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The embalmed heart of Richard the Lionheart (1199 A.D.): a biological and anthropological analysis

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During the Middle Ages, the partition of the cadaver of the elite members was a current practice, with highly technical treatment given to symbolic organs such as the heart. Considered mostly from a theoretical point of view, this notion of dilaceratio corporis has never been biologically explored. To assess the exact kind of embalming reserved to the heart, we performed a full biomedical analysis of the mummified heart of the English King Richard I (1199 A.D.). Here we show among other aspects, that the organ has been embalmed using substances inspired by Biblical texts and practical necessities of desiccation. We found that the heart was deposed in linen, associated with myrtle, daisy, mint, frankincense, creosote, mercury and, possibly, lime. Furthermore, the goal of using such preservation materials was to allow long-term conservation of the tissues, and good-smelling similar to the one of the Christ (comparable to the odor of sanctity).

Richard I, King of England (nicknamed "Richard the Lionheart" because of his reputation as a courageous warrior and military leader) has been a central Christian commander during the 3rd Crusade after the departure of Philippe-Auguste, King of France, fighting against his Muslim counterpart, Saladin (1189–1192). He died in Châlus (close to Limoges, in the Centre of France) on the 6th of April 1199, 12 days after a wound he suffered at the left shoulder close to the cervical vertebra from a French arbalest while fighting without any chain mail[1]. Cause of death was reasonably gangrene and/or septicaemia, even if some fantasized about a poisoning caused by toxics deposed on the arbalest's arrow[2].

According to the common medieval practices, a partition of the cadaver was performed, the internal abdominal and thoracic organs (entrails) were placed within a coffin in Châlus, the heart was embalmed separately and deposed in the church of Notre-Dame in Rouen (head of the English occupation of Normandy territories at that period), and the rest of the body was inhumed at Fontevraud Abbey, close to his father the King Henri II (and later to his mother Eleanor of Aquitaine)[1]. The partition of the body was widespread among the aristocracy at that time[3]; indeed, 16 years before his death, his brother Henri *au court mantel* had received a double grave: entrails, eyes and brain were deposed in Grandmont, while the rest of the embalmed body was inhumed in the church of Notre-Dame in Rouen[1].

An intact 12.2 × 23 × 17 cm lead box containing the remains of Richard's heart – a brown-whitish powder – was discovered on the 31st of July 1838 by the local historian Achille Deville close to the funeral effigy of king Richard I during excavations of the Rouen cathedral[4]. The sealed box was engraved with a funerary inscription (HIC IACET COR RICARDI REGIS ANGLORUM, i.e. "Here is the heart of Richard, King of England") whose characters were typical of the 12th–13th century AD. (Fig. 1a)[5].

In order to better know the context of the death and *post-mortem* treatment of the organ, we submitted samples of the embalmed heart to a complete biomedical analysis (chemistry, palinology, anthropology, paleopathology,

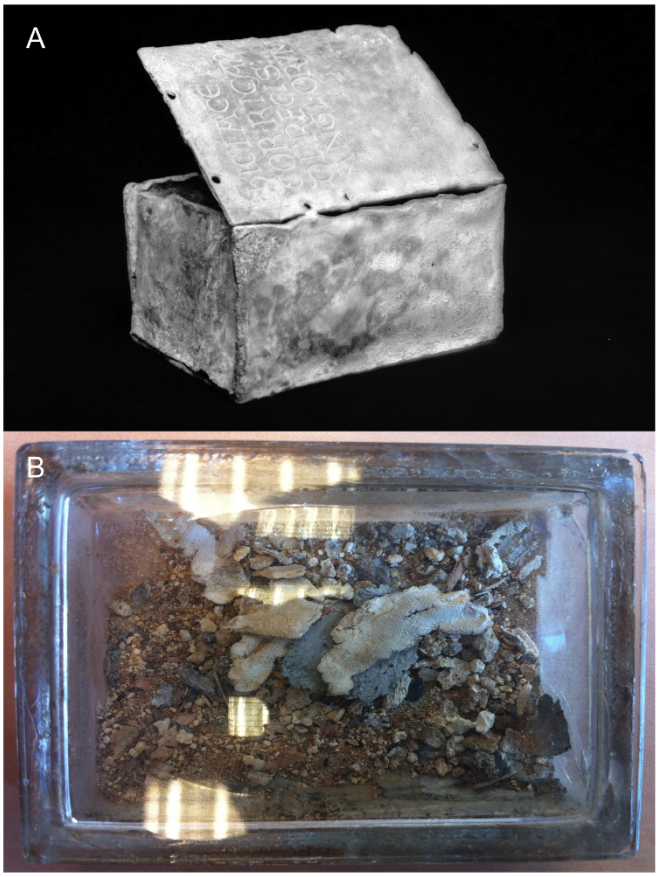

Figure 1 | The heart box of Richard I (photo credit: Musée départemental des Antiquités © Yohann Deslandes/CG76) (A). Actual aspect of the crystal box containing the remains of the mummified heart of Richard I (picture by Philippe Charlier) (B).

microscopy, etc.). Following the will of cultural authorities, for who the authenticity of the remains was everything but dubious, no genetic analysis was carried out. ^{14}C dating was not performed for the following reason: the presence of balm, oil and organic embalming residues may have been at the origin of a huge contamination of the sample and aberrant carbon dating result despite successive solvent extractions, impossible on such a tiny quantity of material.

Results

Preliminary examination under binocular lenses showed the presence of tiny remains of textiles made of linen (a thin equilibrated cloth of 50 threads per centimetre in both directions: chain and weft). Simple threads with a moderate Z torsion (Fig. 2a) were compatible with a 12th–13th c. A.D. and European origin[6].

The optical analysis of the brown-whitish powder showed the presence of numerous vegetal structures, altered cell structures, mineral and crystal formations. No clearly identifiable tissue was visible (heart tissue, e.g. muscle fibres, for example), but the human muscle nature of the altered cell structures was confirmed by a slight to moderate positive signal using antibodies anti-myoglobin (human, MG1) and anti-myosin (human, MY32).

The optical and scanning electron microscopic analysis showed the presence of various pollen grains (Table 1): myrtle, daisy, mint (Fig. 2b), pine, oak, poplar, plantain, bell-flower. Numerous isolated bacteria (*Bacillus sp.*) and fungi (*Aspergillus sp.*) were observed, but of *post-mortem* origin (Fig. 2c and 2d), therefore not related to the cause nor to the manner of death of Richard I. No one parasite was identifiable.

Elemental analyses revealed large amounts of lead and tin, and traces of copper, mercury, and antimony (Table 2)[11]. Calcium may have been added during the embalming process, as the very slight amount of associated aluminium would eliminate an environmental origin (i.e. a soil contamination)[11]: indeed, lime (calcium oxide or hydroxide) is known as disinfectant and desiccant[12], and such properties justify its use during an embalming, in association with other products, including plants.

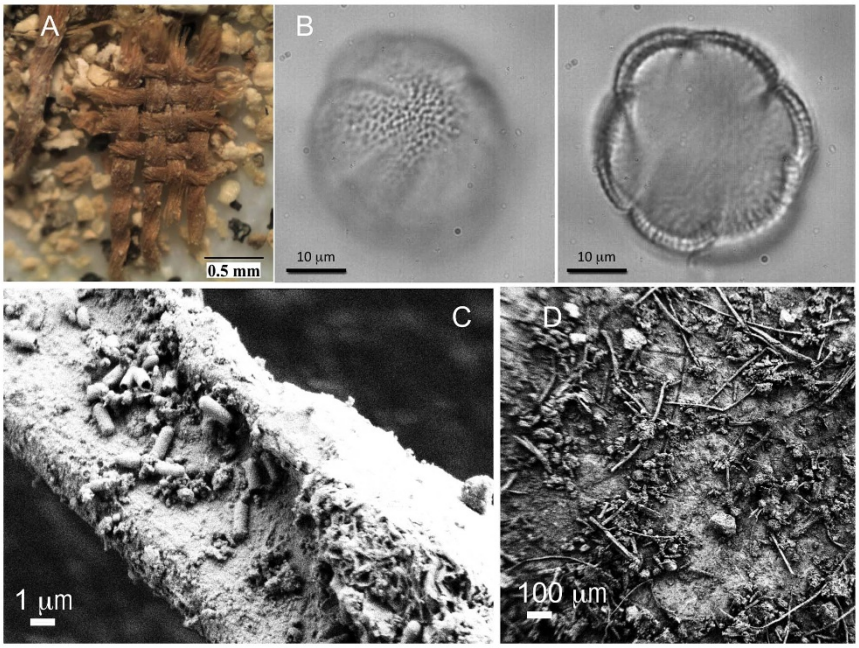

Figure 2 | Detail of the textile fragments and whitish organic powder under binocular lenses (picture by Joël Poupon) (A). Surface view and optical section of a pollen of *Mentha sp.* Lamiaceae under optical microscope (magnification x1000) (picture by Speranta-Maria Popescu) (B). Detail of a group of bacteria (*Bacillus sp.*) within the embalming matter of the mummified heart (SEM, magnification x4840) (picture by Raphaël Weil) (C). General view of the post-mortem development of fungi (*Aspergillus sp.*) within the embalming matter of the mummified heart (SEM, magnification x50) (picture by Raphaël Weil) (D).

Table 1 | Results of palynological analyses on the sample of the white powder from the heart of Richard I

Identified taxa (family, genus and species when possible)	Number of pollen grains	State of preservation of pollen grains	Period of pollination of referred plants	Present-day geographic distribution of referred plants
Pinus, Pinaceae	4	Poor	May-June	(*Pinus silvestris* (Scots pine), only one specie spontaneous in the north-western Massif Central
Quercus ilex (holm oak), Fagaceae	1	Moderate	April-May	Common in the Mediterranean region, but also distributed in Western France up to Brittany
Plantago (plantain), Plantaginaceae	1	Moderate	> April	*Plantago* species widely distributed in western France
Campanulaceae	1	Good	> April	Several genera (*Campanula i.e.* bellflower, *Jasione*, *Phyteuma*, etc.) widely distributed in France
Myrtus communis (myrtle), Myrtaceae	3	Good	May-July	Sweet-smelling plant endemic of the Mediterranean region
Asteraceae Asteroideae (chrysanthemums, maybe the species *Leucanthemum vulgare* (daisy) according to the small size of the pollen grains (<20 μm)	2	Good	May-August	Widely distributed in France
Lamiaceae (*Mentha* (mint), according to the ornamentation of exine)	1	Good	July-October	*Mentha* (mint) displays several species living in Western France such as *M. silvestris* (sweet-smelling plant; blooming July-September), *M. viridis* (August-October), *M. aquatica* (July-September), *M. arvensis* (strong-smelling plant: July-October), and *M. Pulegium* (strong-smelling plant: July-October)
Populus (poplar), Salicaceae	1	Good	March-April	Three species of *Populus* (*P. alba*, *P. tremula*, *P. nigra*) widely distributed in France

SPME analyses did not enable us to retrieve pertinent information. Traces of monoterpene were found, mainly limonene. The direct desorption of the white matter (Fig. 3a) permitted to identify triterpenoid compounds with ursane and oleanane type structure (Fig. 4). From these compounds α-amyrin (Urs-12-en-3-ol), β-amyrin (Olean-12-en-3β-ol), α-amyrenone (Urs-12-en-3-one) and α & β-boswellic acids were identified. These molecules are characteristic of natural gum-resins from the *Burseraceae* family and specifically α & β-boswellic acids characterize olibanum (frankincense)[14]. Olibanum resin from Somalia has been analyzed and confirmed this hypothesis (reference material from Kremer Pigmente n°60270, *gummi olibanum somalia* nr. 1, weihrauch).

The direct desorption of the dark matter (Fig. 3b) permitted to identify triterpenoid compounds with ursane and oleanane type structure, the same as mentioned previously. Saturated fatty acids with even number of carbon atoms from C16 to C24 and the unsaturated oleic acid have also been found; these compounds are present in vegetable oils. In addition, eugenol and vanillin have been detected, associated with several phenolic derivative compounds (mainly guaiacol, 4-ethyl guaiacol, 4-vinyl guaiacol, cresol and 2,6-dimethoxy phenol derivatives). This family of substances is characteristic of wood-tar product, creosote type. Creosote is the portion of chemical products obtained by the distillation of a tar that remains heavier than water, notably useful for its anti-septic and preservative properties.

Discussion

The elemental analyses of the white powder found a huge quantity of lead, obviously originating from the reliquary, explaining also the presence of tin, antimony and bismuth, classically found in poorly purified lead[15] from the Middle Ages[16]. Iron may also be attributed to iron hardware of the reliquary. On the contrary, mercury is attested in embalming both in literature and in Medieval and Renaissance mummification practices; for example, Guglielmo of Saliceto in his *Chirurgia* (1275 ca) and the French surgeons Henri de Mondeville (*La chirurgie*, 1306–1320) and Guy de Chauliac (*La grande chirurgie*, 1363) refer to the use of "quicksilver" in the *post-mortem* treatment of bodies; more, mercury was found in the burial of Jean de Lancastre, duke of Bedford (died 1435) in the Rouen cathedral[17], and in the burials of the French Queen Anne de Bretagne (died 1514) and the French King Charles VII (died 1461) in the St Denis basilica[18]. In 1866, at the first opening of the grave of the Duke of Bedford, metallic mercury was found in great quantity (11.25% of the mass, i.e. 112,500 μg/g). Non-metallic mercury was not determined. Fifty-two years later, a new and more complete analysis performed by Le Roy showed that total mercury represented 8.03% (80,300 μg/g) of the solid mass, and metallic mercury only 4.08% (40,800 μg/g), the rest (3.85% or 38,500 μg/g) being in a combined form[17]. Then, more than fifty years after, 36% of the metallic mercury had disappeared. After several experiments, Le Roy concluded that mercury must have been employed as an emulsion of metallic mercury in a balsamic-like substance[17]. The amount of mercury found in Richard's heart (150 μg/g), even if considerably less than the levels observed in the rest of the Duke of Bedford, may indicate the use of another mercury compound such as mercury chloride (calomel); it cannot be considered in any case as originating from lead impurities, as it is never retrieved in ancient lead[15].

Pollen grains recorded in the heart powder may originate from embalming products and/or airborne contamination. The interpretation of such results needs a comparison with Medieval and

Table 2 | Results of elemental analyses on the white powder from the heart of Richard I

Weight (mg)	Pb (μg/g)	Sn (μg/g)	Sb (μg/g)	Cu (μg/g)	Bi (μg/g)	Hg (μg/g)	Fe (μg/g)	Ca (μg/g)	Al (μg/g)
0.75	183,148	4,280	22	102	13	150	3,580	59,420	700

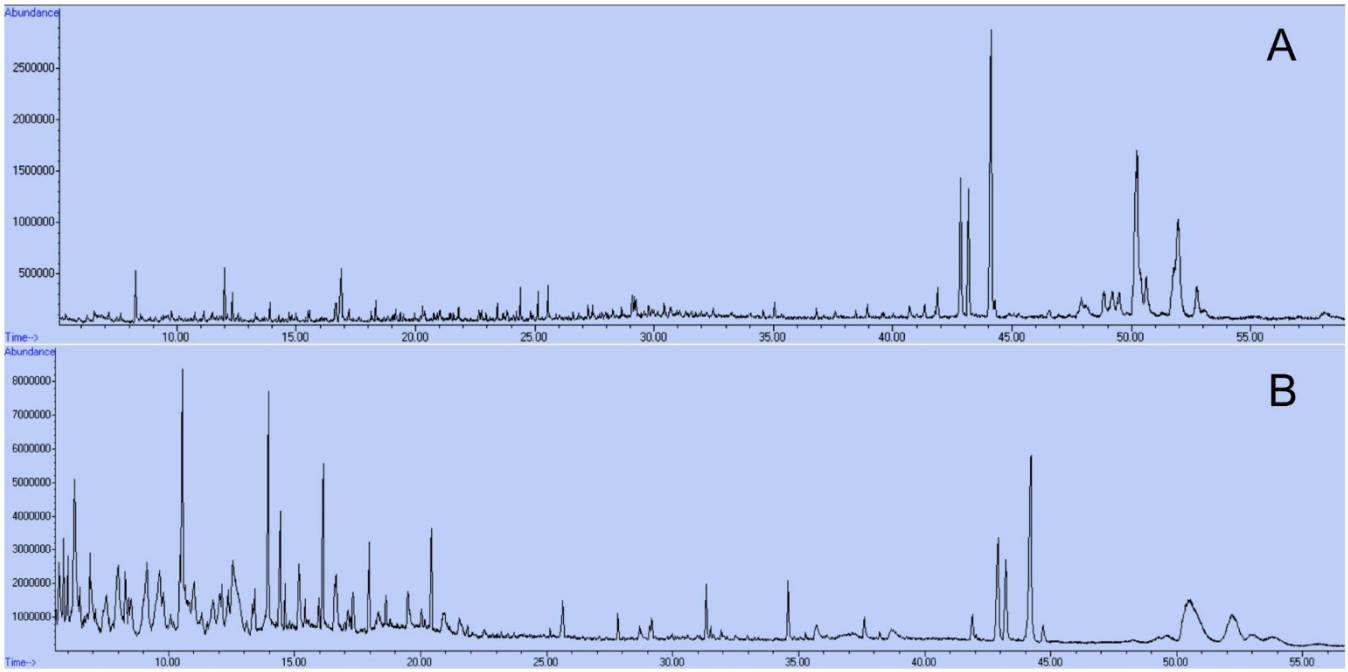

Figure 3 | Chromatogram from the direct desorption of the white matter sample (A) and dark matter sample (B) from the heart's fragment of King Richard the Lionheart.

Renaissance literature about plants and vegetable substances used during the embalming process, but also with the period and localization of the preparation of the cadaver of King Richard I. Some pollen grains must undoubtedly be considered as originating from embalming products (myrtle, daisy, mint), whose pollination occurs long before/after Spring; they also may have been stored before their use during the embalming process (that occurred short after the 6th of April 1199)[7–10]. It is noteworthy that their state of preservation is better than the other recorded pollen grains (Table 1): pine, Holm oak, plantain. That may indicate some transport by air and the resulting oxidation. They are hence considered as contaminated external material, excluding their use during the embalming process, as pine resin is also a substance attested in embalming, for example in the treatise *La practica in arte chirurgica copiosa* by Giovanni da Vigo (1450–1525)[19]. Two other pollen grains, even if we consider them as external contaminations, are well preserved: poplar (characterised by a fragile pollen) and bellflower. Poplar and bellflower were blooming at the time of the death and embalming of the King. Accordingly, we interpret their presence in a so good preservation state in relation with the short time-interval between their pollination and contamination of the heart contain, and probably their nearby distribution (*i.e.* short transport and weak risk of oxidation).

Molecular analyses showed the presence of frankincense (corresponding to the white matter) and wood tar product, creosote type (corresponding to the dark one)[13]. Frankincense was a non-negligible part of all embalming process during medieval times[14], as this symbolic substance appeared at both extremities of the Christ life: presented by the Biblical Magi at His birth, and used during His external embalming after the Passion.

The goal of using such materials was to allow long-term conservation of the tissues, and good-smelling close to the one of Christ (comparable to the odour of sanctity)[20]. Comparable examples from

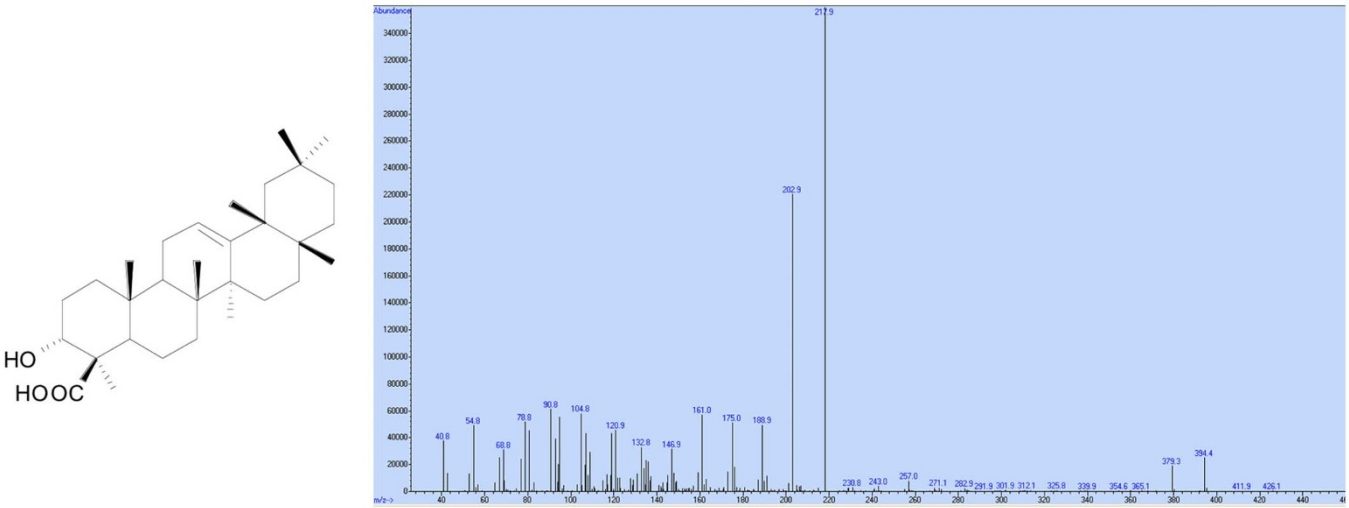

Figure 4 | Oleanane type structure (alpha-boswellic acid) and its mass-spectra.

later periods (13th to 19th c.) have been described, particularly in Italy: Cangrande della Scala (1291–1329)[21,22], members of the Medici family in Florence[23], the Aragonese mummies in San Domenico Maggiore, Naples[24,25], the Blessed Christine of Spoleto (1432–1458)[26], Salimbene Capacci (1433–1497) and his wife Margherita Sozzini (died in 1511)[19], late Medieval and Renaissance Saints[27], etc. Comparable substances and plants known as filling materials of these mummies have been described (mint, rose powder, myrtle, etc.), but the case of Richard I may represent the oldest physical example of their use during an embalming process. Daisy and incense (oliban) have not yet been described in other cases of mummified corpse or anatomical fragment.

In addition, it is important to mention that even if the heart was completely pulverized at the time of our examination (and of its discovery in the 19th c.), it does not mean that the embalming was not successful, just that the equilibrium was lost between the mummified organ and its direct environment due to the alteration of the metal box and water infiltrations from the ground.

The use of such conservation products above-mentioned, reveals the influence of cooking and pharmacy for the embalming of viscera, and particularly the heart. Indeed, the first embalmers (12th c. AD) were cooks, i.e. those who were used to open the meat and cut the offal, but also had access to herbs, spices and other odoriferous substances[28]. Then it was the turn of apothecaries and afterwards, chemists[29], using plants, sometimes exotic and disinfectant solutions proved to be efficient for the medium and long-term conservation of human cadavers after their opening by surgeons and barbers[3].

This embalming process in the case of King Richard was, first of all, necessary for practical reasons: the organs were treated because the King's body had to reach the definitive burial (Rouen) which was far from the death place (Châlus): almost 530 kilometres. Other reasons, political this time, could have motivated this partition of the body, such as the appropriation of a territory using physical parts of the King[30–33]. In the case of the controversial life of Richard I, it is equally possible that the *post-mortem* treatment of the organs (and particularly the heart), inspired by biblical spices, was necessary in order to accelerate his religious apotheosis. Indeed, as stated by a 13th century bishop of Rochester[34,35], Richard the Lionheart spent 33 years in Purgatory as expiation for his sins, and ascended to Heaven only in March 1232.

With embalming, symbolically, the deceased is identified as the Christ whose body was scented with spices by Joseph of Arimathea before being placed in his tomb. This study conducted on the mummified heart of Richard the Lionheart (died 1199) made it possible to ascertain that the organ has been filled or covered with a mix of vegetal and mineral material. Since the studied organ was entirely turned into powder, we ignore if an opening of the heart occurred prior to any embalming, and the exact aspect of the embalming material (liquid and/or salts).

This embalming method is of great importance, as we do not have any procedure or surgical treatise known for this period (end of the 12th c. AD.) describing the methodology and/or composition of the embalming material.

Methods

We sampled this highly fragmented mummified heart in 2012 (a total of 2 grams from an amount of almost 80 grams, now conserved in a crystal box: Fig. 1b).

A preliminary macroscopic examination completed with binocular lenses (magnification ×20 and ×40) was carried out. Further analyses were then performed.

An optical microscope analysis of six samples from the white and black powder was carried out as follows: after a short rehydration and decalcification of 30 minutes in a solution of 10% NaCl diluted in pure water plus 100 µL of 100% acetic acid, 200 µL from the supernatant were sampled. This liquid was then centrifuged (1000 turns per minute for 10 minutes) in order to obtain one spot per slide (Superfrost®). A total of four slides were obtained, two coloured by the technique of Hematein-Eosin-Saffran (HES), two for further cyto-immuno-chemistry analysis (respectively Biogenex® antibodies anti-myosin (human) MG1 and anti-myoglobine (human) MY32): antigen retrieval was performed according to the laboratory recommendations for primary antibodies, then slides were washed in de-ionised water, neutralized of endogenous peroxydase using peroxydase block for 5 minutes, washed in TBS for 2 × 5 minutes, incubated with protein block for 5 minutes, washed in TBS for 2 × 5 minutes, incubated with optimally diluted primary antibodies according to the laboratory recommendations, washed in TBS for 2 × 5 minutes, incubated with post-primary block for 30 minutes, washed in TBS for 2 × 5 minutes, incubated with NovoLink® polymer for 30 minutes, washed in TBS for 2 × 5 minutes with gentle rocking, developed peroxydase activity with DAB working solution for 5 minutes, washed in water, counterstained with hematein, washed in water for 5 minutes, dehydrated, cleared and mounted.

A palynological analysis was performed on only one available sample made of 0.5 gram of the white powder prepared as follows; attack by KOH 5% without heating in order to destruct vegetal tissues without affecting pollen grains. After centrifugation and rinsing, the final dried residue has been diluted within glycerol providing a total volume of 100 µl, being separated into two parts of 50 µl each put between slides and cover glasses. The two slides have been completely examined at optical microscope (x250) and provided a total of 14 pollen grains only (Table 1). Each pollen grain has been observed at magnification ×1000 for the detailed examination of its morphology and its identification. Identification of pollen grains mainly refers to the personal bank of modern pollen grains (pollen slides and photographs) of one of us (S.M.P.) and to the Reille's Atlases[7–9]. Information on plant systematic, distribution and flowering refers to the Coste's Flora[10].

A scanning electron microscope analysis was performed on two samples from the white powder, for both of them, morphology observations and chemical analyses were made (Zeiss® Supra 55 vp with an energy-dispersive X-ray spectrometer Bruker® SDD detector). The field-effect "gun" microscope (FE-SEM) operates at 0.5–30 kV. High-resolution observations were obtained by 2 secondary electron detectors: an in-lens SE detector, and an Everhart-Thornley SE detector. To maintain the integrity of the samples, measurements were taken without the usual deposits of carbon or gold at the surface of the sample.

An elemental analysis was performed on a small sample from the white powder (0.75 mg). Techniques used were: Inductively Coupled Plasma Mass Spectrometry (ICP-MS) (Elan DRCe quadrupole spectrometer, Perkin Elmer®, Les Ulis, France) and Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-OES) (JY 24, Horiba Jobin Yvon®, Longjumeau, France). For both techniques, samples were first mineralized with hot concentrated nitric acid (Nitric acid 65% Suprapur®, VWR, Fontenay-sous-Bois, France) and completed with ultra pure water (MilliQ®, Millipore, Molsheim, France) to obtain a final volume of 0.5 mL. In order to detect elements of interest, a fast semi-quantitative analysis of all elements of the periodic table with the ICP-MS TotalQuant method was first effectuated. Nine elements were thereafter quantitatively measured: Pb, Sn, Sb, Cu, Bi, Hg by ICP-MS and Fe, Ca and Al by ICP-OES.

A molecular analysis was carried out on two samples from the white powder. SPME (Solid Phase MicroExtraction) has been used to trap organic volatile compounds from the samples and gas chromatography/mass spectrometry (GC/MS) analysis has been carried out in order to identify them. Samples have also been directly placed in a glass liner into the injector of the chromatograph and organic components have been directly desorbed at 300°C during five minutes (detail of equipment: GC/MS Agilent 6890 fitted with the Mass spectrometer 5973 mounted with an adapted purge and trap technique; Gerstel® Combipal with the CIS4 injector).

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Author contributions

P.C. headed the whole study, performed the microscopic analyses, and wrote the main manuscript, with significant input from I.H.C., A.M.L., C.H. and G.L.D.L.G. and the other co-authors, based on their direct results. J.P. carried out the elemental analyses. G.F.J. and D.F. carried out the head-space studies. S.M.P. performed the pollen grain analyses. R.W. carried out the MEB examination. C.M. carried out the textile analysis. C.D.P. carried out the subsequent historical documentation. All authors reviewed the manuscript.

Additional information

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