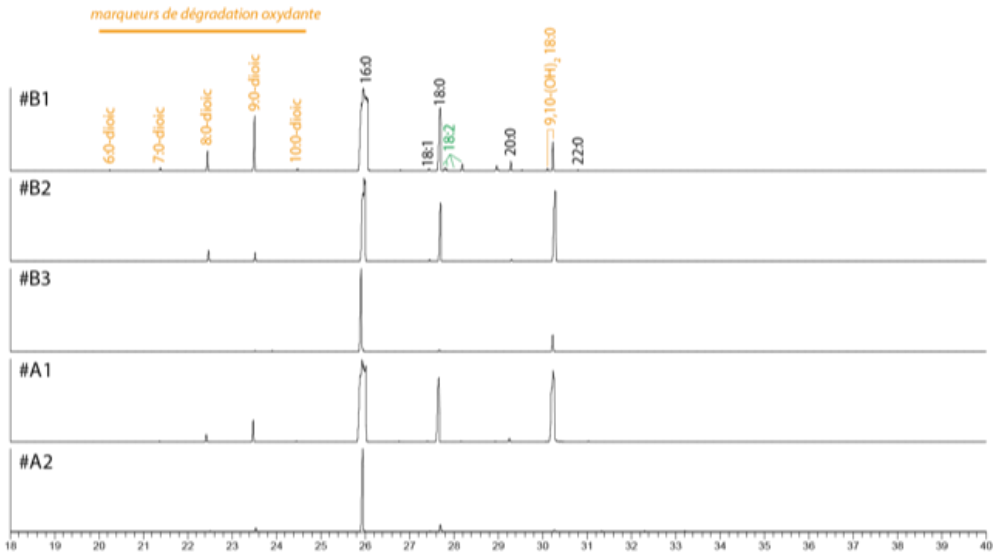

Fig. 5: 1LE.TMS of Paestum of samples from Hydriai A and B; in orange the markers of oxidative degradation.

Fig. 6: Paestum, pollen grain of *Cannabis sativa* L. in sampling from A1.