

Unwrapping the Past

A chemical analysis of context lacking artefacts from the Ptolemaic and Roman Egypt in correlation with the process of mummification.



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Abstract

This paper deals with the chemical identification of artefacts correlated with the process of ancient Egyptian mummification dating to the Graeco-Roman period. The samples were harvested from two artefacts belonging to the Museum of Mediterranean and Near Eastern Antiquities in Stockholm. The original description of the said samples defined them, as natron filled linen bags and bee product (honey?).

To identify the true nature of the samples, advanced methods such as Fourier transform infrared spectrometry (FTIR), gas chromatography/mass spectrometry and powder X-ray Diffractometry were used.

The results were correlated with previous made analyses regarding embalming materials to discover similarities. Furthermore, the research revealed that the previous sample identifications were false, while providing hypotheses based on the new results.

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Cover Image: *The mummy of Artemidorus*, Roman Age, Egyptian mummy (the photo was taken from the official web page of the British Museum)

1. Introduction

1.1 Preface

With scientific advances in the fields of chemistry and archaeology from the 1970's onwards, the possibilities for uncovering more information about the human past increased substantially (Heron & Pollard 2008: 7). The coupling of Gas chromatography (GC) and Mass spectrometry (MS) in the paper of Thorton et. Al (1970) heralded a new day in the study for organic remains analysis of archaeological materials (Evershed 2008: 896). This allowed the study and identification of both organic and mineral artefacts, on a more detailed level than ever before. Thus the recovery and characterization of organic residues in archaeological pottery is becoming an increasingly effective means of identifying economic activities, subsistence practices, and technological tradition throughout history (Heron & Pollard 1996: 8-9).

Thirty five years ago, Bruce Trigger (1983: 7) noted that archaeologists were rather “*generally poorly equipped to criticize the techniques used by other sciences*”, and rarely subjected the conclusions and interpretations of physicists and chemists to the rigorous review they might otherwise demand of their own work or that of their colleagues. Even though the *hoi polloi* of the archaeological discipline might still not see or find reason for the advancement of the archaeometric techniques, it is the insurmountable force of the results, and evidence produced, that pave the way.

Ranging from Smithsonian's research about alcohol consumption and production from the pre-historic to historic times (McGovern 2011: 1-2), to the analysis of organic remains (food crusts) from the Viking age burial place of Alsike parish in Uppland (Forsgren 2006/07), the use of both Fourier transform infrared spectroscopy (FTIR), gas chromatography–mass spectrometry (GC/MS) and powder X-ray diffraction (XRD), have unlocked vast amount of data about the past, helping to formulate a better understanding of it and *ergo*, a better understanding of the human progress and life through the ages.

The use of the FTIR, GC/MS, and XRD methods are far from new in the area of egyptological interests. In 1999, research on organic residues from ancient Egyptian mummies was conducted by the Mummy Research Team, headed by Stephen Buckley (Buckley et. al 1999). The use of FTIR and GC/MS eliminated any possibility of destruction of the mummified bodies due to the very small amount of sample material needed to perform these analyses - in contrast with earlier times, when a full dissection of the mummy was performed. Therefore this allows for the scope of investigations of ancient Egyptian funerary practices to be significantly extended.

In 2009 a group of researchers from the University of Pisa carried out their investigations on Late Roman-Egyptian adhesives to further our knowledge on the technological traditions of this space and time (Ribechini et. al 2009).

Thus, based on the rich background and evolution of said methodologies, the research on the subject became all the more intriguing, as will be seen in the following chapter.

1.2 Aim and research questions

The aim of the study is to identify the composition of two organic samples retrieved from a private collection that, during a latter point, came into the possession of the Museum of Mediterranean and Near Eastern Antiquities in Stockholm. The two pottery vessels containing the organic samples date between the Hellenistic and Roman periods in Egypt (332 B.C. - 400 A.D.)

During the research for this study, the following questions were formulated:

- A. Is the use of FTIR, GC/MS and XRD techniques reliable and valuable methods for this archaeological research?
- B. What new information can the results reveal about the artefacts?
- C. What correlation can be drawn between the artefacts and the mummification context?

1.3 Materials and methods

The focus of this study is based on the samples taken by associate professor and supervisor of this paper Sven Isaksson and Maria Arvidsson and Johanna Bornholm from the Museum of Mediterranean and Near Eastern Antiquities in Stockholm's magazine in Tumba, early autumn 2012. The pottery vessels were originally part of a private collection belonging to one, Major Robert Gayer-Anderson (1881-1945). Due to their unknown place of origin, the vessels are lacking subject and context, making the identification, dating, and organizing of the artefacts rather difficult. The samples were taken from two pottery vessels, MM 18553 (pictured left) and MM 19245 (right, figure 1.).



Fig. 1: MM 18553 & Mm 19245 (Carlotta Database web page)



Fig. 2: MM 18553 (as observed under the microscope, the distance between the scale marks is one millimeter each)



Fig. 3: MM 19245 (as observed under the microscope, the distance between the scale marks is one millimeter each)

From the contents of these two pottery vessels, two small samples were taken. The sample of MM 18553, a heterogeneous yellowish mixture originating from the natron filled bags (seen fig. 1), contained a multitude of fibers, ceramic sand and other materials visible to the naked eye, observations validated when the sample was put under the microscope (Figure 2.).

In contrast with the first sample, MM 19245, although solid, did appear to retain some glutinous properties; its orange brown colour lends agreement to the observations from the museum that the contents of MM 19245, were most likely honey, or some other bee product (e.g. wax) as seen under the microscope (figure 3.). The samples at the time of retrieval had not been amplified or analyzed previously, so after being scrutinized with a microscope, a plan for FTIR and GC/MS tests was underway.

These techniques are to be

described in detail in chapters 3.1 and 3.1.2 under the *methods* section, before presenting the results with which this paper seeks to answer the research questions posed in the previous chapter.

In addition, the contents of MM 18553 were also subjected to X-ray diffraction (XRD), a very precise way to identify minerals (inorganic materials), especially when these represent a very small amount in a larger mixture. X-ray diffraction has been used to successfully characterize different types of pipestone (argillite). Another application would be the identification of ground mineral-based pigments (such as hematite) through the identification of the minerals present in pigments. In this case XRD was used to uncover possible crystalline formations in the heterogeneous sample, and uncover if indeed the textile remains contained natron or not.

2. Background

2.1 The Ptolemaic and Roman Egypt

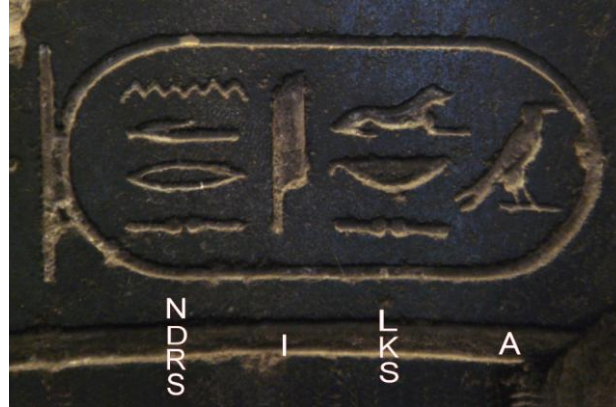


Fig. 4: Cartouche featuring Alexander's name, read from right to left as "ALIKSNDRS" dating to circa 330 B.C. (The Louvre web page)

It dawned like any other day, that warm Egyptian, late-November morning of 332 B.C., or so Arrian (I: 223) and Quintus Curtius (I-V: 227) would have us believe. Alexander the Great of Macedon crossed into Egypt and opened that ancient and mystical land to the wider world, and into the Hellenistic era (323-146/ 30 B.C.). Not only would he enter as a conqueror, but was proclaimed a living god. Alexander was treated both in life and death as a divine Pharaoh, evident by his name depicted in royal Cartouches (see figure 4). It was Alexander's sudden death and the succession crisis that followed, that facilitated the founding of the Ptolemaic kingdom of Egypt, under one of Alexander's companions, Ptolemy I Lagides/Soter (Curtius IV: 559).

Thus the great city of Alexandria upon Nile came to be. Within its walls could be found intellectuals from all over the Mediterranean world, men of letters and books, Greeks and Egyptians come to stay in the city of Pharaohs and the essence of civilization. A microcosm of an early multicultural world, Alexandria came to be the place where the Ptolemies affirmed their ecumenical power (Jacob & Polignac 2000: 31).

Into this already cosmopolitan world entered the Romans. This new introduction, would spell the doom of the illustrious Ptolemies, and herald the rise of Rome as the center of the world.

The end of the Ptolemaic era was not as sharp, or as dramatic, as the many films, plays and novels about Cleopatra's and Mark Anthony's affair would have us believe. Egypt had been only nominally independent for near 200 years by 30 B.C. (Lewis 1983: 10) and the once proud Hellenistic kingdom was reduced year after year into nothing more than an agricultural vassal (Capponi 2011: 12).

To add to this contrasting image, we must understand that Egypt had grown so immensely important for Rome, that by the first century B.C. a large number of Roman citizens traders and soldiers had come to settle in the Greek-Egyptian metropolises (Capponi 2011: 10-11).

The end comes to us preserved in five words sent by Caesar Augustus to the senate of Rome, in 30 B.C.: "*Aegyptus imperio populi Romani adieci*"... "Egypt is added to the Empire of the Roman people" (1983: 9). That day marked the end of the Hellenistic Egypt and the dawn of the Roman province of Aegyptus, an entity that would last for six centuries, until the Muslim conquest, in 642 A.D.

Henceforth the Mediterranean Sea became all but a Roman "*lake*" (Mare Nostrum: latin for "Our Sea") and Rome became the arbiter of the fortunes of all the people living around it.

These historic developments facilitated the emergence of Graeco-Roman Egypt and the blending that would produce a majestic culture in which was found this triangle of native Egyptians, the populous Greeks of the metropolises, and the Roman Gentry. This can be observed as much in the written remains as in the material culture, demonstrated in an exemplary fashion by the Roman mummies and the Roman-Egyptian funerary rights.

2.2 The mummification Process.



Fig. 5: A mural relief, depicting Anubis God of the dead, during the mummification process (BBC webpage)

The mummification process involves the change of a once living body into a state of arrested decay. It can be argued, that a mummy is a physically preserved corpse that resembles its once living morphology, but resists any further decomposure for a long period after the mummified organism has passed away (Aufderheide 2003: 41).

The oldest mummy related find from Egypt, is the mummified arm of Pharaoh Djer, the third ruler of the first dynasty (mid-thirty-first century B.C.). The arm was found by Sir Flinders Petrie in 1901, during secondary excavations in Abydos (Aufderheide 2003:25). This find holds enormous importance because it reveals that mummification

as a funerary tradition can date back to the proto-dynastic, or even to the pre-dynastic period.

The passion about the process and the mummies themselves is by no means new. Most of the information handled by early Egyptologists, derived from ancient Greek and Roman texts, seek, to describe the mysterious and intriguing, almost ritual - like embalming process and the following wrapping of the body (Ikram 2003: 53-55).

The basic principles of the embalming process did not see any dramatic change during the several thousand years of use in Egypt. The process continued to constitute the ritualistic emptying of the human body, followed by bathing in natron, salt or resin and finally having been prepared for the post-mortem decay, the corpse was wrapped in hundreds of meters of linen, then placed into its sarcophagus (Ikram 2003: 53, 2008: 48-50).

The use of natron was of pivotal importance in Egyptian mummification because of its chemical properties in the form of water absorption and behaviour as a drying agent. Moreover it vastly helps in the creation of a bacteria-hostile environment, minimizing the effects of decay and decomposure (Aufderheide 2003: 237, 256)

All that came to change though, when the Greeks and the Romans entered the scene. Focus dramatically shifted from the preservation of the corpse to the esthetics and the external appearance of the mummy (Corcoran 1995: 2-3, Aufderheide 2003: 248).

The most apparent addition during the Graeco-Roman period is the introduction of the portrait of the deceased; although mural reliefs did depict the faces of the dead Pharaohs during the ancient eras of Egypt, they were presented in profile (see figure 5) (Aufderheide 2003: 249), while those portraits from the Roman mummies appear facing the viewer directly, in exquisite realistic details as seen in (figure 6 & 7). In this case, it can be argued that these portraits represent the oldest surviving ancient portraits to be found to this day (Aufderheide 2003: 249, Corcoran 1995: 3, 49).

The practice of embalming and mummifying did not cover only humans but animals as well. An enormous number of these mummified animals have been unearthed during the years, showing that this practice was not the exception, but most likely, the norm (Ikram 2005: 15-17).

During the Middle and the New Kingdom eras, animal cults and mummification seem to have been a prevalent cultural phenomenon, evident by the multitude of both the plethora of species being mummified, but most importantly the sheer number of finds. The reasons for the continuation of these practices during the Graeco-Roman period are unclear and perhaps they can be perceived as an archaizing that paralleled the



Fig. 6: A female mummy portrait from Fayum Egypt (Metropolitan Museum of Art web page)



Fig.7: Portrait of Artemidoros (British Museum, London web page)

continuation of the mummification practices (Ikram 2005: 7-8). One such example are the sacred bull mummies, which were adorned with gilded headpieces, symbolizing their religious importance for the animal cult of the period (Ikram 2005: 96). The animal cult became all the more important with the Christian edicts against paganism during the 4th and 5th century, morphing the animal cults and mummification practices into a symbols of defining the Egyptian identity, in contrast to the opposing and foreign ruling elites that had been ruling Egypt (Ikram 2005: 8).

The end of this over three thousand year old practice came under the pressure of the new religion in the eastern Mediterranean. Christianity's ideals of the second coming of Christ and a wholesome corporeal resurrection made the practice of embalming, and therefore the process of mummification, unacceptable.

It was in 392 A.D. that Emperor Theodosius I forbade embalming. Thereafter very few finds appear to support the notion that the tradition of mummification continued (Aufderheide 2003: 250), and even if such small vestiges did exist, they probably were drawn to an end by the Arab conquest in 642 A.D.

2.2.1 Textile Wrappings

Seen even in form of the mummified hand of Pharaoh Djer, linen was the textile almost exclusively used for the mummification process, the difference between low class and elite mummies being, that often times the wrappings of the elite were inscribed with religious messages for life after death (Aufderheide 2003: 241).

When the subject of mummies appears, it usually is connected to the mummies of the royal dynasties. In reality, embalming and mummification were funerary rights which transcended the social structure of ancient Egypt. New Kingdom non royal mummies from Deir el-Medina appeared to be dried in natron, covered with a generous quantity of resin and wrapped in layers over layers of linen. Salima Ikram presented that even though low class mummies are often found not to be embalmed, the deceased was nonetheless wrapped in linen (Ikram & Dodson 1998: 124).

Apart from the mummy portraits, the mindset behind the wrapping of the body of the deceased changed as well during the Roman period.

As seen in the previous chapters, the cultural practice of mummification under the Graeco-Roman rule changed the attention from preserving the body to focusing on the external appearance of the mummy.

To this end, a change in the use of linen for the wrapping procedure was undertaken; during earlier times, the linen used were usually cast off rags or shredded linens and only royal mummies appeared to have higher quality textiles used for them (Aufderheide 2003: 246-247). Within this period, linen appears to have been woven specifically for the purpose of mummification, often appearing to be inked or inscribed. These developments further support that Roman period mummies in Egypt, were focused on the esthetics presentation of the mummy (2003: 248).

Considerable differences during the Roman period can also be seen in the way in which

the bodies of both humans and animals were wrapped in these textiles. Although the wrapping techniques varied during this long span of time, the basic principles remained simple, the linen bandages spiraling around the body parts of the deceased, special care given to the arms and legs, including the toes and fingers. (Ikram 2005: 28). The Roman-period tradition changed from the simple wrapping of the earlier times to wrapping the body with narrow linen bands in diagonal fashion, creating a diamond like pattern (Aufderheide 2003: 248) often times supplemented with papyrus or golden leaves, so as to make the mummy bindings appear golden.

It is this paper's notion that the linen bags of MM18553 are in fact textiles, woven specifically for the purpose of either human or animal mummification during the Hellenistic or Roman period. To this end a further analysis of the subject will follow in the latter chapters.

2.3 Looting and private collections

Both samples were retrieved from the Museum of Mediterranean and Near Eastern Antiquities in Stockholm, but much like many other artefacts hailing from Egypt or the Near East these artefacts too belonged to a private collection. Major Robert Gayer-Anderson was born in Great Britain in 1881, but having spent most of his life in Egypt, Major Anderson developed a keen interest for the antiquities, purchasing along with his twin brother large amounts of ancient Egyptian artefacts, ranging from the pre-dynastic times to late antiquity. The vast majority of these finds were donated to the Fitzwilliam Museum in England and at the time of his death (1945) the collection numbered over 7500 artefacts (Collector: Gayer-Anderson, (Major) Robert Grenville 'John' 1881–1945).

The existence of Mediterranean and Near Eastern antiquities in western museums is a very sensitive subject due to ethical questions raised. The question of where the artefacts belong is of paramount importance. The mainstream post - colonial consensus tends to lean towards the idea that these artefacts that were either purchased during difficult times of a country, or outright looted from their original context, belong to their homelands. But strictly archaeologically speaking, the homeland of the artefacts is the past and not the specific political entities presently existing on the area of which the artefacts were unearthed.

This stance may of course be highly controversial due to the strong political and national motives behind the self identification of a nation's past.

Much like Major Anderson, the private collector from whom MM 18553 and MM 19245 were received, most of the artefacts during those early days were not “products” of archaeological excavations, but more often the result of wholesale looting, carried out by military personnel often being over enthusiastic about the ancient past, or even by diplomats. Such “bright” example being Sir Henry Salt the British consul general in Egypt who set a pattern to be followed in other ancient parts of the world (Waxman 2009: 47).

Concerning the paper's main subject, vast quantities of animal mummies found themselves being purchased and then shipped to Europe. These types of mummies were so closely intertwined with ancient Egypt by travelers and tourists that buying one as a souvenir was "a must" (Ikram 2005: 15).

Taking advantage of the insatiable thirst of these western gentlemen, local "amateur archaeologists" would quite often fabricate replicas held the appearance of the original antiquities, forgeries that often went as far as the production of mummies. Although it is rather hard to call any kind of a mummy fake, these were clearly not the sort of mummies sought from western museums (Waxman 2009: 126).

The use of modern scientific methods, like the ones to be presented further on, may vastly help both in the preservation of the artefacts and in the identification of forgeries, leading to more complete and better constructed databases.

2.4 Previous Studies

The term *archaeomtery* was coined in the 1950's by Christopher Hawkes to describe the shift in the archaeological discipline towards dating, quantification and physic-chemical analysis of archaeological artefacts (Pollard & Heron 2008: 9).

There have been copious amounts of studies involving the use of chromatographic or other chemical analyses to determine the nature of Egyptian antiquities, with a special interest in mummies and products that were used in the process.

In 2001 Drs Stephen Buckley and Richard Evershed in their paper in *Nature* (2001: 838-840) presented the first systematic chemical investigation of a collection of provenanced Egyptian mummies dating from the mid-dynastic period (c. 1.900 B.C.) to the late Roman period (A.D. 395), which encompasses the period at which the mummification process was at its peak (1.350 ± 1.000 yr B.C.).

Salima Ikram has for over two decades provided continuous research on Egypt. Her two books concern the research on animal mummies (Ikram 2005) and her work on *Death and burial in ancient Egypt* (2003) delves greatly into the inner workings of the embalming techniques and includes details derived from years of research on the mummification process.

In 2003 Arthur Aufderheide published *The Scientific Study of Mummies*, in which he presents copious information on the oils, bee-products, and chemical minerals used in both the embalming and wrapping of the mummies. Furthermore, apart from covering a wide period of time spanning the proto-dynastic to the Graeco-Roman period, Aufderheide, takes on the subject of mummies based on different societal classes, and the degree in which oils, natron, or resins were used for non-royal mummies.

In *Microchemical Journal* vol. 103 (2012), Jannette Lucejko et al. exhibited their study on the analytical approach based on X-ray diffraction, Fourier transform infrared spectroscopy, and gas chromatography/mass spectrometry to characterize Egyptian

embalming materials. Analyzing the mummies, the team discovered a chemical base consisted mainly of a long chain of fatty acids, alkanes and alcohols; in addition the research revealed that the samples contained traces of beeswax, pine tar and resin from a *Pistacia lentiscus* tree, which could have only meant that it had been imported from outside of Egypt.

Drs Buckley and Evershed have exhibited numerous other studies during the previous decade, most of them centered on the chromatographic analysis of fatty acids and vegetable oils, from samples originating in Egypt (Complex organic chemical balms of Pharaonic animal mummies, 2004), (Dead sea asphalt in ancient Egyptian mummies — why? Nissenbaum & Buckley, 2012), along with several others.

Based on the sheer magnitude of research on the subject, it can be concluded that a strong basis for food for thought, existed from the very start, something that came to great use, in the following laboratory research, as seen in the next chapter.

3. Methods

3.1 Hypothesis

Due to both the nature of the artefacts and their origin, hopes were high from the very start on what they could reveal, despite their context-lacking nature. The description of the samples provided by the Museum of Mediterranean and Near Eastern Antiquities in Stockholm delineated MM 18553 as a: *convex jar with a short neck, modelled rim and a semi round base. Red coated and polished. “The wall is grooved. The jar is filled with many small linen bags, filled with natron.”*

And MM 19245 as a: *“small and slender ovoid jar with a concave upper termination, flodeled rim and a pointed base. It has a small lid, composed of densely packed clay and linen. White surface with resin like spots, polished. It contains a solid mass, honey”* (Carlotta Database)

Based on these descriptions, both samples were scrutinized with a microscope in formulate an early hypothesis about the nature, of the samples. In accordance with what was seen with the naked eye, the MM 18553 sample was of highly a heterogeneous nature, consisting of a plethora of ceramic fragments, textile fibers, possible organic material and perhaps a small piece of bitumen. The big surprise came when, during the examination of the sample, the exoskeleton remains of an insect were found. This only strengthened the earlier hypothesis, that MM 18553 contained linen textiles used for the purpose of mummification, either human, or more likely animal; as it was hypothesized, the insect might have been a flea.



Fig. 8: MM 18553 as it appeared under a microscope, revealing its high heterogeneous nature, in the bottom row the remains of the insect can be seen clearly.

Based on these early observations, MM 18553 was defined as a hypothetical sample with a context concerning the process of mummification. In contrast with the previous sample, MM 19245 appeared to be rather easy to define; at least on the basic hypothetical level. According to the museum's antiquarians, the sample was probably honey or some other kind of bee-product, perhaps some mixture of beeswax and oil, a hypothesis made even more plausible after the sample was examined with a microscope. MM 19245 did seem positively honey-like and despite the existence of several heterochromous mineral like flakes (see fig. 9), the hypothesis around the sample, remained much in agreement with that of the antiquarian observations: namely that MM 19245 was indeed either honey, or some mix of vegetable oils and beeswax. If this hypothesis was taken to its extreme, a farfetched link between beeswax and the mummification process could be made.



Fig. 9: As seen under a microscope, easily appearing as a bee product, notice the heterochromous white/black flakes

Table 1: Compilation of the Hypothesis

Sample	Artefact/Object	Description	Interpretation
MM 18553	Vessel, Jar & Natron filled linen bags	Solid heterogenous mix, reddish yellow	Ceramic, Textile fibers, Bitumen, Organic material?
MM 19245	Vessel, Jar, Lid & Solid mass	Glutinous, orange red wax like substance	Honey, Wax, Vegetable oil, Resin?

3.2 Fourier transform infrared spectroscopy (FTIR)

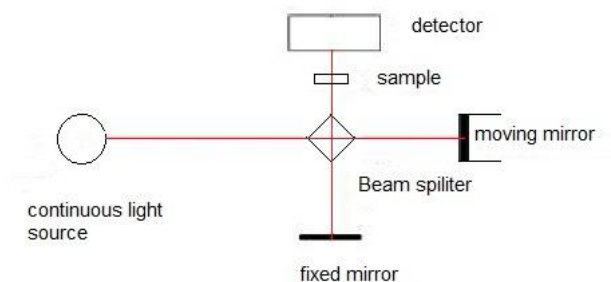


Fig. 10: The main components of a Fourier transform infrared (FTIR) spectrometer.

Following the early assessments based on preparatory microscope analysis, the research continued with an on hands Assessment for Learning (AFL) which commenced by the use of the Fourier transform infrared spectrometer (FTIR). This was done as to receive an approximation of the chemical composition of the samples.

FTIR is the method by which the use of infrared light beam absorption can determine the nature of a test sample's spectrum, based on the characteristic distribution of electromagnetic radiation emitted or absorbed by the test subject, be it solid, liquid or gas. When exposed to infrared beam, the sample components absorb radiation of specific wavelengths which causes the change of dipole moment for the sample's chemical bonds. Consequently, the vibrational energy levels of the sample molecules transfer from static to excited state. The intensity of absorption peaks is related to the change of state and the possibility of the transition of energy levels. Therefore, by analyzing the infrared spectrum, one can readily obtain abundant structure information about the chemical bonds.

This is achieved when an infrared beam containing many frequencies of light at once is "shot" through the sample (see figure 10). This process is then repeated many times. When this process is complete, a computer measures how much of that beam is absorbed for each wavelength by the sample, producing the data results in form of an interferogramic graph (Introduction to Fourier Transform Infrared Spectrometry: 2001).

Due to the non chemical-reactive nature of FTIR, the samples required are of miniscule proportions. This made the technique both easier and cost effective, completing several tests with multiples samples without running the risk of destroying the sample for further analyses. Not requiring an excessive amount of its mass proved to be all the more useful, as for preserving the sample to be used for the more detailed gas chromatographic-mass spectrographic analytical method.

The FTIR is a technique that provides a first glimpse into what the sample may contain, proving advantageous over other methods in numerous ways. First, the need for such a small amount of sample material to perform guarantees very little impact on the object

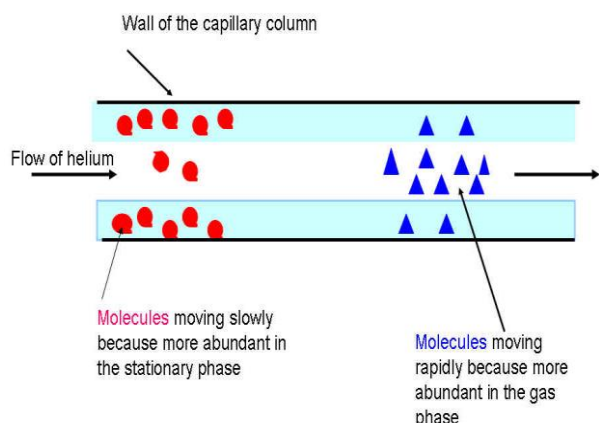


Fig. 11: The basic principles of the gas chromatography column

from which the sample was taken. Secondly, FTIR results are speedily ready. Lastly, the samples require no direct preparation. That said, FTIR has its disadvantages as well, and regardless of its speed and cost effectiveness, a deeper analysis is still warranted and the use of more detailed methods (for example GC / MS) are necessary to achieve more formulated and concrete results.

3.3 Gas chromatography-

Mass spectrometry (GC/MS)

As stated in the previous chapter, the use of Fourier transform methods are deemed, wanting to details and thus a more precise method is required to determine the mass of a molecule such as a peptide from within a heterogeneous mixture; and so, the use of GC/MS is employed. This is done through a two-phase analytical process: first the sample goes through a chromatograph, which separates the chemical mixture into pulses of pure chemicals by use of gas and heat (300-360 Celsius), to separate the chemicals based on their volatility (Evershed 2008: 896 ff, Regert 2008: 179, 193). The mass spectrometer then, uses electromagnetic fields to control the movement of charged molecules (ions) within the instrument (Heron & Pollard 2008: 71ff).

3.3.1 Gas chromatography

More specifically, in chromatography the components in a mixture are separated through continuous repetition of equilibration. This equilibration is caused by the adhesion of atoms, ions, or molecules from a gas, liquid, or dissolved solid to a surface. Once a sample is introduced between 2 phases called (*stationary* and *mobile* phase).

When a gas is used as the *mobile* phase, the technology is called gas chromatography (GC) (Grob & Barry 2004: 5-6). The mobile phase is constantly passed through a separation column (simply called the column, see figure 11). The sample mixture is then injected and instantaneously vaporized in the column inlet. The vaporized sample is carried through by the carrier gas. Passing through the column, each component in the sample is reduced by adhesion or is partitioned to the *stationary* phase according to its characteristic concentration ratio. An equilibration occurs repeatedly between the solid, *stationary* phase, and the *mobile* phase. As a result, the level of adsorption or partition for each component causes differences in the rate of movement for each component within the column (Grob & Barry 2004: 8ff, 13ff).

The instrument for performing gas chromatography is called the gas chromatograph (see figure 12). A of solvent containing the sample mixture of molecules is injected into the

GC then, the sample is carried by inert (non-reactive) gas through the instrument. The carrier gas (helium, nitrogen, hydrogen, argon, etc.) is provided at a reduced pressure of 6 ~ 10Kg/cm² from a gas cylinder connected to the instrument.

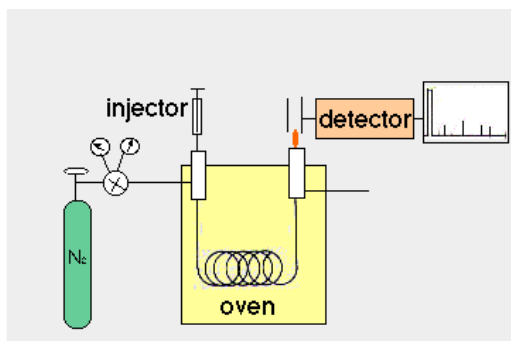


Fig. 12: Basic structure of gas chromatograph GC (Lipid Analysis, by SFU web page)

The carrier gas passes through the sample injection port, column, and detector before finally being purged. The sample injection port, column, and detector are each held within the isothermal oven. The sample solvent is instantaneously introduced into the sample injection port. Thus when liquids or solids sample are used, the chamber is heated to vaporize them. According to the principles described earlier, each component is moved through the column by the carrier gas and separated.

To keep all this information in line and for careful measuring of the micro dosages and temperatures, a detector is used to keep a record of the procedure (Grob & Barry 2004: 288ff). To ensure that the absolute maximum of the residue identification is achieved, Gas chromatography is often coupled with Mass spectrometry.

3.3.2 Mass spectrometry

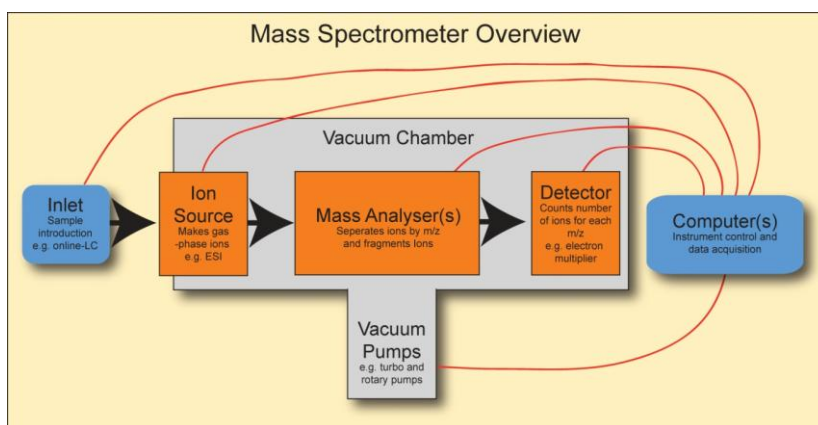


Fig. 13: GC/MS process (Lamondlab web page)

In scientific principle the Mass spectrometer appears, at least in essence, to be based on a simple design (see figure 13). The mass spectrometer is comprised of three basic components the Ion source, the mass analyzer and the detector. The process is rather straight forward. After passing through the GC, the chemical pulses continue to the MS

(de Hoffmann & Stroobant 2004: 388). There they are subjected to a stream of electrons which leads to them breaking apart and turning into positively charged particles (called ions), whose patterns are characteristic of their chemical fingerprint. Mass spectrometers always work with positive ions (de Hoffmann & Stroobant 2004: 51ff, 292). As the ions continue through the MS, they travel through an electromagnetic field that filters the ions based on mass and charge (m/z = mass & charge). The filter continuously scans through the range of masses, based on the range of masses that should be allowed through it as the stream of ions come from the ion source (de Hoffmann & Stroobant 2004: 169).

This finally leads to the detector, which then counts the number of ions with a specific mass. This information is sent to a computer and a mass spectrum is created. The mass spectrum is a graph of the number of ions with different masses that traveled through the filter (see figure 14).

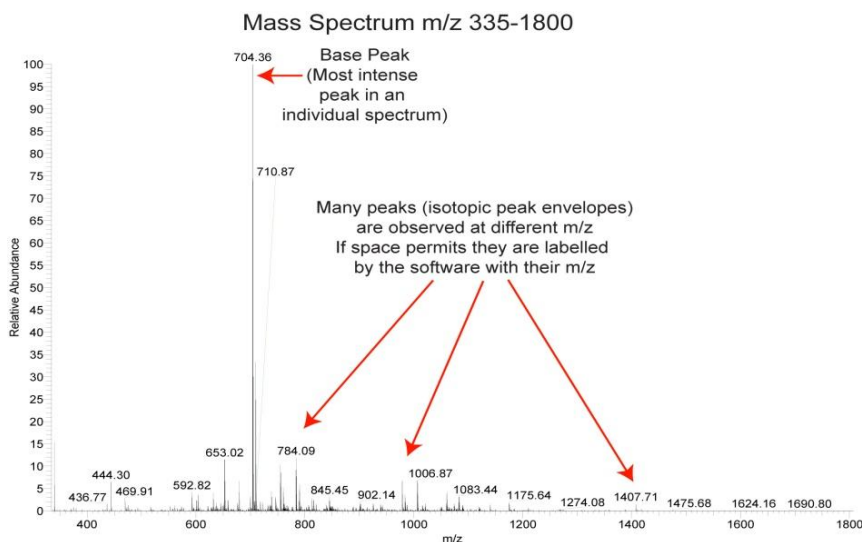


Fig. 14: An example of a mass spectrum (lamondlab web page)

In conclusion, the benefits of GC/MS are based on their high sensitivity as method instruments - they can present detailed results for complex, organic residues that hail from heterogeneous mixtures. This leads to a strain of results being both qualitative and quantitative, results few other methods can replicate.

This doesn't mean that the method of GC/MS comes without its disadvantages; these come in the form of high preparatory work that the samples require, along with the fact, that the samples become vaporized during the process, may prove problematic. Based on all the work required to commence the use of GC/MS, the method proves rather time consuming, when it is put in contrast with say, FTIR.

3.4 X-ray Diffraction (XRD)

While on the closing stages of composing this paper, a chance for further analysis on the inorganic materials of MM 18553 was presented. To this end, the use of an X-ray diffractometer was employed.

X-ray diffraction (XRD) is a rapid analytical technique primarily used for phase identification of a crystalline material and can provide information on unit cell dimensions (Connolly 2007: 1). In this case, the question at hand was if any natron remains could be found in the test sample from MM 18553, or if possible to determine if any other crystalline formation, degraded or not, existed in the heterogeneous sample.

The X-ray diffractometer consists of three basic elements: an X-ray tube, a sample holder, and an X-ray detector. The X-rays are generated in a cathode ray tube by heating a filament to produce electrons, accelerating the electrons toward a target by applying a voltage, and bombarding the target material with electrons (Connolly 2007: 3). When electrons have sufficient energy to dislodge inner shell electrons of the target material, characteristic X-ray spectra are produced.

It is interesting to note that the XRD's geometry of an X-ray diffractometer is such that the sample rotates in the path of the collimated X-ray beam at an angle θ , while the X-ray detector is mounted on an arm to collect the diffracted X-rays and rotates at an angle of 2θ (Connolly 2007: 2) (see figure 15).

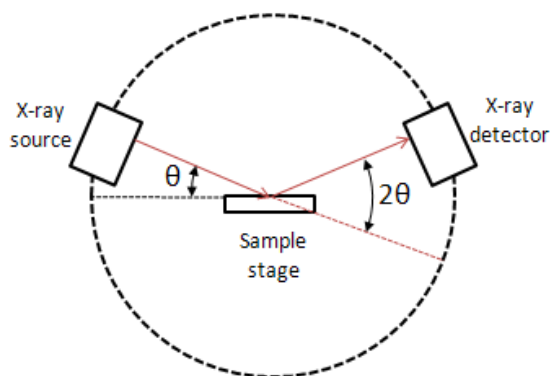


Fig. 15: Diffraction beam path in θ and 2θ mode (UCDavis chemwiki)
 θ = Glancing angle. 2θ = Diffraction angle

Despite the short time available with the XRD, this article comes to these conclusions regarding the advantages and disadvantages concerning the use of a X-ray Diffractometer.

The main advantage of XRD is its powerful and rapid (< 20 min) technique for identification of an unknown mineral. In most cases, it provides an unambiguous mineral determination with minimal sample preparation required.

This being said, homogeneous samples and single phase material are preferable for identification of an unknown mineral, which in this research's case, proved to be rather difficult. It also requires tenths of a gram of material which must be ground into a powder. In this case, the mixed material detection proved problematic, requiring several tests to be repeated, and hours' long calibrations, to retrieve a final result.

3.5 Sample preparations and Analysis

The samples underwent a series of functionalizing procedures, as preparatory measures for the samples to become ready for a GC/MS analysis.

The first step for the functionalizing process commenced by weighing both samples, followed by a chloroform/methanol extraction. The dosage consisted of 1ml of CHCl_3 (chloroform) and 0,5ml's of CH_3OH (methanol). With this part of the separation of lipid fractions complete, the samples then underwent an ultrasonic bath for an extraction through sonication, achieved by a set of 15 minutes ultrasonic baths, with a 20 minute pause between the two. By this point sample MM 19245 had completely lost its solid properties and became diluted in the solution, while MM 18553, although highly diluted as well, retained some of its elements and had formed a muddy like substance on the bottom of the test vial.

The samples were then centrifuged for 20 minutes, whereupon the now clear extracts were transferred in vials. Following the centrifugation, the sample solvents were evaporated using N (nitrogen). With the solvent evaporated, the lipid residues were obtained by treating the samples with a reagent composed of bis(trimethylsilyl)trifluoroacetamide along with a 10% (v) of chlorotrimethylsilane. This mixture was then heated for 20 minutes at 70 °C, which would conclude this phase of the analysis. The samples were then placed once again under nitrogen to remove the reagent, whereupon they became ready for their GC/MS analysis.

The derivatized samples were dissolved in C_6H_{14} (n-hexane), and 1 μl was injected into the GC/MS. The analysis was performed on an HP 6890 gas chromatograph with a capillary column SGE BPX5 (15m x ϕ 220 μm 0:25 microns) of non-polar character. The injection was pulsed splitless (pulse pressure 17.6 psi) at 325 °C via a Merlin MicrosealTM high pressure septum. He (helium) was used as carrier gas with a constant flow of 2.0 ml per minute. The oven was temperature-programmed with an initial isotherm of two minutes at 50 °C, and increased by 10 °C per minute until it reached 360 °. This was followed by a final isotherm at 15 minutes.

The gas chromatograph itself was connected to an HP 5973 Mass Selective Detector via an interface with the temperature 360 °C. The fragmentation of the separated compounds was done by two electronic ionizations (EI) at 70 eV. The temperature in the ion source was 230 °C. The mass filter was set to scan in the range m/z 50-700, giving 2.29 scan / sec, and its temperature was at 150 °C. Finally, the collection and processing of data was done with MSD ChemStation software.

In the case of FTIR, six distinct samples were detected using a microscope in sample MM 18553 along with a test sample retrieved from MM 19425 with a scalpel, which were then promptly placed into the FTIR instrument for analysis. The instrument used was a Thermo Scientific Nicolet iS10 equipped with an Attenuated Total Reflection (ATR) accessory. The instrument was set to measure between wavenumbers 4000 and 525 cm^{-1} , with 4.0 cm^{-1} resolution using 64 scans per sample.

Finally, the remainders of sample MM 18553 were set to undergo a powder X-ray diffraction and using mortar & pestle, the sample was grinded into powder. Following the grinding, the sample was ground in ethanol in order to reduce the risk of phase changes due to the mechanical treatment. The slurry was then used to drop the sample onto the sample holder. The analysis was conducted with a Siemens D5000 X-ray Powder Diffraction (XRD) System, with a precipitated angle ranging from 10 to 100 degrees, set on analyzing every tenth degree. The beam was set at a voltage of 40 kV (kilovolts) and a current of 40 mA (milliamps). The first 8 measurement runs proved to produce inconclusive results, thus an overnight analysis was conducted that bore fruit. This result along with the rest of the results will be presented in the following chapter.

4. Results

4.1 FTIR

The results of the analysis partly confirmed the hypothesis concerning MM 18553, while the results about 19245 were of a rather perplexing nature (see table 2). Several test samples were retrieved from MM 18553 to adequately determine the multitude of remains composing its heterogeneous nature two textile fibers (reddish brown, and white), a brownish organic like material and a black sample. The results ranged from protein and carbohydrates to vegetable oils, carboxylic acids ionized carboxyl, and others.

Table 2: Sample results from FTIR-analysis

Sample	Results
MM 18553 br 1	Organic, traces alkanes, fats, carbonylic
MM 18553 br 2	Vegetable, traces alkanes, hydroxyl groups
MM 18553 fib.	Linen? Vegetable fiber.
MM 18553 redfib.	Red linen? Traces carboxylic acids
MM 18553 lifib.	Crystalline formation, sodium carbonates
MM 18553 b	Quarts? Cermaic? Traces of Silicates and nitrogen
MM 19245	Vegetable oils, traces of hydrocarbon bonds

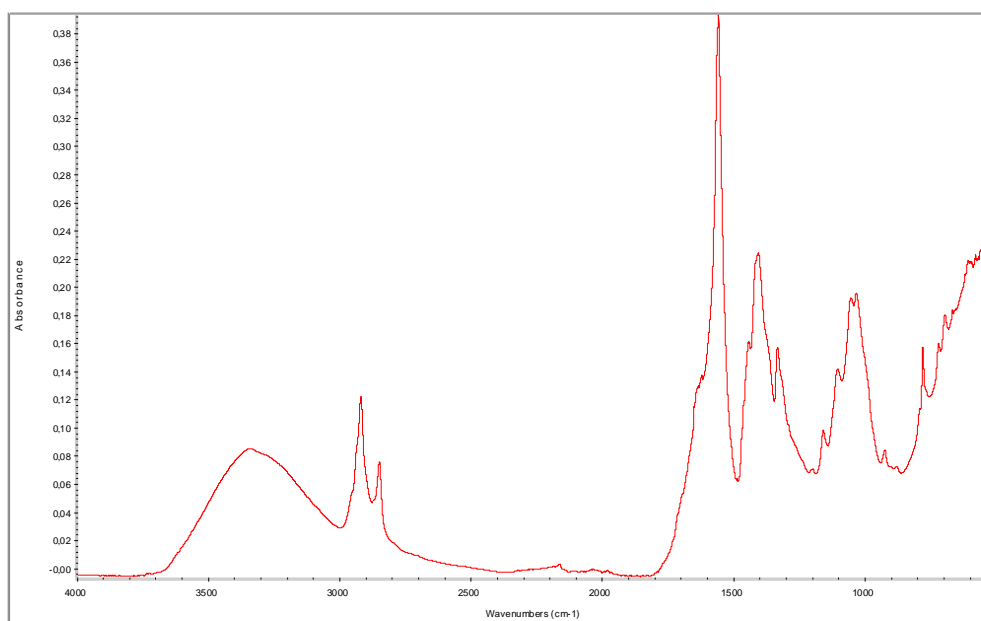


Fig. 16: MM 18553 br. (brownish material)

The peaks between 3000 and 2800 reveal C-H bonds, alkanes and fats, some traces of OH (hydroxide), while in the fingerprint area (2000-1500) carboxylic acids are detected. The highest peak at 1582 derives from ionized carboxylic acids as well (see figure 16).

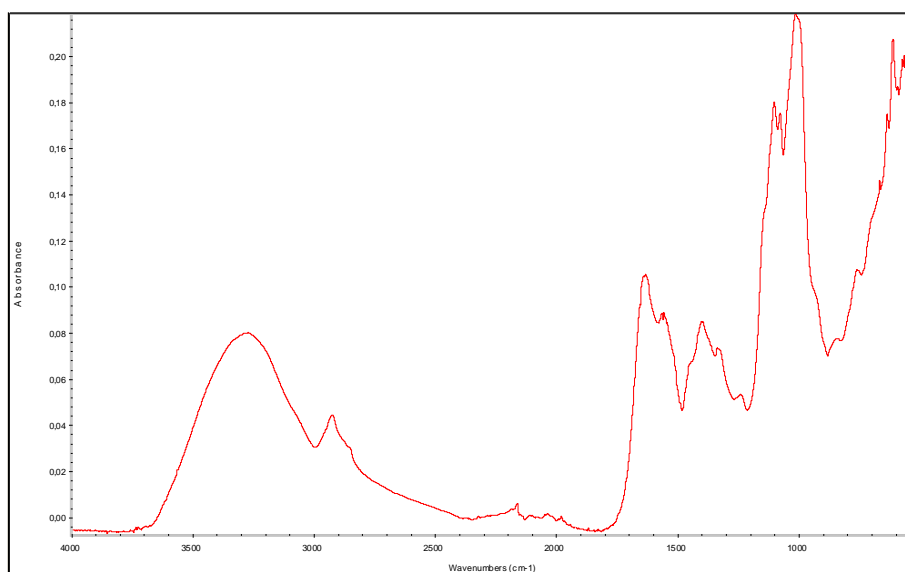


Fig. 17: MM 18553 br. 2 (brownish material)

Much like most of the samples retrieved from MM 18553, br. 2 has an alkane peak, this time with some indications that this sample might contain hydroxyl groups or perhaps some aromatic properties (3500-3000). On the fingerprint area, ionized carboxylic acids (1500) are detected, while on its highest peaks between 1100 and 990 carbohydrates, a possibly vegetable - like nature can be seen (see figure 17).

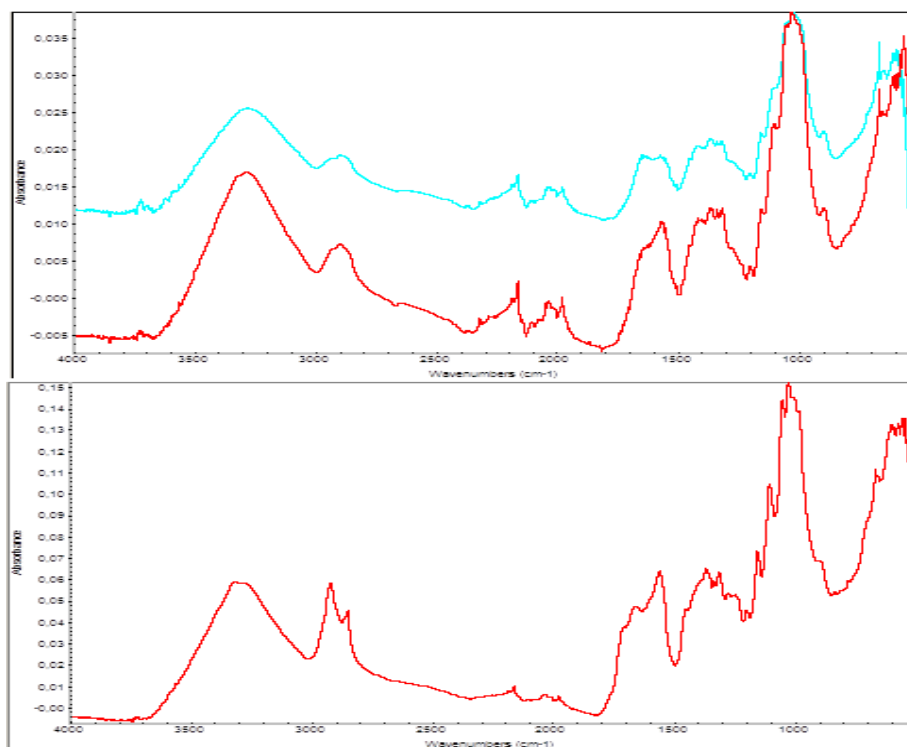


Fig. 18: MM 18553 fib & redfib. On the upper spectra with red we see the results from the sample, while highlighted on light blue is, its most similar spectra, that of linen.

In case of MM 18553 fib., the results corroborate the early hypothesis, about this sample containing linen, with the only difference in the spectrums being the top 1020, pointings towards a vegetable fiber.

In the case of MM 18553 redfib., identification is not as clear cut. Although the spectrum does indeed resemble that of the previous one, there are some evident and striking differences.

The absence of sharp peaks between 2300 and 2000, along with sharp peaks around 3000-2900, showcase C-H bonds and perhaps the use of dyes. Moreover, the peaks 1610 and 1550 might be traces of degraded carboxylic acids. Thus, the hypothesis about this spectra postulates, that MM 18553 redfib. was probably dyed linen or some vegetable fiber, admixed with something more (see figure 18).

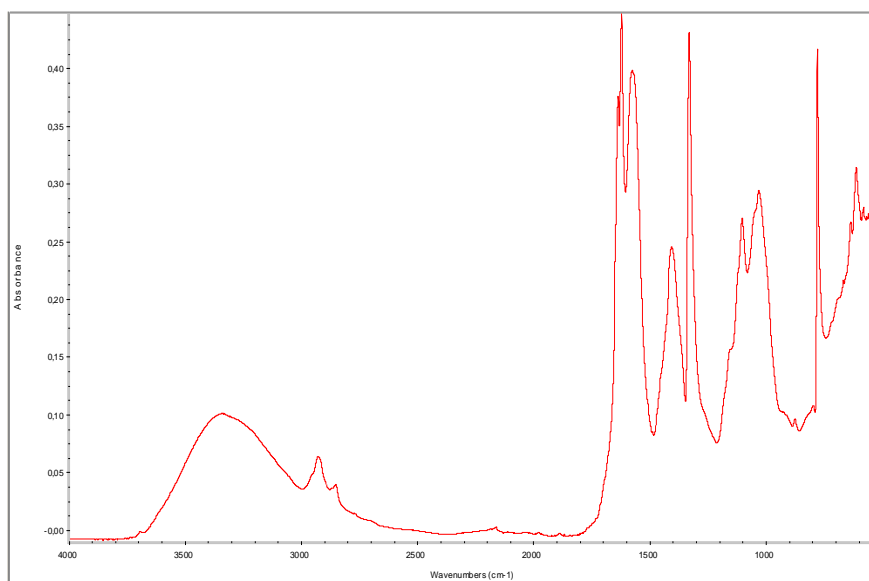


Fig. 19: MM 18553 lifib. (light brown fiberlike sample)

One of the most detailed results is the one that proved the most difficult to determine. The Sample appears rich in coal bonds, sodium carbonates/sulfates, and ammonium. On the fingerprint area, sulfates are found on 1100, while between 1650-1640 traces of N-H can be detected. With no existing similar spectra in the database, the sample provided for initiating a XRD analysis, to determine the nature of this crystalline formation (see figure 19).

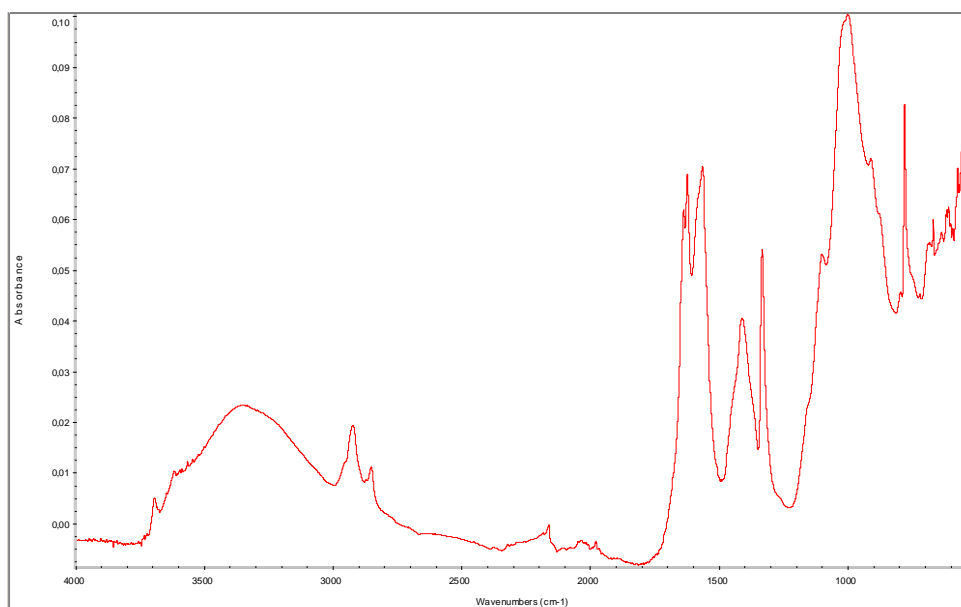


Fig. 20: MM 18553 b. (round black ceramic like sample)

The spectra revealed that this sample could be either quartz or some type of ceramic, while rich concentrations of silicates and coal bonds are evident. Interesting to note, are the double peaks between 1700-1600 that could be of N-H origin as well (see figure 20).

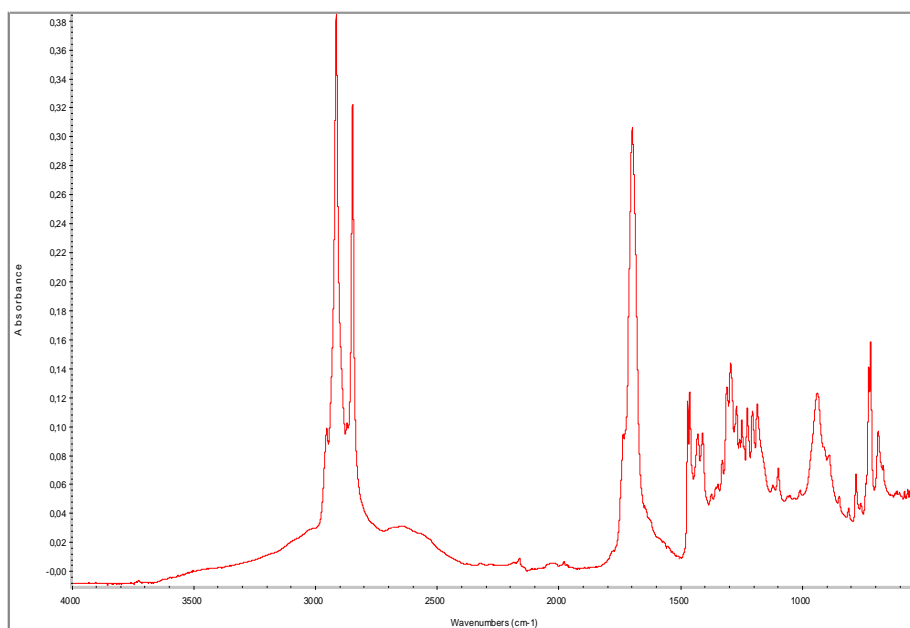


Fig. 21: MM 19245

Despite the information given by the museum, the spectra revealed that MM 19245 was not honey. In fact, no evidence that it contained any bee product (like beeswax) could be assessed. The spectra revealed that MM 19245 was actually some type of vegetable oil rich in hydrocarbon bonds, as seen on the tops between 3000-2800. Although the nature of the sample is all but certainly that of a vegetable oil, carboxylic acids can be clearly traced in peak 1690 one of the highest peaks of the spectrum (see figure 21).

4.2 GC/MS

The sample's results reveal a high consistency of hexadecanoic/palmitic acid (C16: 0) at 56% while the second highest percentage is that of octadecanoic acid, known as stearic acid (C18: 0). Despite the existence of these two fatty acids, the ratio of C16:0 and

Table 3: GC/MS results for MM 19425

Peak	R.T. min	% of total	Substance
1	7.679	1.166%	Nonanoic acid
2	8.486	2.218%	Dihydroxybutanedioic
3	10.546	0.368%	Hexanedioic
4	11.515	0.983%	Octanedioic
5	12.515	1.637%	Nonanoic acid
6	12.969	2.919%	Tetradecanoic acid
7	13.903	0.441%	Pentadecanoic
8	14.592	3.400%	9- hexadecanoic
9	14.819	56.385%	Hexadecanoic
10	15.428	0.445%	14- methyl hexadecanoic
11	16.276	16.214%	9- octanedioic
12	16.338	2.561%	5- hydroxy hexadecanoic
13	16.524	8.961%	Octanedioic
14	17.521	0.529%	4,4- dihydroxy hexadecanoic
15	17.578	0.649%	?
16	17.741	1.123%	?

C18.0 is quite low (C18/C16 \approx 0.16). MM 19245 appears to be of vegetable oil nature, indicated mainly by the absence of cholesterol in the sample,. Which in turn could have meant that the fatty acids came from aquatic oils (see table 3). The dicarboxylic acids C5 - C9 can show that the sample is indeed an artefact on the grounds of the dicarboxylic acids being formed by the process of degradation of fatty acids. Note that this sample dissolved completely during its extractions. Thus, this article comes to interpret MM

Table 4: GCMS results for MM 18553			
Peak	R.T min	% of total	Substance
1	10.563	0.240%	Heptanedioic
2	11.536	0.485%	Octanedioic
3	12.520	0.724%	Nonanoic a.
4	12.973	1.047%	Tetradecanoic
5	13.454	0.138%	Decanedioic
6	13.897	0.149%	Pentadecanoic
7	14.281	0.799%	Hexadecanoic
8	14.505	0.926%	?
9	14.585	1.896%	?
10	14.661	2.730%	?
11	14.744	1.850%	?
12	14.824	33.617%	Hexadecanoic
13	15.698	0.596%	Heptanedioic
14	16.085	5.386%	Octanedioic
15	16.268	0.702%	?
16	16.362	0.753%	?
17	16.449	0.778%	?
18	16.527	8.033%	Octanedioic
19	27.089	10.394%	D32
20	27.542	0.260%	D33
21	27.818	0.347%	D34
22	28.016	18.885%	D34
23	28.899	1.434%	D36
24	32.589	1.267%	T48
25	33.287	3.725%	T50
26	34.115	2.841%	T52

19245 as a heavily degraded vegetable oil. The high concentrations of palmitic acid (peak 14.819) and stearic acid (peak 16.276) can be seen clearly in this chromatograph, further validating the claims raised in the previous paragraph.

Much like its heterogeneous nature, the results concerning MM 18553 are just as perplexing. The sample contains both deteriorated fatty acids as well as traces of intact one's too. Its highest concentration is composed of palmitic acid (C: 16) at 33%, which constitutes evidence for big amounts of deteriorated fatty acids being the end product of decomposition hydrolysis of intact fats. Peak 28.016 contains large traces of deteriorated palmitic acids (18%), this can be postulated as degraded long-chain n-hexadecanes.

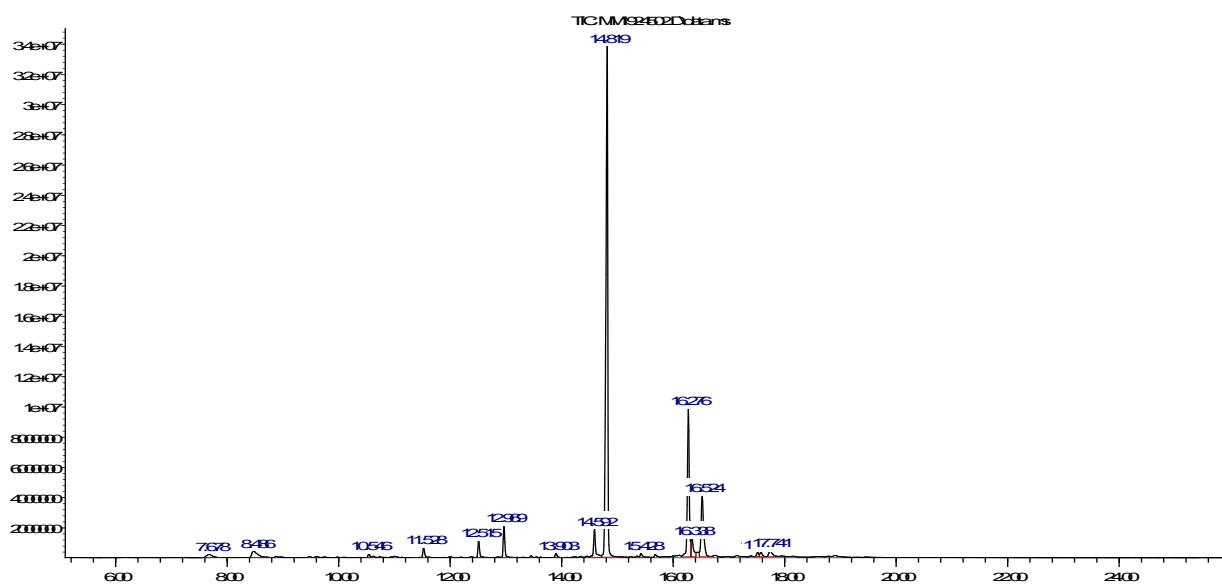
The three triacylglycerides T48, T50 and T48 represent traces of intact lipids. While intermediate decomposition products are the diacylglycerides (D32-36). All of these fatty acids are still bound to glycerine; two fatty acids each for D32-36 and three each in the T48-52.

Peak 27.089 contains 1,3 dipalmitate (10%). Triglycerides are the main constituents of vegetable oil (typically unsaturated), animal fats (saturated) and also known for being a major component of human skin oils. They are common for lipids with long-chain carboxylic acids. Finding triglycerides during the analysis amounted for yet another point supporting the existence of decomposed fatty acids in the sample.

These concentrations cannot on their own support that MM 18553 contained remains of a human or an animal, apart from the obvious lack of cholesterol, the two fatty acids ratio of C16:0 and C18:0 ($C18/C16 \approx 0.40$) is quite low to support a claim like that. Nevertheless it must be noted, that due to the fact, that not all the fatty acids are released yet, the C18/C16 ratio might be different, than the one presented. Despite that, a hypothesis on the basis of these results concludes, that these traces belonged to a terrestrial animal.

This article concludes, it can be theorized that MM 18553 might indeed contain remains belonging to a human or an animal, but these remains have come to be degraded, and thus making it very difficult for an accurate hypothesis or estimation.

Abundance



Time-->

Fig. 22: GC/MS results of MM 192425 presented in a mass spectrum featuring its peaks with the highest one being that of 14.819, representing a high concentration of palmitic acid

Abundance

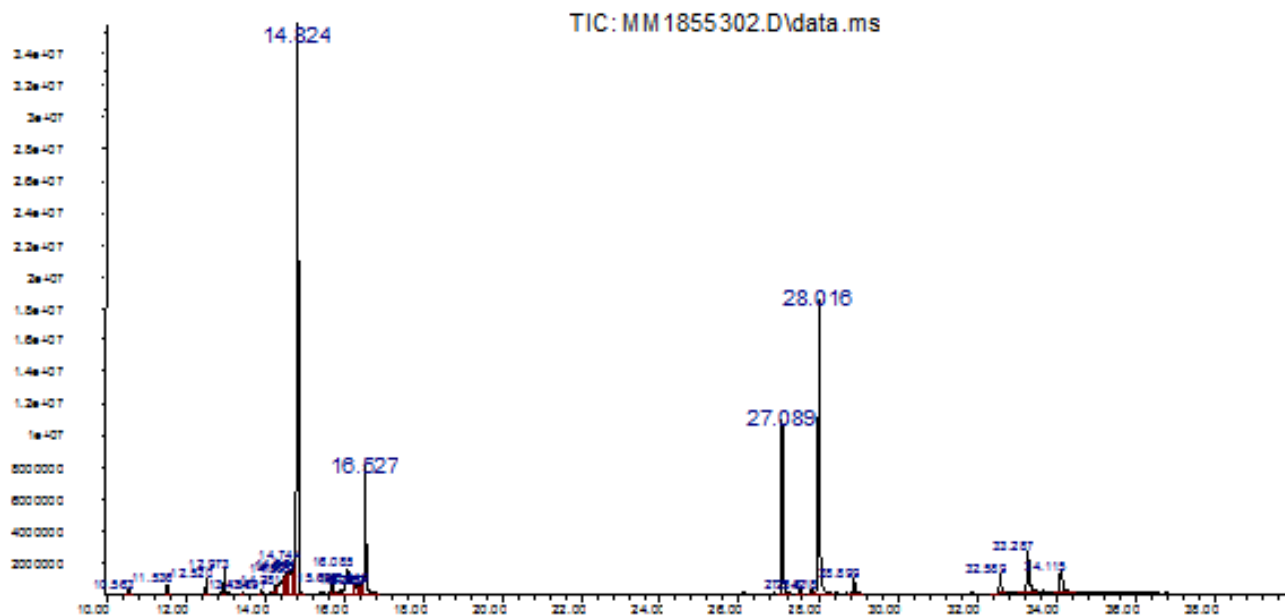


Fig. 23: GC/MS results of MM 192425 presented in a mass spectrum featuring its peaks with the highest one being 14.824 representing a high concentration of palmitic acid, while peaks 27.089 and 28.016 represent the evidence for diacylglycerides, further more small peaks on the plus 30.+ count feature the triacylglycerides, as postulated in the previous page.

4.3 XRD

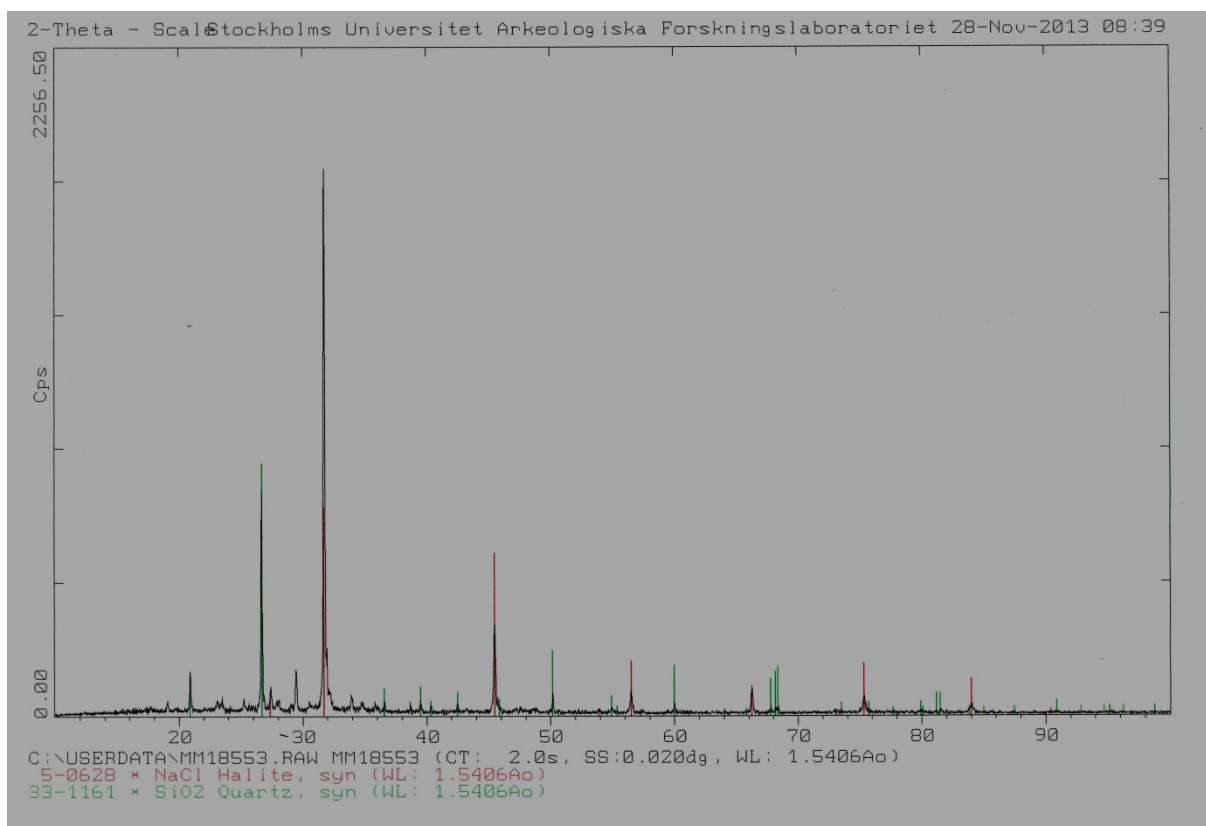


Fig. 24: X-ray diffraction pattern of MM 18553

Although conducted during the final stages of composing this article, one main question still remained concerning MM 18553. During the previous analyses methods, it was proven that MM 19425 was in fact not honey, as the museum had originally theorized. Thus the question, about the existence of natron in MM 18553 was raised.

From the diffraction pattern, it can be seen that quartz and halite were found. The peaks of quartz are high and narrow showing a good crystal state. After a long diffraction session, it was determined that the sample contained halite, also known as rock salt. Moreover, despite the vigorous and long analysis, no natron remains degraded, or whole were uncovered. This discovery was one of the pivotal and most important parts of the research progress, due to the fact that it determined, the lack of the most important ingredient in any artifact, concerning the mummification context.

It can be theorized that salt was used instead of natron, but this hypothesis is to be catered in the following chapter.

5. Discussion and conclusion

5.1 Results and final assessments

The aim of the study was to assess and identify the composition of the samples and to answer the following questions.

- A. Is the use of FTIR, GC/MS and XRD techniques reliable and valuable techniques for this archaeological research?
- B. What new information can the results reveal about the artefacts?
- C. What correlation can be drawn between the artefacts and the mummification context?

As previous studies already have shown (presented in chapters 1.1 and 2.4) artefacts can prove to be extremely difficult to interpret and “reconstruct” after they have been taken out of their original context. To this end the use of scientific techniques in archaeology are opening new horizons, deemed unimaginable in the past. Despite the small sample size the majority of the paper’s test analyses results are covered and supported by at least two full sequences for each sample.

This, along with the new data retrieved from the results, make all but certain that the use of FTIR, GC/MS and XRD sequences are both reliable and valuable methods to base an archaeological research on, the fact that this research was able to uncover the nature of their contents, with almost no damage inflicted on the artefacts themselves, is by all means gripping. The use of these advanced techniques, not only ensured that the artefacts may be properly identified, but did so, both in timely order and in a cost-effective way.

In terms of results, this research not only casted away the previous identifications of these samples, but also provided results on which further hypothesis may be formulated.

Namely, sample MM 19245 stood out due to interpretation by the museum, as, honey, or some other kind of bee product. Still the sample proved to have fewer components than MM 18553 *ergo*, easier to identify. MM 19245 can be safely interpreted as a degraded vegetable oil, at large. This is similar to test results from the study of Pharaonic and Greek - Roman mummies (Buckely and Evershed 2001) where the main components of their samples consisted of oil in the sample. Oils were meant to be used as cheap bases to more complex mixtures with other more expensive materials added. Could this perhaps be a vessel with an oil base that was later mixed with other components prior to using it on the mummy? A farfetched hypothesis perhaps, but one that did not exist before, nonetheless. In addition, although MM 18553 proved a lot harder to identify, the discovery that it contained no natron, was in fact of larger importance, than if natron was indeed found. Furthermore, the discovery of halite may still prove to be a viable link in correlation with the mummification process. According

to Ikram (2005: 17-18, 26) and Auferheide (2003: 182), salt was also used to desiccate the bodies of both humans and animals when natron was not available. Thus it can be once again argued, that artefact sample MM 18553, can be reconstructed and correlated within the mummification context, despite its complex results concerning fatty acids, and the lack of natron, in this case; it is this article's hypothesis based on the analyses results, that the linen bags containing halite (not natron) were used to desiccate animals, that were in turn mummified.

Furthermore, the insectoid exoskeleton found when sample MM 18553 was scrutinized under a microscope was photographed, and send to Dr. Philip Buckland, Deputy Head of Department Senior lecturer in Environmental Archaeology Director of the SEAD and Fellow of the Royal Entomological Society, his observations were that, the exoskeleton probably belonged to a *Anthrenus museorum*, commonly found in museums being notorious for consuming any organic material that comes to their way, being a common occurrence in museums and collections.

The good condition in which the exoskeleton was found in led Dr. Buckland to summarize, that it most probably is a modern contamination. The larva has several steps in its life, leaving shells behind them, and the shells are then usually found in museum collections.

Given that these artefacts were devoid of context. This research has provided new data that has considerable value for these and may provide, for a further unwrapping of the past.

5.2 Further studies

For future studies, a more in depth analysis on the unidentified substances could be given by comparing the mass spectra with previous surveys. This research managed to prove two earlier identifications wrong, and provide new ones. The Museum of Mediterranean and Near Eastern Antiquities of Stockholm retains a plethora of artefacts that are devoid of context, artefacts that if put under similar thorough research, may provide for gripping information, and furthering the archaeological knowledge.

6. Summary

This paper deals in part with the chemical identification of context lacking antiquities and partly with the process of mummification and the textiles used during the process. Based on samples retrieved from two vessels, and their contents are analyzed with FTIR, GC/MS and XRD, this was done to identify the chemical components and thus reveal whether these artefacts were used in the embalming process.

The early hypothesis, based on the information provided by the museum's antiquarians, postulated that the artefact MM 18553 composed of linen bags containing natron, could have indeed be used in the embalming process, while MM19245 being harder to

correlate with the mummification context, was hypothesized as a bee product that in a farfetched scenario could have been used, as the base for other embalming materials.

The results showed that the descriptions provided by the museum did not stand. Although organic materials were found in MM 18553 the artifact is devoid of natron, but featuring rock salt (halite). While MM 19245 proved to be a vegetable oil, far from any bee-product.

Nevertheless components of the samples could in fact support the hypotheses raised by this article regarding the mummification process, halite was known to be used as a cheaper solution to natron, and vegetable oils were indeed used to create more complex embalming mixtures. Also revealed, are similarities between these samples and those of previous surveys, thus strengthening both the results concerning the research questions, but also regarding the use of scientific techniques in archaeology, proving to be all more resourceful, in regards with the identification of artefacts, and the vast help they presented when these artefacts lack their original context or subject, and thus need to be placed in one.

Most importantly, both artefacts were properly identified and placed in a broader context, something which was not the case before this research.

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Photo material

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Fig 1 - <http://collections.smvk.se/carlotta-mhm/web/object/3007343> &

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Fig. 4 - <http://www.louvre.fr/en/expositions/kingdom-alexander-great-%E2%80%93-ancient-macedonia>

Fig. 5 -

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Fig. 6 - http://farm2.staticflickr.com/1111/765568141_8311270b06_o.jpg

Fig. 7 -

http://karin.fq.uh.cu/~cnv1/qf/Parte_3_3A_01_08Martes/Fayum/_d_files/61au66cKweL.jpg

Fig. 11 -

<http://www.lamondlab.com/MSResource/images/lcms/MassSpectrometerOverview.jpg>

Fig. 13 - <http://www.sfu.ca/bisc/bisc-429/gcmap.gif>

Fig. 14 - <http://www.lamondlab.com/MSResource/images/lcms/MassSpectrum.jpg>

Fig 15 -

[http://chemwiki.ucdavis.edu/@api/deki/files/232/xrd.png?size=bestfit&width=323&height=237
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