Case study of a 19th century gypsum cast of the Parthenon Frieze

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Uppsats för avläggande av filosofie kandidatexamen i Kulturvård, Konservatorprogrammet
15 hp
Institutionen för kulturvård
Göteborgs universitet

2019:15

Naturvetenskapliga fakulteten

GÖTEBORGS UNIVERSITET

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Kandidatuppsats, 15 hp
Konservatorprogram
Lå 2018/19

GÖTEBORGS UNIVERSITET
Institutionen för kulturvård

ISSN 1101-3303
ISRN GU/KUV—19/15—SE

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Program in Integrated Conservation of Cultural Property
Graduating thesis, BA/Sc, 2019

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ABSTRACT

This thesis is a case study of a 19th century gypsum cast of block WXI of the Parthenon Frieze. The gypsum cast is part of a continuous collection of eleven gypsum casts of the west part of the Frieze, casts of the blocks WI - WXI. The collection is housed in the Conservation Department at the University of Gothenburg. The collection has no accessible documentation about ownership or location. The origin and history of the collection is not fully known. The gypsum casts are covered with a cracking and flaking yellow grey paint. Some of the blocks are very dirty and have losses in the gypsum. In the study, material analysis of block WXI is combined with archive research to identify the materials present and their historical significance. The aim of the archive research is also to strengthen the provenance of the collection. Visual examination, cross section microscopy, XRF-, FTIR-, and UV- analysis is used to identify the composition of the paints and gypsums present. Archival documents mention three occasions when materials are added to the object. In 1906-1908 the gypsum collection was painted because it was sooty, in 1914 gypsum and paint was added because of a new mounting, and in 1960 repairs and repainting was done due to relocation of the collection. Both the paint added in 1914 and the paint added in 1960 are oil based and contain zinc white. The archive research confirms the collection was acquired by Göteborgs Museum in 1892 as part of a gypsum cast collection financed by a donation from colonel Paul Melin. The Parthenon gypsums were bought from D. Brucciani, London, who made casts for the British Museum. The archive research also proves the collections path from Göteborgs Museum to its present location at the University. The gathered information can provide a basis for establishing documents about ownership and location, as well a basis for a conservation treatment plan for the collection.

Title in original language: Case study of a 19th century gypsum cast of the Parthenon Frieze
Language of text: English
Number of pages: 50
Keywords: Plaster casts, gypsum, Parthenon Frieze, Göteborgs Museum

ISSN 1101-3303
ISRN GU/KUV—19/15--SE

Preface

I would like to thank my mentor Austin Nevin for great help and support throughout the project. I would also like to thank Stavroula Golfomitsou for suggesting the Parthenon gypsum collection as a thesis subject.

Lastly, I would like to thank Björn Fredlund, Jan Rosvall, Margareta Edebo, Maria Höijer and Charlotta Hanner Nordstrand for sharing their knowledge about the collection and the Gothenburg art scene during the last century. Thank you, your help has been invaluable for the project.

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1. INTRODUCTION

This thesis investigates the materials and history of a 19th century gypsum cast. The work is a bachelors' degree project and comprises 15 ECTS credits. The thesis is written in the spring 2019 and is the final project in the bachelors' program in Conservation at the University of Gothenburg.

1.1. Background

The gypsum cast investigated in this study is part of a collection of eleven gypsum casts. The gypsum reliefs are casts of the west frieze of the Parthenon temple on Acropolis, in Athens, Greece. The collection is located at the Department of Conservation, Gothenburg University. Four of the reliefs are on display in the hallway, the rest are stored in the basement. There is uncertainty about the origin and ownership of the collection, and about the circumstances regarding the housing of the collection at the department. The history and origin of the collection is investigated in this study in chapter 4.3. Archive Research.

The collection is facing difficulties such as deteriorated surface treatments with cracking and flaking paint, losses in the gypsum and poor storage solutions. In this study, the materials and condition of one of the representative blocks are examined and analysed.

This thesis, when discussing the different marble- or gypsum blocks of the Parthenon frieze, uses the same nomenclature as the Acropolis Museum (parthenonfrieze.gr). The block examined in the study, for example, is *WXI*, where *W* stands for the west part of the frieze, and *XI* is block number eleven counting from the left. When discussing the eleven gypsum casts as a collection, they are called *the Parthenon gypsums.* In the literature, gypsum casts are commonly called *plaster casts*. In this thesis, the term *gypsum cast* is used, since it more precisely defines the material. Gypsum cast is also a direct translation of the Swedish word *gipsavgjutning*, the term used in both literature and archival documents. The photographs and illustrations in this thesis are by the author, if not otherwise stated.

1.2. Research and knowledge base

A comprehensive collection of papers on gypsum casts are found in *Plaster casts: making, collecting, and displaying from classical antiquity to the present*, edited by Rune Frederiksen and Eckart Marchand (2010). The papers offer different perspectives on gypsum casts, mostly from an art historic and historic point of view, but the volume also contains three case studies on the conservation of gypsum casts. Two other sources on the history of gypsum casts are the chapters by Anne-Marie Leander Touati and Elisabet Tebelius-Murén in the Swedish Nationalmuseum's publication on authentic art and forgery, *Falskt och Äkta* (2004). Another of Nationalmuseum's publications, *Gips: tradition i konstens form,* edited by Solfrid Söderlind (1999), discusses gypsum cast collections in their own museum and elsewhere, which has been useful as a reference when discussing the Parthenon collection.

The material gypsum is a little overlooked in the conservation literature. However, in recent years, there have been several articles and papers published on the topic. Among the publications found on cleaning gypsum, some have been more informative sources. The publication from Cesmar7 by Anzani et al. (2008) about cleaning gypsum sculpture with agarose gel, is both detailed and instructive. Eliza Doherty and Shayne Rivers (2017) paper on the removal of paint layers from a gypsum cast, also has a detailed description of how the conservation strategy is worked out and completed. Another publication useful for the thesis is Kathryn Brugioni's article about eraser cleaning of gypsum (2015), where the physical properties of the material are discussed. As gypsum also is used for decorative architectural elements, such as stucco, some building oriented literature has been useful as well. *Mortars, renders & plasters* edited by Alison Henry and John D. Stewart (2011) and *Conservation of plasterwork: a guide to the principles of conserving and repairing historic plastering* edited by Mandy Ketchin (1994), both contain chapters on the material properties of gypsum, and how gypsum interacts with other materials.

The Parthenon and its sculptures have been researched, documented and debated during centuries. The amount of literature on the subject is abundant. For the purpose of this study, literature with a more general perspective is required, which provides a background for the artworks the gypsum casts are representing. The Acropolis Museum's website is a very good resource for the study of the Parthenon sculptures. Mary Beard's *The Parthenon* (2004) is a good introduction to the subject. In the book Beard writes about the Parthenon's history from its building until the 21st century. From Joan Breton Connelly's *The Parthenon enigma* (2014), some chapters provide complementary, if a slightly different, perspective.

Ian Jenkin's article *Acquisition and supply of casts of the Parthenon sculptures by the British Museum* (1990) offers an insight into the British Museums casting business from the early 19th -to early 20th century. Another useful article on the topic of British gypsum casting businesses, in this era, is the article *How the Smiths made a living* by Peter Malone (2010), published in the earlier mentioned volume by Frederiksen and Marchand.

Jeff Werner (2009) writes about the development of the exhibitions in the Göteborgs Museum (Gothenburg Museum), and in the Gothenburg Art Museum, in his article in Skiaskope volume 1. The article has been a valuable starting point for further research in the archives. Although Werner (2009) does not mention the Parthenon gypsums specifically, he discusses the *Melin collection,* to which the Parthenon gypsums appear to belong (see chapter 4.3). Charlotta Hanner Nordstrand's book about the Gothenburg Museum in the 19th century (2008), provides an understanding of the museum environment when the Parthenon gypsums were acquired.

1.3. Problem statement and Research questions

The Parthenon gypsum collection is in need of conservation treatment. On the block examined in this study, the paint is cracking and partially flaking. There are also losses of gypsum along the edges of the object. The collection does not have a full provenance, or accessible documentation concerning ownership and the housing of the collection at the University. Well informed decisions concerning conservation treatments, are not possible without further knowledge about the object's material and history.

Questions arising include:
- What materials are present on the gypsum cast? What is the stratigraphy of the paint layers?
- When and why was the paint applied?
- What information can be found that strengthen the collection's provenance?

1.4. Objectives and Aims

The objective of this study is to contribute to the knowledge about the Parthenon gypsum collection housed in the Conservation Department, Gothenburg University. The research into the history and materials of this specific collection, may also add to the general knowledge about gypsum cast collections.

The aim of the study is to put together a document useful for working out a conservation strategy for the collection, as well as for establishing documents concerning ownership and housing.

1.5. Limitations

Out of the eleven blocks in the gypsum collection, only one block is examined in the study. Some of the other blocks in the collection have been surface cleaned, retouched and infilled. The condition of the block examined in the study is not representative for the previously treated ones. Apart from this, the eleven blocks seem to have similar materials and similar degrees cracking and flaking of their paint layers, but this still has to be verified. Because of its size, weight and unstable edges, lifting and moving the gypsum cast involves significant risk of damage. For this reason, the examination of the object is limited to what can be done in situ. For the same reason, access to the back of the object has been limited. The back is therefore not as well documented as the front.

Stored together with the collection of gypsum casts of the Parthenon frieze, are two gypsum casts of metopes. The metopes are also casts from the Parthenon. The metopes are claimed to belong to the same collection as the casts of the frieze. The two metopes are not included in this study. When the casts of the frieze are mentioned in the archival documents used for this study, there is no mentioning of metopes.

With no accessible documentation about ownership of the object, interventions are strictly limited. Because of this, the sampling for analysis focused on fragments and paint flakes already lost from the object. This limits which materials are possible to analyse. For the same reason, no tests of any conservation treatments have been carried out. This makes the discussion on treatment options more theoretically than practically oriented.

Because of limitation in time and space, further archive research and repeated analysis would be necessary to complete the study. Also because of the time limit, the section on conservation of gypsum casts is focused on cleaning rather than potentially necessary conservation of structural issues, such as infills, rejoining parts and change failing inner supports.

1.6. Ethical issues

The ethical position, constituting the fundament for this thesis, is clearly stated in ICOMOS 2003 charter *Principles for the preservation and conservation-restauration of wall paintings*, article 2:

All conservation projects should begin with substantial scholarly investigations. The aim of such investigations is to find out as much as possible about the fabric of the structure and its superimposed layers with their historical, aesthetic and technical dimensions. (ICOMOS 2003, p. 2)

A thorough investigation of the object's historical, aesthetic and technical dimensions is crucial for understanding how, and why, the object should be conserved. According to Salvador Muñoz Viñas (2008), it is the conservator's moral duty to find out *why* an object is being conserved. To find out why, the conservator must learn about the object's values and how the object is being used. Muñoz Viñas also stresses the importance of the discussion on conservation ethics taking place *before* the conservation process begins (Muñoz Viñas 2008, p. 204, 214).

Sampling for analysis requires that material is removed from the object. *ECCO (European Confederation of Conservator-Restorer's Organisations) Professional Guidelines (II) Code of Ethics* (2003) addresses this issue in article 15:

The conservator-restorer shall not remove material from cultural heritage unless this is indispensable for its preservation or it substantially interferes with the historic and aesthetic value of the cultural heritage. Materials, which are removed, should be conserved, if possible, and the procedure fully documented. (ECCO 2003, p. 2)

In this study, sampling is done on the microscopic scale, from fragments and paint flakes already lost from the object. Still, the process is destructive. Material, that could be reintegrated, is lost. The benefits of the analysis have to be weighed against the loss of material. In this case, the information that could be gained from analysis, was considered to justify the loss.

1.7. Methodology

The methodology of this study is a combination of material analyses and archive and literature research. The analytical techniques used, as well as the archive research method, are summarised in the following paragraphs.

1.7.1. X-ray Fluorescence Spectroscopy

X-ray fluorescence spectroscopy (XRF) reveals elements present in the material. In XRF- analysis the material is exposed to X-rays or gamma-rays. The energy from the X-rays excites electrons in the lower orbitals to higher orbitals, leaving behind a void. Electrons in higher orbitals fill these voids, and when doing so, they emit energy, photons. The photons emitted are specific for each element. The emissions are registered and plotted in a spectrum. XRF analysis can detect elements heavier than aluminium, but cannot detect lighter elements, chemical states or compounds. XRF can be used as a non-destructive technique. The method is indicative rather than quantitative (Dran & Laval 2009, pp. 210-213).

1.7.2. Fourier Transform Infrared Spectroscopy

Fourier Transform Infrared Spectroscopy (FTIR) measures transmission and absorption of infrared radiation. The energy of the radiation in the infrared spectrum is not high enough to affect the electrons inside the atom, but it causes the bonds between the atoms to vibrate. Different bonds in the molecules vibrate at different and characteristic wavelengths. When using FTIR with a transmission application, a detector registers which wavelengths are absorbed and which are being transmitted through the sample (Derrick, Stulik & Landry 1999, pp. 4-14). In this study, the FTIR is used with an Attenuated Total Reflection (ATR) application using a diamond crystal. The ATR measures the refraction of the infrared radiation, instead of the transmission, which allows for analysis of solid, non-transmittable substances. The sample has to have surface contact with the crystal in the ATR-device (Smith 2011, p. 129, 141).

In FTIR-ATR data is plotted in a spectrum. The spectrum shows bands, or peaks, in a plot of reflected radiation vs. wavenumber. The spectrum is unique for each compound. The spectrum is compared with existing spectra of known substances for interpretation and assignment.

1.7.3. Cross-section Microscopy

Cross-section microscopy analysis of micro fragments gives a visual image of the layered structure of an object. The spot for sampling should be chosen carefully, when possible on the edge of the object or near an existing crack (Derrick, Stulik & Landry 1999, p. 33). A cross-section can provide information about the materials present, as well as their stratigraphy. The layering of the substrate, paints, dirt, repair materials, varnishes and so on, gives an insight into the chronology of the materials. Apart from being studied in reflective visual light microscopes, as in this study, the cross-section samples can be further analysed with other techniques, such as scanning electron microscopy or fluorescent staining and UV-microscopy. Cross-section microscopy is a destructive technique, even if the samples can be as small as 100 microns (Wolbers, Buck & Olley 2012, pp. 326-335).

1.7.4. USB-microscopy and UV-analyses

A portable USB-microscope enables close-up imaging of an object that cannot be moved to the lab for microscopy. A USB microscope is plugged into the USB-port in a laptop. A software displays the microscope image on the laptop screen and is also used to capture the microscopic photographs. The Dino-Lite USB microscope has a UV-light function that can be useful for determining what materials are present on the surface of the object.

When exposed to ultraviolet (UV) radiation, some substances absorb this radiation and re-emit radiation of longer wave lengths, visible to the human eye. The re-emitted radiation is called UV-fluorescence. The colour of the fluorescence is significant for the substance and can be useful for identification (Buzzegoli & Keller 2009, p. 204).

1.7.5. Archive research

An archive consists of documents that gradually build up as a result of the archive creators' activities. The word *archive* also refers to the building or institution where the archives are kept. (Lindroth 1994, p. 9). By researching archival material, one gets access to the primary sources instead of other researchers' interpretations of the same. In this way unpublished material from the archives may contribute to new perspectives, and more perspectives, on a subject (Wångmar & Lennartsson 2018, p. 366).

For the purpose of this study, information about the history of the Parthenon gypsums is gathered from archival material, literature and oral sources. Information from oral sources is gathered in different ways, from short questions and conversations in person, to phone calls, emails and more structured interviews. When possible, the information from the oral sources has been verified by written documents. In cases where no written source has been found, or even exists, specific people, with their approval, are referred to as the source.

2. CULTURAL CONTEXT

This chapter aims to give a cultural background to the kind of objects, gypsum cast copies of antique sculpture, discussed in this study. The chapter provides an insight into the history of casts, as well as their status as reproductions, in contrast to original artworks. Lastly, this chapter contains a short paragraph on the issue of record keeping, which is relevant for the discussed collection's current situation. For the background of this specific collection of gypsum casts, see chapter 4.3. Archive Research.

2.1. The Parthenon frieze

The Parthenon temple was built in the 4th century B.C.E. The building of the temple was initiated by the politician and general Pericles, as part of the rebuilding of the old temple site Acropolis that took place during the time of his reign. The construction of the temple is ascribed to the artist and architect Phidias. Phidias was also in charge of making the marble sculptures decorating the temple, and of the thirteen meter high ivory and gold statue of the goddess Athena housed inside the temple (Beard 2004, pp. 45-46).The frieze of the Parthenon was situated inside the colonnade, running along the top of the cella wall. The frieze, in total about 160 meters long, consists of carved marble blocks depicting animals and humans (Connelly 2014, p. 152). Since the 18th C. C.E., the most frequent interpretation of the motif of the frieze is, that it shows the Panathenaic procession, a feast celebrating Athena. Other interpretations of the motif exist as well (Connelly 2014, p. 158, pp. 164-165). The marble relief of the frieze, as well as other sculptures in the temple, were polychrome. Today only traces of the paint remain (Connelly, p. 302).

Figure 1. The Parthenon temple on Acropolis 1978. Photograph Steve Swayne. Original image is in colour. https://commons.wikimedia.org/wiki/File:The_Parthenon_in_Athens.jpg#file Licence: Creative Commons Attribution 2.0 Generic.

Over the centuries the Parthenon has had different functions. In the 12th century it became a Christian church, and in the 17th century a mosque (Beard 2004). In 1687 the Parthenon was used as an ammunition warehouse and was partly ruined when a military attack set the ammunition to explode (Beard 2004, p. 85). The Parthenon temple today is much the result of the archaeological excavations that took place in the 19th century (fig. 1). During these excavations the Acropolis was cleared from much of its history. The remains of the church and mosque were eliminated during this time (Beard 2004, pp. 106-107).

In 1801-1811 the English Lord Elgin was, together with his assistants, collecting antique objects from Athens and other places in Greece. From the Parthenon, Elgin and his assistants collected about half of the temple's sculptures and shipped them to England. The legal circumstances were obscure. The sculptures collected were both fragments picked up from the ground and sculptures taken from the building itself (Beard 2004, pp. 93–98). From the west part of the frieze Elgin took the first two blocks, the rest of the west part remained in Athens (parthenonfrieze.gr). 1816 Lord Elgin sold his collection to the British Museum (Beard 2004, p. 157). The British Museum still has the Parthenon marbles. This is the subject of an ongoing repatriation conflict between the UK and the Greek government, which believes all the Parthenon sculptures belong in the Acropolis museum in Athens (Brown 2019).

2.2. Replication in the tradition of antique sculpture

The repetition and copying of sculptures were common practice in the Classical Antiquity. It seems the repetition of a motif was considered something positive, enabling more people to see the artworks (Leander Touati 2004, p. 25). Few of the antique sculptures we know today are *the original* artworks. Most of them are copies, made in the first centuries C.E. (Tebelius-Murén 2004, p. 157). In the 16th century renaissance Europe, there was an increasing demand for copies of antique sculpture. The large scale mass production of copies, beginning in Italy around this time, was a new phenomenon. Copies were made both in plaster and marble (Marchand 2007, p. 50). The first gypsum cast collection of antique sculpture in Sweden was brought to Stockholm by Nicodemus Tessin the younger in 1695. With the cast collection Tessin wanted to *support the good taste and enlighten the youth*. Tessin's collection was the foundation for the gypsum cast collection at the Royal Art Academy in Stockholm (Tebelius-Murén 2004, p. 160).

In the 19th century, museums and other institutions were enthusiastically building up extensive collections of reproductions of antique sculpture. Copies of equal value were swapped between countries and institutions (Bibley & Trusted 2007, p. 466). The fact that most antique sculpture originally was polychrome had not yet gained a broad acceptance. The white surfaces of the gypsum casts were considered representative for the marble originals (Söderlind 1999, p. 24). Gypsum casts, both of antique sculpture and of nature, were used in drawing classes in the increasing number of art- and design schools in 19th century Europe (Malone 2007, pp. 163-164). The British Museum sold gypsum casts of its collections, among them casts of the Parthenon Frieze, to institutions in Europe and USA. Casts of the frieze were made both from the originals in their own collection, and from parts of the frieze left in situ in Athens. Casts of the frieze left in Athens, were made from moulds taken by lord Elgin around 1810 (Jenkins 1990). In the 20th century, the appreciation of the mentioned gypsum cast collections decreased drastically. The gypsum casts were often seen as worthless copies in a time when only *the original* was regarded as valuable. Furthermore, the gypsum cast collections represented a western canon of art, which was often rejected during this time (Frederiksen & Marchand 2007, p. 1).

Figure 2. A 19th century gypsum cast collection is seen in the print The Private Sitting Room of Sir Thomas Lawrence. Aquatint by Archibald Keightley 1830. National Portrait Gallery, London. NPG D37049. Sir Thomas Lawrence (1768-1830) was a portrait painter, collector and president of the Royal Academy. Licence: http://creativecommons.org /licenses/by-nc-nd/3.0/

2.3. Replication and authenticity in museums

In a museum, a copy of an artwork can have many different purposes. As in the case of the 18th and 19th century plaster cast collections described above, a copy can provide access to an artwork otherwise out of reach (Frederiksen & Marchand 2007, p. 3). In some cases, when the original is too frail to be on display, a replica can substitute the original. This solution saves the material of the original, while instead exposing the material of the replica (Tebelius-Murén 2004, p. 157). When replicas are produced truthfully to the original material and technique, they can be means for learning about the original artwork, as well as a way of preserving the immaterial heritage of the craft (Scharffenberg & Milnes 2014, p. 173). Copies of an artwork can contain information now lost in the original. This may be the case of the casts of the west part of the Parthenon frieze, both the casts of the blocks in the British Museum and in the Acropolis Museum. The moulds for these casts were made in the early 19th century. In the following years, the part of the frieze left in situ on the Parthenon until year 1994, was exposed to outdoor climate and pollution, which has caused erosion of the marble (Jenkins 1990, pp. 111-113). In the 1930's, a large part of the Parthenon sculptures housed in the British Museum were cleaned from its patina, causing loss of the original surface (Jenkins 2001, p. 45).

Morena (2014) discusses authenticity in relation to materiality in her paper on the conservation of a costume dress. *The original* in her study is a technicoloured green dress in a movie. She discusses whether this original, the immaterial dress you experience when you watch the movie, is best represented by the worn-out original costume or the well-made replica, lit bright green (Morena 2014, pp. 119-130). Zemach (1986) argues that an artwork, and the material it consists of, are two separate entities, only temporarily overlapping. The artwork can exist at several places at the same time. This rather extreme view suggests that wherever there is a good enough replica of the artwork, there is also the artwork (Zemach 1986, pp. 245-246). Benjamin (1992) thinks that a reproduction of an artwork, however good, is always lacking *the aura*, the presence in time and place, of the original (Benjamin 1992, pp. 214-215). With time, the reproductions themselves, if they survive, gain their own history and significance. Representing both the object they are reproducing and the time in which they were made, they can be ascribed a kind of *alternative authenticity* (Brooks 2014, p. 6).

2.4. Documentation and record keeping

For a museum, keeping an up-to-date catalogue of the collections is one of the basic preservation strategies (Michalski 2004, p. 58). ICOM, the International Council of Museums, has a committee for documentation, CIDOC. In their 1995 standard for museum documentation, the CIDOC stresses the importance of the documentation being accessible to everyone interfering with the objects. The documentation should consist of information about the object's or collection's origin, ownership, location, who is responsible for the object and what interventions, such as conservation treatments, have been made (CIDOC 1995, p. 19). A good documentation makes illicit trading more difficult, and stolen or misplaced objects easier to find. Before intervening with an object, the owner must be consulted. Without documentation about ownership, any conservation treatment is impossible (ECCO 2003, p. 3). An object without records, a disassociated object, is more likely to be neglected, mistreated or lost.

3. GYPSUM CASTS

The properties of the material gypsum are introduced in this chapter. The techniques of gypsum casting are briefly described. The basis for conservation of gypsum casts is discussed, with focus on how different cleaning methods may affect the material.

3.2. The material gypsum

Gypsum is a naturally occurring mineral composed of calcium sulphate dihydrate [$CaSO_4 \cdot 2H_2O$]. When gypsum is burnt at 150-160 °C, the crystallized water evaporates and calcium sulphate hemihydrate [$CaSO_4 \cdot {}^1/_2H_2O$], or plaster of Paris, is formed. When water is added to plaster of Paris, the water is incorporated into the crystal structure, and gypsum is formed once again (Henry & Stewart 2011, pp. 50-51). One of the largest findings of gypsum in Europe is under Montmartre in Paris, hence the name *plaster of Paris* (Proudfoot 2006, p. 162). Depending on the burning method, the plaster of Paris has different properties. Plaster of Paris used for casting is burned in open kettles, forming beta-hemihydrate with a higher porosity and lower strength (Henry & Stewart 2011, p. 50). If a gypsum cast is burnt again, the gypsum once again becomes plaster of Paris, and the material can be reused (Brugioni 2015, p. 206).

Gypsum is slightly soluble in water. At the drying point the solved gypsum recrystalizes on the gypsum surface, creating a powdery texture (Proudfoot 2006, p. 164). Because of the sensitivity to water, gypsum is not used for outdoor sculptures or exterior plasterwork (Marchand 2010, p. 69). Gypsum is a soft mineral with only hardness 2 on Mohs scale, and the surface of a gypsum sculpture is therefore very sensitive to abrasion (Brugioni 2015). Of the water added to the plaster of Paris, about 25% is crystallized in the formation of the gypsum. The rest of the water evaporates, leaving the material very porous (Anzani et al., p. 39).

3.1. Gypsum cast production

Traditionally, gypsum casts have been used both as an intermediate step in the production of marble and bronze statues, and as a way of making reproductions of existing sculpture (Tebelius-Murén 2004). When gypsum casting is used in the process of making a marble sculpture, it is usually by the *lost mould* technique. The sculpture is first modelled in clay. A gypsum mould is made of the clay model, from which the malleable clay is easily removed. Plaster of Paris is poured into the mould, and, when set, the gypsum mould has to be destroyed to release the gypsum cast (Tebelius-Murén 2004, p. 164). This category of gypsum casts is often called *original casts,* since they are the model for the marble sculpture and not reproducible (Greg Sullivan, 2010). Casts of this kind often have pencil marks as guides for transferring the dimensions of the plaster model to the marble block. These original casts also show detail from the process of making the first clay model, detail that may not be transferred to the marble (Greg Sullivan 2010, p. 301).

When a gypsum cast is made to reproduce an existing sculpture, the mould has to be either flexible or made in pieces, a *piece mould*, to enable the removal of the mould from the sculpture. Flexible gelatine moulds were used from the mid 19th century (Ketchin 1994, p. 11). In modern times the gelatine has been replaced by silicon. A gelatine mould wears out quickly and does not allow as many casts as a piece mould made of gypsum (Tebelius-Murén 2004, pp. 164-166). The pieces of a piece mould are wedge-shaped and removable from the three dimensional original. The more intricate the shape of the original, the more pieces are required. In casts from piece moulds, lines are often visible from where pieces are joined together (Tebelius-Murén 2004, p.165).

3.3. Conservation of gypsum casts

The physical and chemical properties of gypsum, its porosity, softness and solubility, make the gypsum cast sensitive to environmental conditions and human interventions. (Kliafa & Doulgeridis 2010, p. 404). The same properties make gypsum casts difficult objects to treat.

When wet cleaning methods are used on gypsum, there is always the risk of dissolving some of the material. Another thing to take into account when using wet cleaning methods is the porosity of gypsum, which makes water rapidly diffuse deep into the material (Anzani et al. 2008, p. 48). Instead of being removed, the dirt can migrate deeper into the material along with the diffusing water, causing tidelines on the surface. (Brugioni 2015, p. 206).

Poultices can be used in wet cleaning, reducing the amount of water or other solvents introduced to the material. Poultices, commonly used to clean stone, are also used on gypsum surfaces. When applied on the surface, the poultice solves and absorbs the contaminants, which are then removed together with the poultice material (Goldberg 1989, p. 19). Treatment with poultices, though it may be effective, has been found to slightly damage the gypsum surface (Kliafa & Doulgeridis 2010, p. 409).

Gels, another wet cleaning method, have also been used on gypsum. A gel is a thickened water-based formula, the thickener often being a polymer (Stulik & Dorge 2004, p. 3-7). Gels reduce the evaporation of the water or other solvent present in the formula. The advantages of cleaning gypsum casts with gels is the minimum abrasion of the surface and, as with the poultice, the absorption of the dirt into the gel. An agarose gel, prepared with boiling water, can be brushed onto the surface from 45°C until it reaches its gelation temperature of 38°C (Anzani et al. 2008, pp. 42-43). This method allows distribution of the gel on three dimensional objects with irregular surfaces (Anzani et al. 2008, p. 35).

When dry cleaning gypsum, there is a risk of scratching the surface. One dry cleaning method used on gypsum is eraser cleaning. Depending on the type of soiling and the kind of eraser used, eraser cleaning has been found to give good results without causing too much abrasion of the gypsum surface (Brugioni 2015, p. 220).

Lasers have been used for cleaning gypsum, as it seems with varying results. Kliafa and Doulgeridis (2010) give an example of a successful cleaning of a plaster sculpture, although the long-term effect of the treatment is still to be evaluated (Kliafa & Doulgeridis 2010, p. 409). Anzani et al. (2008) experienced significant yellowing when cleaning two gypsum casts with laser. They also found it difficult reaching into the negative forms of the sculptures' surfaces (Anzani et.al. 2008, p. 41). The degree of yellowing of the gypsum due to laser cleaning may differ, depending on what substances are removed (de Oliveira, Vergès-Belmin, Demaille, & Bromblet 2016, p. 137).

Deterioration of a cast may be further increased by supports inside the cast, such as iron rods. When exposed to high humidity, the iron may rust and expand, and cause cracking and staining of the gypsum (Halahan & Plowden 2003, p. 120).

Sometimes the gypsum has a coating, a paint layer or another surface treatment such as shellac. As long as the paint is in good condition, it may facilitate the cleaning of the object. The dust is easier to remove from a painted surface than from the porous gypsum, and water cannot penetrate as deep into the surface. But when the paint is deteriorated, when cleaning one has to keep in mind both the flaking paint and the gypsum surface (Halahan & Plowden 2003, p. 120). A paint layer deteriorates due to a number of factors. In the case of painted gypsum casts, cracking and flaking seems to be a common problem (Doherty & Rivers 2017; Halahan & Plowden 2003). When the surface tension of the paint is stronger than the bond to the substrate, the paint cracks and flakes. When the substrate is as soft and soluble as gypsum, the paint added cannot be too strongly bound (Henry & Stewart 2011, p. 454). The same relation between substrate and added material has to be taken into account when repairing broken parts. The adhesive used should not be stronger than the gypsum (Halahan & Plowden 2003, p. 120).

Apart from disfiguring the object with cracks and flakes, layers of paint may also obscure fine detail in the sculpted surface (Ketchin 1994, p. 40). If a decision is made to remove the paint layers from a gypsum sculpture, the procedure has to be carefully worked out to make sure the gypsum is not damaged. Doherty & Rivers (2017) describe the removal of several paint layers from a large gypsum cast sculpture. The authors use gels, containing solvents and chelators, to carefully remove one paint layer at the time, while saving the original shellac coating (Doherty & Rivers 2017, pp. 122-124).

4. THE STUDY

This chapter contains the study of block WXI of the Parthenon gypsum collection. The object examination and the analyses refer specifically to block WXI, while the archive research refers to the collection of the eleven Parthenon gypsums as a whole. XRF and FTIR analysis is carried out with assistance from senior lecturer Austin Nevin. The results of the analysis and the archive research are summarized and compared in chapter 4.4. Results.

4.1. Documentation of gypsum cast Block WXI

Photograps in this chapter are taken with a Nikon D60 digital camera, except for photographs of detail taken with a USB microsope, Dino-Lite Digital Microscope (see chapter 4.2.5.).

Figure 3. Front of gypsum cast WXI.

4.1.1. Description of object

The object is a gypsum cast of block eleven of the west part of the Parthenon frieze. On the block are two horsemen and their horses in relief. The two galloping horses and their riders are all facing left. The cast has the losses of its marble original, such as the missing faces of rider and horse, and the missing parts on the right side of the block. The object is part of a collection of eleven blocks of the west part of the Parthenon frieze. The casts were made by the British Museum in the 19th century (see chapter 4.3 archive research). The object is kept in the basement storage in the Department of Conservation, University of Gothenburg.

The gypsum is painted with a yellow-grey paint. The paint is unevenly applied with visible brush strokes. The paint layer is thick is some places and, in some places, very thin, with an underlaying darker surface visible (fig. 7). In the upper part of the block the relief is higher than in the lower part, as the original frieze was made to be seen from below (Beard 2004, p. 131).

The back of the cast has an uneven surface, inverting the basic shape of the relief on the front. (fig. 4) The thickness of the gypsum varies from approximately 45 mm around the edges to about 120 mm where the relief is at its highest. The cast has a support of metal rods, visible in the area of loss in the lower right corner. Lines from the joints of the piece mould are visible (fig. 8). There is no visible makers mark on the cast.

Figure 4. The back of the object has an uneven surface with a lot of dust. Pencil writing is seen close to the upper edge.

4.1.2. Condition of object

Losses:

Figure 5. Map of Losses on block WXI.

There are no visible cracks threatening the main structure of the object. The gypsum is damaged in several places (fig. 5, fig. 7). Along the edges are at least two different later additions of gypsum visible, probably infills from previous mountings (fig. 12). These later additions of gypsum are not well adhered to the substrate and have for the most part fallen off. The paint is cracking and, in some areas, flaking (fig. 10, 11). An underlaying paint is visible in some areas along the edges of the object.

Dust build deposits and marks on surface:

Figure 6. Block WXI. Map of dust deposits and marks on surface.

The whole surface of the object is covered with an even layer of dark dirt ingrained in the paint. On horizontal uncovered surfaces are deposits of dust (fig. 6). On vertical surfaces facing right are also thick layers of dark dust, indicating that the relief has been stored standing on its left side (fig. 9). On the back of the object there is also dark dust. On the paint surface are four brown round marks, probably residues from a cushioning material used in a mounting. Circular grey marks are visible in the top left corner. In the same corner there is also a yellow-brown mark which is probably adhesive from tape. There are drops of white paint or gypsum on the surface on the right half of the object (fig. 11). Red paint is visible close to the back horse's ear, probably from abrasion of a red painted object.

Pencil writing on the front says "IX" and pencil writing on back says "N 9 Venster", or possibly "N 2 Venster" (N 9 or N 2 Left). Since the cast is made from block eleven of the west frieze, it is possible the writing on front is upside down and meant to be read as "XI". But if the writing on back is 9 and not 2, it is more probable that the writing on front says nine (IX) as well. The numbers may be intended as a guidance when mounting the collection.

4.1.3. Storage

In the basement storage, the block WXI is stored together with other blocks from the Parthenon collection. The blocks are standing on pallets covered with cardboard. The blocks are leaning against each other, with the most inner blocks leaning against the wall. Between the blocks are sheets of cardboard. The blocks are covered with bubble wrap.

Figure 7.Damaged gypsum on the left edge of the object. An underlaying paint is visible in the area of damage.

Figure 8. The latest paint is unevenly applied with visible brush strokes. Lines from the piece mould are visible.

Figure 9. Deposit of dark dust on a vertical surface.

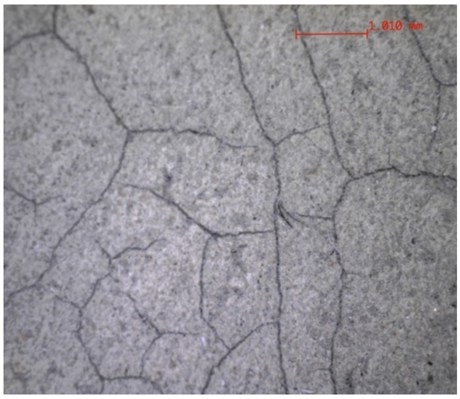


Figure 10. Cracks visible in the paint. Photograph taken with USB- microscope.

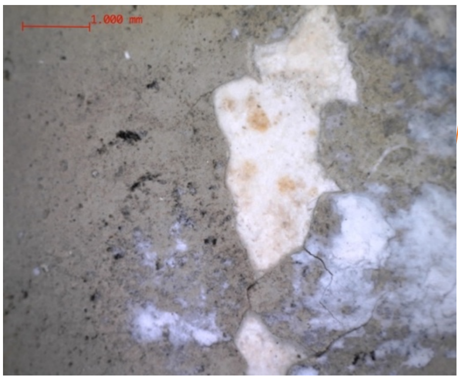


Figure 11. An area with flaking paint and gypsum or white paint on the surface. Photograph taken with USB- microscope.

Figure 12. Two additions of gypsum are visible on the bottom of the object.

4.2. Analysis

4.2.1. The samples

For analyses where a sample is required (FTIR and Cross sections), the fragments and paint flakes used are already lost from the object (see chapter 1.6, ethical issues).

For location of the fragments and paint flakes on the object, see the map in appendix 1. In this map, the spot on the object for the XRF analysis of the original gypsum (gypsum E), is also marked. The fragments and paint flakes collected are marked and saved in a box, together with the map of their location on the object. The cross sections and paint samples used for FTIR analyses are saved in the same box. This material is kept if further analysis is required in the future. The box is placed in the storage in the lab in the Conservation Department at the University.

4.2.2. XRF

In this study, three different gypsums present on the object are analysed with XRF, as well as two different paint layers. The gypsums analysed are the original gypsum (E) and what is believed to be two later additions of gypsum, here called additional gypsum 1 (sample 5) and additional gypsum 2 (sample 3) (fig. 12). The purpose of the analysis is to verify that the material in the three samples really is gypsum, and to see if there is any difference in the composition among the three.

Two different paint layers on the object are analysed with XRF, the paint on fragment of additional gypsum 1 and the latest paint. The elements present can indicate what pigments have been used in the paint. Pigment identification can be helpful in determining when the paint was applied. For the XRF- spectra from analysis of the paints, see appendix 2.

Table 1. XRF analysis of gypsum.

XRF analysis of gypsum on Block WXI. Date: May 2019							
Elio Device: SN1253 Tube Voltage: 40kV Tube Current: 20 μA Acquisition Mode: Manual							
Elements	Sample 5 Acq. 5a (60 s.)	Sample 5 Acq. 5b (60 s.)	Sample 5 Acq. 5c (60 s.)	Sample 3 Acq. 3a (60 s.)	Sample 3 Acq. 3b (60 s.)	Sample 3 Acq. 3c (60 s.)	Location E on object (40 s.)
S	33,66 %	52,36 %	47,1 %	54,98 %	53,97 %		
Ca	62,94 %	47,56%	52,65 %	44,96 %	45,96 %	99,73%	95,95 %
Sr	0,06 %	0,06 %	0,05 %	0,04 %	0,05 %	0,27%	0,58 %
Zn	0,27 %	0,02 %	0,16 %	0,01 %	0,02 %		3,46 %
Ar	3,07 %						

Of the elements in gypsum [$CaSO_4 \cdot 2H_2O$], calcium [Ca] and sulphur [S] are heavy enough to be identified with XRF. Calcium is detected in all acquisitions, and sulphur in all acquisitions except 3c and E. Strontium [Sr] is present in a small amount in all acquisitions. The alkaline earth metal strontium occurs in natural gypsum. The strontium indicates that the gypsum is natural, and not an alteration product of calcium carbonate (Franceschi & Locardi 2014, p. 522). A small amount of zinc [Zn] is present in sample 5 and 3, and in a slightly higher amount in the spot analysed on the object. The zinc could come from the gypsum having had surface contact with the paint (see table 2). The argon [Ar] present in 5a is probably from the surrounding atmosphere. Acquisition 3c may have hit an impurity of calcium carbonate in the gypsum sample. On the object, location E, only one acquisition was made. Since there is no sulphur detected, and a very high amount of calcium, it is possible the spot analysed is not the pure gypsum, but an area covered with primer (see chapter 4.2.5.).

Table 2. XRF analysis of paint samples 5 and 3.

XRF analysis of paint layers on Block WXI Date: 2019-05-04				
Elio Device: SN1253 Tube Voltage: 40kV Tube Current: 20 µA Acquisition Mode: Manual				
Elements	Sample 5 Acq. 5_1 (40 s.)	Sample 5 Acq. 5_2 (40 s.)	Sample 3 Acq. 3_1 (40 s.)	Sample 3 Acq. 3_2 (40 s.)
Ca	65,94 %	67,3 %	54,73 %	32,71 %
Zn	20,05 %	19,2 %	35,47 %	54,65 %
Cl	9,56 %	10,47 %	8,29 %	10,6 %
Fe	2,22 %	2,14 %	1,29 %	1,35 %
Ba	2 %			
Ti		0,67 %		
Ni				0,15 %
Pb			0,16 %	0,41 %
Sr	0,23 %	0,22 %	0,07 %	0,13%

The zinc [Zn], present in both samples, is most likely the white pigment zinc oxide [ZnO]. The industrial production of zinc oxide began in the mid 19th century, and the pigment has been commonly used in oil and water-based paints since the late 19th century (Hansen & Jensen 1991, pp. 115-116). The iron [Fe] is probably also from pigments. Iron [Fe] in different oxidation states, is a component in both the common earth pigments, such as the umbers and ochres, and in synthetically produced pigments (Harley 2001, p. 89, 91, 148).

The calcium [Ca] could come from calcium carbonate [$CaCO_3$]. Calcium carbonate is used as a white pigment in water- based paint, and as a filler in oil-based paint (Hansen & Jensen 1991, pp. 138-139). The high amount of Ca detected in sample 5, could be due to the XRF detecting calcium not only in the paint layer, but also in the underlaying primer (see chapter 4.2.5.)

The following detected elements have a rather high error rate and therefore their presence cannot be determined with certitude (see appendix 2). The titanium [Ti] detected in 5_1 could be traces from the paint layer seen on top of the first paint layer in the cross-section, interpreted as a primer for additional gypsum 2 (table 5, sample 3.2). Titanium dioxide [TiO_2] was not commonly used as a pigment until it was industrially produced in the 1920s (Hansen & Jensen 1991, p. 42). The dating of the pigment titanium dioxide makes the detected titanium more likely to come from the primer for additional gypsum 2, than the paint on added gypsum 1 (see chapter 2.4.). Barium [Ba], nickel [Ni] and lead [Pb] are also components of pigments, such as lithopone [$BaSO_4 + ZnS$], titanium yellow [$NiTi_4O_9$], and lead white [$Pb_3(CO_3)_2(OH)_2$] (Hansen & Jensen 1991, p. 142, 58, 144). The use of lead white for indoor work was prohibited in Sweden already in 1869, and in 1929 there was a general ban on the use of lead carbonates (Karlsdotter Lyckman 2005, p. 64). This makes the lead unexpected in the latest paint.

The strontium [Sr], detected in a small amount in all acquisitions, may come from the gypsum substrate. Why strontium is detected and not sulphur, may be because strontium is a heavier element and more easily detected by the XRF than the sulphur. The chloride [Cl] could come from sea water mist. Göteborg is located by the sea, and thereby has a high level of chlorides in the atmosphere (Gustavsson & Franzén 1996, p. 977).

4.2.3. FTIR

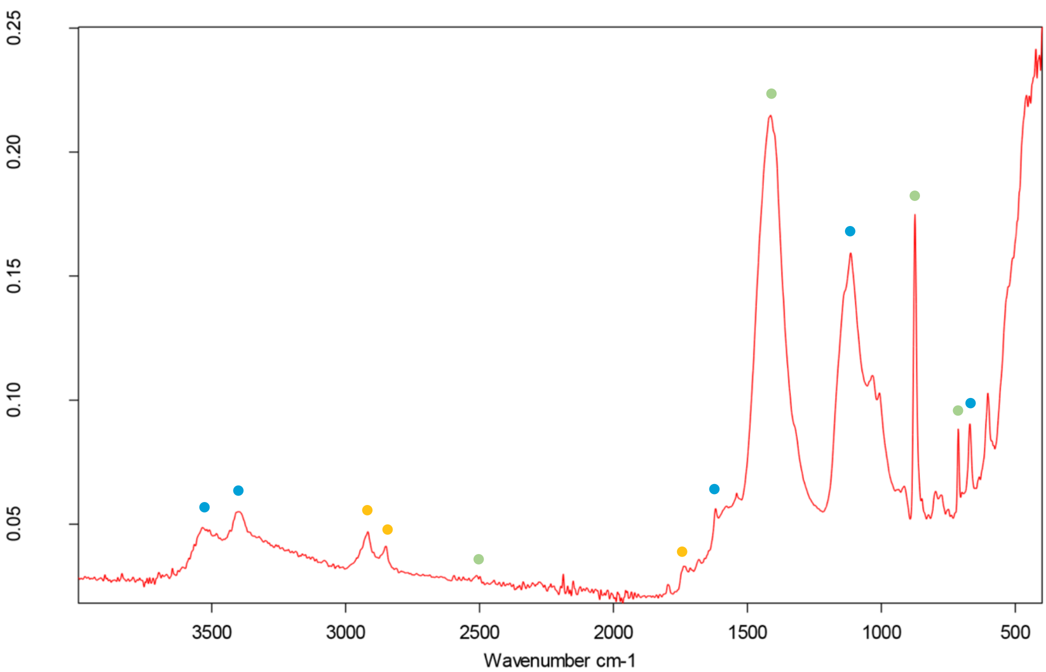
In this study, samples from two different paint layers on the object are analysed with FTIR: latest paint and paint on additional gypsum 1. The purpose of the analysis is to determine the binding media in the two paints. Information about binding media is important when working out a treatment plan for the object. Since different binding media have been used in different times, it can also be an indicator on when the paint was applied.

Paint samples are taken from two fragments, fragment 6 and fragment 5. The area for sampling is gently cleaned with a little deionized water on a cotton swab. Paint is scraped off the fragment with a scalpel in an amount of approximately 0,5 x 0,5 mm^3. All work is done under microscope.

When a sample consists of a mix of compounds, like paints, all compounds are plotted in the same spectra. The spectra of the different compounds in the mix are then overlapping each other, and all peaks may not be visible (Derrick, Stulik & Landry 1999, p. 83). The two spectra acquired from the FTIR analysis are compared with with spectra from IRUG (Infrared and Raman Users Group). IRUG has an online database with interactive FTIR-spectra of conservation related materials (irug.org).

Table 3. FTIR analysis of paint sample 5.

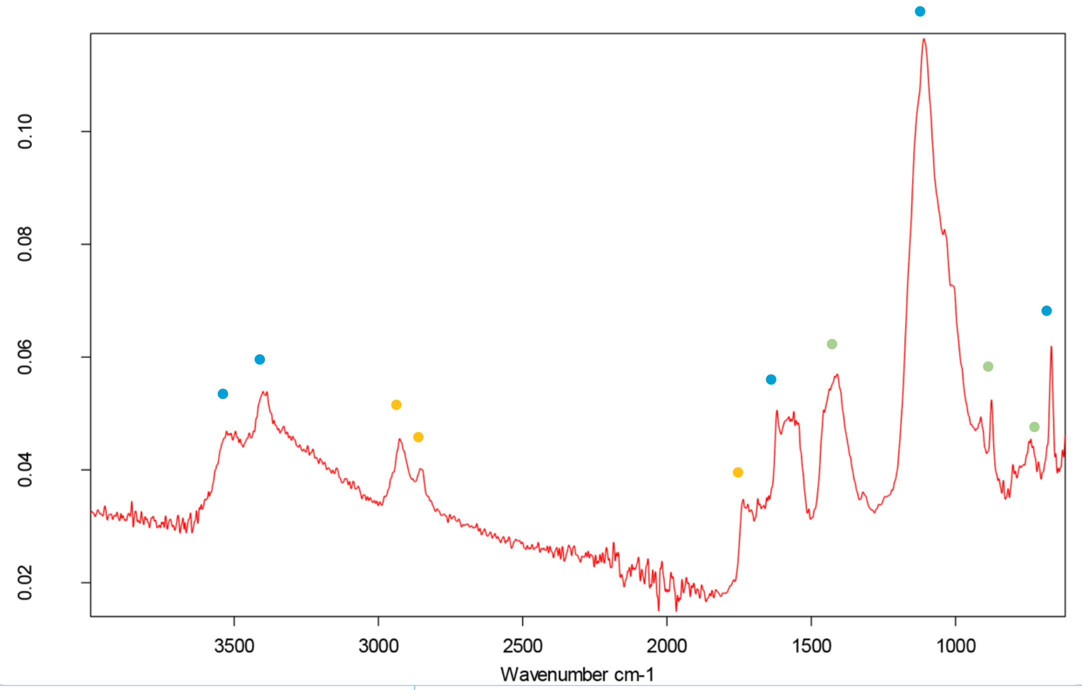
FTIR-ATR analysis of paint layers on Block WXI
Device: Alpha Brooker Date: 2019-05-02
Sample name: 5. Representing: Paint on additional gypsum 1



Identification:		Position of peaks (wavenumber cm^{-1}):
	Gypsum	3534, 3402, 1619, 1114, 668
	Oil	2916, 2848, 1738
	Calcium carbonate	2511, 1796, 1412, 874, 712

In the spectrum for sample 5, the spectras representing gypsum, oil and calcium carbonate can be recognised. The gypsum is most likely from the substrate. Of the peaks recognised as oil, the two peaks at 2916 and 2848 could indicate a number of compounds, but the peak at 1738 identifies the spectrum as representing oil (Derrick, Stulik & Landry 1999, p. 103). The dating of this paint layer to 1915 (see chapter 4.4.1.) makes the drying oil binder very likely to be linseed oil (Karlsdotter Lyckman 2005, pp. 39-43). Considering the paint evidently has oil as a binder, the amount of calcium carbonate seems too high. It is possible that sample 5, representing the paint visible on additional gypsum 1, also contains an underlaying primer (see chapters 4.2.4, 4.2.5.).

Table 4. FTIR analysis of paint sample 6.

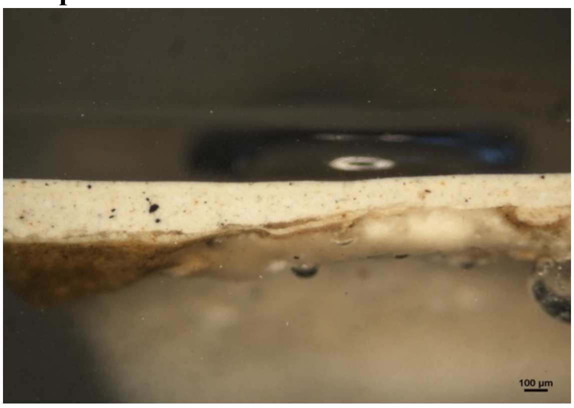
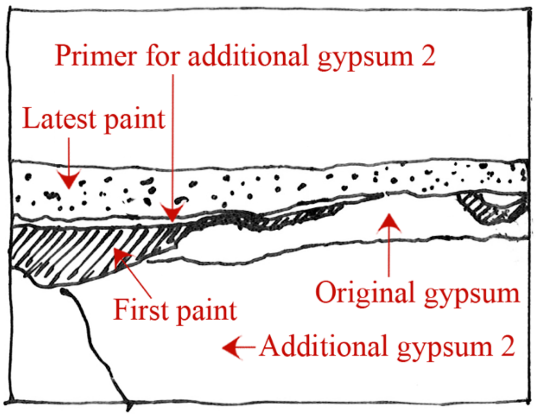
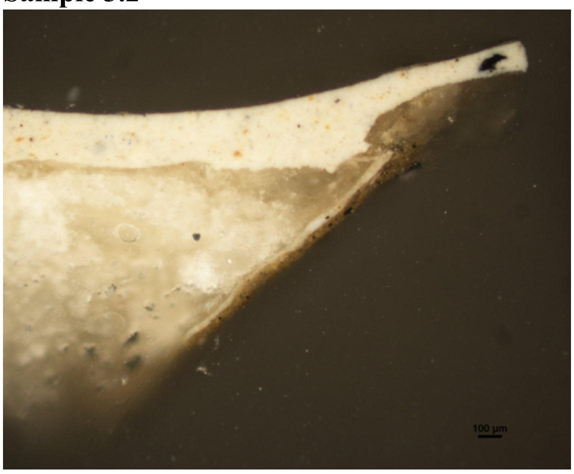
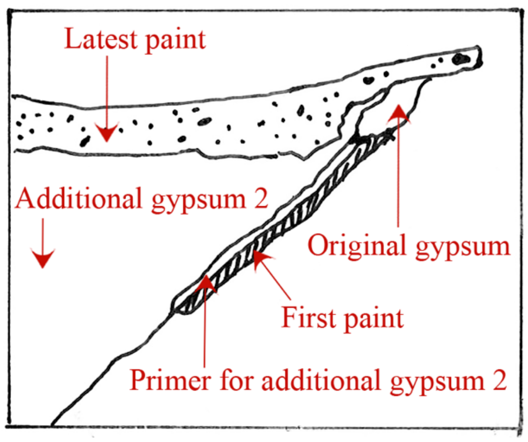
FTIR-ATR analysis of paint layers on Block WXI	
Device: Alpha Brooker Date: 2019-05-02	
Sample name: 6. Representing: Latest paint	
	
Identification:	Position of peaks (wavenumber cm^{-1}):
Gypsum	3525, 3399, 1619, 1109, 667
Oil	2926, 2847, 1735
Calcium carbonate	1409, 875, 712

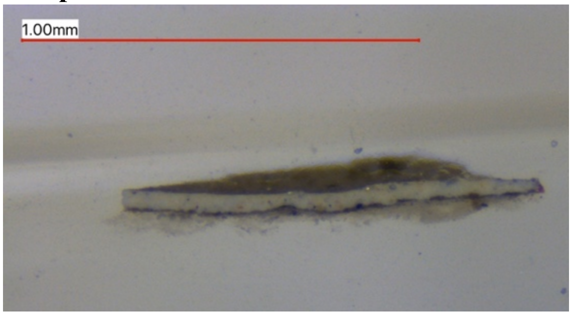
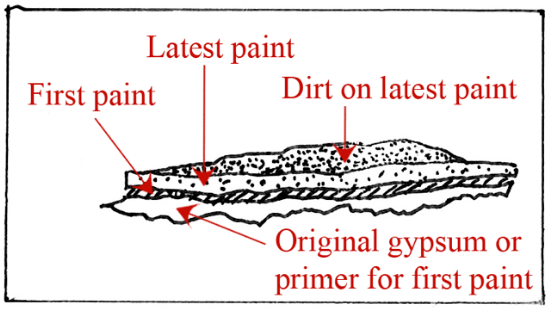
In sample 6, latest paint, are also the spectra of gypsum, oil and calcium carbonate. The amount of calcium carbonate is lower than in sample 5. Calcium carbonate could be used as a filler in the latest paint. As in sample 5 there are the peaks in the C-H stretching region 3200-2800 together with a peak at 1735, indicating oil. Considering the dating of the paint layer to 1960 (see chapter 4.4.1.), the drying oil binder in the paint could either be linseed oil, or another drying oil such as an alkyd. In sample 6 there are more unidentified peaks in the carbon double bond region 1800-1500 than in sample 5, which may also support the presence of an alkyd medium (Derrick, Stulik & Landry 1999, p. 94).

4.2.4. Cross-section Microscopy

Cross sections are made from samples from fragment 3 from the bottom of the object and from a loose flake from an area of loss on the front horse shoulder, called location E (see Appendix 1). The collected fragments and flakes are examined under the microscope to identify areas of interest. Samples approximately 1x1 mm2 are cut from the fragments with a scalpel. Since the samples are small and fragile, they cannot be handled with forceps. A bamboo stick is sharpened, moistened with deionized water and used to lift and move the samples. The samples are embedded in light curing resin. The samples are first wet polished and then dry polished. Dry polishing gives a better result than wet polishing in this case. This may be because particles from the gypsum, when solved by the water, scratches the resin surface. The samples are placed on a slide and a drop of glycerine and a coverslip is put on top.

Table 5. Cross sections of sample 3 and E.

<table>
<tr><td colspan="2">Cross sections Block WXI</td></tr>
<tr><td colspan="2">Equipment used:
All samples: Light curing resin Technovit 200 LC from Kulzer and blue light oven Technotray Power
Sample 3.1 and 3.2: light microscope Nikon Optihot with camera Nikon Digital Sight DS-Fi1.
Sample E: stereo microscope Leica LED3000RL with camera Leica MC 170HD
Date: April 2019</td></tr>
<tr><td>Sample 3.1
</td><td>
</td></tr>
<tr><td>Sample 3.2
</td><td>
</td></tr>
</table>

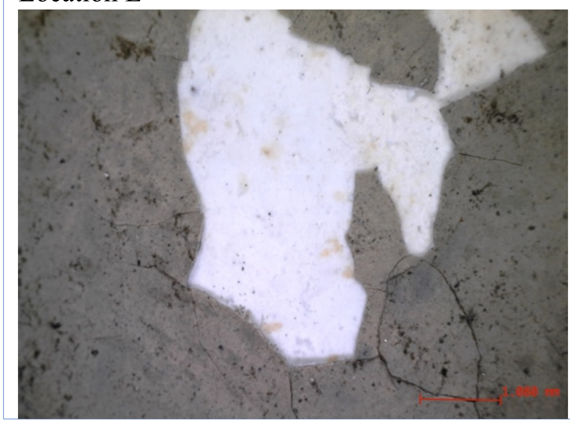
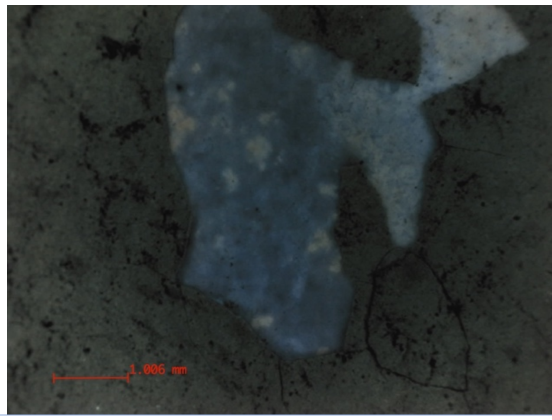
Sample E 	

Sample 3.1 cuts horizontally through an area on fragment 3 where additional gypsum 2 is next to the original gypsum. Sample 3.2 is showing a vertical cut through the same area as sample 3.1.
In cross section 3.1, the layer of the latest paint is visible with its pigment particles of varying size. The surface of the paint is quite smooth, indicating it contains a lot of binder. The latest paint seems to be painted directly on additional gypsum 2. In cross section 3.2, it is apparent that the paint layer believed to be the first paint, at the bottom right diagonal, has a paint layer on top. Since there is no similar paint layer between the first and latest paint in sample E, this paint layer is interpreted as a primer for additional gypsum 2. The difference in thickness of the paint layers is obvious in all three cross sections.
Cross section E shows the latest paint right on top of the first paint. On the surface of the latest paint is a layer of dark dirt. The white seen underneath the first paint is probably the primer, together with some original gypsum.

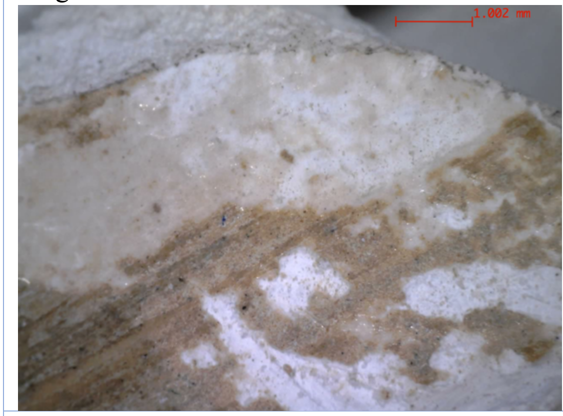
4.2.5. Examination with portable USB microscope and UV-light

When examining the gypsum cast WXI with the Dino-Lite microscope, images are captured of areas of interest. For comparison, images are captured with both normal light and UV-light. Photographs of fragment 5, from the area where the sample for FTIR is taken from, are also included in the table below.

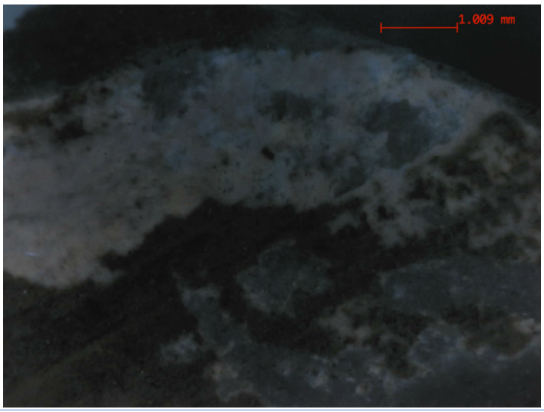
Table 6. USB- microscopy and UV- analysis.

USB-microscope and UV fluorescence Block XI	
Equipment used: USB- microscope Dino-Lite. UV-wavelength: not specified Date: April 2019	
Visible light	**UV - light**
Location E 	. 

Fragment 5

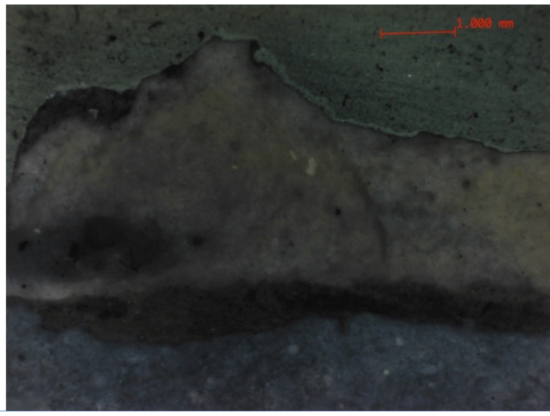


.



Location F

.



The photographs of Location E show an area of loss on the front horse's shoulder. In the UV-light photograph it is obvious that there are different materials present on what looks like almost bare gypsum in the visible light photograph. The fluorescence is not strong, maybe due to a mix of materials present, disturbance of ambient light, or the UV-light in the microscope not being sufficiently strong. The fluorescence visible on location E, is interpreted as the violet fluorescence of gypsum and the yellow fluorescence of linseed oil (aiccm.org.au). The pictures of fragment 5 are interpreted similarly. In the visible light photograph of fragment 5, the paint sample used for FTIR is scraped off from the light yellow area to the left in the picture. The yellow fluorescing material seen on top of the gypsum in the photographs of both location E and fragment 5 could be linseed oil containing primers for the following paint layers. The very porous and absorbant gypsum needs a coating of primer to before painting. Traditionally, gypsum stucco has been coated with shellac, or with a linseed oil based primer (Beier 1995, p. 221).

The materials on the photographs of location F are interpreted as, from bottom to top, additional gypsum 2, first paint, original gypsum and latest paint. There seems to be a varying amount of residues from the primer on the original gypsum, appearing with different shades of yellow fluorescence. The latest paint has a green fluorescence, although faint, which suggests the pigment zinc white (aiccm.org.au).

4.3. Archive Research

This chapter summarizes information about the history of the Parthenon gypsums gathered from archival material, literature and oral sources. The archives visited are Faktarummet at Stadsmuseet, Stads- och Regionarkivet and the archive at the Conservation Department, Gothenburg University. The reference libraries in the Gothenburg Art Museum and in the University Library have also been sources of information. For an overview of the collection's chronology, see Appendix 3.

Göteborgs Museum acquired the Parthenon gypsums in 1892 (RGS Göteborgs kommun nr 627-1, G3A:5, p. 148). The year before, the museum was granted a donation of 7250 Swedish crowns from colonel Paul Melin, who was also a former board member of the Museum (Snoilsky 1892, p. 3). The donation was reserved for buying a collection of gypsum casts of antique sculptures from Greece and Italy. A condition for the donation was that art history professor Karl Warburg would be in charge of the acquisition (Lindholm, 1892, p. 6). Warburg had several times, during meetings with the art societies Konstnämnden and Gnistan, stressed the importance of a representative gypsum collection for educational purposes (Göteborgs Handels- och Sjöfartstidning 1892). In 1891, the museum already had a collection of gypsum casts of artworks from Assyria, Egypt and Greece (Brusewitz 1885, p. 111). This collection was initiated and acquired by Brusewitz, curator of the historic department of the museum between the years 1862 and 1891 (Nordstrand 2008, pp. 53-56). Brusewitz started collecting the gypsum casts, and also some original artworks, in 1879. He travelled to London and bought casts from, among others, the British Museum. In his record for the Historic department in the Museum's 25th yearbook (1886), his acquisitions are described in detail. The Parthenon frieze is not mentioned in his records (Brusewitz 1886).

An article in the newspaper Göteborgs Handels- och Sjöfartstidning from May 25th1892 reports from the opening of the exhibition of the new gypsum cast collection. The collection is housed in the vestibule and the West Gallery. The collection is not yet complete, more casts are on their way, but the casts of the west part of the Parthenon frieze have arrived and are on display (Göteborgs Handels- och Sjöfartstidning 1892).

The donation from Paul Melin is noted in the museum's accounts for April 1891 (RGS Göteborgs kommun nr 627-1, G3A:5, p. 85). In the following year, money from the fund is spent regularly, sometimes with the note *various* and sometimes with the name of a person or a firm. Among the names present is D. Brucciani, receiving 390,51 plus 703,43 Swedish crowns in June 1892 (fig. 13) (RGS Göteborgs kommun nr 627-1, G3A:5, p. 148). Dominicano Brucciani (1815–1880) was an Italian *formatore*, modeler and plaster figure maker. He was born in Barga in the province Lucca, in Italy, and was working in London (Wade 2014, pp. 250-251). Brucciani's firm was one of the main suppliers of gypsum casts for the Government Schools of Design (Malone 2010, p. 165). Brucciani was engaged as a *formatore* at the British Museum from 1857 until his death 1880, meanwhile also running his own casting business. After his death, the firm kept the name D. Brucciani & Co, and had still access to the moulds from the British Museum (Jenkins 1990, p. 108). British Museum's catalogue of casts available for purchase, printed year 1867, has Brucciani's name in capitals on the cover (fig. 14). Some of the blocks from the Göteborgs Museum's Parthenon gypsum collection, such as the blocks WV, WVI and WVII, has a maker's mark; the letter A and a number. This mark corresponds with the British Museums catalogue numbers for these specific blocks, both in the 1867 and 1905 editions (BM 1867; BM 1905). The moulds for the west part of the frieze, except for block WI and WII, originates from the moulds made for Elgin in Athens year 1802. The moulds in use around the time for Göteborgs Museum's purchase, though, are not the original Elgin moulds. In the 1850s the Elgin moulds were considered worn out, and a new set of moulds were made from store casts. The Elgin moulds were probably disposed of around this time (Jenkins 1990, p. 97). This new set of moulds of the west part of the frieze, made from casts of Elgin´s moulds, seem to have been used until around 1912 (Jenkins 1990, p. 109).

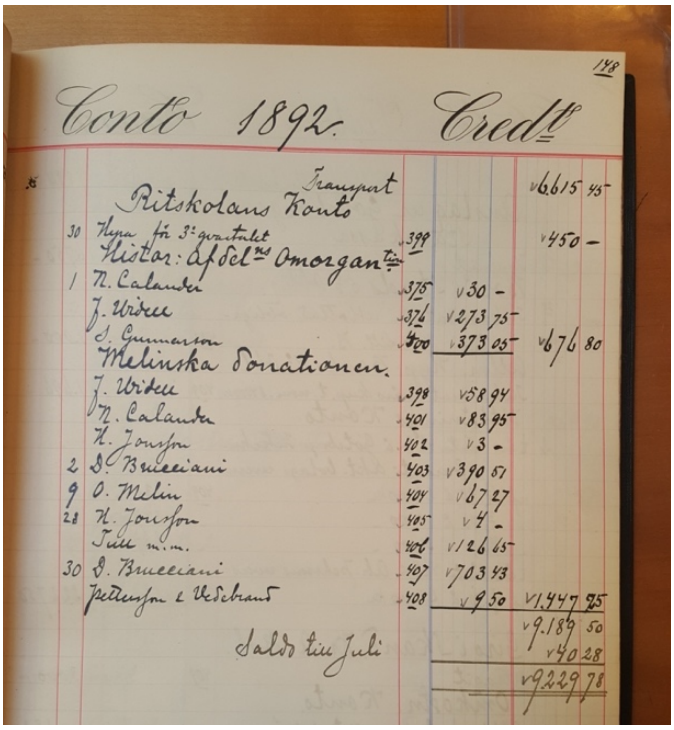


Figure 13. Costs for the Melin donation in Göteborgs museums accounts for 1892. D. Brucciani is noted as one of the costs.

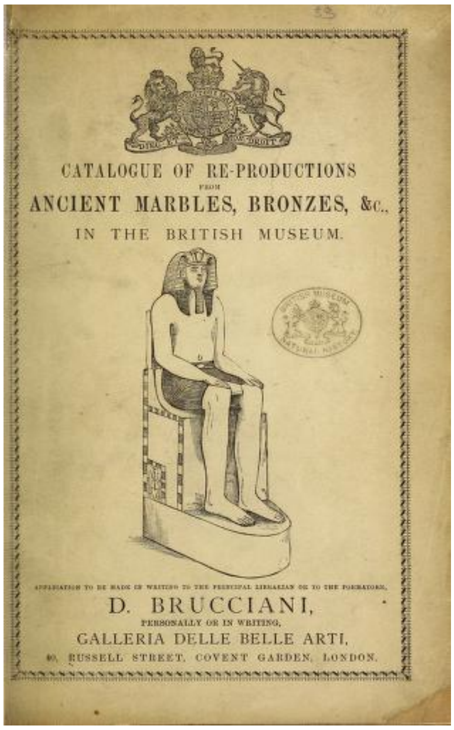


Figure 14. British Museum´s catalogue of casts 1867 with the name of formatore D. Brucciani on the cover. www.archive.org

In 1896 the gypsum casts collection was relocated in three rooms in the newly renovated Göteborgs Museum (fig. 15). The gypsum casts were sorted by time periods and provided with informative signs (Lindholm 1897, p. 10). This period was the heyday of the Melin gypsum cast collection (Werner 2009, p. 84). In 1906 Axel Romdahl was employed as the new director of the art department. He had a special interest in the scientifically instructive aspects of the art collection, such as the gypsum cast collection (Romdahl 1911, pp. 224-225). Inspired by measures taken in the Albertinum in Dresden, he painted, or let someone else paint, the now sooty gypsums in the colours of marble and bronze (Romdahl 1951, p. 102). The gypsums whose original was marble were painted in a yellow-grey colour (Romdahl 1909, p. 51).

In the yearbook for 1914 Romdahl wrote that during the year the collection of gypsum casts had to make place for drawings and sculptures. Original artworks were prioritized, and the gypsum casts set aside. They were arranged closer together and, in some cases, moved to the warehouse, *awaiting better times* (Romdahl 1915, p. 66). The Parthenon gypsums were not put in storage at this time. The following year they were moved to a new *gypsum room* on the bottom floor of the Wilson wing. The separate blocks were joined together and displayed on a moulding, integrating them with the behind wall. The paint on the gypsums was bettered (Romdahl 1916, p. 73).

Romdahl´s description of the events 1915 is the last archival material found about the gypsums until they appear again in 1958. The new Gothenburg Art Museum opened in 1925, and the Göteborgs Museum´s art collection was moved to the new building. Romdahl writes in his autobiography that there was no room for gypsum casts in the new Art Museum (Romdahl 1951, p. 102). The whole gypsum cast collection was probably put in storage around this time. The Parthenon gypsums are not listed in the Art Museums Catalogues for the year 1948 (GKM 1948).

Figure 15. The Melin collection year 1898. The Parthenon gypsums are mounted as separate blocks on the wall. They are uniform in size and their edges are straight, unlike how they are today. The picture shows the sequence of blocks from WIX to WXVI. The collection apparently contained all sixteen blocks in 1892, a complete west frieze. Photograph: Carlotta digital archive, www.samlingar.goteborgsstadsmuseum.se, photographer unknown.

Alfred Westholm succeeded Romdahl as director of the Art Museum in 1947. In the yearbook for the years 1956-1966 Westholm wrote that the museum did not have the capacity to house all its collections and had therefore relocated a large number of paintings as well as sculptures as long term loans in institutions belonging to the City of Gothenburg (Westholm 1966, p. 82). In November 1958 Westholm asked the Göteborgs Konstnämnd, (the Art Committee of Gothenburg), if they could finance the transfer and installation of *some gypsum casts of antique sculptures* from the museum to one of the city's schools, suggesting the girls' school Vasa Kommunala Flickskola (source 1) (RGS Göteborgs kommun nr 1006-1, A1A:3). The Konstnämnd accepted, and in its accounts for 1960, there is an invoice for the transport of twelve gypsum reliefs to Vasa Kommunala Flickskola. The same year there is an invoice for the Art Museums expenses for *taking down* reliefs, cement work and costs for gypsum workers. The invoice does not specify what reliefs have been taken down (RGS Göteborgs kommun nr 1006-1, A1A:4). Since there are no records of any other agreements between the Konstnämnd and the Art Museum around this time, it is likely the reliefs mentioned are the Parthenon gypsums. A question that then remains unanswered is from where the reliefs were *taken down*.

Around year 1990, the head of the Conservation Department at the University of Gothenburg was asked if he could take care of the gypsum reliefs hanging on the walls in Vasa Kommunala Flickskola. The gypsums were considered of no value and were going to be disposed of, hence the gypsums were transported to the Conservation Department at Bastionsplatsen, Gothenburg (source 2). Some of the gypsum blocks were cleaned by conservation students and mounted on the walls, the rest kept in storage (source 3). In the years 2006-2007 the Conservation Department moved to new facilities on Guldheden, Göteborg, and the Parthenon gypsums moved along. Around this time a document concerning the housing or lending of the gypsums was written, the parties being the head of the conservation department and the owner, supposedly the Gothenburg Museum of Art (source 4). This document has been searched for, but not found, during the time working on this thesis.

4.4. Results

This chapter summarises the information about the origin, composition and layering of the materials on gypsum cast WXI. The information is gathered from visual examination, analysis and archive research. The information is compared to see if and how the archival information correlates with the analysis results and the visual examination of the object. Below is a summary material by material.

4.4.1. Comparison of results from Analysis and Archive Research

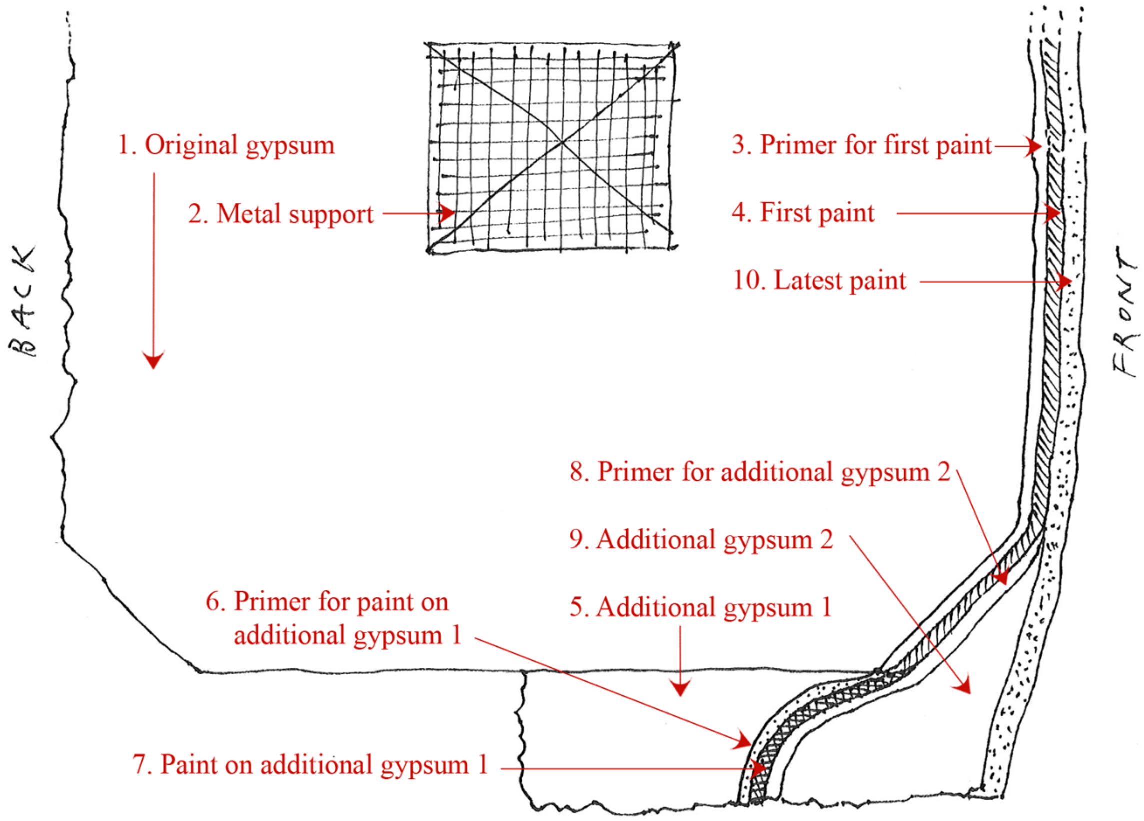


Figure 16. Cross section illustration of the stratigraphy of materials present in gypsum block WXI.

1. **Original gypsum** approx.1890
   Composition: Gypsum (no reliable XRF-result, see XRF location E.)
   Cast made in Brucciani´s workshop, London, from British Museum´s moulds.

2. **Metal support** approx.1890
   Composition: Not identified

3. **Primer for first paint** 1906- 1908
   Composition: Not analysed. It is possible the paint has a composition similar to no. 6 (primer for the paint on additional gypsum 1).
   The paint layer is probably a primer for the following paint.

4. **First paint** 1906-1908
   Composition: Not analysed. It is possible the paint has a composition similar to no. 7 (paint on additional gypsum 1).

The gypsum cast was first painted in 1906-1908 on the initiative of Romdahl, director of Göteborgs Museum´s art department. The gypsum casts were painted because they were sooty and dark. The paint was yellow-grey, intended to resemble marble.

5. **Additional gypsum 1.** 1915
   Composition: Gypsum, containing strontium. (XRF sample 5)
   This addition of gypsum is believed to originate from the 1915 mounting in the gypsum room in the Wilson wing. The Parthenon gypsums were joined together and placed on a moulding to look integrated with the wall.

6. **Primer for paint on additional gypsum 1.** 1915
   Composition: Not analysed. Probably linseed oil and calcium carbonate (FTIR sample 5) (chapter 2.2.4. UV fragment 5).

7. **Paint on additional gypsum 1**. 1915
   Composition: Linseed oil, zinc white, pigments containing iron oxides. (FTIR sample 5, XRF sample 5)
   After being remounted in the Wilson wing, the paint on the Parthenon gypsums was *bettered*. The bettering is believed to include painting the new additions of gypsum.

8. **Primer for additional gypsum 2.** 1960
   Composition: Not analysed. Visible in cross sections 3.2.

9. **Additional gypsum 2.** 1960
   Composition: Gypsum, containing strontium. The gypsum might be non-homogenous with calcium impurities. (XRF sample 3)
   The gypsum is believed to originate from the repairs made before the 1960 relocation of the Parthenon gypsums to Vasa Kommunala flickskola. An invoice states costs for *taking down* reliefs and costs for *gypsum workers*.

10. **Latest paint.** 1960
    Composition: Drying oil binder and pigments containing zinc, iron, nickel and lead.
    There is only one paint layer on top of the added gypsum 2. Considering the Parthenon gypsums were going to be displayed in the school, they must have been painted shortly after the gypsum repairs, and before, or in conjunction with, being mounted on the walls in Vasa Kommunala flickskola.

5. DISCUSSION AND CONCLUSIONS

5.1. Discussion and Conclusions

The Parthenon gypsums' history seems to be representative for many other 19th century gypsum cast collections. Frederiksen and Marchand (2010) conclude that many of these collections have faced a century of decline and rejection, been moved into storages and, in many cases, been professionally destroyed (Frederiksen & Marchand 2010, p. 1). In 1914, when Romdahl decided to move parts of the *Melin collection* to the storage, the gypsum cast collection in the Swedish Nationalmuseum was moved to storage too (Söderlind 1999, p.147). When the Parthenon gypsums arrived in Göteborg in 1892 there were sixteen blocks in the collection, a complete collection of casts of the West Frieze. The archival photograph from 1898 (fig. 15) shows the sequence of gypsum blocks WIX to WXVI, and the eleven blocks now housed in the conservation department are a continuous sequence of the blocks WI to WXI (Göteborgs Universitet 2013). The archival documents from when the collection was moved to the girls' school in 1960 states the transport of twelve gypsum reliefs. The whereabouts of these missing five gypsum blocks from the right side (or south side) of the West Frieze is not known. The original marble blocks of the right side of the West Frieze have more areas with losses than the blocks to the left. If the purpose of the collection in the girls' school was mostly decorative, it may not be a coincidence that it is the right side of the collection that is missing today. It may indicate a change in the use and value of the Parthenon gypsums, from being representatives of their originals in the 19th century, to being viewed as decorative architectural elements in the mid 20th century.

In the recent decades, there has been a renewed interest in the 19th century gypsum cast collections. Their function as life size representations of absent artworks, and as teaching tools, seem to have regained some of its 19th century appreciation. Also, with an increasing interest in the history of collecting, and in the history of artists´ training and working methods, the gypsum cast collections have gained a new meaning as research material (Frederiksen & Marchand 2010, p. 1-10). This renewed interest in gypsum cast collections is mirrored in a wish to care for the collection housed in the Conservation Department. In 2013, members of the staff applied for funding to conserve the Parthenon gypsum collection and display the eleven blocks in their original sequence (Göteborgs Universitet 2013).

Documents found in the archive research strengthen the provenance of the Parthenon gypsums. They were acquired by Göteborgs Museum 1892 from the firm D. Brucciani who made casts for the British Museum. Maker´s marks on blocks in the collection match the numbers in the British Museums catalogue. The documents from Konstnämnden 1958 and 1960 explain how the Parthenon Gypsums were moved to the Vasa Kommunala flickskola, from where they were brought to the Conservation department around year 1990. It seems that the Gothenburg Art Museum is still the owner of the collection.

When the Parthenon gypsums arrived in Göteborgs museum 1892, they do not seem to have been painted. In his autobiography, Romdahl imagines that the Melin gypsum cast collection was *shining white* at the time of the acquisition, compared to how dark and sooty it was in 1906, when he started working at the museum (Romdahl 1951, p. 102). The later additions of paints and gypsums all seem to correlate to events noted in the archival documents. There seem to be three occasions when materials are added:

- 1906-08. The Parthenon gypsums are painted because they are dirty.
- 1915. Gypsum and paint are added because of a new mounting.
- 1960. Repairs and repainting are done because of the relocation of the collection in the Vasa Kommunala flickskola.

When examined under microscope, the first paint (1906 - 08) and the paint on additional gypsum 1 (1915) look alike. Since the paint on additional gypsum 1 seems to be an addition to the pre-existing first paint, it is possible they have a similar composition as well as being similar visually. There are only eight years between the addition of these two paints, and Romdahl was involved in both occasions.

When being removed from the 1915 mounting, where the blocks were joined together, it is likely there was damage to the gypsum, original and added. When supposedly being repaired before being moved to the Vasa girls´ school 1960, the gypsum workers do not seem to have removed the 1915 gypsum on the bottom of the object. Instead, gypsum was added to create a flat surface (fig. 11, fig. 16). The paint added around this time, no 10 "latest paint" is unevenly applied (fig 7). The paint is in some places quite thick (approx. 300 µm or 0,3 mm), and the smooth surface of the paint indicates that it contains a lot of binder (see chapter 4.2.4., cross section 3.2). The latest paint probably contributes to stress-induced flaking of the paint layers on the object. While being well adhered to the underlaying first paint, the latest paint lifts this paint as well (fig. 10).

The seemingly good correlation between material analysis and archive research is due to the relatively few materials present on the object, and to the archival material being accessible. Since the Göteborgs Museum was, and the Gothenburg Art Museum is run by the city of Gothenburg, the archival documents are kept in public archives. However, one has to know where to start searching. Without clues from people with first hand knowledge of the time and place of the events, some information would never have been found.

5.2. Discussion on possible interventions

The aspects of preventive conservation have to be considered before any other interventions, as stated in article 8 in ECCO professional guidelines (ECCO 2003, p. 2). In the case of the Parthenon gypsums, urgent issues for preventive conservation are the present situation in the basement storage, as well as the lack of documentation. These two issues need to be addressed, since they put the collection at risk (Michalsky 2004, p. 58). As discussed in chapter 2.4., a collection without records is more likely to be mistreated or lost. The situation of the Parthenon gypsums seems to confirm this theory. While seemingly being without records, the collection has lost five of its sixteen blocks and is today poorly stored. Documentation concerning ownership and housing would state who is responsible for the collection and should be established as soon as possible.

In the basement storage at the University, the gypsums are not sufficiently protected (see chapter 4.1.3.). The gypsum blocks risk being hit when equipment is moved around in the storage. Since they lean against each other, there is a risk of abrasion if one of the blocks is moved. Also, the weight of the objects may cause cracking. In case of a flooding in the basement, the height of the pallets may not be enough to keep the gypsums above water level. The blocks would be better protected if stored one by one, laying down on shelves. A padded support, strong enough to carry the weight of the object, would make it possible to move the objects in a safer way (Rowlison 1994, pp. 209-210). For protection against dust, the objects could be covered with Tyvek, or a similar material.

When the issues above have been addressed, other interventions can be considered. Cleaning the gypsums in the storage from dust and ingrained dirt would improve their appearance. Removal of dust could also be beneficial from a preservation point of view, since dust is hygroscopic, and the gypsum is sensitive to humidity (Fjæstad & Norlander, 1999, p. 71). If cleaning is considered, one should research how the blocks on display in the hallway have been cleaned. If there is accessible documentation of these interventions, the long-term effect (at least 10 years) of the cleaning could be evaluated. This information would be valuable when working out a cleaning strategy for the blocks in the basement storage.

In working out how to treat the flaking and cracking paint, one would have to consider what aesthetic and historical aspects will be valued, or lost, with the different treatment options. Also, of course, one would need to take into account the practical issues of each treatment.

Keeping the paint layers would preserve material evidence of the collection´s history from 1906 and forward, both Romdahl´s marble-inspired first paint and the paint added in 1960. The original gypsum surface would not be visible, and some detail may be hidden under the paint. On the practical side, keeping the paint would require research on how to best consolidate the cracking and flaking oil paint to the gypsum surface.

Removing the paint layers could reveal some of the original surfaces of the gypsum casts. Most likely they cannot be as *shining white* and without surface damage as they may have been in 1892. Since painting them in 1906 was considered a better alternative than cleaning them, one can suspect there is soot underneath, and possibly mixed in with, the first paint layer. All dirt and paint may not be possible to remove from the porous gypsum. Without the added paint, more details in the sculptures' surfaces would probably be visible. This would make the gypsum casts more accurate representations of the original marble sculptures, as they were at the time when the moulds were made. When removing paint from gypsum, one would have to carefully work out a suitable strategy. From the literature used for this study, gels seem to be the best alternative for both cleaning and removing paint from gypsum.

5.3. Future Research

When the blocks WXII to WXVI were lost from the Parthenon gypsums is not clear, nor why they got lost or how. Archival photographs from when the collection was located in the gypsum room in the Wilson wing at Göteborgs Museum, and from when it was in Vasa Kommunala flickskola, could reveal which blocks were present during these time periods. The two metopes, stored together with the collection in the basement, also seem to have been brought to the University from Vasa kommunala flickskola. The metopes seem to have the same paint as the casts of the frieze, which suggests they were brought to the girls' school at the same time as the rest of the collection. Photographs from Vasa Kommunala flickskola could possibly clarify this.

There is uncertainty about where the Parthenon gypsums were located from around 1920 until 1960. From the archival documents, it seems that the collection is moved from the gypsum room in the Wilson wing at Göteborgs Museum to the storage at the Art Museum in 1925, but it is not clearly stated. The collection being in storage 1960 is contradicted by the costs for *taking down reliefs* noted in the receipt concerning the moving of the collection to the girls' school. It is possible the collection was mounted elsewhere during this time period, or maybe it was left on the walls in the Wilson wing.

The final destiny of the rest of the *Melin collection,* to which the Parthenon gypsums belonged, is beyond the scope of this study. It would be interesting to know if other objects from the collection still exist, or if the Parthenon gypsums are the only ones left.

6. SUMMARY

The objective of this thesis has been to contribute knowledge to the collection of eleven gypsum casts of the Parthenon Frieze, housed in the Conservation Department at the University of Gothenburg. Four of the blocks are displayed in the hallway, the rest stored in the basement. The whole collection is painted in a yellow- grey paint that is cracking and flaking. The blocks stored in the basement are at risk because of poor storage solutions. The collection is in need of conservation treatment.

The origin, history, ownership and terms considering the location of the collection at the department was not fully known at the beginning of this study. This information is required for creating a conservation strategy for the collection. The historic significance of the materials present on the object has to be defined, and also, the owner must be consulted before any interventions with the objects. One of the gypsum blocks in the collection, block WXI, was examined and its materials analysed.

The study tried to find out what materials are present on the object, when and why the paint was applied and what archival documents could be found that strengthen the collections provenance. The aim of the study was to put together a document that could be useful when working out a conservation strategy for the collection, as well as for establishing documents concerning ownership and terms regarding the housing of the collection at the University. The methodology was a combination of material analysis and archive research. Sampling for analysis was done at a limited scale due to ethical issues and lack of documentation about ownership. Literature from diverse fields was researched to provide a cultural and technical background to 19th century gypsum casts of antique sculpture, the category of objects to which the collection belongs.

Block WXI was visually examined and its current preservation status documented. A USB-microscope was used for microscopic examination in situ. The techniques used for material analysis were XRF, FTIR, cross section microscopy and examination with UV-light. XRF was used to identify elements present in three different gypsums, the original and two added. All the gypsums contained strontium, an indication that they are natural gypsums and not alteration products. The paint layers, one from 1915 and one from 1960, both appeared to contain zinc, indicating the pigment zinc white has been used in both paints. FTIR was done to determine the kind of binding media used in the same paints. The analysis proved both paints has drying oil as a binder. Cross section analysis showed the layered structure of the materials, and the difference in thickness between the paint layers. In UV-light, another surface treatment was visible underneath the paint, and was identified as possibly being a primer containing linseed oil.

The archive research gathered information from archives, literature and oral sources. The research confirmed the collection was cast from the British Museums moulds and acquired by Göteborgs Museum in 1892. The research also proved the collections path from the museum, via the girls' school to the University. From the research, Gothenburg Art Museum seems to be the current owner of the collection.

Archival documents from three different occasions mention materials being added to the objects in the collection. This information was compared with the results from the analysis and visual examination. The results seemed to correlate and provided a picture of what materials were added, when and why.

The study has strengthened the provenance of the collection and can be used as a basis when establishing new documentation concerning ownership and housing of the collection. The analysis together with the archive research provides knowledge about the materials present and their historic significance. This will be useful information when working out a conservation strategy for the collection.

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A1A:4 Konstnämndens protokoll 1960-1963

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Source 3. Maria Höijer. Research engineer and senior lecturer, Conservation Department, University of Gothenburg. Conversation: April 2019.

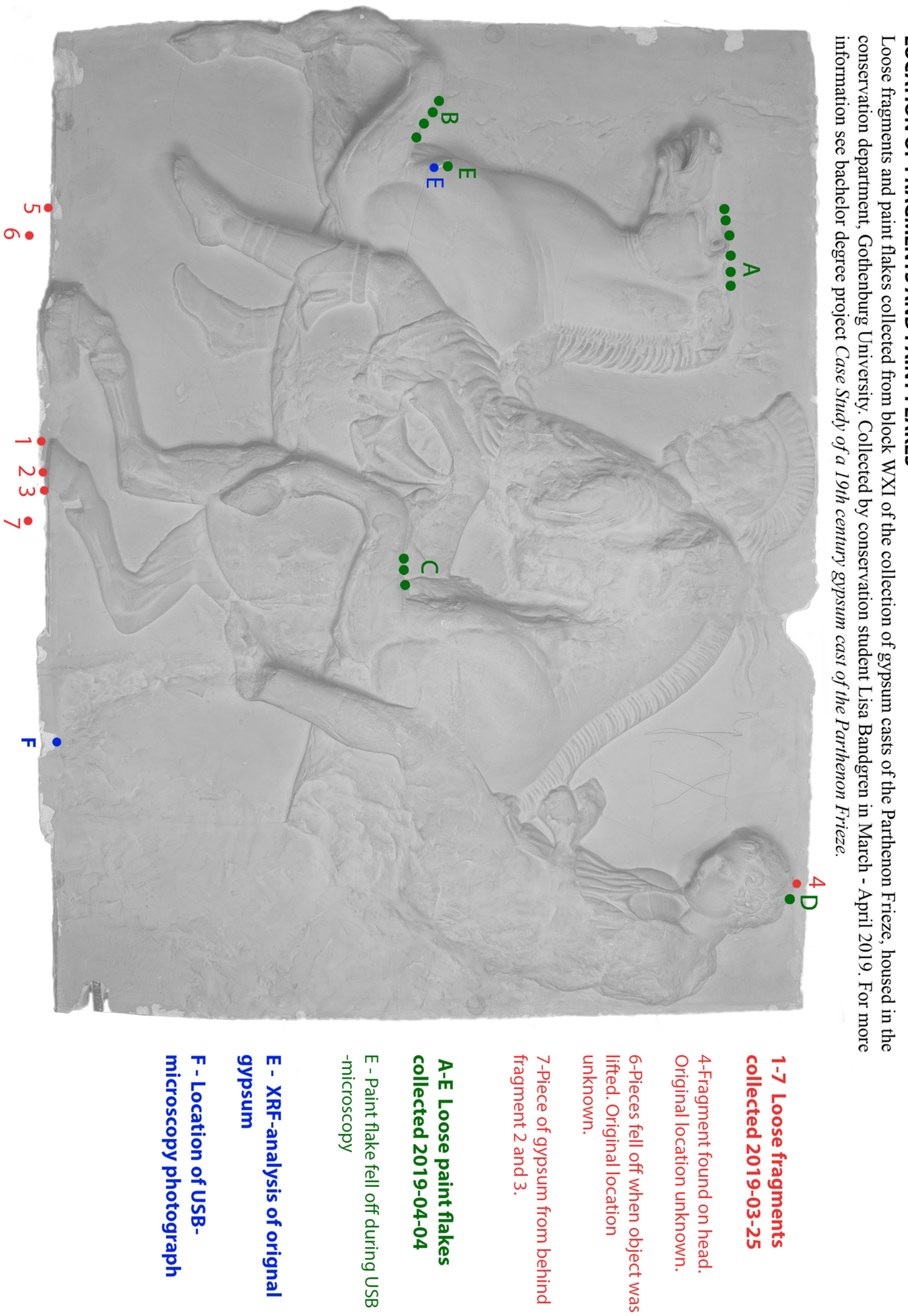
Source 4. Margareta Edebo. Senior lecturer emerita, Conservation Department, University of Gothenburg. Telephone conversation: 2019-03-13.

Figures

Tables

8. APPENDICES

APPENDIX 1. Location of fragments and paint flakes.



APPENDIX 2. XRF-measurements of *paint on additional gypsum 1*, sample 5 and *latest paint*, sample 3.

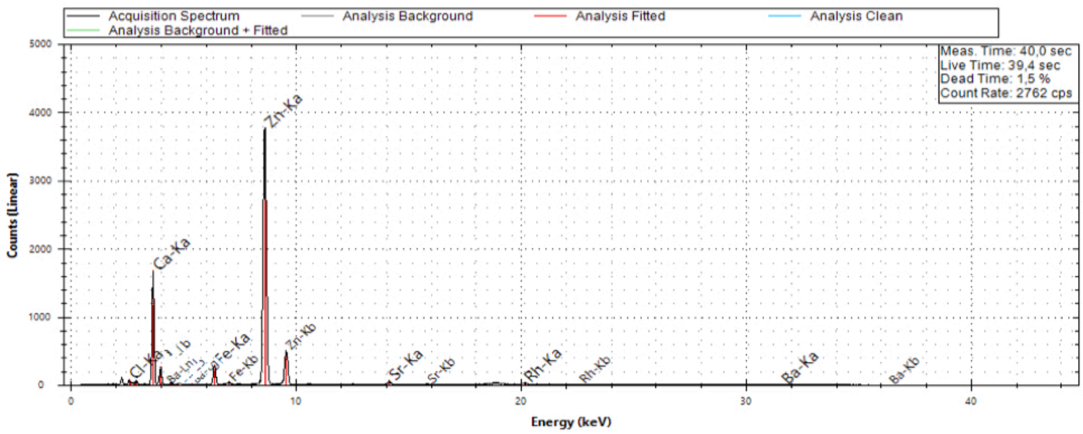
Lisa_Sample 5

05/04/2019 15:04:57

X and Gamma Ray Electronics

Measurement Time: 40,0 s
Tube Voltage: 40 kV
Tube Current: 20 µA
Tube Target Material: Rh
Elio Device: SN1253
Device Mode: Head
Acquisition Mode: Manual
Acquisition Channels: 4096
Sample to Detector Material: Air

Spectrum:



Analysis Results:

Element	Concentration	Error
Ca	65,94%	±0,87%
Zn	20,05%	±0,49%
Cl	9,56%	±4,78%
Fe	2,22%	±1,94%
Ba	2%	±6,58%
Sr	0,23%	±3,84%

Analysis Date and Time: 05/04/2019 15:04:09
Analysis Type: Automatic
Spectrum Left Cut: 1 keV
Spectrum Right Cut: 50 keV
Spectrum Upper Limit: 50 keV
Use M Line: True
Super Impose Peak Areas: True

Excluded Elements for Fitting Analysis:
H, He, Li, Be, B, C, N, O, F, Ne, Na, Mg, Kr, Xe, Rn, At, Po, Fr, Ra, Ac, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Th, Pa, U, Np, Pu, Am, Cm, Bk, Cf, Es, Fm, Md, No, Lr, Pd, Ru

Excluded Elements for FP Analysis:
Rh, Ar, Ag:L, Tc:L, Nb:L, Mo:L, Cd:L, In:L, Sn:L, Sb:L, Pb:M, Bi:M, Tl:M, Hg:M, Au:M, Pt:M, Ir:M, Os:M, Re:M, W:M, Ta:M, Hf:M, La:M

Notes:

Project File: Parthenon Object.xga 1

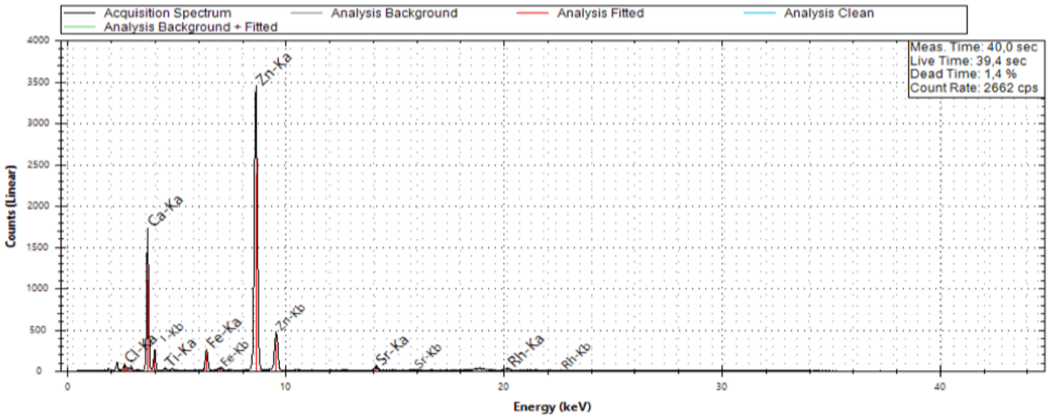
Lisa_Sample 5_2

05/04/2019 15:07:07

XG LAB
X and Gamma Ray Electronics

Measurement Time: 40,0 s
Tube Voltage: 40 kV
Tube Current: 20 μA
Tube Target Material: Rh
Elio Device: SN1253
Device Mode: Head
Acquisition Mode: Manual
Acquisition Channels: 4096
Sample to Detector Material: Air

Spectrum:



Analysis Results:

Element	Concentration	Error
Ca	67,3%	±0,91%
Zn	19,2%	±0,52%
Cl	10,47%	±4,95%
Fe	2,14%	±2,08%
Ti	0,67%	±7,35%
Sr	0,22%	±4,13%

Analysis Date and Time: 05/04/2019 15:06:13
Analysis Type: Automatic
Spectrum Left Cut: 1 keV
Spectrum Right Cut: 50 keV
Spectrum Upper Limit: 50 keV
Use M Line: True
Super Impose Peak Areas: True

Excluded Elements for Fitting Analysis:
H, He, Li, Be, B, C, N, O, F, Ne, Na, Mg, Kr, Xe, Rn, At, Po, Fr, Ra, Ac, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Th, Pa, U, Np, Pu, Am, Cm, Bk, Cf, Es, Fm, Md, No, Lr, Pd, Ru

Excluded Elements for FP Analysis:
Rh, Ar, Ag:L, Tc:L, Nb:L, Mo:L, Cd:L, In:L, Sn:L, Sb:L, Pb:M, Bi:M, Tl:M, Hg:M, Au:M, Pt:M, Ir:M, Os:M, Re:M, W:M, Ta:M, Hf:M, La:M

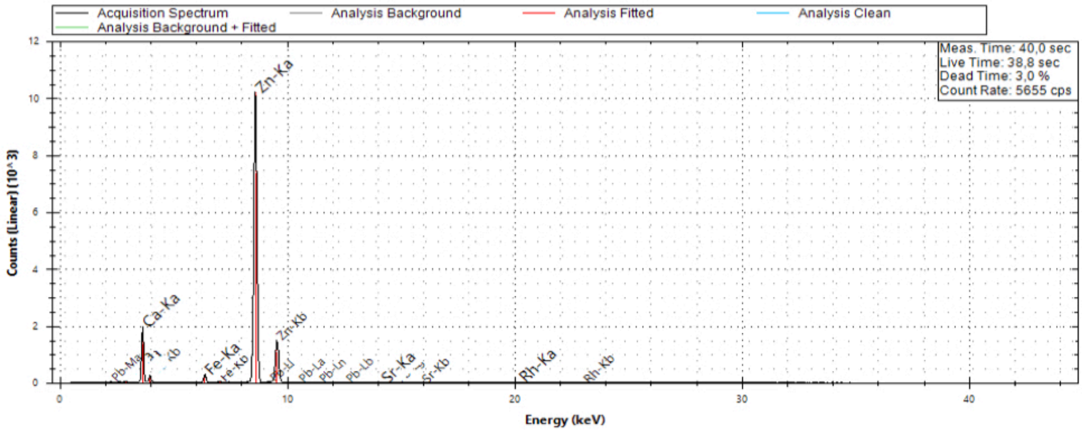
Notes:

Lisa_Sample 3_1

05/04/2019 15:09:26

Measurement Time: 40,0 s
Tube Voltage: 40 kV
Tube Current: 20 μA
Tube Target Material: Rh
Elio Device: SN1253
Device Mode: Head
Acquisition Mode: Manual
Acquisition Channels: 4096
Sample to Detector Material: Air

Spectrum:



Analysis Results:

Element	Concentration	Error
Ca	54,73%	±0,81%
Zn	35,47%	±0,3%
Cl	8,29%	±5,04%
Fe	1,29%	±1,94%
Pb	0,16%	±5,45%
Sr	0,07%	±6,51%

Analysis Date and Time: 05/04/2019 15:08:53
Analysis Type: Automatic
Spectrum Left Cut: 1 keV
Spectrum Right Cut: 50 keV
Spectrum Upper Limit: 50 keV
Use M Line: True
Super Impose Peak Areas: True

Excluded Elements for Fitting Analysis:
H, He, Li, Be, B, C, N, O, F, Ne, Na, Mg, Kr, Xe, Rn, At, Po, Fr, Ra, Ac, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Th, Pa, U, Np, Pu, Am, Cm, Bk, Cf, Es, Fm, Md, No, Lr, Pd, Ru

Excluded Elements for FP Analysis:
Rh, Ar, Ag:L, Tc:L, Nb:L, Mo:L, Cd:L, In:L, Sn:L, Sb:L, Pb:M, Bi:M, Tl:M, Hg:M, Au:M, Pt:M, Ir:M, Os:M, Re:M, W:M, Ta:M, Hf:M, La:M

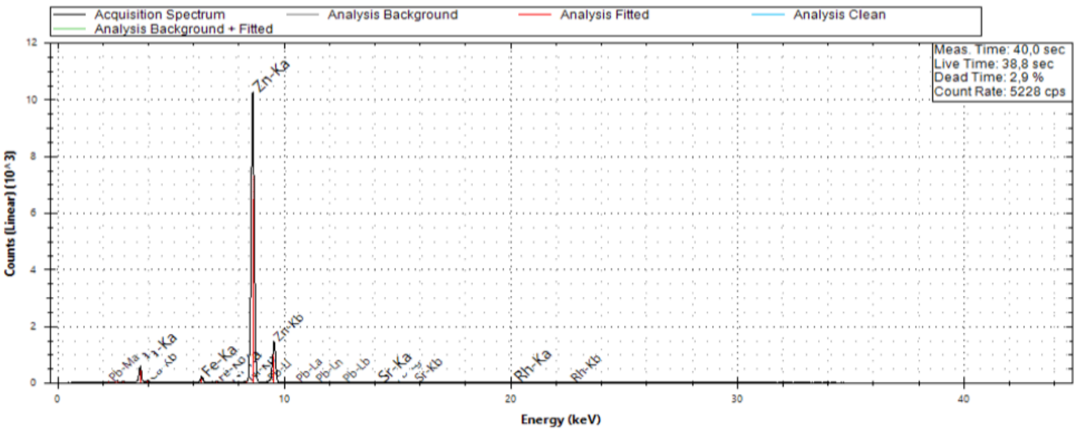
Notes:

Lisa_Sample 3_2

05/04/2019 15:10:47

Measurement Time: 40,0 s
Tube Voltage: 40 kV
Tube Current: 20 µA
Tube Target Material: Rh
Elio Device: SN1253
Device Mode: Head
Acquisition Mode: Manual
Acquisition Channels: 4096
Sample to Detector Material: Air

Spectrum:



Analysis Results:

Element	Concentration	Error
Zn	54,65%	±0,32%
Ca	32,71%	±1,5%
Cl	10,6%	±5,74%
Fe	1,35%	±2,3%
Pb	0,41%	±5,06%
Ni	0,15%	±3,91%
Sr	0,13%	±6,95%

Analysis Date and Time: 05/04/2019 15:10:04
Analysis Type: Automatic
Spectrum Left Cut: 1 keV
Spectrum Right Cut: 50 keV
Spectrum Upper Limit: 50 keV
Use M Line: True
Super Impose Peak Areas: True

Excluded Elements for Fitting Analysis:
H, He, Li, Be, B, C, N, O, F, Ne, Na, Mg, Kr, Xe, Rn, At, Po, Fr, Ra, Ac, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Th, Pa, U, Np, Pu, Am, Cm, Bk, Cf, Es, Fm, Md, No, Lr, Pd, Ru

Excluded Elements for FP Analysis:
Rh, Ar, Ag:L, Tc:L, Nb:L, Mo:L, Cd:L, In:L, Sn:L, Sb:L, Pb:M, Bi:M, Tl:M, Hg:M, Au:M, Pt:M, Ir:M, Os:M, Re:M, W:M, Ta:M, Hf:M, La:M

Notes:

APPENDIX 3. Chronology.