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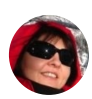

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The embalming of John of Lancaster, first Duke of Bedford (1435 AD): A forensic analysis

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Abstract

During the Middle Ages and Renaissance, embalming the cadaver of the elite was common practice, being a highly technical treatment mixing vegetal and mineral substances. To assess the exact kind of embalming reserved for the dead body (with the practical necessities of desiccation and good odour), we performed a full biomedical analysis of the mummified remains of John Plantagenet of Lancaster, first Duke of Bedford, regent of France for his nephew, the English King Henri VI (died 1435 AD). Here, we show, among other aspects, that the body was embalmed using substances whose origins were in apothecary and botany: mercury, myrtle, mint, frankincense, lime and, possibly, cinnamon and copper.

Keywords

Forensic anthropology, identification, history of medicine, status of the cadaver, microscopy, palynology, elemental analyses, toxicology, SEM, embalming

Introduction

John Plantagenet of Lancaster, first Duke of Bedford (Figure 1), was the third surviving son of King Henry IV of England by Mary de Bohun. Born on 20 June 1389, and brother of the King Henry V, he acted as regent of France for his nephew, King Henry VI. Bedford had been Governor in Normandy between 1422 and 1432 where the University of Caen was created under his auspices. He defeated the French several times, most notably at the Battle of Verneuil, until the arrival of Joan of Arc rallied the opposition. In 1431, Bedford had Joan tried and executed at Rouen, then arranged a coronation for the young Henry VI at Paris.[1] He died suddenly on 14 September 1435 during the Congress of Arras at his castle of Joyeux Repos in Rouen, and was buried on 30 September 1435 at Rouen Cathedral (where he had been received as a canon in 1430).[2,3] Calvinists mutilated the black marble monument in 1562 during the French Wars of Religion, and the rest of the monument was destroyed entirely in 1734–1736, although the coffin remained intact in the ground until its discovery by the abbot Cochet on 19 October 1866.[4,5]

The lead coffin, east–west oriented, was discovered 95 cm under the 1736 pavement. It was 1–2 mm thick (thinner at the foot than at the head), 20–25 cm high, and 20–25 cm round. It had been previously conserved in a 3–4 cm thick oak coffin, according to nails discovered during the excavations. The lead coffin was already open because of the pressure of the ground on its upper part, from the head to the knee. A chemist examined the laminated lead coffin upon discovery, and found that it comprised 97% lead, 1.62% tin, 1.38% iron and zinc. The body was lying on its back, both hands crossed on the abdomen. Its was excellently preserved, due to a 2 cm thick blackish

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Figure 1. John, Duke of Bedford (left), as seen on a contemporary miniature (British Library, London, MS 18850, f°256v).

crust covering the whole cadaver. No metal was present inside the coffin. A white textile (identified as linen) was filed on the body, forming a cross. After careful examination, the whole body was placed back into its original coffin, and samples of the blackish embalming substance were separately conserved for further analyses.[4,5]

According to common medieval practices, embalming occurred after death, but no historical chronicle mentions any segmentation of the cadaver (*dilaceratio corporis*), a practice that was widespread among the aristocracy at that time.[6] The fully embalmed body was inhumed 16 days after death at the Cathédrale Notre-Dame in Rouen (capital of the English occupation of Normandy territories in that period).

Just after the remains were discovered, samples of the hairs and embalming substance were conserved in a sealed crystal box (2.2 cm × 8.4 cm × 5.4 cm), now conserved at the Departmental Archaeological Museum in Rouen (N° Inv. 1172.1). A second sealed crystal box (N° Inv. 1172.2), containing some lead fragments and an altered sheet of silk from the same grave, has not been sampled. At the end of the archaeological excavations, the rest of the body was conserved at its original place.[5]

In order to understand better the context of the death and post-mortem treatment of the dead body, we submitted samples of the embalmed material to a complete biomedical analysis (chemistry, palynology, microscopy, etc.). Following the wishes of cultural authorities, for whom the authenticity of the remains was anything but dubious, no genetic analysis was carried out because of the very limited quantity of the remains. ^{14}C dating was not performed because of contamination of the sample by the presence of balm, oil and organic embalming residues, and successive solvent extractions would have been impossible on such a tiny quantity of material.

Figure 2. Actual aspect of the crystal box containing samples of the cadaver of John, Duke of Bedford (N° Inv. 1172.1; picture by Yohann Deslandes, Departmental Museum of Antiquities © Department of Seine-Maritime).

Materials and methods

We sampled this highly fragmented mummified material in 2012 (a total of 2 g from an amount of almost 50 g, now conserved in a crystal box; Figure 2). The protocol was comparable to that of the remains of the heart of Richard the Lionheart conserved at the same museum.[7,8]

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

A palynological analysis was performed on only one available sample made of 0.5 g of the black powder prepared as follows. First, an attack by KOH 5% was carried out without heating in order to destroy vegetal tissues without affecting pollen grains. After centrifugation and rinsing, the final dried residue was diluted within glycerol, and 50 µL of the residue was placed between a slide and cover glass. The slide was examined completely with an optical microscope (×250) and provided a total of 108 pollen grains (Table 1). Each pollen grain was observed at a magnification of ×1000 in order to examine its morphology and identification in details. A pollen study was performed using a ZEISS SUPRA 55 VP scanning electron microscope (SEM-FEG-GEMINI field emission column), allowing a spatial resolution down to 1.0 nm. Topographic images (secondary electron images) were realised using the InLens and Everhart-Thornley SEM detectors.

Table 1. Results of palynological analyses on the sample of the mummified remains of the Duke of Bedford.

Identified taxa (family, genus and species when possible)	Number of pollen grains	Period of pollination of referred plants	Present-day geographic distribution of referred plants
Onopordum and *Serratula*, Asteraceae Asteroideae	49	May to June	*O. acanthium* and *S. tinctoria*, blooming from June to September and July to September, respectively. In the past, the latter was intensively used by dyers to make a yellow dye.
Artemisia genus, Asteraceae	36	September and October	Among the species living in north-west France (*Artemisia absinthium*, *A. vulgaris*, *A. campestris*, *A. maritima* and *A. gallica*), *A. maritima* shows a pollen with many similarities with those recorded within the heart (thick ectexine and endexine, large columellae).
Lamiaceae, *Mentha* (mint)	11	July to October	This stephanocolpate pollen, specific of Lamiaceae, shows an ornementation of exine similar to that of *Mentha* (mint) which displays several species living in northern France such as *M. rotundifolia* (strong and rather unpleasant smelling plant), *M. silvestris* (sweet and rather pleasant smelling plant), *M. aquatica* (strong-smelling plant), *M. arvensis* (strong-smelling plant) and *M. pulegium* (very strong-smelling plant). Present pollen grains of four of these species have been observed and pollen morphology allows two species to be selected: *M. aquatica* and *M. arvensis*.
Centaurea	1	June to October	Five species (*C. pratensis*, *C. nigra*, *C. scabiosa*, *C. amara* and *C. jacea*) inhabit north-west France.
Asteraceae Cichorioideae	1	–	This typical pollen, fenestrate, cannot be identified within this large subfamily.
Myrtus communis, Myrtaceae	1	May to July	This morphologically unique pollen belongs to the sweet-smelling plant *Myrtus communis* (myrtle), endemic of the Mediterranean region.
Apiaceae	3	–	These pollen grains, characteristic of Apiaceaes, cannot be identified at the genus level because of the large morphological homogeneity of this widely distributed family.
Poaceae	2	–	These pollen grains cannot be more precisely identified within this large family, abundantly distributed in north-west France.
Plantago	1	–	
Brassicaceae	1	–	
Rosaceae	1		Pollen grains of the rich and widely distributed family of Rosaceae are rarely identified at the genus level.

Note: One pollen grain poorly preserved could not be identified.

Pollen grains were identified mainly by referring to the personal bank of modern pollen grains (pollen slides and photographs) of one of the authors (S.M.P.) and to botanical atlases.[9–11] Information on plant systematic, distribution and flowering refers to European and North African flora.[12]

An analysis of elements was performed on a small sample (2.4 mg) of the black powder using inductively coupled plasma mass spectrometry (ICP-MS; Elan DRCe Quadrupole Spectrometer; Perkin Elmer, Les Ulis, France) and inductively coupled plasma optical emission spectrometry (ICP-OES; JY 24; Horiba Jobin Yvon, Longjumeau, France). For both techniques, samples were first mineralised with hot concentrated nitric acid (nitric acid 65% Suprapur®; VWR, Fontenay-sous-Bois, France) and completed with ultrapure 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 in the periodic table was carried out using the ICP-MS TotalQuant method. Nine elements were thereafter quantitatively measured: Pb, Sn, Sb, Cu, Bi and Hg by ICP-MS, and Fe, Ca and Al by ICP-OES.[13]

A molecular analysis was also carried out on two samples of the black powder. Solid-phase microextraction (SPME) was used to trap organic volatile compounds from the samples, and gas chromatography/mass spectrometry (GC/MS) analysis was carried out in order to identify them. Samples were also placed directly in a glass liner into the injector of the chromatograph, and organic components were directly desorbed at 300°C for five minutes (GC/MS Agilent 6890 fitted with the Mass Spectrometer 5973 mounted with an adapted purge and trap technique; Gerstel® Combipal with the CIS4 injector).

Results

Preliminary examination under binocular lenses showed the presence of tiny remains of translucent brown formations (Figure 3), and a diffuse powder made of a blackish substance corresponding to the mummified viscera mixed with the embalming crust (Figure 4). No remains of any textiles were identified.

The optical and scanning electron microscopic (SEM) analysis showed the presence of various pollen grains (Table 1 and Figures 5 and 6). Three pollen types were prevalent (often grouped, suggesting the presence of stamens or flowers): an Asteraceae Asteroideae, *Onopordum* or *Serratula* (45% of pollen total, $n = 49$), *Artemisia* (33%) and a Lamiaceae, *Mentha* (10%). The residue also included masses of vegetal tissues (cuticles with stomatae) and spores of fungi. The most abundant pollen grains come from plants (at their systematic level of identification), which are found in Normandy and which were blooming at the time of death of the Duke of Bedford (autumn); they illustrate the regional coastal meadows. Some of them are fragrant plants (mint, myrtle, rose?). Calcium carbonate (or its roasted/heated form, calcium oxide, i.e. lime) was also used during the embalming process, as supported by the presence of some calcareous coccoliths. No bacteria or parasite was identified.

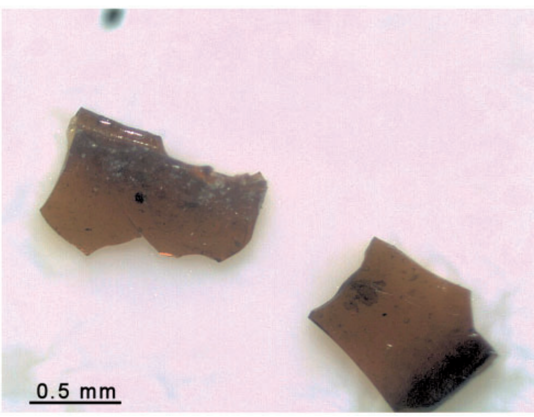

Figure 3. Close view of the semi-transparent dark formations associated with the mummified remains of John, Duke of Bedford, under binocular lenses, at ×40 magnification (picture by Joël Poupon).

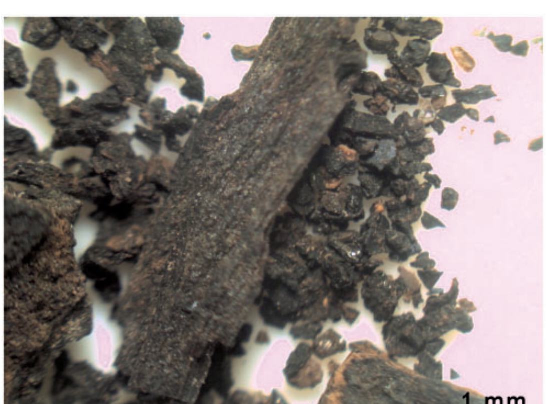

Figure 4. Close view of the mummified remains of John, Duke of Bedford, under binocular lenses, at magnification ×20 (picture by Joël Poupon).

Elemental analyses revealed large amounts of mercury, iron, calcium and lead (Table 2). Calcium may have been added during the embalming process, as the very slight amount of associated aluminium would eliminate an environmental origin (i.e. soil contamination).[13] Indeed, lime (calcium oxide or hydroxide) is known as a disinfectant and desiccant,[14] and such properties justify its use during embalming, in association with other products, including plants. Its use for embalming the Duke of Bedford has already been suggested by Le Roy.[15]

SPME analyses did not result in any pertinent information. Traces of monoterpenes were found, mainly limonene. The direct desorption of the sample permitted the identification of triterpenoid compounds with ursane and oleanane structure (Figure 7). From these compounds, α- and β-boswellic acids were identified. These molecules are characteristic of natural gum resins from the *Burseraceae* family, and specifically α- and β-boswellic acids characterise olibanum resin (frankincense).[16] Olibanum resin from Somalia has been analysed, confirming this hypothesis (reference material from Kremer Pigmente n°60270, *gummi olibanum somalia* nr. 1, weihrauch). Fatty acids were also found, mainly palmitic acid and oleic acid. These compounds occur in vegetable oils. In addition, several phenolic derivative compounds were detected, mainly guaiacol and 2,6-dimethoxy phenol derivatives, indicating the use of a wood-tar product. Eugenol and vanillin were also been detected, in direct relationship with, respectively, the use of specific plants during the embalming process (cinnamon, nutmeg or clove) and the decomposition process.[17]

Discussion

The elemental analyses of the blackish powder found a huge quantity of lead, obviously originating from the coffin, explaining also the presence of tin and antimony, classically found in poorly purified lead from the Medieval and Renaissance periods.[18] The origin of iron and copper is questionable, as testimonies of the exhumation mention that no metallic object was present in contact with the body. Nevertheless, iron could reasonably be attributed to

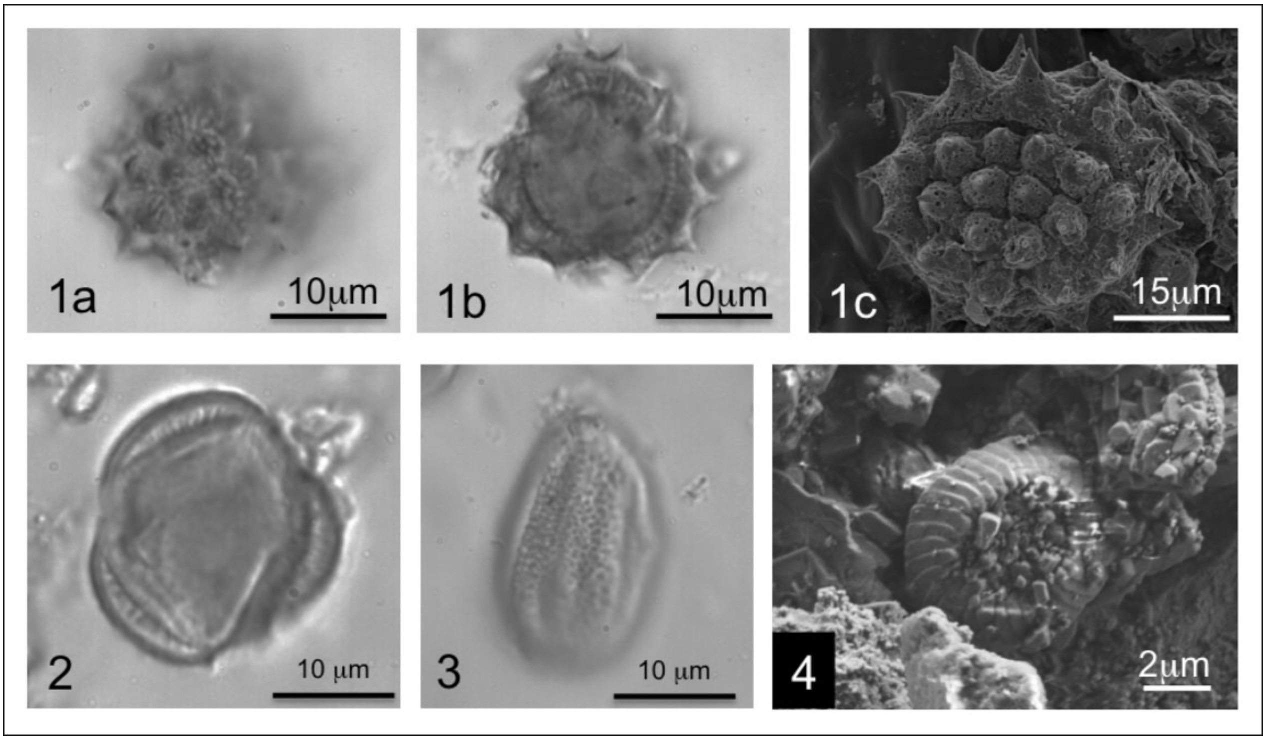

Figure 5. 1a–f, *Myrtus communis*; 2a–e, *Mentha* sp.; 3, Rosaceae (pictures by Speranta-Maria Popescu and Omar Boudouma).

iron nails used for the oak coffin and found at the first opening.[5] For copper, no such use is known, although the presence of a copper plate cannot be ruled out. Copper may also have been added during the embalming process, since its conservative properties were known in this period.[14]

Mercury is attested in embalming both in the literature and in Medieval and Renaissance mummification practices. Mercury was found in the composition of the embalming substance of Richard the Lionheart's heart (1199 AD).[7] Even if the amount found was considerably less than observed in the rest of the Duke of Bedford (150 μg/g vs. 3122 μg/g), it indicates the use of a mercury compound such as mercury chloride (calomel), and cannot be considered as originating from lead impurities, as it is never found in ancient lead.[15,18] Other examples of the use of 'vif argent' during the embalming processes are given by Guglielmo of Saliceto in his *Chirurgia* (c. 1275), and the French surgeons Henri de Mondeville (*La chirurgie* of Henri de Mondeville, 1306–1320) and Guy de Chauliac (*La grande chirurgie*, 1363) who refer to the use of 'quicksilver' in the post-mortem treatment of bodies. Mercury was also found (and macroscopically identified because of mercury droplets and further chemical analyses) in the burials of the French King Charles VII (died 1461) and the French Queen Anne de Bretagne (died 1514) in the St Denis basilica.[19]

In 1866, at the first opening of the grave of the Duke of Bedford, metallic mercury was found in great quantities and could be identified by simple physical separation.[20] It represented 11.25% of the mass, that is, 112,500 mg/g, and non-metallic mercury was not determined.[5] In his official report made to Cochet, Girardin, who did the analysis, thought that mercury was surely used as a mercury compound, but, in absence of chloride and sulphate, Girardin thought that neither mercuric chloride nor mercuric sulphate were used. He suggested, but as he confessed without any proof, that mercury oxide could have been employed combined with a resin. This mercury oxide would have been further reduced by the organic matter to produce elemental mercury. Curiously, a few years later, Girardin wrote that the presence of mercury could only be explained by the use of 'sublimé corrosif', which means mercuric chloride. Fifty-two years later, a new and more complete analysis performed by Le Roy showed that total mercury represented 8.03% (80,300 mg/g) of the solid mass, and metallic mercury only 4.08% (40,800 mg/g), the rest (3.85% or 38,500 mg/g) being in a combined form.[15] Then, more than 50 years later, 36% of the metallic mercury had disappeared, even if we cannot exclude a great heterogeneity of the samples analyses by the two chemists. Indeed, we confirmed that chlorides and sulphates were present only at the trace level. After several in vitro experiments, Le Roy concluded that mercury must have been employed as an emulsion of metallic mercury in a balsamic-like substance. Our analysis shows that, today, metallic mercury is no longer present, and total mercury represents only 0.3% of the black powder.

Pollen grains recorded in the blackish powder may originate from embalming products and/or airborne contamination. The interpretation of such results

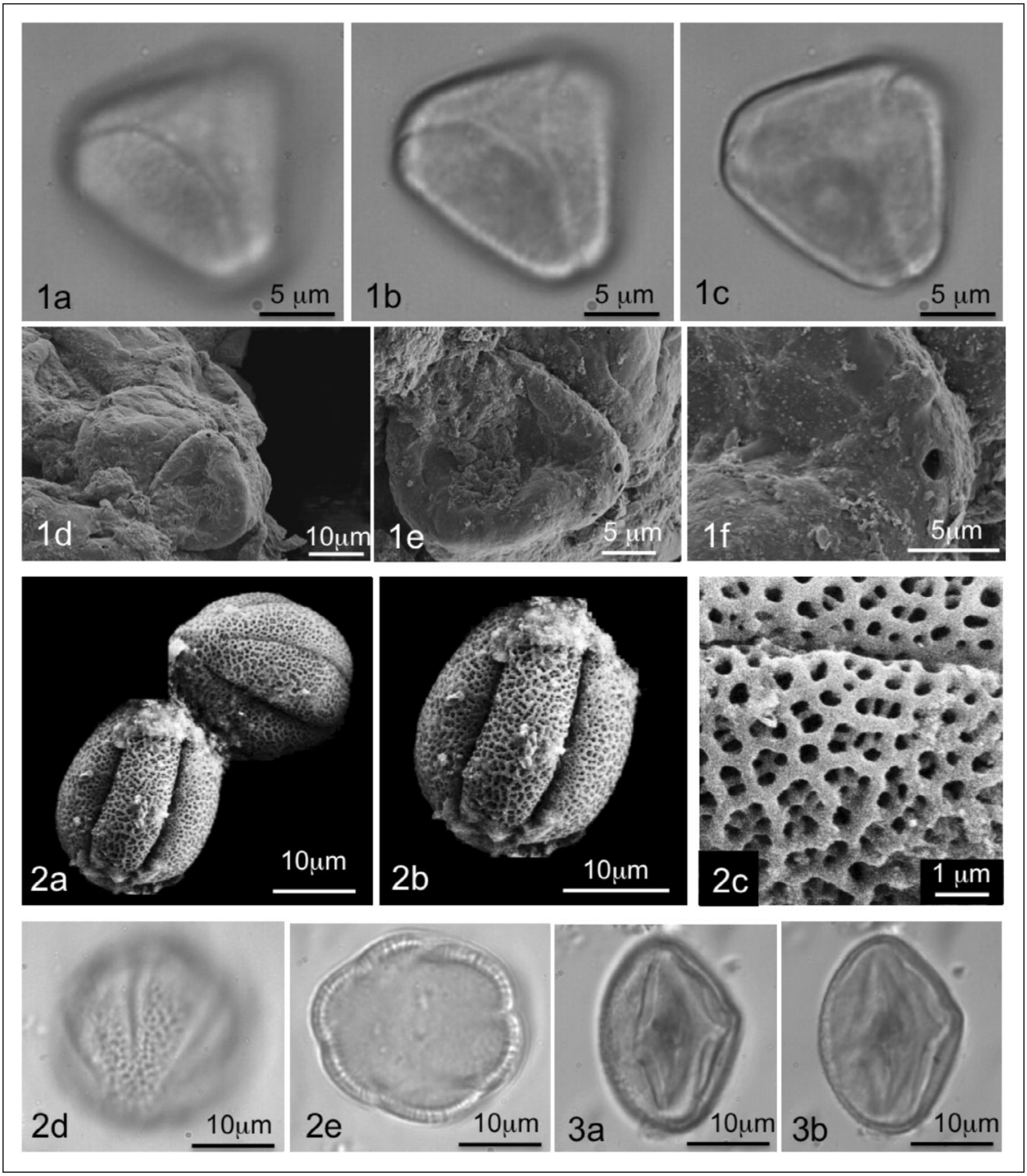

Figure 6. 1a–c, Asteraceae Asteroideae; 2, *Artemisia*; 3, Brassicaceae; Calcareous coccolith *Cyclagelosphaera* (pictures by Speranta-Maria Popescu and Omar Boudouma).

Table 2. Results of elemental analyses on the sample from the body of the Duke of Bedford.

Sample	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)
Black powder	2.42	1411	641	97	488	4	3122	8595	31,318	36
Semi-transparent elements	1.32	2942	173	6	19,203	5	70	345	8663	ND

ND: Not determined.

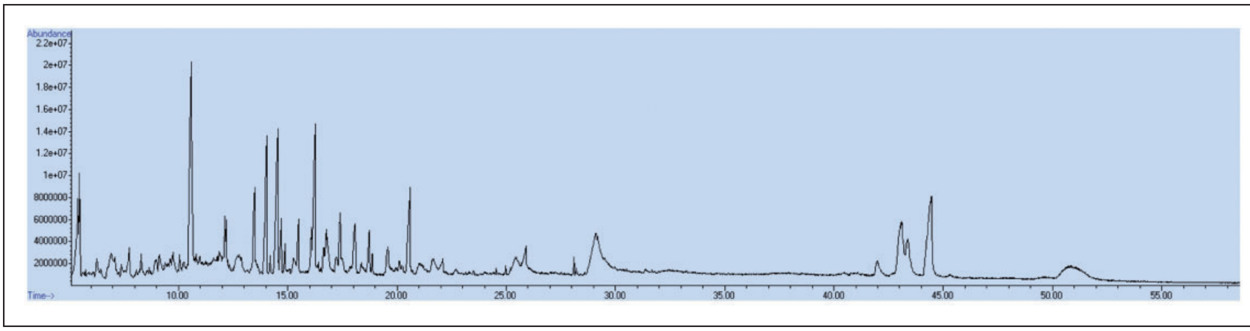

Figure 7. Chromatogram from the direct desorption of the sample from the remains of the Duke of Bedford.

needs a comparison with Medieval and Renaissance literature about plants and vegetable substances used during the embalming process, but also with the period and localisation of the preparation of the cadaver of the Duke of Bedford (September, region of Rouen, Normandy). Some pollen grains must undoubtedly be considered as originating from embalming products (myrtle, mint, rose?), whose pollination ends at the period of death. They also may have been stored before their use during the embalming process (that occurred short after 14 September 1435).[9–12] It is noteworthy that their state of preservation is better than the other recorded pollen grains (Table 1): *Artemisia*, *Apiaceae*, *Poaceae*, *Centaurea*, and *Plantago*. That may indicate some transportation by air and the resulting oxidation. They are hence considered as contaminated external material, excluding their use for the embalming process. The identification of Asteraceae Asteroideae (*Onopordum* and *Serratula* genera) may be explained by the tinctorial properties of one of the species, *S. tinctoria*, intensively used by dyers in this period to make a yellow dye.

Molecular analyses showed the presence of frankincense (likely corresponding to the translucent formations observed under binocular lenses),[16] that is, a non-negligible part of the embalming processes during the Medieval and Renaissance periods.[21] Indeed, gum resins are symbolic substances linked to the birth and death of Christ: presented by the Biblical Magi at his birth and used during his external embalming after the Passion.[22] The goal of using such materials was not only to allow long-term conservation of the tissue, but also to leave the body with a good odour, like the body of Christ,[23] as previously shown in the case of the mummified heart of Richard the Lionheart.[7] Comparable examples from later periods (13th–19th centuries) have been described, particularly in Italy: Cangrande della Scala (1291–1329),[24,25] members of the Medici family in Florence,[26] the Aragonese mummies in San Domenico Maggiore, Naples,[27,28] the Blessed Christine of Spoleto (1432–1458),[29] Salimbene Capacci (1433–1497) and his wife Margherita Sozzini (died in 1511),[21] late Medieval and Renaissance Saints,[30] and in the treatise *La practica in arte chirurgica copiosa* by Giovanni da Vigo (1450–1525). Comparable substances and plants known as filling materials of these mummies have been described (mint, rose powder, myrtle, etc.), but the case of the Duke of Bedford may represent the most complex example of the embalming process (associating seawater, lime, mercury, copper, various flowers and frankincense). The identified coccolithes are *Cyclagelosphaera*, that is, 174 to 61 millions year-old fossil, originating from the calcium carbonate or lime used for the embalming process. From a geological point of view, Rouen is located in the occidental part of the Seine basin, a zone rich in very thick layers of chalk used for the production of lime.

Since the studied samples were entirely turned into powder, the original presentation of the embalmed body has been ignored, but testimonies dating from the period of the exhumation report that the fully mummified body was wholly covered by a 2 cm blackish crust, including dark hairs on the head.[4,5]

In any case, the embalming described above seems to have been only an external one, as no description of any opening or partitioning of the body is attested in the case of the Duke of Bedford (i.e. no secondary graves for the viscera and/or the heart).[31–34] Traditionally, the embalming process was carried out by cooks (12th century AD), as they were used to preparing meat and offal but also had access to herbs, spices and other odoriferous substances.[6,35] Then, post-mortem preparation was executed by barbers, surgeons, apothecaries and, later, chemists, using plants; sometimes exotic and disinfectant solutions proved to be efficient for the medium- and long-term conservation of human cadavers.[36]

Unlike the Egyptian embalming process where the conservation of the body was considered an elite status marker, embalming in this case was necessary for practical reasons rather than religious or symbolic ones. The full body was treated because the Duke's cadaver had to wait 16 days (14–30 September) before its inhumation in the cathedral. The body, even if not directly visible, had to conserve a stable aspect, without any odor or liquefaction during official presentations. As previously seen in the case of the English King Richard the Lionheart, 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 (or at least to help) his religious apotheosis. Indeed, with embalming, symbolically, the deceased was identified with Christ, whose body was scented with spices by Joseph of Arimathea before being placed in his tomb.[7]

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Declaration of conflicting interests

All authors declare no competing financial interest relevant to the subject of this research.

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