Biographies carved in wood

Reconstructing narratives for medieval polychrome sculptures

Volume I of II

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Image overleaf:

Torsken Virgin

1. Introduction

This PhD research is part of the Norwegian Research Council (NRC) funded project 'After the Black Death: Painting and Polychrome Sculpture in Norway, 1350-1550' (ABD), initiated by Noëlle Streeton. The project focuses on a collection of liturgical objects from the late-medieval period owned by the Museum of Cultural History (MCH) at the University of Oslo, Norway. The PhD thesis builds on a selection of object-based case studies of late-medieval polychrome sculptures originally from churches in northern Norway. The ecclesiastical nature of most medieval art implies that the sculptures would have formed a crucial active component of the medieval church interior prior to the Reformation, when many altarpieces, sculptures and church furnishings became redundant. Originally part of larger assemblages such as shrines or altarpieces, the investigated sculptures have survived for centuries in remote coastal towns, and entered the MCH collection in the second half of the 19th century.

When initiating this PhD project, I was presented with a selection of individual sculptures from the MCH collection by the ABD project leaders, and tasked to build a research project around these. Initially, the disparate nature of these sculptures made it somewhat difficult to formulate an overarching research question. By pursuing in-depth material studies, the material itself guided the direction that this thesis took. Thus, this project is to be seen as a preliminary study of late-medieval sculptures in Norway based on a select number of in-depth case studies, rather than an exhaustive examination of the subject, as this was beyond the scope of the study. Given that similar investigations within a Norwegian context have in the past focused on early-medieval material (see section 1.4 for further details on the current state of research), the research project contributes important insights into an underrepresented field of study.

The selection of case studies was narrowed down to a group of sculptures that were originally housed in churches in northern Norway, as joint provenance from northern coastal towns was a common factor amongst them. I was particularly interested in the relationship between the fishing trade and the wealth of medieval inventory along the coast of northern Norway. Thus, I focused my investigations on a group of three sculptures from Karlsøy on Karlsøya, a set of sculptures from Berg on Senja island, and a sculpture from Torsken, also on Senja island (figure 1). The Torsken sculpture was compared to a sculpture from Schwanbeck, northern Germany.

Comparative analyses were carried out on other sculptures belonging to the MCH collection, as well as additional material in Scandinavia and Germany. Late-medieval sculptures in Norway are mostly considered to have been imported from northern Germany along Hanseatic trade routes during the later Middle Ages, and comparative studies of late-medieval sculpture in Germany were also undertaken to a limited extent. Due to unforeseen complications, the scope of the thesis was further narrowed in 2017 so as to ensure timely completion. As a result, the number of case studies included in the PhD thesis was reduced from three to two case studies, with the research into the sculptures from Karlsøy to be published at a later stage.

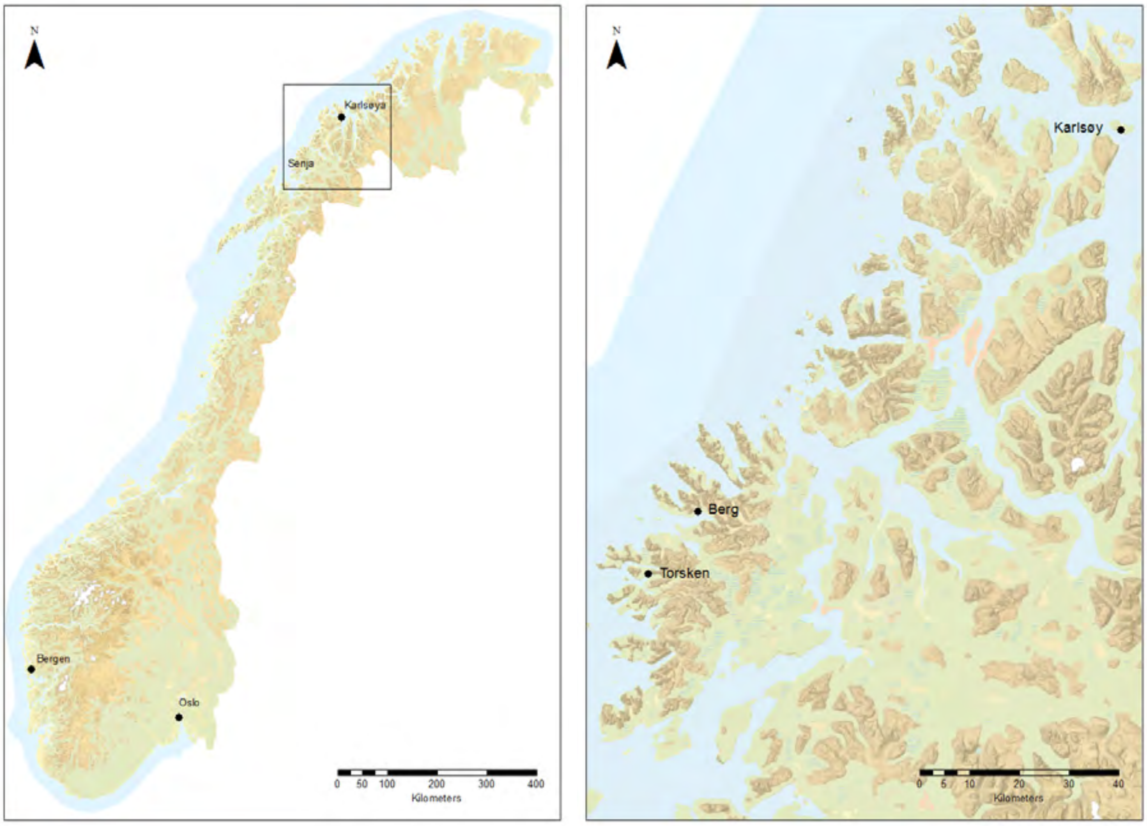

Figure 1: Map of northern Norway

The thesis consists of an object-centred conservation studies approach, using the sculptures as primary source material. My aim has been to develop a holistic picture of late-medieval sculpture in Norway, contributing to knowledge about their material condition and wider contexts. Thus, the project encompasses investigations into the relationships between condition, appearance, use, context and cultural meaning of late-medieval sculpture in Norway, both in the past as well as in contemporary and potential future life stages of the objects. Consequently, the object biographical approach (as seen in Hoskins 1998, Gosden and Marshall 1999, for example) underpins the theoretical framework employed (see section 2 for details). Mapping changes in function and appearance of medieval sculptures over time contributes to their contemporary interpretation and shapes a future context for these sculptures within a modern museum setting.

My background as practicing paintings conservator has made me acutely aware of the consequences of restoration and conservation treatment (or lack thereof) on works of art. I consider it crucial to reflect on conservation and its impact on object interpretation, as we have to concede that conservators are not mere passive custodians, but have helped shape the object's current appearance (see also van Saaze 2013). Thus, intervention must be acknowledged (be that stripping of paint, scraping off of ground, visual reintegration, or consolidation, for example) and told as part of the object's narrative.

1.1 Research themes

This research project argues for the conservator's role as mediator in reading and giving meaning to material evidence by means of suitable modes of interpretation. The overarching aim of the thesis has been to demonstrate how investigations of the material nature, treatment history and context of late-medieval sculpture can contribute to their broader interpretation. Given that the sculptures' roles, function and appearance have irreversibly changed, conservators are in a position to facilitate access to the various stages in their narrative. Appreciating the many ways in which their appearance and function have been modified over time allows for an illustration of the object biographies of selected late-medieval sculptures in Norway. This interdisciplinary approach offers insight gained from methods and techniques employed in conservation studies, thus contributing to a richer interpretation of material culture.

In this sense, building contextual narratives around the sculptures has been of primary importance. A suitable theoretical framework for the contextual approach was considered to be object biographies (see, for example, Kopytoff 1986, Hoskins 1998, Gosden and Marshall 1999, Jones and Foster 2008), and the applicability of the object biographical perspective in the field of conservation was tested by approaching the sculptures from this angle. Building object biographies of the sculptures highlights their continued relevance within the Norwegian cultural heritage narrative despite their status as Hanseatic import art.

By close reading of the material, meaning can be derived from fragmentary evidence, which, when taken with comparative data from objects elsewhere and in different condition, may help clarify the nature of changes that the sculptures have undergone. To a lesser extent, former workshop attributions would be examined and re-assessed as part of this process, resulting in updated knowledge about sculpture imported to Norway during the late-medieval period.

In sum, the key research themes and relevant sub-themes addressed in this thesis may be framed as a series of intimately interlinked questions, as follows:

1. How may 'foreign' sculptures be considered as relevant within a Norwegian cultural heritage context? In what manner does information derived from examinations of their object biographies affect their interpretation and heritage status?

2. How can conservation studies contribute to the study of material culture? In what manner may in-depth material and technological analysis enrich an object biographical study of late-medieval polychrome sculpture? What can the results of analytical techniques common to conservation studies reveal about the sculptures?

3. In what manner may the object biographical approach be considered a useful theoretical framework for conservation studies? May it be considered complementary to more traditional approaches employed in the discipline? How is a conservation studies approach to object biographies different from or complementary to other approaches that investigate object biographies?

Together, these themes contribute to addressing the overarching aims of the thesis by demonstrating the relevance of a conservation studies approach to the holistic interpretation of late-medieval polychrome sculpture as material culture.

1.2 Summary of publications

The thesis is conceived as an article-based thesis consisting of four papers that, together with the introduction and discussion, act as a unified scholarly work. I am the sole author of all four papers included in the thesis.

1.2.1 Paper I

A skewed balance? Examining the display and research history of the medieval collection at the Museum of Cultural History, University of Oslo

Journal of the History of Collections, published online 10th July 2017, print version volume 30, issue 1, March 2018, pp. 139-151.

DOI: https://doi.org/10.1093/jhc/fhx021

The first paper in this thesis deals with the research status of late-medieval sculpture in Norway. I discuss the late-medieval collection of the Museum of Cultural History, University of Oslo, as seen in the Sverre Fehn installation of 1979, particularly with regards to display, choice of objects and aesthetics. The research history of the late-medieval liturgical collection is set against the early-medieval collection and examined from the angle of Norwegian nation building in the 19th and early 20th centuries. Attitudes towards the later Middle Ages are explored through a discussion of Norwegian history education as well as the traditional grand narrative of Norwegian history. The German connection of the late-medieval collection is re-examined, leading to a more nuanced understanding of the display choices and research history of the collection.

Paper I encompasses a literature review of the history of research into late-medieval Norwegian sculpture, and is meant to outline the dearth of investigations into late-medieval material in Norway, thus paving the way for the further papers in the thesis. Consequently, paper I addresses the broader background to research theme 1.

1.2.2 Paper II

Composite wainscot block construction in medieval sculptures: A question of quality?

In: *ICOM-CC 18th Triennial Conference Preprints, Copenhagen, 4-8 September 2017,* ed. J. Bridgland, art. 1703, Paris: International Council of Museums.

Online access: https://www.icom-cc-publications-online.org/PublicationDetail.aspx?cid=fd04b572-153e-4f6e-8d26-2b630f240963

This paper explores a late-medieval technique for constructing polychrome wooden sculptures. This rare "composite block" method used blocks made from wainscot boards glued together. The technique is compared to the more common method of carving a solid block cut from a tree trunk, followed by hollowing out of the block to reduce the risk of cracking and splitting. The composite block technique is not widely known and has not yet been comprehensively studied. It merits further attention because it reveals the medieval carver's advanced technical skills, in-depth material knowledge and concern for quality. Development of the construction technique during the 15th century in Northern Europe is explored by means of a case study of one such sculpture from the Museum of Cultural History, Norway. Northern German, northern Netherlandish and Florentine composite block techniques are examined, pointing to parallels within art production both north and south of the Alps.

Paper II was written to shed light on and contextualise an intriguing construction technique employed for one of the case-study sculptures. As a result of the focus on construction technique, the paper also acts as an exploration of the sculpture's 'birth', a significant first stage in its object biography. At the same time, the question of material quality is explored in relation to medieval wood use. Paper II may be linked to research theme 2.

1.2.3 Paper III

Saintly relationships or grounds for divorce? An examination of workshop links between two medieval polychrome sculptures

Journal of the Institute of Conservation, June 2018, volume 41, issue 2, pp. 95-112.

DOI: https://doi.org/10.1080/19455224.2018.1463923

This paper employs a combined approach of technical analysis and object biographical research to reassess a 1930s art historical attribution. Two late-medieval polychrome sculptures are examined in the case study. Art historian Eivind Engelstad had suggested that the two sculptures had previously been part of the same altarpiece. This hypothesis is re-evaluated by means of material investigations. Comparisons of the construction techniques and wood used are highly indicative of different workshops. In addition, painting techniques, pigments and layering structures used in the polychromy emphasise the differences between the sculptures. The sculptures' treatment history on entry into the museum has further accentuated their differences, and has led to divergent conditions of preservation and current appearance of the sculptures. This highlights the effect that conservation treatment or lack thereof can have on an object and its interpretation. Material investigations have not been able to lend support to Engelstad's theory, and analytical results suggest a revised interpretation of the sculptures.

The third paper consists of a re-examination of an art historical attribution with the aid of technical analysis and the object biographical approach. This is the first paper in the thesis to explicitly introduce the object biographical framework, while highlighting the effect of conservation treatment history on object interpretation. Paper III deals with issues raised in research themes 2 and 3, and to a lesser extent theme 1.

1.2.4 Paper IV

Biographies carved in wood: Turning points in the lives of two medieval Virgin sculptures

Journal of Material Culture, published online 21st November 2018.

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By comparing two medieval polychrome sculptures of a combined enthroned Virgin and nativity scene, important and hitherto unnoticed stages in their object biographies can be described. Provenance and attribution are addressed by virtue of stylistic and material comparisons, and the sculptures' wider iconographic, social, historical and spatial contexts are outlined. The article demonstrates how conservation science investigations feed into knowledge regarding the sculptures' material composition, use, transformation and treatment histories. Thus, the applicability of the conservator's approach to examining objects and shedding light on wider historical contexts is outlined by virtue of this case study.

The fourth paper was envisaged as a demonstration of the object biographical approach, wherein contextual investigations are supplemented with data gathered from material analysis of the sculptures. Thus, it demonstrates the applicability of the theoretical framework to conservation studies, while at the same time bridging disciplines and highlighting that conservation research has much to offer to a wider audience interested in material culture studies. Consequently, paper IV addresses research themes 1, 2 and 3.

1.3 Terminology

At this stage, certain crucial terms used throughout the thesis need defining so as to explain how said terms are used and understood within the scope of the thesis.

1.3.1 Polychromy

Polychromy involves the use of colour for the decoration of architecture, sculpture, pottery and more. The meaning derives from the Greek, and the etymology of the term makes it clear that poly and chrome means many colours. Large numbers of medieval sculpture were polychromed, though unpolychromed or partially polychromed works also exist, famously seen in works by Tilman Riemenschneider, for example. With regards to medieval polychrome sculpture, the German word *Fassung* comprises essentially all decorative steps after carving of the sculpture. These include ground application as well as patterns and forms created by modelling the ground, such as, for example, veins, hair or three-dimensional blood drips.

Fassung also incorporates, in addition to painting, the gilding or application of metal leaves to the sculpture. This may consist of the use of metal leaves such as silver, gold, tin or *Zwischgold* (part-gold), stencilled patterns or decoration, coloured glazes known as lustre on metal leaf, or *sgraffito* as well as imitation gold consisting of silver leaf coated with pine resin. Other elements may include applied tin relief, punched or incised patterns in metal leaf, inset precious stones, applied paper cut-outs or cast metal decoration, and pressed brocades (Oellermann 2015).

I use the term polychromy in this context to equate to the all-encompassing German term *Fassung*, which covers the entire visual unity, gilding, colour, and other applied elements, rather than just colour on its own. This is not a new interpretation of the term; other medieval scholars use the term polychromy in a similar manner (Kollandsrud 2018, 20), given that there is no English equivalent that is as comprehensive as the term *Fassung*.

1.3.2 Late-medieval

There are several ways in which scholars have subdivided the medieval period, and this depends on numerous factors including geography and politics. In a pan-European case, the Middle Ages are generally divided into three periods, the Early, High and Late Middle Ages. In this case, the Early Middle Ages usually range from the end of the Roman Empire around the year 500 and up to the year 1000, while the High Middle Ages range from circa 1000 to 1250, and the Late Middle Ages from 1250 to around 1500. In Scandinavia, on the other hand, the medieval period is generally accepted as beginning after the Viking period and with Christianisation around 1000 to 1050.

The Late Middle Ages gradually made way for the early modern period, and in German-speaking regions are variously seen to end with events such as the Reformation in 1517, or the Peasants War of 1525, for example. Art historically, the terms late Gothic and early Renaissance have been applied somewhat interchangeably to art and architecture of the late-medieval period, although the term Renaissance is more often applied in an Italian context when thinking of artists such as Brunelleschi or Donatello, for example, who are often seen as some of the earliest proponents of the Renaissance. Given that I find periodisation to be somewhat problematic, as labelling appears to neatly categorise and 'pigeon-hole' despite the fact that boundaries and timeframes are often far more fluid, I prefer not to use such art historic categorisations in this thesis.

Instead, I follow the system used by many conservators and art historians in Norway, wherein the 14th century is considered to be a period of stylistic change. Unn Plahter's pioneering research (2004a, b) into altar frontals from the period 1250 to 1350 is a prime example of investigations into important early-medieval material in Norway. Similarly, Kaja Kollandsrud (2018) has extensively examined material dated between 1100 and 1350. Therefore, the range 1350 to 1400 is usually associated with the beginning of a new period, namely the late-medieval period. For example, Eivind Engelstad's *Senmiddelalderens Kunst i Norge* (1936) encompasses material from 1400 to the 1530s, ending with the arrival of the Reformation in Norway. Per Jonas Nordhagen, on the other hand, refers to the late-medieval period as running from 1350 to 1573 (Lidén et al. 1981, 375).

The late-medieval period as defined by the ABD project leaders encompasses the period 1350 to 1550, using the arrival of the plague in Norway in 1349 as a dividing marker between early- and late-medieval. The sculptures that were investigated as part of my thesis fall into the period 1400 to 1500, generally accepted as late-medieval times.

1.3.3 Northern Germany

It is commonly recognised that there are stylistic differences in medieval painting and sculpture depending on which region in Germany they derive from. However, most literature does not actually define these regions, instead using general terms such as southern Germany, the Rhineland, and northern Germany. Engelstad, for example, in *Senmiddelalderens Kunst i Norge*, separates art from southern Germany from the art of the Hanseatic region, which he centres around Lübeck (Engelstad 1936). The publication *Malerei und Skulptur des späten Mittelalters und der frühen Neuzeit in Norddeutschland* is based around regions including the Rhineland, Westphalia and all the way to the Baltic (Krohm, Albrecht, and Weniger 2004).

Historically, the development of Germany as a unified nation state in central Europe has been complex, growing out of an amalgamation of extremely varied territories and duchies that at one time encompassed almost all of Central Europe as part of the Holy Roman Empire. Migration eastwards and northwards was a feature of the 12th century, and colonisation of arable land in territories such as Silesia and the Baltic areas went hand in hand with population increase (Fulbrook 1990, 20). With the end of the Hohenstaufen dynasty in the 13th century, a number of competing powers arose, including the Houses of Habsburg, Luxemburg and Wittelsbach. Imperial reform in the 15th century, such as at the Diet of Worms in 1495, led to constitutional developments for the Empire (Angermeier 1984). However, it is crucial to remember that the question of when Germany as a nation developed is a complicated matter (Fried 1987, Reinhard 2004, 65), and both during the Middle Ages and in modern times Germany has been characterised by regionality as opposed to centrality.

During the Middle Ages, the northern regions were dominated by the Hanseatic League, a merchant union of guilds and towns trading around the North Sea and Baltic Sea (figure 2). The economic area over which the Hanseatic League extended encompassed not just the northern part of the Holy Roman Empire, but also parts of the Kingdom of Poland, the State of the Teutonic Order (*Deutschordensland*) which formed the precursor to Prussia, and Novgorod to the northeast.

It is clear that in the Middle Ages, borders were far more insignificant than in modern times (Boockmann 1987, 306). A Low German regional identity certainly existed in relation to the Hanseatic League as a result of migration within the northern German region. Family ties between merchants were strong, as was cooperation and friendship between individual merchants, and could be part of the reason for the long-standing success of the Hanse despite

Figure 2: The Hanseatic League, circa 1400, by Droysen/Andrée - Plate 28 of Professor G. Droysens Allgemeiner Historischer Handatlas, 1886, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=17108274

its lack of a solid organisational structure (Selzer 2010, 82, Jenks 2013, 199, Wubs-Mrozewicz 2013, 10).

The boundary of northern Germany is notoriously difficult to define, as this varies depending on the angle being examined, be that geography, politics, culture, language and more. For example, the central mountain range, or *Mittelgebirgsschwelle*, separates the northern German plains from the southern regions geographically. Linguistically, northern Germany is characterised by the common language Low German (*Niederdeutsch*), as opposed to Upper German (*Oberdeutsch*), which is a series of dialects spoken in the southern German territories in what is now Franconia, Swabia, Bavaria, as well as German-speaking parts of France, Switzerland, Italy and Austria. In more recent times, the Main line (*Mainlinie*) separated Prussia from Austria during the 19th century, creating the North German Confederation, or *Norddeutscher Bund,* which formed the precursor to the German Empire in 1871 (Nipperdey 1990, 23). Even nowadays, the Main line is often considered to be the boundary between northern and southern Germany.

Thus, if one were to generalise, in modern terms northern Germany encompasses states along the northern coast, such as Mecklenburg-Vorpommern, Lower Saxony, Schleswig-Holstein, Hamburg and Bremen, as well as Berlin, Brandenburg, Saxony-Anhalt and North Rhine-Westphalia. The shift from northern to central Germany is somewhat fluid, and the North could arguably be said to extend down to Frankfurt am Main. With regards to a late-medieval context, these modern states can be equated to the duchies and territories of Friesland, Holstein, Mecklenburg, Brandenburg, Saxony, Pomerania, Hesse, Thuringia, Lausnitz, smaller dioceses in the area, as well as parts of the Teutonic Order, Silesia and Bohemia.

1.4 Research status

The history of research is discussed in the first article of this thesis, ‘A skewed balance’ (paper I) (Ebert 2018a). However, instead of being a traditional literature review, the focus of the article was angled towards the politics of cultural heritage due to my participation at a PhD course with an early draft version of the paper.[1] Thus, the article traces the museum collection’s origins, and places these in the wider context of Norwegian history education and the traditional grand narrative. It is clear though, that this in itself may also be considered a ‘skewed’ approach. In order to clarify, what follows is a brief outline of the research status of late-medieval polychrome sculpture in Norway in the light of more recent developments in the field, as well as a summary

1 The Politics of Heritage: Museums, Landscapes, Material Culture. PhD course, Pitt Rivers Museum at the University of Oxford, April 4-8, 2016. Dialogues with the Past. The Nordic Graduate School in Archaeology. See http://www.hf.uio.no/iakh/english/research/dialogues-with-the-past/courses/the-politics-of--heritage%3A-museums-landscapes-mate.html

of the state of research into northern German late-medieval polychrome sculpture in general.[2]

Due to my personal interest in museum collections and display strategies, the aforementioned article examines late-medieval art in Norway by focusing on both the research status as well as the display history of the medieval collection of the MCH. Therefore, in addition, the following section is also intended to act as an update to and commentary on the MCH's medieval display strategy.

1.4.1 Late-medieval polychrome sculpture in Norway

Norway's collection of late-medieval sculpture remains largely unknown internationally due to the absence of any serious attempts at re-evaluating and updating art historic stylistic interpretations dating to the first half of the twentieth century by art historians including Harry Fett (1909, 1925, 1938), Eivind Engelstad (1933, 1936) and Anders Bugge (1933). Research into late-medieval sculpture and Hanseatic influence in Norway turned a new page in the 1990s, with publications by Henrik von Achen, Margareta Kempff, Jan von Bonsdorff and Fredrikke Schrumpf, amongst others, all of whom attempted a more critical stance. Von Achen (1994) critically reassessed whether Bergen could have been a production centre for art in the late-medieval period, while Kempff (1994) questioned attribution to a small handful of known masters. Similarly, von Bonsdorff (1993, 2000) suggested alternate research strategies including art geography and economy over the former emphasis on master attributions. Schrumpf (1999) critically re-evaluated Engelstad's catalogue of late-medieval art in Norway. Nordhagen (1994), on the other hand, reasserted the view that until systematic material studies could prove otherwise, the theory of a total absence of local Norwegian production during the late-medieval period remained valid. While the overall art historic stance has become more critical, conservation studies and technical analysis of the late-medieval corpus in Norway were necessary in order to provide material evidence for solid reattributions.

Awareness of late-medieval art in Norway will hopefully change in the near future as a result of art technological and conservation research undertaken by researchers at the Norwegian Institute for Cultural Heritage Research (NIKU), Kristin Kausland, myself and researchers linked to Streeton's ABD research project. In Trondheim, Daniela Pawel (2014) has investigated a late-medieval altarpiece from northern Norway, linking it to Lübeck. The ABD research project was conceived as an interdisciplinary project to reassess and contextualise late-medieval art in Norway (Streeton 2013). As part of this, publications have included an assessment of the reasons behind touching and mutilation of sculptures (Streeton 2017a) as well as an outline of the technique employed for non-invasive dendrochronology (Daly and Streeton 2017), and a review of Lübeck attribution of Hanseatic art in Norway (Streeton 2018).

2 Erla Hohler (2017) has recently compiled an inventory of all medieval wooden sculptures in Norway, as well as a bibliography of literature relating to these, up to and including 2016.

Kausland situated herself squarely within art technology and technical art history (2017a, 11) while focusing her PhD study on five altarpieces belonging to the MCH collection. She complemented this with a systematic study of thirty altarpieces in-situ along the Norwegian coastline, with the overarching aim of reattributing their existing Lübeck or northern German provenance (Kausland 2016a, 2017a). As a result, Kausland (2016b, 2017a) has demonstrated that numerous late-medieval altarpieces were likely produced in Norway as part of a 'mixed enterprise', showing that the later Middle Ages were not necessarily a period of decline, without any local art production. In addition, Kausland (2017b) was able to reattribute a number of altarpieces to a northern Netherlandish tradition on the basis of their construction method. Kausland (2018) is set to continue her research into Norwegian altarpieces and the question of German, Netherlandish or Norwegian production with an NRC funded mobility grant.

My PhD thesis, originally part of the ABD research project, is to be seen as an initial attempt to fill the gap on material investigations and contextualisation of late-medieval sculpture in Norway. Challenging former attributions has been of secondary importance in my research, as my main interest has lain in the sculptures' object biographies (paper IV) (Ebert 2018c). In addition, I have also characterised composite wainscot block construction techniques specific to northern German and both northern and southern Netherlandish workshops (paper II) (Ebert 2017), and provided a critical reassessment of joint altarpiece attribution of two sculptures (paper III) (Ebert 2018b).

1.4.2 Museum display of late-medieval sculpture in Norway

The display of early-medieval and late-medieval sculpture at the MCH as discussed in the article 'A skewed balance' was current from the 1970s until the end of 2018. In early 2019, a new exhibition called 'Transformation' is set to open at the MCH as part of the ABD research project aims, with a particular focus on the museum's late-medieval collection. A bilingual exhibition catalogue (Bjerregaard 2019) was written to coincide with the new exhibition, and includes entries written by myself based on case studies of the Torsken and Berg sculptures.

In addition, several late-medieval sculptures belonging to the MCH collection have been on long-term loan to numerous regional museums, thus bringing the sculptures back to a local audience near their centres of provenance prior to entry into the MCH collection. For example, a number of sculptures from Hasvik in Finnmark are on exhibition at Alta Museum, while sculptures from Kvæfjord are on display at the Sør-Troms Museum in Trondenes. Other important collections in Norway that have late-medieval sculpture on display include the university museums in Bergen, Tromsø and Trondheim.

1.4.3 Northern German late-medieval polychrome sculpture

The posthumous publications of Johannes Taubert (1978) may be seen as a defining moment in the study of polychrome sculpture. The recently updated English translation (Taubert and Marincola 2015) is testament to the pioneering nature of Taubert's studies and their continued relevance almost half a century after their first publication. Similarly, Arnulf von Ulmann's (1984) seminal study of medieval carving techniques retains contemporary relevance. The volume *Figur und Raum* (Albrecht, Bonsdorff, and Henning 1994), proceedings from an international conference held in 1992, demonstrated a marked shift in interest towards contextual research around medieval altarpieces. The proceedings gathered in *Malerei und Skulptur des späten Mittelalters und der frühen Neuzeit in Norddeutschland* (Krohm, Albrecht, and Weniger 2004) follow on from this, while Peter Tångeberg's study of 14th century altarpieces and retables from Gotland also continues in this vein, placing the objects of study within their wider European context (Tångeberg 2005).

However, as of now, there have been few systematic material studies of northern German late-medieval polychrome sculpture. One of the exceptions is Tångeberg's (1986) methodical study of medieval sculpture in Sweden, wherein he specifically addresses late-medieval techniques, and on which I have based a significant amount of my own material comparisons and interpretations. In addition, individual case studies published in journals, conference proceedings and edited books have added to the body of knowledge about construction techniques, ground, paint and gilding techniques. For example, proceedings of a colloquium held in 1990 in Germany contributed to research on late-medieval German altarpieces (Krohm and Oellermann 1992). Similarly, proceedings of a colloquium held at the Louvre in 1991 include a number of technical studies covering German polychrome sculpture originating in a range of different regions in Germany (Guillot de Suduiraut 1993). Publications gathered in *Unter der Lupe* (Moraht-Fromm and Weilandt 2000) focus on a wide-ranging series of case studies that further enhance our knowledge of medieval sculpture. Proceedings of three interim meetings from 2010, 2012 and 2013 of the ICOM-CC working group *Sculpture, Polychromy and Architectural Decoration* contribute to scholarship relating to carving and construction techniques (Seymour 2014b), artistic tradition (Seymour 2014a) and decorative practice (Seymour and Litjens 2017). While the proceedings cover polychrome sculpture from a range of time periods and regions, several contributions address late-medieval sculpture originating in Germany.

The inter-disciplinary research project *Let the Material Talk. The Technology of late-medieval Cologne Painting from the 'Master of Saint Veronica' to Stefan Lochner (1380-1450)* (Wallraf Richartz Museum, Fondation Corboud, and Doerner Institut der Bayerischen Staatsgemäldesammlungen 2014) is one example of a successful overarching study, though it focuses on panel paintings from a different region of Germany, making it somewhat problematic when attempting to infer material comparisons with polychrome sculpture from northern German centres of production. Nevertheless, it has been demonstrated that wainscot was also occasionally used in Cologne. An important contribution to material knowledge about the Lübeck master Hermen Rode comes from the 2013-2016 project *Rode Altarpiece in Close-up* in Tallinn, Estonia, winner of the prestigious 2017 Europa Nostra European Union Prize for Cultural Heritage. A further example of a combined art technological and art historical study into polychrome sculpture focuses on the polychromy of 17th and 18th century German sculpture, counterpoised with a study of Japanese polychromy (Kühlenthal and Miura 2004). While the focus is on a different time period, the study is exemplary in its broad approach and close attention to material studies.

The question of material technology in northern German late-medieval sculpture has also been addressed by a number of authors over the last few decades. Edith Fründt's (1962) investigation into the use of walnut wood instead of oak was picked up at a later stage by Johannes Voss (2004), who questions the attribution to the Rhineland, citing instead numerous examples of the use of walnut and limewood in northern towns such as Wismar, Rostock and Stralsund. Tångeberg (1993), on the other hand, describes a selection of sculptures carved out of walnut, and claims Gdańsk, and thus the State of the Teutonic Order, to be the place of origin for such sculptures.

Peter Knüvener (2011a, b, 2015) makes an important contribution with his discussion of late-medieval altarpieces, sculpture and panel paintings in the Margraviate of Brandenburg. However, these are art historical studies, and while he makes comparisons to other regional styles and techniques, Knüvener (2011a, 320) underlines the need for art technological investigations of the material. In Schleswig-Holstein, Uwe Albrecht (2005, 2012, 2016) is the guiding force behind the multi-volume catalogue of medieval art in the region, which does include some dendrochronological and limited material data, where available. Julia Trinkert (2014) and Steffen Lindemann (2016) have made significant contributions with cataloguing and art historical studies of late-medieval material in Mecklenburg, though once again we lack art technological studies. Kathrin Wagner's (2011) contribution to the research field with her study of the late-medieval altarpieces of Rostock is an important art historic study. Similarly, Anja Rasche's (2013) study of Hermen Rode, as well as Miriam Hoffmann's (2015) art historic investigations into late-medieval panel paintings from Lübeck, have both contributed to updated art-historic knowledge of late-medieval art production in and around Lübeck.

This brief overview of the state of research in material studies of late-medieval northern German polychrome sculpture demonstrates the value of further detailed material and contextual studies as undertaken in this PhD thesis. In-depth material and technological investigations performed during this study allow questions to be addressed that are often out of reach when employing standard art historic approaches. Thus, the contribution that this research project makes is significant for a more profound understanding of the production and circulation of religious art during the late-medieval period.

Image overleaf:

Berg St Anne

2. Theoretical framework

This section outlines the theoretical stance that forms the framework for the thesis as a whole, acting as the central theme running through the thesis. Subsequently, the reasons for the theory's application are outlined in order to explain why it is considered a suitable theoretical stance. Naturally, given the varying content, publication venues and associated format constraints, not all of the papers included in the thesis engage with the theories subsequently described to the same level. Therefore, the individual papers' relationship with some of the theoretical stances outlined here will be discussed later in the thesis. The theoretical approach outlined below is intimately linked with research themes 2 and 3, the results of which contribute to answering research theme 1.

2.1 Object biographies

Given the position of Conservation Studies at the University of Oslo within the Department of Archaeology, Conservation and History, and my participation in research seminars organised within Archaeology, an engagement with archaeological discourse developed naturally as a result of exchange with colleagues working in other disciplines. This inspired me to think along the lines of object biographies due to the relatively long lifespan of medieval polychrome sculpture and the associated changes in use, appearance and valuation that these objects have gone through over the course of many centuries. In the words of Chris Caple (2006, 12), "as objects may have long lives, they may exist in many different contexts through the lifetime of an object". More than that, the "time continuum" enables objects to encompass different values, contexts as well as a host of varying or competing "interpretations of significance" (Leigh et al. 1994, 273).

The object biographical framework first developed out of the work of anthropologists investigating commodities, exchange and gift theories and seeking to examine the 'social lives' of things (Appadurai 1986, 3). In particular, Igor Kopytoff (1986), in his seminal essay as part of the edited volume *The Social Life of Things*, is to be credited for coining the idea of "the cultural biography of things", wherein objects or commodities move between various identities, with a whole range of associated shifts in status and added drama to their biographies. Essentially, things, in their role as commodities, can inform our understanding of culture by virtue of the relationships between people and things, and the manner in which people construct meaning around objects (Kopytoff 1986, 90). As mentioned by Arjun Appadurai (1986, 34) and subsequently reiterated by Jody Joy (2009, 542), one must also note the difference between object biographies which focus on specific individual case studies, and life history approaches which seek to examine classes of objects on a larger scale. In the latter case, these life histories invariably focus less on the interrelationships between people and things, being more vested in broader themes such as technological changes over time, for example.

Of course, the idea that objects could have biographies and that "every thing has its history" (Briggs 1988, 27) is not necessarily new if one considers, for example, the 18th century literary sub-genre of the it-narrative (Blackwell 2004, 2007, Bernaerts et al. 2014). It-narratives were characterised by inanimate objects or animals recounting their life stories by virtue of the people they interacted with, and can accordingly be seen as the fictional precursors to academic object biographies (see, for example, Coventry 1751, Bridges 1771, Johnstone 1775). It-narratives found their continuation in the work of 19th century Victorian popular science writers such as Annie Carey, for example, whose "*Autobiographies of a lump of coal; a grain of salt; a drop of water; a bit of old iron; a piece of flint*" and similar works were aimed at introducing science to children (1870, 1873). Nevertheless, it would appear that Kopytoff provided the impetus for academic research employing the biographical approach.

Over the next decades, the intertwining of human and object biographies began to be explored extensively by anthropologists and archaeologists who adopted the object biographical framework as a useful tool for exploring the relationships between people and the things that we surround ourselves with. For example, a themed issue of *World Archaeology* published in 1999 was based around "the cultural biography of objects", thus making direct reference to Kopytoff (Marshall and Gosden 1999). As could be expected, the approaches and subject matter in the themed issue varied significantly, ranging from the Elgin marbles (Hamilakis 1999) and an early-medieval cross (Moreland 1999) to appropriated equestrian imagery in Chilean rock art (Gallardo, Castro, and Miranda 1999), pearls traded between Amerindians and Europeans in the 15th century (Saunders 1999), and an embroidered beaded bag linked to the North American fur trade (Peers 1999), amongst others. Nevertheless, all papers sought to address "the links between people and things" and "the ways meanings and values are accumulated and transformed" (Marshall and Gosden 1999, 172). The breath of scope of these object biographies is indicative of the fact that things are not "static embodiments of culture but are, rather, a medium through which identity, power, and society are produced and reproduced" (Avrami, Mason, and de la Torre 2000, 6). In addition, a large number of journal articles, numerous books, edited volumes and PhD theses have been published that continue the theme of object biographies or social lives of things (see, for example, Riggins 1994, Hoskins 1998, Myers 2001, Fontijn 2002, Holtorf 2002, Whitley 2002, Olson, Reilly, and Shepherd 2006, Jones and Foster 2008, Tythacott 2011, Dudley and Pearce 2012, Hill 2012, Williams, Kirton, and Gondek 2015, Kirton 2016).

Certainly, the notion of cultural or object biographies has also been critiqued and alternative approaches presented, particularly with regards to prehistoric objects. Cornelius Holtorf (2008, 415), in discussing prehistoric monuments, claims that the object biography approach is flawed due to the "multi-temporal" nature of landscape, wherein "past, present and future are […] constantly intermingled with each other". Therefore, he claims that monuments do not have "a stable identity…over time" and it might be better to see them as numerous different monuments (Holtorf 2008, 423). Andrew Jones, Marta Díaz-Guardamino and Rachel Crellin (2016) argue along the same lines, suggesting that certain things are better approached as "multiple objects" rather than having an individual biography. Nanouschka Burström (2014), on the other hand, argues for closer engagement with the "humanistic perspective" of object biographies, namely the literary disciplines. Jody Joy (2009, 545) critiques the linear nature of biographies, and instead recommends looking at relational biographies as "the sum of the social relationships that constitute" an object. Consequently, Joy claims that it is possible to pick out phases within an object's biography that are considered socially important instead of attempting to construct a linear narrative. On a similar level, Rosemary Joyce (2015, 30) proposes the idea of object itineraries rather than biographies in order to break from the unilinear format dictated by the biographical framework, and demonstrates that "things have not just a chronological but also a simultaneously unfolding spatial trajectory". I consider this to be a valuable and inspiring addition to the object biographical framework, and the papers gathered together in an edited volume centred around object itineraries provide for enlightening reading, as the concept of itineraries allows for greater freedom beyond the usual birth, life and death sequence (Joyce and Gillespie 2015).

2.2 The concept of biographies within conservation

The use of object biographies is to a certain extent not new to museology or conservation either, being implicit in the direct engagement with material culture. Investigations into object provenance are a crucial element of collections management in museums, and conservation treatment history plays an important role in condition reports, as do alterations resulting from changing uses of objects over time. These points are addressed in paper III, where the sculptures' treatment and display histories are examined. As noted by Chris Caple (2003, 70), the act of documenting an object and creating a conservation report, arguably one of the most important unsung stages in the conservation process, is in itself an acknowledgement of the fact that conservation is "part of a series of ongoing processes which last for the whole of the object's life. It also acknowledges that there are many people who will come after the present conservator who will need information about the object and who will undertake further investigation, revelation or preservation work". Accordingly, the conservator is an active agent in the object's biography. As confirmed by Avrami, Mason and de la Torre (2000, 10), "the prospect of stewarding for future generations the material markers of the past, imbued with the cumulative stories and meanings of the past as well as of the present, is the essence of conservation".

Labelling of museum displays may occasionally incorporate interesting aspects of an object's biography, thus affording glimpses into the "slippery identity of objects" (Appelbaum 2018, 345). Take, for instance, a reliquary bust by Michel Erhart on display at the museum of Ulm, in southern Germany (figure 3). The gallery label describes the bust's early role as reliquary

Figure 3: Michel Erhart, Mary Magdalen reliquary bust, circa 1475, Ulm Museum © Wolfgang Adler

container, its loss of reliquary function with the Reformation, and outlines how the sculpture was subsequently altered and put to new use. The bust entered the museum collection in the form of a *Leuchter- or Lüsterweibchen*[3] (figure 4), having been attached to a chandelier made from antlers at an unknown point in the past and only reverted to its former function in 1934. During the 19th century, several plaster casts and carved copies of the *Leuchterweibchen* were made, one of which even hung in the town hall of Aachen up until World War II (Rief 2011, 97). Without reading the gallery label, the museum visitor would only see yet another medieval reliquary bust, with no knowledge of an entire life stage of the object.

As shown above, object biographies have a long tradition of use in anthropology, archaeology and related disciplines such as material culture studies, and are also finding their way into conservation studies. Conservator Dinah Eastop (2006) has published in the field of material culture, and her chapter on "Conservation as Material Culture" contains two case studies outlining how conservation plays a role in the biography or social life of an object. Gabriella Barbieri (2007) has used an object biographical framework in the examination of an 18th century concealed garment. In Barbieri's study (2007, 209), radiography was employed as analytical technique to examine and document the condition of the object, leading her to conclude that interventive conservation was inappropriate at this stage as all the different periods in

Figure 4: Leuchterweibchen, circa 1540, Suermondt-Ludwig Museum, Aachen © Wuselig [Public domain], via Wikimedia Commons

3 From the German, literally meaning 'chandelier woman'.

the garment's biography were equally important. Chris Caple (2006, 13-17) has developed a systematic framework of study he terms "OPUS (object production and use sequence)", which allows for a "holistic approach to object study", in keeping with the biographical approach. This thorough system looks at production, which involves materials, tools and expertise, before moving into the use and reuse of objects, followed by loss and abandonment, and ending with recovery and curation within the museum context, for example.

Elizabeth Pye (2001, 57-60) encourages the conservator to understand the different contexts of an object prior to undertaking conservation and advocates sensitivity towards an object's significance, as this is invariably determined by changing values or attributes allocated to the object at various stages in its life. Thus, the varying values assigned to objects during the course of their lives are subject to change due to shifts in fashion and taste, and invariably affect an object's preservation. Pye (2001, 64) suggests that the changes of significance which an object passes through could be called its "conceptual biography", and the changes in physical condition could be its "material biography". This is an interesting concept, though I prefer a more fluid approach, much as Pye (2001, 65) further emphasises that "there is no such thing as a single truth about an object", and that "each object has undergone so many 'life changes' and functional modifications that its 'life history' must be elucidated, and not just assumed, by materials scientists or conservators".

Similarly, Barbara Appelbaum (2010) has suggested the use of a biographical approach in determining value when planning conservation treatment methodologies. Salvador Muñoz Viñas (2005, 61) proposes that simple objects are turned into objects worthy of conservation by virtue of their property as symbols, and that their "webs of meaning" may change over time. Muñoz Viñas (2005, 181) argues that a contemporary theory of conservation looks beyond the classical theory of truth, moving instead towards function, value and meaning, all of which are temporally distinct elements that can and do change throughout an object's biography. More than that, the act of conservation itself "plays a significant role in constructing meanings" and thus directly influences the creation of values and significances (Clavir 2002, 36). Nevertheless, it would appear that "conservation is on its weakest, least articulated ground when it comes to discussing the relationships between things … conserved in one way or another, and the social and economic meaning that a culture derives from those things"(Bluestone 2000, 66).

Noëlle Streeton (2017b, 419), on the other hand, seeks to, in her own words, "address disciplinary shortcomings" in directing her attention to theoretical frameworks for conservation, yet does not take into account pre-existing work undertaken by Pye in assessing significance and examining the biographies of objects. By focusing on "disciplinary incompatibilities" and "disciplinary barriers" (2017b, 420-424), Streeton overlooks the fact that there are art historians who have worked towards closer integration with other disciplines or increased involvement with materiality and material culture (see, for example, Prown 1982, Wicker 1999, Yonan 2011); thus, Streeton unfortunately enforces disciplinary divisions despite having set out to break down barriers.

The issues raised in research themes 2 and 3 are mirrored in some of the theories discussed above, demonstrating that conservators must bear in mind the object's biography when investigating objects or undertaking treatment. In particular, changing values and significance assessments are crucial elements in a contemporary theory of conservation. In paper IV, some of the shifting values of the Torsken and Schwanbeck sculptures are outlined, acting as a demonstration of how the object biographical approach may be used to explore material culture.

2.3 The interdisciplinarity of material culture

This raises another angle that must be discussed and which ties in with research theme 2, namely that of interdisciplinarity and material culture. Disciplines that are engaged with material culture to one extent or another include art history, archaeology, conservation, museology and material culture studies amongst many others. The relatively recent development of technical art history as a sub-discipline is similar to the development of archaeometry, as both demonstrate a marked interest in the materiality of material culture. At the heart of technical art history is interdisciplinarity (Ainsworth 2005), be that the engagement with methods and theoretical frameworks deriving from different disciplines within an individual researcher, or in the form of multidisciplinary collaboration between researchers from a variety of disciplines.[4] Instead of focusing on disciplinary boundaries, interdisciplinarity allows us to take advantage of a common interest in material culture, and to use theoretical frameworks and methodologies from a variety of disciplines as considered relevant and useful for a particular set of research questions. Avrami, Mason and de la Torre (2000, 9) also question why "assessment of cultural significance is not more meaningfully integrated in conservation practice", and come to the conclusion that this is due to the technical nature of conservation, which places it apart from other social sciences.

A number of researchers have previously called for a reintegration of art historic enquiry with materiality and the making of art. David Summers (1994, 592), for example, argues for an engagement with a work of art's facture, as we must not ignore the "indexical evidence" of the object as culturally specific. Nancy Wicker (1999, 166), on the other hand, concerns herself with the overlapping engagement between the work of art historians and archaeologists, and I would argue that what she terms the "cross-fertilization of art-historical and archaeological methods and theories" applies just as much to other disciplines vested in material culture. What first drove me away from the discipline of art history as an undergraduate student some fifteen years ago and led me towards my career in conservation was my perception of art history's overenthusiastic theoretical engagement with works of art on a visual and representational

4 I favour Nancy Wicker's (1999, 169, note 54) distinction between the terms multidisciplinary and interdisciplinary, and particularly the apt description of how "interdisciplinary research happens in one person's head whereas multidisciplinary research involves two or more people".

level while negating or downplaying their material status.[5] As Michael Yonan (2011, 238) puts it, large tracts of art historic discourse have been “privileging the idea or image over the object as a thing”.

Yonan (2011) advocates closer integration or “fusion” of art history and material culture studies, and laments the fact that Jules David Prown’s (1982) theoretical and methodological framework for material culture studies from the early 1980s has not been as influential as one might have expected, blaming this on the concurrent theoretical and textual turn within art history. The framework that Prown delineates can just as well be equated to technical art history or conservation studies rather than solely material culture studies. Much like Pye encourages the conservator to consider the range of values and contexts involved in an object’s biography, so Prown (1982, 3) suggests that the “inherent and attached value” of objects clearly demonstrates how objects “embody and reflect cultural beliefs”. Prown (1982, 6) theorises that an object, once it is made, becomes a constant while the people and values surrounding it change over time. As a result, an object can become a signifier of the cultures that it lives through, from the original society in which it was first made, via “any other society intervening in time or removed in space for which there are recorded responses”, to current society and our own “cultural bias” (Prown 1982, 4, 6). Crucially though, much like Ian Hodder (2011, 160) and Michael Shanks (1998) critique the perceived constancy of objects, I would claim that the object itself is not static but acts as Prown’s “recorded response” by virtue of material changes, degradation and alteration visible to the conservator’s trained eye.

Prown’s methodological framework for material culture proposes description as first step prior to interpretation. In this, he points out that “internal evidence” from the artefact itself must first be collected, and that such “description can also involve the use of scientific equipment” (Prown 1982, 7). This is a cue for the technical art historian or conservator, as it aptly describes one of the skills that we are arguably best at. Similarly, the “sensory engagement” that follows as part of the deductive stage of analysis is inherent in the work of conservators who are trained to physically handle artefacts on a daily basis (Prown 1982, 9). In not engaging with the framework proposed by Prown, there is an important oversight in Streeton’s previously discussed theoretical stance, particularly given that the original publication from 1982 has been reprinted several times over subsequent decades, and is thus quite accessible (Pearce 1994a, Prown 2001).

I suggest herewith that my work and that of conservators or technical art historians pursuing material studies and linking these with contextual research has much in common with Prown’s theoretical and methodological framework for material culture studies. Thus, by linking Prown’s system with standard analytical and interpretative approaches common to conservation studies, questions raised in research theme 2 may be addressed. Perceived disciplinary boundaries are

5 The exception to this was the outstanding “Object and Medium” module in my first year of undergraduate studies at the University of Birmingham, which first prompted me to engage with the making of works of art and to closely examine some of the paintings in the collection of the Barber Institute of Fine Arts, to which the History of Art Department is intimately linked.

unhelpful in my opinion, and we are better served to employ our strengths in finding answers to questions that we are all bound to ask in one way or another. Or, to use Prown's words (1982, 10), "the methodologies and techniques of various disciplines can be brought into play according to the nature of the questions raised and the skills and inclinations of the scholar". Paper IV is to be seen as a demonstration of such an interdisciplinary approach.

2.4 Building bridges

In what manner can Prown's framework be related to the concept of object biographies? In other words, what is the relationship between research themes 2 and 3? And how does the combination of approaches offered in those two questions contribute towards finding answers for research theme 1? To put it simply, it is possible to trace the life or biography of an object, and thus the changing values and shifts in culture associated with it, if one pays attention to the material evidence found on the object itself. Humans engage intimately with things on a daily basis, and an examination of materiality, using Christopher Tilley's (2007) understanding of the term, that is our relationship with things, can afford new insights into history and culture on a wider level. Approaching material culture from the perspective of conservation research allows the use of material or scientific evidence from the objects being studied to be linked with contextual evidence, thus providing the missing link that has been absent from many object biographies within other contexts such as anthropology and archaeology. I am certainly not the first to lament a lack of engagement with the material properties or physicality of objects in studies on materiality (see, for example, Boivin 2004, Ingold 2007a, b, Hodder 2011).

This brings me to the work of archaeological scientists such as Andrew Jones (2002, 2004, 334), who advocates much "closer integration of analytically derived data with theoretical argument", and hence between archaeological theory and archaeological science, and Nicole Boivin (2005, 177, 2008), who critiques the textual or linguistic turn and campaigns for renewed focus on the materiality of things in order to bridge what she sees as a "debilitating science-theory divide". In much the same way, Jones (2004, 328) claims that the linguistic turn has emphasised the division between archaeological theorists and scientists. He purports that if we attempt to combine the theoretical pluralistic approaches of social archaeology with scientific analysis of the material evidence, we have at our disposal "an extremely powerful analytical tool" (Jones 2004, 336). Similarly, Chris Caple's call (2006, 17) for a "holistic approach to object study" is highly relevant to my research. These are points of view that I support, and this thesis follows in their footsteps. Consequently, I will end this section with the following quote:

"The future challenges of the conservation field will stem not only from heritage objects and sites themselves but from the contexts in which society embeds them. These contexts – the values people draw from them, the functions heritage objects serve for society, the uses to which heritage is put – are the real source of the meaning of heritage, and the raison d'être for conservation in all senses" (Avrami, Mason, and de la Torre 2000, 4).

Image overleaf:

Samples ready for injection into the GC column


10
15
20

3. Methodology

The methodological framework employed in this thesis derives from the interdisciplinary approach outlined in the previous theoretical chapter. I have attempted to combine material analysis with contextual research and theoretical engagement in order to demonstrate the applicability of the object biographical framework within conservation studies. As a result, the thesis acts as an illustration of the importance of the conservator's role in reading and giving meaning to material evidence by means of selected modes of interpretation (see chapter 1.1). I engage with materiality (Tilley 2007) by focusing on material analysis and linking this with contextual investigations in order to paint a holistic picture of late-medieval polychrome sculpture in Norway within changing contexts across time. In this manner, I follow a similar approach to archaeological scientists such as Jones (2004) and Boivin (Boivin 2008), as previously outlined.

At the heart of such interdisciplinary work lies qualitative case study research. The analytical methods employed for the case study sculptures are largely the same with some small variations as necessary, in order to observe how far analytical tools and methods traditionally employed within conservation can be used to trace object biographies. Archival reports and images were consulted for all the sculptures. The Berg and Torsken case study sculptures belonging to the MCH were examined visually and documented with an examination report and a range of imaging techniques including standard photography, reflectance transformation imaging (Berg St Anne), photogrammetry (Berg St Anne), radiography and dendrochronology. Subsequently, portable X-ray fluorescence spectroscopy was employed for non-invasive investigations of the gilding and pigments present on the sculptures. Further confirmation of the materials and techniques used was achieved with limited sampling and a variety of microscopic techniques. Scanning electron microscopy coupled with energy dispersive X-ray spectroscopy provided further information on gilding structure, degradation, pigments and layering systems employed. Binding media investigations were undertaken using quantitative gas chromatography coupled with mass spectrometry. Given the Schwanbeck sculpture's in-situ church location, techniques that could be employed were more limited. Thus, the sculpture could not be X-rayed, nor could dendrochronology be undertaken at this stage. Due to the minimal presence of paint and gilding remnants, sampling would not have been ethical, and only non-invasive portable X-ray fluorescence spectroscopy was undertaken.

The subsequent sections outline the methods employed as part of the study, the reasons for their application, as well as some of the limitations faced. The chapter is organised following a hierarchy of investigation, beginning with visual observation and documentation, followed by non-invasive analytical techniques, and complemented with a small selection of invasive analysis in order to answer outstanding questions. This approach is considered standard within conservation practice when following professional codes of ethics (United Kingdom Institute of

Conservation 1996, American Institute for Conservation of Historic and Artistic Works 1998), and investigations into the case study sculptures were approached in this manner so as to build on knowledge gained from initial visual examination and reduce sampling to a minimum.

The various codes of ethics and guidelines for practice available to the conservation profession nationally and internationally delve into the issue of scientific analysis to differing extents (see, for example, United Kingdom Institute of Conservation 1996, American Institute for Conservation of Historic and Artistic Works 1998). Commentaries relating to the Guidelines for Practice of the American Institute for Conservation of Historic and Artistic Works (AIC) (1998), for example, expand on the issue of examination and scientific investigation by stating that justification must be provided as to why certain procedures are to be undertaken. Furthermore, consent must be obtained in advance; a minimum of sampling must be undertaken; remaining samples are stored; and most importantly, "the choice of testing techniques, the amount of sample required, and the expected value of the information gained, must be weighted against the effect of removal of the sample upon the cultural property"(American Institute for Conservation of Historic and Artistic Works 1998).

Certainly, permission for non-invasive investigations, sampling and material analysis was sought from the custodians of the objects, in this case the MCH and the community in Dassow, northern Germany. I filed initial applications for non-invasive study of the sculptures at the museum, beginning with archival research, visual examination, imaging, portable X-ray fluorescence and non-invasive dendrochronology. Subsequently, an application for sampling and micro-invasive analysis was submitted, as this was considered necessary to provide a deeper understanding of the techniques and materials employed on the sculptures by means of material characterisation. The applications were approved by the department leader on the condition that remaining sample material, raw data as well as analytical results would be archived at the museum for future use, re-interpretation and further analysis. The analytical techniques employed were selected as they would clarify construction techniques, material makeup, ageing and deterioration phenomena, and consequently help in building a more complete picture of the case study sculptures. Given that systematic material investigations of late-medieval polychrome sculpture in Norway have been few and far between (see chapter 1.4.3), it was considered helpful to undertake additional sampling and micro-invasive study of the material for thorough material characterisation.

3.1 Initial investigative research methods

3.1.1 Examination and documentation

The combination of visual and haptic examination provides the backbone of the conservator's approach to object-based studies. In order to familiarise myself with the case study sculptures, the study was initiated by close visual examination of the sculptures in order to complete a condition report (see appendix 2). The condition report was adapted from templates in order to better suit the type of objects studied. Examination with the naked eye was complemented by the use of loupes and microscopes as considered necessary (table 1). Small handheld torches emitting visible and ultraviolet (UV) light were used as light sources, and the angle of incidence varied so as to improve visualisation of specific surface characteristics or phenomena.

Given the German case study sculpture's presence in a church rather than in the conservation studio, available equipment was more limited, and only the head loupe could be used for examination. For comparative sculptures examined in museums elsewhere, visual examination with the naked eye was considered appropriate, although some sculptures could be examined in more detail with the use of head loupes, thanks to cooperation with the relevant curators and conservators. Additional documentation of all sculptures by means of photography (appendix 1) was undertaken using a selection of cameras (table 1).

Table 1: Microscopes, loupes and cameras

Microscopes and loupes	
Zeiss OpMi-1 microscope	Eyepiece/Ocular: 12.5x Magnification: manual magnification changer from 6x to 40x
Leica Wild M690 microscope with Leica MEL 48 control unit	Eyepiece/Ocular: 10x/21B widefield Magnification: motorised 1 to 5 magnification
Zeiss head loupe L	Magnification: D4 to D6, equivalent to 1.25x and 1.4x
Cameras	
Canon Powershot SX40 HS digital camera	Inbuilt lens
Canon EOS 400D DSLR camera	Canon EF-S 18-55 mm f/3.5-5.6 lens
Canon EOS 6D DSLR camera	Canon EF 100 mm f/2.8 USM macro lens

3.1.2 Archival research

Following visual examination of the sculptures stored in the MCH conservation studios, condition and treatment reports together with existing photographic documentation in the museum archives were examined. Archival reports in Norwegian posed an initial language barrier that was later overcome. A conscious choice was made to look at the sculptures first before reading archival reports, as it was felt that looking at the sculptures with fresh eyes without being influenced by what other conservators had previously seen and documented could be helpful.

While some of the sculptures had been treated at the museum in the 1970s and had extensive condition and treatment reports associated with them, others had only minimal if any documentation. For example, treatment of the sculpture of St Anne from Berg was documented with a thorough report written in 1976, and numerous unmounted paint samples and cross-sections were located in the sample archive; however, four brief handwritten lines were all that could be found for the Bishop sculpture from Berg. Consequently, varying amounts of information available on the case study sculptures meant that my own examinations of the sculptures were an important addition to the archives, as the sculptures had not all been examined to the same extent in the past.

A further important archival resource at the MCH were the notebooks of preparator Louis Smestad (also included in the appendix in Kollandsrud 1994), as they highlighted a unique consolidation treatment that a large portion of the medieval collection was subjected to during the 1920s and 1930s. As attested to in Smestad's notes, some of the paint and gilding was affected by the treatment, and the present condition of some sculptures is in part due to this treatment. These details helped clarify some of the ambiguous results obtained during binding media analysis (see section 3.4.4 and paper III). Upon request, the regional Institute for Preservation in Schwerin[6] also kindly provided me with the examination and treatment report from the 1970s relating to the Schwanbeck sculpture. These reports were important in clarifying conservation treatment history of the objects under study, and provided a window into treatment of polychrome sculpture in the 1970s, when the conservation profession was still in its early stages. The archival reports had particular relevance to treatment history and thus the later stages in the sculptures' object biographies, as described in papers III and IV.

In addition to published literature on medieval churches in Norway, an important resource that I was able to tap into came from church historian Jan Brendalsmo, who kindly shared his unpublished resources on churches in Troms county. This added contextual information to a significant stage of the sculptures' history and biographies, as outlined to a limited extent in paper III, and to a more detailed level in paper IV.

Archival photos of museum displays at the MCH were useful in gaining a more complete picture of the sculptures' display history on entry into the museum, of particular relevance to papers

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I, III and IV, as they address the life stage post-entry into the museum. In addition, my interest in museum display led me to examine more closely the 1979 medieval display at the MCH (see paper I). So as to better understand the choices made in selecting certain sculptures for display, I organised a discussion at the museum in June 2016 and invited individuals who were part of Sverre Fehn's team at the time. Through various newspaper and social media discussions, I had come to realise that there were strong emotions linked to the 1979 display, with one camp claiming that it was dated, and the other suggesting that it be kept as testament to Sverre Fehn and his legacy. It was my hope that such an informal discussion would tease out some of the display's underlying aesthetic choices and conceptualisation, and clarify to what extent the various individuals credited for the exhibition were involved. I chose to keep the discussion informal instead of following a scripted interview. Therefore, the talk developed organically, and not all questions were dealt with to the same level. However, this was felt to be a more suitable format so as to put the participants at ease and give them the chance to speak about topics of concern to them. The participants provided permission for me to use the information gained, and parts of this discussion fed into ideas for paper I in this thesis.

While this discussion may seem somewhat tangential to the case study sculptures included in the thesis, two of the Karlsøy sculptures which I had initially studied but subsequently removed from the scope of the thesis (see introduction) were included in the 1979 exhibition. Consequently, this exploration of the display history would have fed directly into their object biographies. I consider such detailed understanding of the exhibition and display history of the sculptures crucial to completing their object biographies, contributing to points raised in research theme 1. It may be argued that the same level of attention could also have been placed on former medieval displays at the MCH, such as that by Eivind Engelstad or Gerhard Fischer, for example. However, this would have involved a significant amount of archival research that I could not justify, given that I had to prioritise object-based studies.

3.1.3 Site visits

Numerous museums and churches were visited as part of the study in order to examine comparative sculptures from Scandinavia, the Low Countries, Northern and Southern Germany. In Scandinavia, some of the museums visited included the Sør-Troms Museum in Trondenes, Alta Museum, Stockholm Historiska Museet and the university museums in Bergen, Tromsø and Trondheim. Furthermore, the National Museum of Finland in Helsinki and Turku cathedral had significant collections of medieval sculpture. In Germany, numerous museum and church collections were explored, including Ulm Museum and Ulm Minster, St Annen-Museum and churches in and around Lübeck, the Germanisches Nationalmuseum in Nuremberg, the Landesmuseum Baden-Württemberg in Stuttgart, and many more. Countless churches throughout Germany were also visited in order to see sculptures and altarpieces in situ. These visits were important in providing an overview and allowing me to situate the case study sculptures within the broader picture of medieval polychrome sculpture in Germany and beyond.

Figure 5: Torsken church on Senja island

A selection of medieval stave churches and post-medieval churches in central and northern Norway were visited so as to appreciate where the case study sculptures were formerly housed, and to get a feeling for the landscape within which the sculptures were situated for many centuries. On the island of Senja, villages, churches and chapels on the west coast of the island were visited, including Berg, Torsken and Medfjordvær (figure 5). Similarly, I spent time on Karlsøya, visiting Karlsøy church and surroundings (figure 6). These visits provided me with much information for the object biographical approach towards the sculptures, addressing aspects of research themes 1 and 3, as I was able to experience the close-knit communities, the remoteness of the locations, as well as the strong ties with the fishing trade that still exists nowadays. In looking beyond the sculptures and seeing the other church furnishings still extant, I was able to visualise what roles the sculptures could have played in their past lives (see paper IV).

Figure 6: Karlsøya

Similarly, I visited the community in Dassow, northern Germany on several occasions. In addition to examining the case study sculpture, I took part in the religious service and spoke to many members of the community. I spent a significant amount of time in the church, examining the other church furnishings and setting of the Madonna sculpture. I also visited the nearby site of the former Schwanbeck chapel so as to search for any remains of the chapel foundations. Visiting the area helped understand the political relationship relating to the former inner German border, and thus the reasons for the chapel’s removal. The visits provided rich material for completing the biographical approach (paper IV).

While it would have been ideal to spend more than a few days in these places in order to better appreciate the communities, landscapes and environments involved, the timeframe of the PhD was limited, and other research had to be accommodated as well.

3.2 Specialised imaging techniques

3.2.1 Reflectance transformation imaging

Reflectance transformation imaging (RTI) is a low-cost and remarkably simple to use high resolution imaging technique that enables enhanced visualisation of topographical characteristics on objects. It is based on standard photography combined with the use of directional light sources. Surface normal information in the resultant images is associated with each pixel, together with the usual RGB (red, green and blue) information used in colour photography (Cultural Heritage Imaging 2002-2018b). A mathematical algorithm is then applied during processing (for further details, see Malzbender, Gelb, and Wolters 2001), such that the resultant file can be viewed and manipulated with specialised software provided by the non-profit Cultural Heritage Imaging group (CHI). The technique has been succinctly summed up by the developers as a method of texture mapping based on a computational model that extracts information from "multiple images of a static object with a static camera under varying lighting conditions" (Malzbender, Gelb, and Wolters 2001, 2).

The technique was first developed in 2001 (Malzbender, Gelb, and Wolters 2001), and since then has been used extensively in the examination and documentation of rock art, paintings and a broad variety of museum objects and archaeological artefacts, as it greatly improves visualisation of subtle surface variations that are otherwise difficult to document or may be obscured by colour associated with the object itself (see, for example, Graeme et al. 2011, Artal-Isbrand and Klausmeyer 2013, Díaz-Guardamino et al. 2015, Newman 2015, Jones, Díaz-Guardamino and Crellin 2016, Porter et al. 2016).

RTI was employed in this study for St Anne from Berg (C2912) and one of the Karlsøy sculptures (C3124), as it was considered a useful additional documentation tool for carving, construction or structural details and tool marks. For example, construction details and tool marks visible on the base of the St Anne sculpture could be documented in one file and examined subsequently without further need for handling of the sculpture (paper II). Standard raking light photography only documents certain features at any given time since the oblique angle of incidence highlights certain features while obscuring others. Thus, multiple raking light images would have to be taken to document the entirety of features visible on the base. The RTI technique could hypothetically also be used to document a particular tool mark such as, for example, a chisel with a small discrepancy, which could then be used as a fingerprint for a particular sculptor's tool.

RTI offers improved documentation of surface texture information over conventional photography or freehand sketches (Mudge et al. 2006). Furthermore, it reduces handling and examination of the object, as once the images have been taken, the proprietary freeware allows the user to manipulate lighting conditions in order to extract varying information from the assembled files by means of a virtual light source. The processed files can also be shared with other researchers, allowing for remote study of objects. CHI provides free software and tutorials, as well as a kit with reflecting spheres for purchase. These black spheres are used to extract the original direction of lighting on the basis of specular highlights that are visible on the spheres which are incorporated in the field of view of the camera (Mudge et al. 2006). Thus, limited portable equipment is necessary (table 2) and RTI is relatively easy to learn and employ successfully.[7]

Table 2: RTI equipment

RTI equipment and software	Canon EOS 6D DSLR camera with Canon EF 100 mm f/2.8 USM macro lens
	Benro C2980T Mg-Carbon Fiber tripod with Pro V3E ball head
	Handheld LED light (Rift Labs Kick Light)
	CHI RTI highlight capture starter kit
	X-rite ColorChecker passport professional colour management
	Macbook Pro (2014) laptop with 2,6 GHz Intel Core i5 processor, 16 GB 1600 Mhz DDR3 memory and Intel Iris 1536 graphics, OS X El Capitan version 10.11.6
	RTIBuilder version 2.0.2 software
	RTIViewer version 1.1 software
	Adobe Bridge CC version 8.0.1.282 software

In this study, the highlight-based RTI method was employed (Mudge et al. 2006), while following user guidelines provided by CHI (2011, 2013a). The object of interest was positioned on a stand in front of a neutral background. Two reflective black spheres were placed near the object and within the camera's field of view such that they were in plane with the object. In addition, the ColorChecker was inserted within the field of view. The camera was attached to a stable tripod in front of the object, and weighted to reduce movement of the equipment during photography. The camera was tethered to a laptop for remote shooting, such that shutter release would not produce movement of the camera, which could result in a blurred file.

The highlight RTI method involves the use of a moving light source positioned at a range of angles and a fixed distance within a hemispherical space or virtual dome centred around the object. A useful visualisation tool involves imagining the dome as an umbrella spreading out in front of the object. The distance of the light source from the object or detail being photographed should approximately measure between two and four times the diagonal of the area being photographed. A simple string helped in placing the light at the right distance from

7 Together with Duncan Slarke and Helene Skoglund-Johnsen at IAKH, I drafted an RTI practical user guide for conservation students. I also provided training for the MA students so that the technique could be added to their existing toolkit.

the object. This distance was the same for each light position and photograph. The virtual dome or hemisphere can conveniently be divided into segments according to the face of a clock to ensure complete coverage during photography. Three lighting positions were photographed at each section, at roughly 15, 45 and 65 degrees angle of inclination. The lighting positions should be slightly offset from the individual segments to ensure as thorough coverage of the dome as possible.

One assistant stood near the object holding the light source, beginning at the position relating to 1 o'clock and moving through the three different angles and faces of the clock, while another person controlled the computer and shutter release for each separate lighting sequence. Once the six o'clock position was reached, it was found best to switch to standing on the other side of the object to reduce shadow interference. Communication between the individuals handling the camera and lighting was crucial, and it was found best to wait a few seconds between each photograph to reduce any movement of the setup, which would affect the quality of the final file.

Adobe Bridge software was subsequently used to process the RAW files, adjust white balance, crop out the colour management tool, and convert the files to JPEG format for further processing using the RTIBuilder software. RTIBuilder consists of a number of tools that are used to process the images and create the final RTI file. The polynomial texture map (PTM) algorithm was selected for processing. The first step involved locating the exact light positions by demarcating one of the reflecting spheres. Subsequently, the outline of the sphere had to be adjusted to match the sphere accurately, as this is used by the software to compute the exact position of the light in each image based on the position of the highlights reflected in the spheres. The images were then manually checked to determine whether the centre of all the highlights had been accurately detected. Once this was deemed successful the images were cropped, keeping only the object and area of interest, and the final RTI file was generated.

RTIViewer was then used to open and examine the compiled RTI file (figure 7). This allows for close virtual examination of the object under varying lighting conditions. Various rendering modes can be selected, and the direction of light controlled manually. Since RTI keeps a record of surface normals with RGB colour information for each pixel, algorithms can be applied to enhance a variety of features (see Cultural Heritage Imaging 2013b for further details).

One of the limitations with RTI is that slightly more equipment and know-how is necessary compared to standard raking light photography. An additional person is useful to have to hand, as the light source needs to be moved for each image taken. Furthermore, a camera with live view function is ideal, as it simplifies workflow. Care needs to be taken when setting up the object to be documented, the camera and the black spheres, as the quality of the final RTI file is dependent on reducing any movement other than the light sources to an absolute minimum. Pressing the camera shutter was also experienced to result in a blurred file, and remote shutter release is helpful to offset this problem. Setting up, taking the images and processing them requires some time, though usually not more than an hour in total. Once initial difficulties with movement and vibration were overcome, the technique was experienced as fast and rewarding to use.

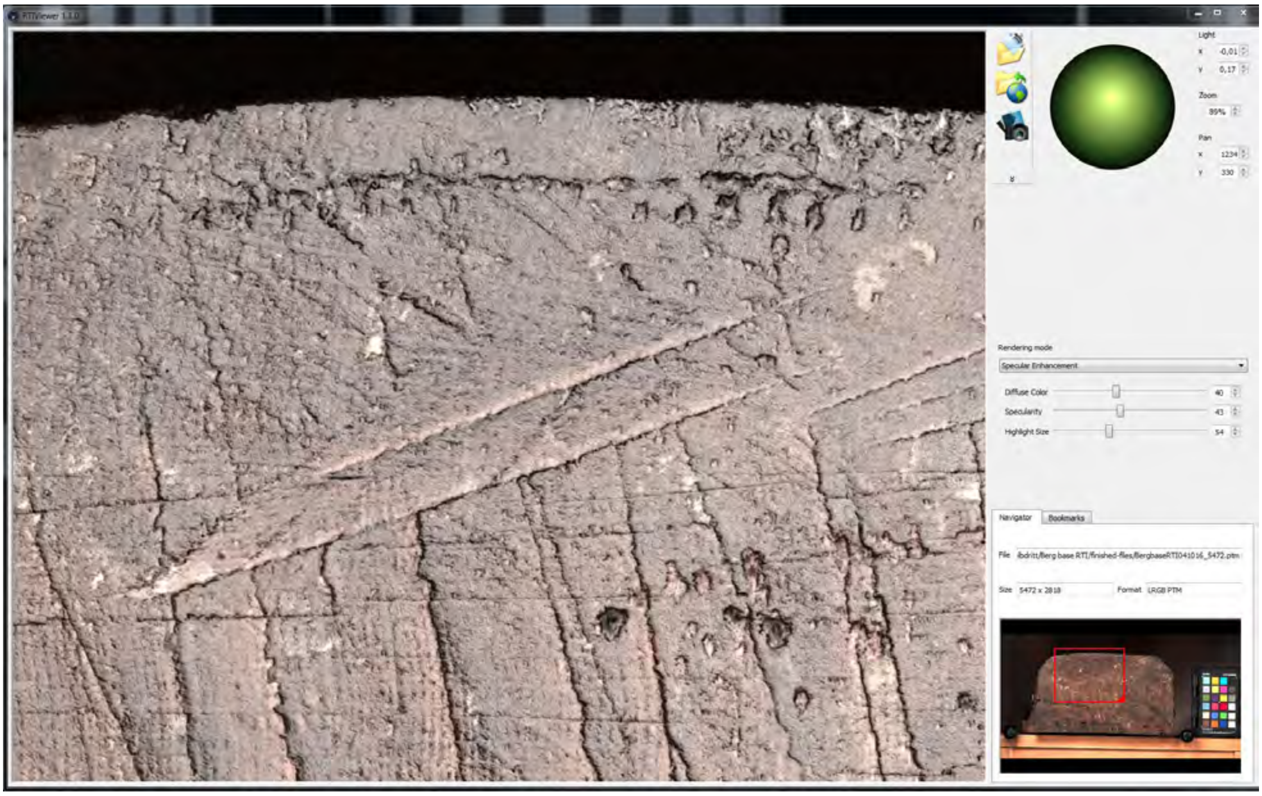

Figure 7: Screenshot of RTI Viewer interface

3.2.2 Photogrammetry

At many institutions, sculptures are photographically documented with a series of frontal, side view and back view photos. While simple, this essentially turns a three-dimensional (3D) object into a number of two-dimensional representations, none of which can document the object in full, showing the relationship between all the sides to the whole object. Consequently, frustrations with standard photographic documentation of 3D objects such as polychrome sculpture pushed me to explore other documentation means that might be low-cost and suitable.

I consider 3D documentation ideal for such objects, and believe that it is also useful for dissemination and research purposes (Graham 2012, 53). In fact, documentation, research and dissemination are currently the three main uses for 3D models within the heritage sector (Wachowiak and Karas 2009). For example, 3D photogrammetry models of sculptures in storage at the MCH could be provided to researchers so as to make the museum collection more visible internationally (see also Graham 2012, 26). Similarly, Porter, Roussel and Soressi (2016, 12) cite limited access to objects as the prime reason for digitising a collection of lithic samples. The

Smithsonian Institution is one of a number of museums currently prioritising digitisation, given that “only 1% of collections [is] on display in Smithsonian museum galleries” (Smithsonian Institution). As a result, digitisation and 3D visualisation are used effectively by the Smithsonian within its Museum Conservation Institute, and to allow researchers and the public to engage with the bulk of their collections (Wachowiak and Karas 2009). Users can even download a 3D model of certain objects and create their own replica if they have access to a 3D printer.

Of course, creating 3D models is a time-consuming and expensive process, though photogrammetry is significantly more low-cost compared to laser or structured light scanning, for example, as the main requirement is a camera and suitable software (see Akca 2012 for details on structured light systems and their benefits over laser scanning). This means that even small institutions should be thinking about digitisation. At the MCH, digitisation has been of prime importance as part of the Saving Oseberg project (Museum of Cultural History 2018), and is also being used within the archaeological department of the museum, though it is not currently being employed for the medieval polychrome sculpture collection. Essentially, photogrammetry is a measurement technique that requires a series of overlapping photographs documenting an object from all angles, which are subsequently stitched together to create a three-dimensional model of the object using specialised software such as Agisoft PhotoScan, for example. My brief engagement with photogrammetry was considered as a rough starting point from which further steps could be taken if considered fruitful.

Table 3 lists the equipment used for photogrammetry in the current study.[8] Rendering of objects with complex surfaces requires that the object is captured from a variety of viewpoints and angles, while ensuring that the entire surface is photographed with sufficient overlap between photographs. Around 66% overlap between photos is considered suitable (Cultural Heritage Imaging 2002-2018a). Greater overlap provides more detail, though it means more photos are required, therefore significantly increasing processing time.

For complex objects such as polychrome sculptures, ensuring that the entire object is photographed is best achieved with the use of a turntable, such that the object is rotated in increments in relation to the camera, instead of the camera moving around the object.[9] The sculpture was placed on a turntable located inside a photography tent so as to reduce the appearance of surrounding elements in the images to a minimum. As I wanted to include the sculpture base in the 3D model, the sculpture’s position had to be changed for some photographs. The use of the photography tent helps in this instance, as the software is more likely to successfully render the entire object in this situation, despite the sculpture having changed position. The size of the tent is a limiting factor, and larger objects need to

8 As for RTI, I wrote a user manual on photogrammetry together with Duncan Slarke at IAKH, and held workshops for MA students. Since then, Samantha Porter (2016) has published a more detailed step-by-step guide accessible online as supplemental material.

9 Porter, Roussel and Soressi (2016) mention that varying shadows cast from light can confuse the photogrammetry software when rotating the object rather than moving the camera around a static object. This problem was mitigated by using a synchronised flash system instead of static lighting.

be photographed in situ with the background masked out of the model subsequently during processing.

Table 3: Photogrammetry equipment

Photogrammetry equipment and software	Canon EOS 6D DSLR camera with Canon EF 100 mm f/2.8 USM macro lens
	Benro C2980T Mg-Carbon Fiber tripod with Pro V3E ball head
	Hensel Expert Pro 500 studio lights with soft boxes
	Phottix photography tent
	Turntable
	X-rite ColorChecker passport professional colour management
	Macbook Pro (2014) laptop with 2,6 GHz Intel Core i5 processor, 16 GB 1600 Mhz DDR3 memory and Intel Iris 1536 graphics, OS X El Capitan version 10.11.6
	Agisoft PhotoScan standard edition software version 1.2.5 build 2614

Studio lights with soft boxes were placed at 45 degree angles to the object, and the flash coupled to the camera shutter using a hot-shoe adapter. The camera was mounted on a tripod with ball head frontally facing the object. The white balance was manually adjusted using the X-rite ColorChecker on a test shot prior to taking photographs of the sculpture. The sequence of photography was planned beforehand to ensure that the entire object would be captured successfully. A series of images was taken and the sculpture rotated about 10 to 15 degrees on the turntable between each image. Once the entire object had been photographed from this angle, the camera tripod was adjusted, and the process repeated at a different angle. Consequently, the sculpture was systematically photographed from all possible angles. A series of 100 to 150 photographs was found to be ideal for depicting the entire sculpture.

Image processing and 3D model construction is a complex system encompassing four main stages. The standard version of Agisoft PhotoScan was used on a Macbook Pro (table 3). The photographs were imported into PhotoScan and aligned. In this step, the software located the camera position for each image, and matched common points on the photographs (figure 8). The next step involved complex algorithms which allow the software to build a virtual dense point cloud that reflects the shape of the object photographed based on camera positions for each photograph. Once the dense point cloud was built, the model had to be edited manually to remove unwanted points not relevant to the object being modelled. A polygonal mesh was subsequently built based on the dense point cloud. Thus, the form and surface of the object was reconstructed using points present in the dense cloud. Finally, texture was mapped onto the mesh, and an orthomosaic laid over the three-dimensional model generated, resulting in the final model.

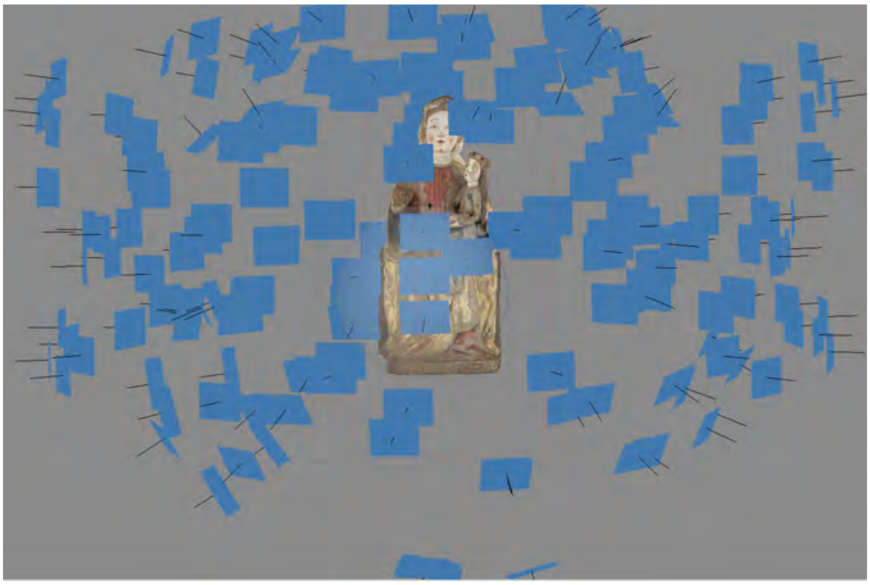

Figure 8: Photo alignment, blue rectangles depict camera positions

Extensive experimentation with the photography setup and workflow were necessary before achieving suitable photographs that could be used for further processing. Additional technical challenges that arose during the processing stages led to the decision to discontinue with the original plan to document all the case study sculptures using this method, the main problem being the amount of time involved. Since the base of the sculpture is on an entirely different plane from the rest of the sculpture, depicting the base in addition to all other sides was not straightforward. Furthermore, transparent or highly reflecting surfaces pose additional problems that may require the use of other techniques (Pavlidis et al. 2007).

One of the main limitations experienced was difficulty in exporting and sharing the 3D digitised model with other users without access to proprietary software. While an interactive pdf file can be generated, this is limited in size, meaning that the resultant model lacks sufficient detail to be considered successful. Instead, uploading the model to a platform such as Sketchfab, and sharing the link to allow others to access and view the model proved the most effective solution. This was undertaken with a model of the sculpture of St Anne from Berg (C2912) (paper II).

Access to suitable computers with the necessary computing power is crucial in reducing processing time (Wachowiak and Karas 2009, 154). Such resources were initially not accessible, and proved to be a significant limiting factor. Resorting to processing files on a personal laptop with limited computing power, it was found that the time used was not sustainable. It has been demonstrated that in successful photogrammetry, "the final outcome is a function of the time spent" (Pavlidis et al. 2007, 97). Despite it being a potentially useful method, it was not possible to allocate more time to the technique at this stage.

3.2.3 Radiography

Radiography, an imaging technique that employs X-rays, was undertaken in order to examine internal construction details and aspects relating to the underlying wooden structure of the sculptures in the MCH collection. The results contributed to discussions relating to material quality in papers II, III and IV, addressing themes linked to facture or the production stage in the sculptures' biographies. Radiography has been employed for a long time in the examination of cultural heritage as a non-destructive tool, and is particularly useful with sculpture as internal defects or structural inconsistencies that are not or only partially visible externally can be visualised using this technique. The sculptures that were radiographed at the MCH (see appendix 3) included the two sculptures from Berg (C2912 and C2913), the Torsken Virgin (C2686) and the unknown saint from Karlsøy (C3124). Initial visual examination of the sculptures had highlighted the presence of woodworm tunnelling on some of the sculptures, though the extent of woodworm damage was unclear, as typically only a few flight holes are visible. Tapping of the wood can acoustically uncover cavities that hint at further internal damage, but radiography is necessary to reveal the full extent of such damages. Furthermore, radiography could help with clarifying construction issues such as the use of several pieces of wood and the manner of their attachment.

The theory behind X-ray radiography is described at length in the literature, and will not be outlined in detail here (see Lang and Middleton 2005 for details). X-rays are a form of short-wavelength electromagnetic radiation between the ultraviolet and gamma regions of the electromagnetic spectrum. The degree to which the radiation is attenuated as it passes through an object is displayed on radiographic film as lighter and darker areas, resulting in a radiograph that provides information similar to a photograph. The radiograph is subsequently interpreted based on an understanding of the degree of attenuation, density of the object imaged and pre-existing knowledge of the object as a result of visual examination. An X-ray generating source is required, and the object is positioned between the source and the imaging plates. Health and safety requirements were stringently adhered to, as radiography involves the use of ionising radiation.

The X-ray generating tube used at the MCH is housed in a shielded cabinet in a designated radiography room, and was controlled externally by Duncan Slarke, who is licensed to use the equipment. The sculpture to be examined was placed on top of an imaging plate and securely positioned on a table, with the tube pointing downwards at the sculpture, and with a lead filter underneath to reduce backscatter affecting the image. Several tests were undertaken to determine the best instrument settings for the sculptures, as material composition and density of each sculpture pose somewhat different requirements for the equipment. The degree of attenuation varies with density, thickness and atomic number (Z). High Z elements absorb more than low Z elements. As a result, organic material such as wood often results in low contrast images (Sobczyk et al. 2014, 983). On the other hand, paint layers may be visible on radiographs depending on the type of pigments used, and can indicate the use of lead-based paint, for example, since heavier elements attenuate X-rays more effectively, which is visible as less exposed, brighter areas on the resultant radiograph. Consequently, voltage (kilovolts), current (milliamps) and exposure time (seconds) were varied so as to achieve the best possible results with optimum contrast for each sculpture (see table 4 for details). The sculptures had to be imaged in two or three sections due to the size of the imaging plates compared to the size of the sculptures. The digital radiographs were subsequently stitched together using Adobe Photoshop software.

Table 4: Radiography equipment and settings

Device	GE Isovolt 225 Titan E with Comet MXR-225 X-ray tube, nominal focal spot (IEC 336) 0.4 mm, 1 mm Be filtration GE CRx25P scanner and GE IPS A3 phosphor imaging plates in rigid cartridges without lead filters	
Software	GE Rhythm RT 5.0.38.0 (image scanning) and GE Rhythm Review 4.3 (image manipulation) flash filter	
Imaging conditions	C2686 Torsken Virgin	40 kV, 2 mA, 15 s
	C2912 Berg St Anne	40 kV, 2 mA, 15 s and 50 kV, 2 mA, 15 s (side view)
	C2913 Berg Bishop	45 kV, 2 mA, 15 s
	C3124 Karlsøy saint	60 kV, 1 mA, 10 s

The resultant radiographs clearly revealed the presence of woodworm tunnelling and the use of lead-based paint for skin tones on the Torsken Virgin (see paper IV). In addition, it was possible to determine the number of wooden pieces and manner of construction for the Berg Bishop (see paper III). The plinth for this sculpture has tree rings oriented in a different direction from the main body of the sculpture, but the presence of overlying paint meant that the manner of attachment of the plinth was not possible to discern without the use of further imaging techniques. On the other hand, it was not possible to adequately visualise the presence of three wainscot boards used in the construction of St Anne from Berg (papers II and III), and computed tomography (refer to section 3.2.4 for more details) would prove to be more effective for this.

3.2.4 Non-invasive dendrochronology using X-ray computed tomography

Dendrochronology was undertaken in order to try and date as well as provenance the timber used in construction of the sculptures. The method was applied to the sculptures in the MCH collection and contributes to research theme 2, with results feeding into papers II and III, and to a lesser extent paper IV. Such rigorous scientific dating would complement stylistic dating undertaken in the 1930s (Engelstad 1936), and potentially shed light on timber provenance. Dendrochronology is often described as the science of dating wood by means of tree ring measurements. Annual growth rings are formed by trees growing in temperate climates, and ring widths vary depending on the weather. Trees of the same species growing in one region will exhibit a similar pattern of rings by virtue of being exposed to the same climate, thus allowing for cross-matching between tree ring curves, and leading to the production of master chronologies (English Heritage 2004, 5). Tree-ring patterns from unknown timber objects can be matched with known chronologies, leading to relatively precise dating.

However, in addition to dating, in some cases dendrochronology is also able to determine the provenance of the timber used, thus illuminating aspects of medieval trade in timber, and in particular Baltic oak in Northern Europe (Bonde, Tyers, and Wazny 1997, Wazny 2002). This is made possible by collaboration between dendrochronologists working across national boundaries and sharing site and master chronologies, which allows for cross-dating (using t-values)[10] of wooden objects by virtue of dendro-provenancing (Bonde, Tyers, and Wazny 1997, 202, Haneca et al. 2005, 263, Daly 2011, 108).

In the current study, dating and provenancing of timber was undertaken by Aoife Daly using non-invasive dendrochronology by means of X-ray computed tomography (CT) (see appendix 4) (Daly 2016, Daly and Streeton 2017). Usually, dendrochronology requires that core samples are taken, or exposed end grain is prepared by scraping or smoothing of the surface with sharp tools to improve visualisation of the tree rings. In our case, non-invasive techniques were desired by the MCH, resulting in the use of CT. There is significant benefit in using CT over traditional dendrochronological methods as it is non-invasive as opposed to micro-invasive. Furthermore, since the resultant CT scans can be viewed either as two dimensional cross-sections (as was done in this case to measure tree rings) or as 3D tomographic reconstructions (see, for example Morigi et al. 2010), internal structures and components can be visualised and examined via virtual slices through the object. The quality and type of wood used is also discernible, pointing to the use of Baltic wainscot, for example, a material highly sought after for its fine grain and dimensional stability (paper II) (Haneca et al. 2005, 263, Ebert 2017, 4).

X-ray computed tomography involves principles similar to radiography, as described in section 3.2.3. However, instead of taking individual radiographs, 3142 sequential digital X-ray images are captured as the sculpture is rotated slowly through 360 degrees in front of the target. These images can be viewed as individual slices, or compiled into a 3D tomographic reconstruction. An industrial CT scanner was employed at the Norwegian Geotechnical Institute (NGI), as this provided micron resolution necessary for dendrochronology (Bill et al. 2012) (table 5).[11]

The procedure employed developed out of the DendroCT project in Oslo, which began in 2007 (Bill et al. 2012). As explained by Jan Bill et al. (2012, 226), “resolution is limited by object size”, and while the X-ray target has a focal spot size of 3 µm, resulting in “an approximate 5 µm voxel[12] resolution representation of an object under optimal conditions”, reaching such resolution requires extremely small samples (see also Stelzner and Million 2015, 191). Thus,

10 “T-values are a measure of similarity between two tree-ring series which show how well the series cross-date” (Bonde, Tyers, and Wazny 1997, 202).

11 Most medical CT scanners are of insufficient resolution to be useful for tree ring measurements (Reimers et al. 1989, Preuss, Christensen, and Peters 1991), as well as having too large a spot size for the X-ray target (Bill et al. 2012, 229).

12 A voxel is a unit of information defining a point in 3D space.

for successful dendrochronology, “the maximum diameter that can be scanned in one scan is ca. 30 cm, resulting in a resolution of 150 µm” (Bill et al. 2012, 226). This means that for wider sculptures such as St Anne from Berg (C2912), scanning was undertaken in two stages in order to visualise as many sequential tree rings as possible. The sculptures were positioned vertically on medium density fibreboard stands loaned from Jan Bill, and secured with cotton tape. Each scan took approximately two hours. Aoife Daly subsequently used Able Image Analyser for tree-ring measurements, and the programs DENDRO and CROS for statistical analysis and calculation of t-values, in addition to cross-checking numerous chronologies (appendix 4 and Daly 2016, 2).

Table 5: CT equipment and settings

Device	Standard imaging conditions
Nikon Metrology XT H 225 LC industrial type CT scanner with micron resolution and full protective enclosure Microfocus 225 kV reflection target X-ray source with 3 µm focal spot size 45 x 45 cm^2 Perkin Elmer flat panel detector with 2048 x 2048 pixel matrix	80 kV and 95 µA, no filter

The use of CT for dendrochronology is to be recommended, as its non-invasive nature allows for scientific dating of timber in cases where sampling or preparation of the wood is considered unethical or is not possible due to the presence of painted surfaces, for example. However, there are currently limitations with regards to object size and weight that can fit into the X-ray chamber (Bill et al. 2012, 226). In addition, the objects need to be stable enough to be transported to the equipment, as well as tolerating slow rotation within the CT scanner. Not all objects can successfully be dated, particularly if insufficient tree rings are present. According to Daly, objects with less than 80 rings cannot usually be dated successfully (Daly and Streeton 2017, 431), while other authors suggest a minimum of 50 rings (English Heritage 2004, 13).

For precise dating, both the heartwood and sapwood need to be present. However, in practice, this is rarely the case as sapwood was commonly removed prior to wood use, and guild statutes often stipulated the use of heartwood only (Ulmann 1984, 105).[13] The presence of sapwood in a CT scan needs to be confirmed with visual examination of the object, as it can at times be difficult to distinguish (Bill et al. 2012, 228). Oak usually has fixed numbers of sapwood rings depending on the region of origin. Thus, a range of sapwood estimates are used based on the geographic source of the timber under investigation, which provide an estimate of the approximate felling date of the tree. In cases where no sapwood is preserved, it is only possible

13 The softer nature of sapwood means that it is often preferentially attacked by insects; thus, the removal of sapwood prior to use makes practical sense.

to provide a date *terminus post quem*, that is the earliest possible felling date, which is obtained by adding several years to the last measured tree ring, depending on the region of origin (English Heritage 2004, 13, Daly and Streeton 2017, 431).

Of course, it also needs to be considered that wood had to be transported after felling, and was often seasoned over a period of several years to allow it to dry out prior to use. Thus, while relatively precise dating is possible by means of dendrochronology, additional factors such as sapwood estimates, seasoning and storage of timber need to be taken account of when discussing date ranges. Finally, one must remember that not all timber can be dated successfully, as evidenced here with two of the case study sculptures (C2913 and C2686).

3.3 Non-invasive analytical methods

3.3.1 Portable X-ray fluorescence spectroscopy

Portable X-ray fluorescence spectroscopy (pXRF) was employed in this study on all case study sculptures for the examination of paint and gilding so as to gain an initial idea of the materials employed in the polychromy of the case study sculptures (see appendix 5). This contributed to research theme 2 while providing data for papers III and IV. Portable XRF is a non-invasive analysis technique that provides qualitative and/or semi-quantitative information about the elemental composition of the sample. Based on elemental data, an initial non-invasive characterisation providing information on the materials that may have been used can be carried out. However, it must be noted that pXRF does not provide molecular information, and the identification of compounds (such as pigments, for example) can only be deduced based on the elements identified in the spectra, meaning that such results are inferred rather than conclusive, and other complementary techniques should be considered in cases where conclusive identification is considered important (Mantler and Schreiner 2000, 4, McGlinchey 2012, 143).

In cases where sampling is permitted, subsequent identification of compounds corresponding to the identified elements requires the implementation of complementary techniques such as Raman spectroscopy or Fourier transform infrared spectroscopy (FTIR), which may be used for molecular characterisation, or the use of polarised light microscopy (PLM) and scanning electron microscopy coupled with energy dispersive spectroscopy (SEM-EDS) (see section 3.4.3 for further details).[14] Therefore, when examining paint layers in order to identify pigments, pXRF should be considered as an initial non-invasive technique to be followed up by complementary methods where necessary.

14 Note that EDS provides spectra similar to XRF, with the difference that localised information may be obtained, as smaller areas may be selected for examination.

Since pXRF is a non-invasive technique, it allows sampling to be reduced to a minimum for those cases where further confirmation is needed. Thus, subsequent analysis of cross-sections by means of SEM-EDS was informed with knowledge gained from pXRF. It is important to remember that while pXRF can be used as a quantitative method for certain types of material such as metal alloys, for example, in the case of paint layer analysis data interpretation is significantly more complex due to the stratified heterogeneous nature of painted surfaces. Consequently, quantification should not be attempted for the pXRF analysis of paint layers (McGlinchey 2012, 131).

The theory behind XRF is discussed at length in the literature, and only a brief outline of the physics involved will be given here (see, for example, Jenkins 1999, Jenkins 2000). In principle, an X-ray tube is used as excitation source, emitting radiation over a broad continuum of energies which interacts with the elements in a sample. Characteristic radiation is emitted from the sample by virtue of electron interactions, which can be measured as the radiation hits the detector in the instrument, forming the basis for element identification.

A high-energy X-ray photon from the target hits an atom, and if the incoming photon is of higher energy than the binding energy or absorption edge of an electron, the electron can be ejected from its orbital shell (figure 9).[15] This results in a vacancy and resultant instability within the atom. Stability is regained if a higher energy electron from an outer orbital shell moves in to fill the vacancy of the inner orbital. This electron emits secondary energy in the form of fluorescence as it moves into a lower energy position, and since the energy of the emitted

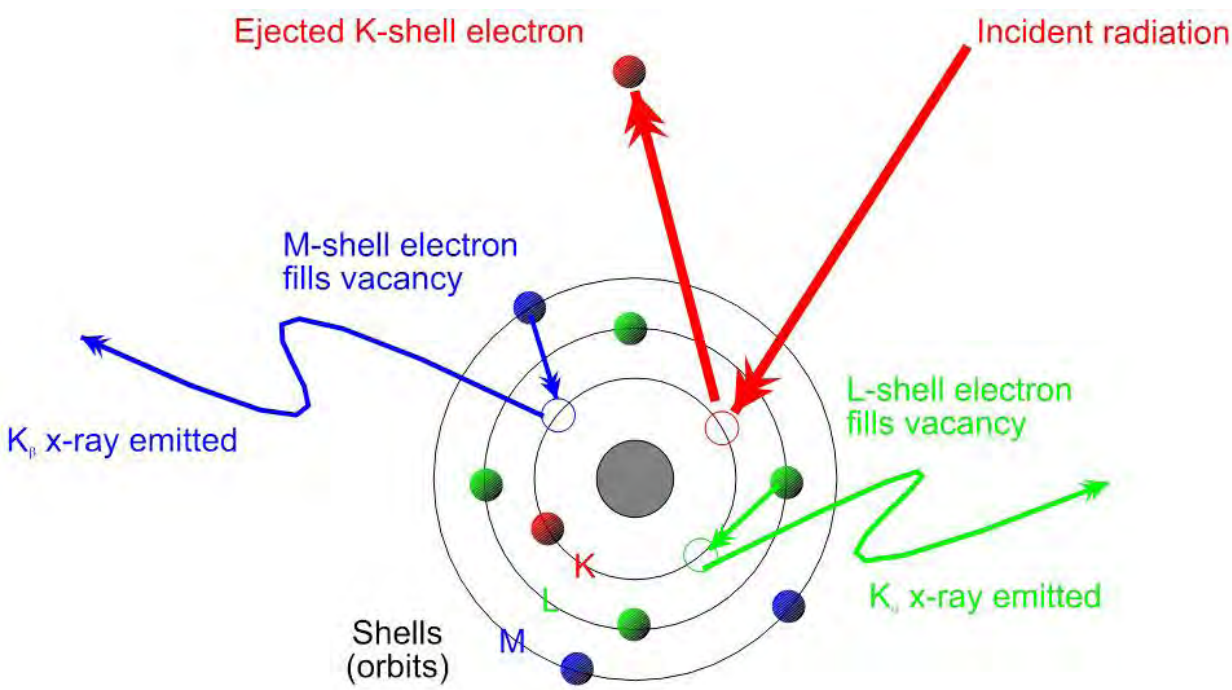

Figure 9: X-ray and electron interactions © Bruker, via https://www.bruker.com/products/x-ray-diffraction-and-elemental-analysis/handheld-xrf/how-xrf-works.html

15 The electron shells are given alphabetical labels, with the innermost shell near the nucleus being the K shell, and the subsequent ones being L shell, M shell, and so forth.

X-ray photon is proportional to the difference in energy states of the electrons within the atom, the resultant lines or peaks from an element are characteristic of that particular element, a relationship known as Moseley's law (Jenkins 2000, 3). An electron moving from the L shell into the K shell emits energy referred to as the Kα-line, while the characteristic energy emitted as an electron moves from the M shell into the K shell is called the Kβ-line. Similarly, an Lα-line is the characteristic energy resulting from a photon emitted as an electron from the M shell fills a vacancy in the L shell, while an Lβ-line is characteristic of the energy emitted as an electron from the N shell fills a vacancy in the L shell. A number of other effects also occur which can be seen in the resultant spectra, such as Rayleigh scattering, wherein no energy is lost as photons collide with electrons in the element, and Compton scattering, wherein some energy is lost in the process.

Instrument training and certification was undertaken at Holger Hartmann AS so as to independently use the pXRF equipment owned by the Conservation Studies department. I also attended a workshop on XRF co-organized by the Getty Conservation Institute and the Yale Institute for the Preservation of Cultural Heritage, which significantly improved my ability to reliably interpret the spectra obtained.[16] Health and safety guidelines were strictly adhered to since pXRF employs ionising radiation. At the MCH, the instrument was used in the conservation laboratories at the far end of the lab while facing away from the entrance, such that any scattered radiation would not be a risk to anyone entering the lab during analysis. In Dassow, analysis was undertaken in the church vicinity outside of opening hours. Analysis was only undertaken when other individuals were at least a metre behind the operator. The instrument nose was always pointing away from the operator such that radiation exposure was as low as reasonably possible.

A systems check was run at the beginning of each instrument use session. Analysis was undertaken using mining mode (Cu and Zn) settings with a spectra acquisition time of 120 seconds per sample site (see table 6 for details). The mining mode (Cu and Zn) is generally recommended for analysis of painted surfaces using the Niton instrument. Background spectra were taken from 10 cm thick polyethylene foam and from bare wood on the objects analysed, so as to determine and subtract element contributions arising from the instrument itself or from the background material.[17] A background scan will consist of bremsstrahlung, Compton and Raleigh peaks as well as peaks from instrument contributions (table 7).

16 The workshop "XRF boot camp for conservators" was hosted by Stichting Restauratie Atelier Limburg (SRAL) and held at the Bonnefantenmuseum in Maastricht, Netherlands from 8 to 11 November 2016. Attendance at the workshop was funded by Conservation Studies on the basis that I would subsequently run a workshop at IAKH to share knowledge gained. As a result, a successful workshop with around 15 participants from IAKH and other museums in Oslo was held with the support of Duncan Slarke on the 13th of January 2017.

17 Plexiglass is an alternative material recommended for taking a background scan (McGlinchey 2012, 147).

Table 6: pXRF equipment and settings

Device	Thermo Scientific Niton XL3-t 950-He Goldd+ pXRF, 50 kV / 200 µA X-ray tube with silver anode and Amptek GOLDD detector (geometrically optimized large drift detector)
Software	Niton Data Transfer Version NDT_REL_8.2 Alpha for qualitative spectra evaluation Adobe Photoshop for sample maps
Standard measurement conditions	Mining mode (Cu and Zn); spot size 3 mm / 8 mm; acquisition time: 120 seconds (30 seconds per range), prolyne window Main range: Voltage 50 kV, current up to 40 µA, Al filter High range: Voltage 50 kV, current up to 40 µA, Mo filter Low range: Voltage 20 kV, current up to 100 µA, Cu filter Light range: Voltage 8 kV, current up to 199 µA, no filter Note: Current is automatically set by the instrument to optimise detector dead-time. The exact composition and thicknesses of filters are proprietary and deemed confidential by Thermo Scientific. In some cases (Mo, Al, Ag) they are 'sandwiches' of several metals. Some Fe is actually in the 'Al filter'.

Table 7: Element contributions from Thermo Scientific Niton XL3t-950-He GOLDD+ pXRF instrument itself (background or instrument artifacts)

Element	**Source**
Ag	X-ray tube target
Mo, Al, Fe, Cu	Proprietary filters
W	Shutter and small spot collimator
Ni	SDD casing

Portable XRF is a close-contact analytical method, and the instrument was handheld in contact with the sample sites for the duration of data acquisition. Given the three-dimensional curved nature of the sculptures, the handheld approach was considered more suitable than the use of a tripod, as it facilitated access to areas analysed.[18] A thin polyethylene foam protective strip was attached to the instrument nose to prevent any damages from occurring to the paint and gilding layers on the sculptures as a result of contact (see also McGlinchey 2012, 144). Measurement sites were chosen based on areas of interest and accessibility. Where possible, three sample sites were selected per colour field or area of interest in order to confirm accuracy of results via a direct comparison between readings. At the beginning of each analysis, a spot photo was taken by the inbuilt camera, which could be used as a record of the exact measurement site. The area analysed measures either 8 mm in diameter, or 3 mm when the small spot collimator is in place. Sites were numbered consecutively on a sample map created with Adobe Photoshop (see appendix 5).

With pXRF, energy is limited compared to benchtop instruments, and low-Z elements result in K peaks, while high-Z elements result in only L-lines. Medium-Z elements produce both K- and L-lines on the resultant spectra, while the very light elements emit such weak energy that it is absorbed in air, meaning that they are not detectable (Shugar and Mass 2012, 26). Thus, the lighter elements are difficult to analyse as the emitted energy is absorbed by the atmosphere in the gap between sample and detector (Schreiner et al. 2004, 5). Consequently, helium purge is to be recommended if the detection of lighter elements is important. This involves purging the air gap between the sample and instrument nose with helium, thus displacing argon, nitrogen and oxygen within the air, and resulting in greater sensitivity for low-Z elements (McGlinchey 2012, 151). Helium purge could not be employed in the current study, as the containers had not been replenished.

The benefit of portability means that pXRF has become the initial analytical method of choice in a broad variety of cultural heritage contexts as it can be used in situ (Shugar and Mass 2012, 19). One of the main concerns arising from this is that while pXRF is a ‘point and shoot’ instrument, it does have its limitations given that the instrument was initially designed for scrap metal sorting and the mining sector, while requirements for cultural artefacts are somewhat different. Thus, one needs to be aware of the limitations and capabilities of the instrument, particularly when attempting to gather quantitative data (Shugar and Mass 2012, 24). It is crucial to have a certain level of insight into the technique to know how to ask the right questions and get the most out of this tool. Spectral interpretation is quite complex for painted surfaces in particular, and the resultant spectra should be interpreted carefully, given that we are dealing with layered heterogeneous structures that have often deteriorated significantly. For example, coatings, dirt or corrosion products may attenuate characteristic radiation (Mantler and Schreiner 2000, 4). It is also important to be aware of scattering effects that result in peaks so that these peaks are not erroneously interpreted as elements present in the sample analysed.

18 In the case of canvas or panel paintings, the use of a tripod is to be recommended instead, as the flat two-dimensional nature makes it easier to position a tripod, and direct contact between the instrument nose and the painted surface is usually avoided so as to prevent the occurrence of pressure damages to the surface analysed. In addition, the use of a tripod reduces the possibility of slight drift and operator fatigue, as the instrument is relatively heavy to hold stable during analysis for extended periods.

Using a pXRF instrument with a silver anode is not necessarily a drawback when analysing metal leaf or gilding that may contain silver. Since the Niton instrument takes four consecutive scans under different conditions, altering current, voltage and using filters (table 6), it is possible to examine the spectrum taken in the high range with a molybdenum filter, which eliminates silver peak contributions from the anode. All four spectral ranges should be examined in detail during data interpretation, as the different ranges are optimised for the identification of different groups of elements, such as light or heavy elements. This is a point to remember when using alternative pXRF instruments such as those manufactured by Bruker, for example. In such a situation, several protocols should be employed at a range of different settings (McGlinchey 2012, 135). Additionally, one needs to be aware of the possibility of sum or escape peaks when interpreting spectra from instruments other than the Niton, which automatically subtracts such peaks from the resultant spectra.

In addition, each instrument will have its own background spectrum, and comparison between readings from different instruments is therefore considered problematic. Similarly, one must remember not to compare spectra taken with different spot sizes. The data gathered from pXRF needs to be interpreted in context with other pertinent visual information or data gathered. For example, an awareness of the pigments and layering sequences characteristically used in late-medieval painting can help determine what elements should be looked for during spectral interpretation. Pigment concentrations are occasionally equated to peak intensities and element concentrations by those less experienced in XRF data interpretation, despite the fact that low energy lines (those from low-Z elements or L- and M-lines as opposed to K-lines) are more readily attenuated, resulting in lower peaks even when the pigment causing them is present in high concentrations within the paint matrix (Mantler and Schreiner 2000, 5).

Matrix effects are an important factor in heterogeneous samples, as there may be significant interaction between secondary radiation from the different elements present in the sample. Layer thickness also needs to be considered, as it has an impact on the attenuating effect on lower energy lines, which are more strongly attenuated as a factor of depth or thickness. Thus, absorption is a crucial effect to consider as it may skew expected line ratios, but may also give an indication of whether the element identified is present in an upper or lower layer (McGlinchey 2012, 137, Trentelman, Schmidt Patterson, and Turner 2012, 176). Certain peak overlaps can make interpretation challenging, and in the case of medieval polychrome sculpture, the lead, mercury and arsenic lines can be an issue, meaning that spectral interpretation should be undertaken with care (McGlinchey 2012, 140, Shugar and Sirois 2012, 324).

In this study, it was experienced that using pXRF to analyse sculptures with only minimal traces of polychromy left on the surfaces is not straightforward, as very low count rates make it difficult to confirm the presence of some elements. This was the case for the Virgin sculpture from Schwanbeck, for example. In this case, the ubiquitous presence of trace amounts of certain elements is likely due to environmental contamination, treatment or storage of the sculpture over many centuries. In particular, calcium, lead, iron and manganese were found almost everywhere on the sculpture. Occasionally, instrument movement resulted in the paint flake under examination no longer being directly centred within the target area, further reducing count rates. Repeating the analysis several times could have mitigated this, though analysis was done in situ in Germany while interpretation could only be attempted upon return to Norway, meaning that it was not possible to repeat the affected scans. The curved 3D nature of the sculptures also meant that accessibility was occasionally experienced as problematic for data acquisition. For example, blue paint remnants on the Bishop sculpture were difficult to analyse, as curvature of the wood limited access and resulted in low count rates due to a large air gap between the paint and the instrument nose (Ebert 2018b, 104).

3.4 Micro-invasive analytical methods

3.4.1 Sampling and cross-section microscopy

The preparation of cross-sections for the investigation of paintings and cultural heritage dates back to the 1910s, with work published by Eduard Raehlmann (1910) and Arthur Laurie (1914), and subsequently elaborated on by Rutherford Gettens (1932, 1936) and Joyce Plesters (1954, 1956). Sampling of works of art and subsequent cross-section microscopy has become a standard analytical technique since then, given the vast amount of information that can be gained from a minute paint sample (Plesters 1956, 110). As discussed in section 3, ethical guidelines were strictly adhered to with regards to reducing sampling to a minimum, and approval was granted to take a small number of samples from the sculptures for detailed investigations that would complement non-invasive investigations. Results from sampling and subsequent analysis fed into papers II, III and IV. Given that the project was based on detailed case study research, it was considered necessary to undertake a small amount of sampling and micro-invasive study in order to gain as thorough an understanding of the material construction of the sculptures as possible. As Khandekar (2003, 52) aptly puts it, “the damage done [by sampling] is balanced by the information gained”.

Details on samples from the case study sculptures are outlined in appendix 6. Of the three new samples that were obtained from the sculpture of St Anne (C2912), two came from unobtrusive areas such as a canvas fibre from the back of the head and glue from the base, while only one sample was taken from the Virgin’s crown in order to investigate an unusual ground preparation. Sampling had been undertaken during conservation treatment in the 1970s, and these samples which had been stored in the museum sample archive were used for further analysis as part of this study, thus reducing the need for extensive sampling (Ebert 2018b, 107). On the Bishop sculpture (C2913), five samples were taken: two from accretions and canvas fibres on the back of the sculpture, as well as two paint samples and one gilding sample. Due to the importance of characterising the gilding on the Torsken Virgin (C2686), a total of six samples were extracted, consisting of four different areas of gilding as well as two paint samples. No sampling could ethically be undertaken on the Schwanbeck Virgin due to the minimal amount of in situ preserved paint flakes.

Preparation of the paint and gilding samples will be described in this section, while the glue, fibre and accretion samples are discussed in subsequent sections relating to PLM and GC-MS. The samples were extracted from the sculptures under magnification. A suitable area was selected adjacent to existing loss or damage, and the area marked with a temporary paper marker for photography. A new size 11 scalpel blade was used to remove the sample, which was subsequently stored in a clean well depression slide prior to further use (Khandekar 2003, 54). The samples were fractured into several smaller pieces, one of which was mounted as a cross-section while the others were kept for further micro-destructive analysis.

The samples mounted in the 1970s were examined under the microscope, and observed to be rather uneven. Therefore, they were repolished using Micro-Mesh polishing cloth. In certain cases, the resultant cross-section was still of insufficient quality or the embedding resin too degraded or discoloured. For one old sample, the two resin blocks had separated along the central join, shattering the sample that had been held in the middle between them and rendering the sample unusable (see also Khandekar 2003, 61). Therefore another sample fragment was mounted and processed.

The sample to be mounted was first observed under the microscope so as to determine correct positioning within the sample container. EasySections were used, which are pre-cast Perspex sample containers designed specifically for the manufacture of paint cross-sections (Khandekar 2003, 55). Identification labels were printed and cut to the desired shape before applying them to the EasySection using a small drop of resin. A disposable pipette was used to place a drop of light curing resin into the sample well (see table 8 for equipment used). A tungsten needle was subsequently used to orient the sample into the correct position within the well (Pouyet 2014, 47), before the well was filled with more resin. Orienting the sample is crucial as it ensures that the sample is positioned such that a suitable cross-section can be gained on grinding and polishing (Khandekar 2003, 56). The EasySection was then placed in the Technotray light polymerisation unit and cured under blue light for five to ten minutes.[19] Covering varnish was applied and the cast samples left overnight. Any remaining sticky varnish was removed from the surface with ethanol swabs.

19 Numerous other methods for sample mounting exist, and studies have evaluated the most suitable types of casting resins and grinding/polishing techniques applicable to the cultural heritage field (Derrick et al. 1994, Wachowiak 2004, Pouyet 2014). In this study, I was limited by the material available and in use at the department of Conservation Studies.

Table 8: Sampling and microscopy tools and equipment

Sampling	EasySections, Heraeus Kulzer Technovit 2000 LC light curing embedding polymer resin (methacrylate-based) and covering varnish Heraeus Kulzer Technotray light polymerisation unit MOPAS XS hand polishing holder Struers LaboPol-5 with silicon carbide paper for initial wet rotary grinding Final dry polishing using Micro-Mesh polishing sheets of increasing grit size up to 12000
Microscopy	Leica DM LM stereo binocular microscope Objectives N PLAN 5X/0.12BD, 10X/0.25BD, 20X/0.40BD; oculars 10X/20 VIS light source: Halogen 12V 100 W UV light source: 100 W Mercury Olympus UC30 camera and Olympus stream motion image analysis software for photomicrography

For grinding and polishing, the EasySection was positioned within the MOPAS hand polishing holder to ensure a planar surface on all the cross-sections. Hand grinding without a holder often results in somewhat uneven cross-sections as a result of small variations in pressure. Initially, wet rotary grinding was undertaken using silicon carbide paper so as to grind away the upper hard plastic portion of the EasySection. The sample was checked repeatedly under the microscope during wet grinding to avoid exposing the sample. Once the sample had nearly been reached, the sanding process was continued without the use of water using Micro-Mesh polishing cloths of increasing grit size (see Wachowiak 2004 for a discussion of alternative abrasive material and lubricants). Since wet grinding can dissolve water-sensitive layers, dry sanding is considered more suitable once the sample is exposed (Khandekar 2003, 57).

The polished cross-section was wiped clean with lens paper and attached to a glass slide with grey plasticine. A parallel press was then used to firmly position the cross-section prior to microscopy. A cover slip was placed over the cross-section, and a drop of white spirit applied to the edge of the cover slip. Capillary action pulled the solvent underneath, saturating the sample for improved imaging (Khandekar 2003, 58). White balance was carried out using a grey card prior to undertaking photographic documentation of the samples at varying magnifications using both dark-field illumination and ultraviolet light. Layer thickness measurements were made and integrated into the images for archival purposes (appendix 8).

Cross-sections are useful for many different purposes, some of the main ones being visualisation of the stratigraphy, manner of paint application (wet-in-wet or dry), pigment particle size and layer thickness measurements (Gettens 1932, 20). However, it is worth remembering that a small sample cast as cross-section cannot always be representative of the entire area being investigated (Plesters 1956, 112). Overpaint and underdrawing may also be identified on cross-sections, as can fungal growth, coatings, dirt, metal soap protrusions, and many more features. Crucially, loose samples and cross-sections can be used for further analytical work to identify pigments and media used (see sections 3.4.3 and 3.4.4), thus complementing the initial non-invasive techniques employed.

3.4.2 Fibre identification by means of polarised light microscopy

Polarised light is that wherein the wavelength vibrates only within one plane perpendicular to the direction of propagation, as opposed to nonpolarised light, which vibrates in many angles (McCrone, McCrone, and Delly 1995, 49, Murphy and Davidson 2013, 136). Consequently, a polariser is a filtering device that transmits light within a given vibration plane only (Bell and Morris 2010, 76). If two such polarising filters are employed, as in the case of a polarised light microscope, with one positioned between the light source and the sample, and the other located between sample and the viewer's eye, then they are referred to as polariser and analyser, respectively (Murphy and Davidson 2013, 155). Polarised light microscopy (PLM) functions based on this simple principle, and when the two polarisers or polars are "oriented so that their transmission axes are perpendicular to each other, they are said to be crossed, and all of the light transmitted by the polariser (now linearly polarised) is extinguished by the analyser" (Murphy and Davidson 2013, 140). PLM can be employed on "organic, inorganic, biological, crystalline, or noncrystalline unknowns" (McCrone 1994, 102), making it a very versatile tool. However, significant experience is required for the microscopist to be able to confidently identify material.

In practice, the specimen is visible in front of a very dark, almost black background, with certain features more clearly visible than in transmitted light microscopy. As a result, PLM is used extensively for the examination and characterisation of crystalline and cellular material by virtue of its optical properties. Since "interference occurs whenever light interacts with itself", leading to the formation of bright interference colours when birefringent samples interact with polarised light, the interference phenomena produced may be used as diagnostic feature in PLM (Bell and Morris 2010, 81). As the microscope stage is rotated, certain aspects of the specimen appear brightly coloured as a result of interference (McCrone, McCrone, and Delly 1995, 145), with the colour changing and extinguishing on further rotation. Furthermore, "the particle orientation at extinction is characteristic and helps as an additional identifying characteristic" (McCrone 1994, 107).

It is the presence of cellulose within bast fibres which makes them molecularly birefringent

(Rochow and Rochow 1978, 93), or exhibiting double refraction (anisotropism), and causing the fibres to appear bright against a dark background when rotating the stage of the polarising microscope under crossed polars. Polarised light renders morphological features on fibres such as cross markings, nodes and dislocations more visible (Suomela, Vajanto, and Räisänen 2017, 6), therefore helping with identifying characteristic features. While cotton and animal fibres are easily distinguished, bast fibres such as jute, hemp, nettle or flax are very difficult to tell apart (Bergfjord and Holst 2010, 1192, Suomela, Vajanto, and Räisänen 2017, 2). Consequently, a "multi-methodological approach" involving a combination of several different microscopic methods is recommended for conclusive identification of bast fibres (Suomela, Vajanto, and Räisänen 2017, 4). Suomela, Vajanto and Räisänen (2017) suggest first examining morphological features on the fibres, followed by the modified Herzog test for identification of fibrillary orientation (see Haugan and Holst 2013), and finally cross-section examination of the fibres.

However, the authors also point out that the modified Herzog test is an "analytical method [that] is very sensitive to false interpretations" (Suomela, Vajanto, and Räisänen 2017, 8). Since I am not a microscopist and only have limited experience with fibre examination using PLM, I am likely to make errors. Hence, I did not feel confident enough to attempt identification of the fibrillar orientation, as this also requires familiarity with the Michel-Lévy birefringence chart (Haugan and Holst 2013). Instead, I focused only on basic microscopic examination of features visible using the polarising microscope, as well as fibre cross-section examination. Thus, the conclusions offered are indicative rather than conclusive, as specified in appendix 7 where fibre identification results are outlined.

Fibre samples from the two Berg sculptures (C2912 and C2913) were examined using PLM in order to determine the type of material used for the fabric patches. The information gained fed into papers II and III. The fibre samples taken from the sculptures were separated using tweezers and tungsten needles so that the fibre bundles were teased apart and individual fibres would be discernible under the microscope. These were placed on a glass slide, taking care that fibres from clothing and surroundings would not accidentally be incorporated. A 70% solution of glycerine in water was used as mounting medium, and a drop placed on the fibres before covering them with a cover slip (see table 9). The sample should be mounted in a liquid medium so as to reduce scattering effects of the fibre in air (Rochow and Rochow 1978, 113), which is considered to have a refractive index of one. Furthermore, the refractive index of the mounting medium should be close to that of glass at 1.52 to reduce the effect of distortion (Bell and Morris 2010, 53).[20] Under crossed polars, the fibres were rotated on the stage, and morphological features such as cross-markings and nodes or dislocations observed. Several photographs were taken at various angles, and the results compared to known pre-mounted reference samples as well as an online fibre reference image library (National Center for

20 A solution of 70% glycerine in water at 20 degrees has a refractive index of 1.427 (Glycerine Producers Association 1963, 13). Catling and Grayson (1998, 6) recommend using a 50% glycerine solution, while 70% was recommended for use at the Conservation Studies department, though the literature indicates a variety of different mounting mediums may also be suitable.

Preservation Training and Technology 2017).

Table 9: Fibre identification tools and equipment

Sample preparation	70% glycerine in water used as temporary mounting medium for PLM White cotton fibres, metal plate with drilled hole, and razor for cross-section examination
Microscopy	Leica DM LM stereo binocular microscope Objectives N PLAN 5X/0.12BD, 10X/0.25BD, 20X/0.40BD; oculars 10X/20 VIS light source: Halogen 12V 100 W Polariser and analyser incorporated into the microscope Olympus UC30 camera and Olympus stream motion image analysis software for photomicrography

For cross-section examination, a fibre bundle was sandwiched between cotton fibres, pulled through a small hole in a metal plate, and cut with a sharp razor (table 9) (Suomela, Vajanto, and Räisänen 2017, 4). A thin lumen with relatively thick cell walls was visible, though the presence of wax from conservation treatment rendered further details difficult to discern.

Unfortunately, flax, nettle and hemp all have dislocations, and their optical and topographical characteristics are so similar that they should not be used as distinguishing features between the fibres (Bergfjord and Holst 2010, 1193). Similarly, cross-section size and shape is not conclusive (Bergfjord and Holst 2010, 1192) even though it is commonly employed to distinguish between bast fibres. Therefore, a multi-methodological approach as recommended by Suomela, Vajanto and Räisänen would have been ideal in this case.

3.4.3 Scanning electron microscopy-energy dispersive X-ray spectroscopy

Scanning electron microscopy (SEM) coupled with energy dispersive X-ray spectroscopy is a powerful enhanced visualisation tool as well as a method of elemental analysis commonly used in conservation studies due its versatility for material characterisation of a diverse variety of cultural heritage (see, for example, Meeks et al. 2012 for a broad variety of applications). The resolution of optical microscopes described in sections 3.4.1 and 3.4.2 is limited by the wavelength of light, meaning that a resolution of around 200 nanometres may be achieved at most (Pollard et al. 2007, 109, Schreiner, Melcher, and Uhlir 2007, 738). The electron microscope, on the other hand, employs electrons rather than visible light, which have a much shorter wavelength by several magnitudes, and consequently can reach resolutions of around 0.1 nanometres. Furthermore, the images produced by an electron microscope have a much greater depth of field compared to those deriving from traditional optical microscopes, making them particularly useful for visualisation of microscopic features (Rochow and Rochow 1978, 289, Price and Burton 2011, 77). The SEM is generally coupled with a detector that allows for elemental characterisation. In this case, the detector used was an energy dispersive X-ray spectrometer, referred to as both EDS or EDX (Ivarsson and Holmström 2012, 799). This method was applied to cross-sections from the sculptures in the MCH collection (C2686, C2912, C2913 and C3124) (appendix 8), with the results contributing to papers III and IV and addressing questions of production as raised in research theme 2.

SEM-EDS functions based on physical principles similar to XRF as described in section 3.3.1, with the main difference being that an electron beam is used to generate the energy to dislodge electrons from their shells, rather than an X-ray source. Samples are prepared and placed inside a sample chamber.[21] When non-conductive samples such as paint cross-sections are to be examined, they need to be prepared by coating with a thin layer of a conductive material, often gold or carbon (Pollard et al. 2007, 111). This is done by vaporising a very thin layer (in the order of 10 nanometres) of carbon on to the surface of the sample by means of ion sputtering (see table 10 for equipment used) (Electron Microscopy Sciences 2018). In addition, the samples are mounted with conductive carbon tape onto stubs for placement in the sample chamber (Goldstein et al. 2018, 139). Such preparation ensures that charging effects are reduced to a minimum (Bower, Stulik, and Doehne 1994). The benefit of SEM-EDS over XRF is that the technique provides localised information on elemental distribution within the various layers of the sample, which may be illustrated with elemental maps. Since paint samples are heterogeneous layered structures, this is a very important factor as it helps in distinguishing the composition of individual layers within the cross-section.

In SEM-EDS, the air is evacuated from the sample chamber, creating a vacuum which reduces scatter and attenuation of electrons (Pollard et al. 2007, 109). A focused beam of electrons is aimed at the sample and scanned in a raster pattern over the specimen (Goldstein et al. 2018). The electrons interact with the sample, leading to several effects. The main products of interest generated are backscattered electrons (BSE) and secondary electrons (SE), both of which can be used for image formation. Backscattered electrons are beam electrons that emerge with much of their energy intact after interactions with the nucleus of an atom. Secondary electrons, on the other hand, are electrons ejected from their shells within the sample. Since they are of lower energy, the majority is absorbed while only those from a shallow depth are emitted. Detectors measure the BSE and SE emitted, and convert them into an image of the surface being examined. Thus, while an SE image provides information about topography due to the shallow nature of SE emission (figure 10), BSE images provide elemental information in greyscale due to BSE intensity being a factor of the atomic weight of the interacting nucleus, with heavier elements appearing

21 The instrument was operated by Calin Steindal of the Saving Oseberg project at the MCH, while data interpretation was undertaken by the author.

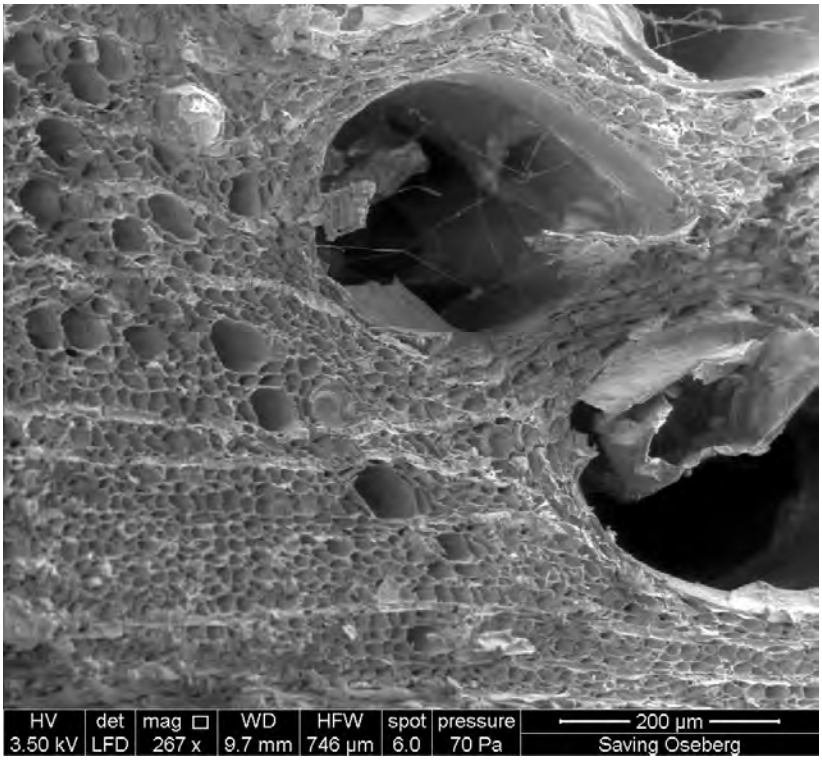

Figure 10: SE image of wood cells from C3124, providing topographical information

brighter in the resulting image (figure 11).

In addition to electron interactions, X-rays are generated as the electron beam interacts with the specimen (see section 3.3.1 for further details). EDS is used to detect and generate spectra resulting from X-ray emission, the interpretation of which provides qualitative and quantitative information on the elemental composition of the sample. Certainly, as for XRF, awareness of the physics behind X-ray generation and detection is required when reviewing software-generated peak identifications in order to obtain reliable measurement results (Goldstein et al. 2018, XI). While the limits of detection with EDS are similar to XRF, it does provide numerous advantages, particularly relating to the ability to focus the electron beam. This makes it possible to analyse very small spots, run line scans to see changes in elemental concentration along a particular section, or to undertake elemental mapping of an entire area on the sample (Pollard et al. 2007, 112). All these features were taken advantage of during this study. Of course, one of the main drawbacks of SEM-EDS is that it is a method of elemental analysis and does not provide conclusive evidence of compounds present. For this, other techniques such as Raman spectroscopy would be necessary.

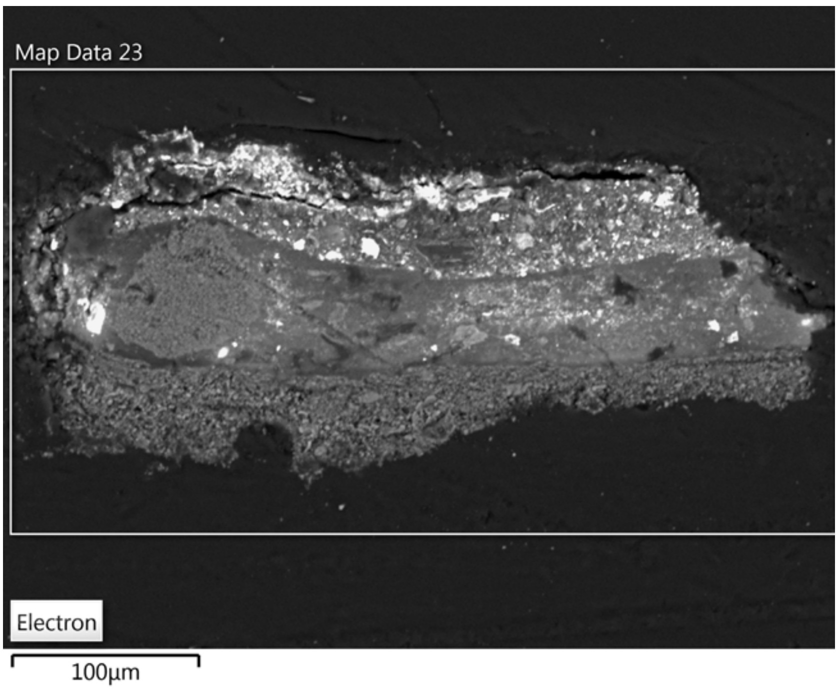

Figure 11: BSE image of sample L59.5 from C2912, providing elemental information

The environmental SEM, or ESEM, is a development over traditional SEM which, as described above, requires high vacuum around the sample being analysed, as well as conductive samples to reduce electron charging effects. Instead, the sample chamber in the ESEM allows the specimen to be surrounded by water vapour or gas in low vacuum, allowing for much greater flexibility (Doehne 2006, Thiel 2006, Ivarsson and Holmström 2012). This means that non-conductive samples can be imaged without prior coating, and that biological or dynamic processes can be observed in real time without desiccation or similar pre-treatment of the sample (see Rochow and Rochow 1978, 196 for different types of sample preparation). Within the ESEM, "electron-induced charge buildup" is neutralised via "ionization of water vapour in the chamber" (Doehne 2006, 45), thus eliminating the need for coating of insulating samples. Coating may be considered undesirable as it may interfere with the sample. For example, a coated paint cross-section needs to be sanded and polished to remove the coating if further optical microscopy or other analysis is to be undertaken subsequently to answer additional questions.

Table 10: ESEM-EDS instrumentation and settings

Instrumentation	FEI Quanta 450 electron microscope with Oxford Instruments X-Max^N 50 SDD (silicon drift detector size 50 mm^2) for EDS analysis AZtec 3.1 SP1 software by Oxford Instruments
Measurement conditions	10 mm working distance 22 kV accelerating voltage Variable livetime between 500 s – 2000 s High vacuum or low vacuum mode as necessary
Carbon sputter coating	Jeol fine coat ion sputter JFC-1100 Agar scientific carbon rod grinder T580 Agar scientific 6 mm shaped carbon rods (E429) 35 mm of carbon evaporated onto the samples

One of the drawbacks of using ESEM for examination of uncoated paint cross-sections is that signal-noise ratio can be problematic with imaging (Doehne 2006, 45), and clarity or field of view may be compromised, as experienced on some samples at high magnification (Ivarsson and Holmström 2012, 804). On the other hand, ESEM is suitable for fragile samples that may be affected by the high vacuum environment necessitated by standard SEM. Thus, the benefits and disadvantages of both SEM and ESEM had to be considered together with the analytical requirements before deciding which samples required examination at high vacuum, and which should be imaged using ESEM conditions. In general, imaging of samples using ESEM yielded somewhat poorer images due to the working distance of 10 mm (table 10). A smaller working distance would have improved image quality, but is not as suitable for EDS (Bower, Stulik, and Doehne 1994, 404), hence the working distance was maintained at around 10 mm throughout for ESEM-EDS investigation. One of the samples examined during this study (177.2) exhibited fracturing of the surface as a result of electron damage, highlighting the fact that specimens may be affected by radiation during analysis (Bower, Stulik, and Doehne 1994, 406, Pollard et al. 2007, 113).

3.4.4 Quantitative gas chromatography-mass spectrometry

Gas chromatography (GC) is an instrumental technique used for the separation of unknown mixtures into their respective molecular components such that these may be identified (Pollard et al. 2007, 137). GC is often combined with a mass spectrometer (MS) as detector, allowing the separated components to be qualitatively determined and quantified. Quantitative gas chromatography-mass spectrometry (GC-MS) is a sensitive analytical technique that is of use for identification of components present in trace amounts, such as deterioration products, organic binding media in ground and paint layers as well as subsequent additions including conservation and restoration materials (Schilling 2005). Therefore, the method was applied to samples from the sculptures in the MCH collection (C2686, C2912, C2913 and C3124) in order to address research theme 2, with the results discussed in papers II, III and IV. Full analytical results are listed in appendix 9.

Certainly, during visual examination of paint layers a broad variety of optical properties such as chroma, gloss, saturation, texture, opacity, translucency and manner of application among others can provide visual clues about the likely binding media used (Plahter 2004b, 165, White and Kirby 2006, 215, Kollandsrud 2018, 142). However, given that this research project involves detailed case study investigations, it was decided that conclusive evidence by means of binding media analysis would complement informed guesswork, as this can only ever be indicative rather than conclusive. Additionally, GC-MS analysis could highlight the presence of conservation materials, thus providing insight into the later life-stages of the sculptures, as raised by research theme 3.

Essentially, GC-MS involves the separation of complex compounds into their individual components as they are transported via a mobile phase through a stationary phase, which interacts with the compounds and slows them down such that they are separated and leave the system at different speeds towards a detector (Mills and White 2006, 16, Poole 2012, 24). Helium is used amongst other gases as the mobile phase to act as carrier gas for the sample, since it is inert and does not react with either the sample or the stationary phase (Lundanes, Reubsaet, and Greibrokk 2014, 19). The stationary phase is a high molecular weight liquid applied as a thin layer lining the inside of a capillary column (Karasek and Clement 1988, 5), located within an oven that allows the temperature to be controlled during separation, thus regulating retention and elution. Retention time "is the time taken for a particular component to elute from the system, measured from the time the mixture is injected"(Pollard et al. 2007, 139). GC-MS requires samples that are sufficiently volatile in order to pass through the column with the gaseous mobile phase. Since paint samples are complex mixtures of high molecular weight components, volatility is achieved by pre-treatment of the sample in a process known as derivatisation. This involves breaking down the sample "by chemically replacing or altering the functionalities" of the chemical components (Pollard et al. 2007, 142).

The derivatised sample in solution is injected into the system using an autoinjector via splitless injection. This requires temperature programming and is employed where trace amounts are to be determined, since it allows for low limits of detection, thus making it suitable for the identification of very small samples (typically in the order of 50 µg) from cultural heritage objects (Schilling, Khanjian, and Souza 1996, 47, Schilling 2005, 186).[22]

When GC is coupled with a mass spectrometer (MS) for detection, the separated components are ionised as they leave the column and enter the MS by virtue of an inlet system with the relevant ion source. The ions in gaseous phase are then separated based on their mass to charge (m/z) ratios before reaching the detector, where a mass spectrum may be produced for molecular identification. The mass spectrum plots the relative abundance of the ions against their m/z ratio (see section 3.4.4.3) (Giorgi 2009, 42).

Since different protocols are required for the identification of plant gums, proteins and fatty acids, the samples were first examined using Fourier-transform infrared spectroscopy (FTIR) in order to preselect the most suitable method. FTIR analysis was carried out on the samples, with selected particles placed on a diamond window and flattened using a pressure anvil. The samples were analysed using a 15X Cassegrain objective attached to a Bruker Optics, Inc. Hyperion 3000 FT-IR microscope housing a liquid nitrogen cooled mid-band MCT detector, and purged with dry air. The spectra are the sum of 64 scans at a resolution of 4 cm^{-1}. Reference spectra from the infrared spectral database were utilised in the identification process. Opus software was employed for analysis while Omnic was used for reference library searches.[23] Since no natural gums were identified in the paint samples, a combined GC-MS method for the identification of proteins and fatty acids could be employed.[24]

Over the last few decades, scientists at the Getty Conservation Institute (GCI) have developed successful protocols for GC-MS analysis of paint samples (Schilling 1990, Schilling and Khanjian 1996a, b, Schilling, Khanjian, and Souza 1996, Schilling 2005, Mazurek et al. 2014). I was given

22 Splitless injection differs from split injection which is used for analytes that are in high concentration. In this case, a large volume is injected but only a portion of the sample enters the column, with a large amount syphoned off to waste by means of a splitter outlet valve (Lundanes, Reubsaet, and Greibrokk 2014, 23).

23 FTIR analysis and interpretation was undertaken by Herant Khanjian and Joy Mazurek at the GCI.

24 The only sample that contained a polysaccharide, possibly starch, was sample L177.4, an accretion originating from the back of the Berg Bishop.

the opportunity to undertake hands-on GC-MS analysis and learn the basics of the technique during a research stay at the GCI in 2017, since expertise in this field was limited in Oslo. GC-MS analysis was undertaken in a two-step method developed at the GCI, wherein the same sample was first analysed for fatty acids and subsequently tested for the presence of proteins (Mazurek et al. 2014, 78). This ensures that only miniscule sample amounts are required, making the technique preferable over other GC-MS protocols developed for the analysis of cultural heritage which often require very large sample amounts (see, for example, Colombini et al. 2010 and references therein, Lluveras et al. 2010).[25]

The samples were prepared by separating them into subsamples consisting of individual layers such as ground and paint layers (Colombini and Gautier 2009, 242, Colombini et al. 2010, 719). Separation was undertaken by manipulating the sample on a glass slide using a scalpel with the aid of a microscope (figure 12). In numerous cases, the paint layers were too thin and fragmented during layer separation; therefore several layers had to be analysed in bulk. The separated layers were transferred into small aluminum cups for weighing on a microbalance, and placed in alphabetically labelled vials.

Figure 12: Separation of layers and weighing of samples

3.4.4.1 Oil, wax and resin analysis

After layer separation, the samples had to be derivatised for fatty acid analysis. The reagent used was a 1:2 mixture of Meth Prep II and toluene (table 11). The samples were sorted into batches by virtue of sample size, with waxes also in a separate group (table 12). In addition, reference samples were prepared for analysis in the same manner as the paint samples. Three reference samples were used, consisting of one sample of chalk bound in egg, one sample of chalk bound

25 Compare paint sample sizes of 1700 µg and 1200 µg used by the team working with Maria Perla Colombini (Lluveras et al. 2010, 378), to sample sizes as small as 40 µg in the current study.

in animal glue, and one sample of lead white bound in poppy oil.[26] All the samples were placed in an oven at 60°C for an hour for solubilisation.

Table 11: GC-MS instrumentation and materials

Sample preparation	Wild Heerbrugg microscope, Plan 1x, eyepiece 10x/21 Cahn C-32 microbalance with remote weighing unit and aluminium cups
Sample derivatisation	Pierce Reacti-Vap III (nitrogen) Pierce Reacti-Therm III hotplate Rainin E4XLS automatic micropipette Meth Prep II (m-trifluoromethylphenyl trimethylammonium hydroxide), CAS 68254-41-1 Toluene Hydrochloric acid 6M sequanal grade Pyridine Ethyl chloroformate Ethanol Chloroform Sodium sulfate anhydrous Water (GC grade)
GC-MS	Agilent 6890N network GC system Agilent 6890 series GC system Plus+ 6890A (G1530A) oven Agilent 7683 series injector Agilent Technologies 5973 inert Mass Selective Detector Agilent red crimp cap 11 mm and clear crimp top micro-sampling vials

Reference standards of a fatty acids mixture at 400 ppm concentration were placed into vials so as to produce a calibration curve for quantitative analysis (Pierce, Nadeau, and Synovec 2012,

26 Reference samples of chalk bound in an aqueous medium were painted out onto glass slides and aged for four days with UV exposure. The reference sample of lead white bound in poppy oil was prepared in 1994 and aged in a Weather-o-meter. The samples derive from the GCI binding media library.

429).[27] Five vials were filled with 25, 20, 15, 10 and 5 µl respectively. The solvent was evaporated off with a stream of nitrogen, and 250 µl of the Meth Prep II/toluene reagent mixture was then added at a 1:10 ratio to the vials, and the standards placed in the oven for one hour at 60°C.

Table 12: Fatty acid derivatisation

Batch	Sample weight	Reagent	Samples
Small	≤ 100 µg	20 µl reagent mixture	B, C, D, E, G, L, R
Medium	100 – 350 µg	50 µl reagent mixture	A, H, O, P, Q, S, T, U
Large	≈ 500 µg	100 µl reagent mixture	J, K, M, N, W, X
Reference samples	400 – 500 µg	150 µl reagent mixture	Chalk – egg Chalk – animal glue Lead white – poppy oil
Wax	not weighed	Only toluene, no Meth Prep	F (30 µl toluene) I (100 µl toluene)

The GC was given an initial Meth prep II wash to ensure that the column was clean before running the samples overnight, using the following protocol. The samples were injected into the GC-MS, and a Zebron ZB-5HT Inferno GC capillary column (30 m x 0.25 mm x 0.1 µm) was used for separation. Helium carrier gas at 1 ml/min flow was set to linear velocity of 40 cm/s. Splitless injection was used with a 60 s purge off time, and set to 300°C. Temperature of the MS transfer line was set to 320°C. The GC oven temperature program was: 80°C for 2 min; 10°C/min to 320°C, isothermal for 5 min; 20°C/min to 380°C, isothermal for 3 min. Solvent delay was 5.1 min. Total run time was 39 min per sample.

3.4.4.2 Protein analysis

Once the samples had been tested for fatty acids, they could be prepared for subsequent protein analysis. For this purpose, the vial caps were removed with a decrimper, and the samples warmed on a hotplate at 55°C for 10 min. Simultaneously, nitrogen flow was used to evaporate off some of the solvent. 100 µl of 6 M HCl was added to each vial for acid hydrolysis, the vials flushed with nitrogen to remove any oxygen, and new crimp caps put on. The samples were hydrolysed in the oven at 105°C for 24 h. After cooling, the crimp caps were removed and acid evaporated off using nitrogen flow and hotplate set to 55°C. 60 µl of GC grade water was added to all the vials to reconstitute the samples, agitating them to ensure complete mixture of the residue with water.

27 The standards were pre-made by Joy Mazurek.

Reference amino acid standards were placed into vials so as to produce a calibration curve for quantitative analysis.[28] Five standards (S1-S5) were used, and vials filled with 40, 30, 20, 15 and 10 µl respectively. Water was added to make up the final volume to 200 µl. At this stage, norleucine was added as an internal standard for protein analysis. While 20 µl norleucine was added to the reference samples and amino acid standards, 5 µl was added to the other samples.[29] The final volume of reference samples and standards was 200 µl, while the final volume for all other samples was 30 µl. One blank vial was also prepared to check for any contamination during GC analysis (Mills and White 2006, 171).

The material was transferred into small culture tubes, and the following solvents added: 32 µl ethanol, 8 µl pyridine, and 5 µl ethyl chloroformate (ECF). The resulting solution was shaken for 5 s or until bubbling stopped. Next, 100 µl 1% ECF in chloroform was added so as to extract out the derivatisation product. The solution was shaken for 10 s. Two layers formed in the vial, with water at the top and chloroform sinking to the bottom. A new set of empty culture tubes was prepared, with a small spatula full of sodium sulfate added to each tube. This acts as drier to remove any water that might still be present in the samples. A long manual pipette was used to extract the bottom layer of chloroform from the mixture, which was subsequently transferred into the new tubes. A second extraction with 100 µl 1% ECF in chloroform was performed, and the chloroform solution again transferred into the new sample tubes. The tubes were shaken before holding them at an angle to remove the solution with a syringe. This ensures that only the solution is removed, while the sodium sulfate drier remains in the tube. The solution was transferred into new GC vials, and nitrogen flow used to evaporate the solution. Subsequently, the solutions were concentrated by adding 30 µl chloroform to the samples, and 200 µl chloroform to reference samples, blank and standards.

The samples were injected into the GC and an INNOWAX (25 m x 0.20 mm x 0.2 µm) capillary column was used for separation. Helium carrier gas was set to linear velocity of 40 cm/s and a flow rate of 1ml/min. Splitless injection was employed at 240°C and a 60 s purge off time. The MS transfer line was set to 240°C. The GC oven temperature program was: 70°C for 1 min; 20°C/min to 250°C, isothermal for 3.5 min. Solvent delay was 4 min. The total run time was 12 min per sample.

3.4.4.3 Data interpretation and quantification

What follows is an account of the manner in which data deriving from GC-MS may be quantified and interpreted. As the separated compounds elute from the gas chromatographic column, they are ionised in the detector, leading to the formation of ions. A mass spectrum plots the relative abundance of the ions against their mass, and is used for molecular identification (Giorgi

28 Amino acid standards were pre-made by Joy Mazurek.

29 Even though sample size varies, the proportion of amino acids is unknown. Therefore, a standard amount was used based on the smallest sample size, and the samples diluted as necessary during later stages.

2009, 63). The automated mass spectral deconvolution and identification system (AMDIS) library from the National Institute of Standards and Technology (NIST) was used to identify unknown components during data interpretation. In addition to mass spectra, chromatograms of compounds eluting over time are also produced, where abundance of ions is plotted against time. The chromatogram displays analytical data both quantitatively (peak areas and heights) and qualitatively (retention times that are characteristic of individual components) (Karasek and Clement 1988, 7). For the analysis of oils, waxes and resins, a total ion current (TIC) chromatogram is of use, while protein analysis is undertaken with selected ion monitoring (SIM), since only the ions relevant to certain amino acid markers are necessary for identification. SIM is particularly useful for the identification of materials that may be in low abundance, since only the pre-selected ions are scanned by the system, allowing for great sensitivity when dealing with trace amounts (Karasek and Clement 1988, 117).

Organic material present in samples analysed by GC-MS may be identified in a number of different ways, including the identification of individual marker compounds, examination of the overall chromatographic pattern, and quantitative analysis (Colombini et al. 2010, 719). The use of reference materials is also essential for comparison purposes (Colombini and Gautier 2009, 249). Mono- and dicarboxylic fatty acids are the individual building blocks required for the identification of oils, resins and waxes, while amino acids are used to determine the presence of proteins in paint samples. Different proteins have different amino acid profiles, thus allowing for the determination of the presence of egg, casein or animal glue (Colombini et al. 2010, 722). Some chromatographic patterns that are easily identified, for example, are the characteristic "fish bone" patterns of long chain fatty acids visible on the TIC of high molecular weight waxes commonly used in conservation treatment.

In the current study, reference standards of known weight were used to create calibration curves for quantitative analysis of fatty acids and amino acids. The concentration of standards was calculated and plotted to create a calibration curve against which the unknown samples could be measured. Furthermore, quantification of amino acids for protein identification was achieved with the use of an internal standard of norleucine. Norleucine was used since this amino acid is never present in paint samples, and it is recommended that an internal standard is used which is "of similar functionality and molecular weight to the unknowns" (Pollard et al. 2007, 145). Quantitative analysis is achieved by calculating and comparing ratios of peak heights (or areas) of internal standard and analyte (Karasek and Clement 1988, 188).

The molar ratios between certain fatty acids are commonly used for the differentiation between individual drying oils. In particular, the ratio of palmitic to stearic acid (P/S) is considered an important marker in the differentiation of drying oils, while the ratio of azelaic to palmitic acid (A/P) is used to differentiate between drying oils and egg lipids (Mills 1966, Mills and White 2006, 171, Colombini and Modugno 2009, 9, Colombini et al. 2010, 722).

Calculation of correlation coefficients is also used to aid in identification of unknowns (Schilling and Khanjian 1996a, 212). In this case, a perfect match would be a correlation coefficient of 1.0. The amino acids considered to be stable are alanine, valine, isoleucine, leucine, glycine, proline, and hydroxyproline since they are not affected by ageing or pigment interaction (Schilling and Khanjian 1996a). The quantitative stable amino acid composition of the samples was compared to reference data, thus determining the closest possible match (Schilling, Khanjian, and Souza 1996, Schilling 2005, 189). However, if a mixture of binding media is present in the sample, correlation will be poor, and in this case the amino acid composition was compared to hypothetical mixtures (Schilling and Khanjian 1996a, 212).

For most samples, a correlation coefficient of 0.93 was considered an acceptable match due to high amounts of glycine present. Ideally, the samples would have been diluted and run again if more time had been available, thus improving the correlation coefficient results for protein identification. However, the schedule for the research stay at the GCI was too tight to allow for this, and it was only possible to repeat analysis on one diluted sample, L59.1 from C2912 (see appendix 9). In this case, diluting the sample and running it again through GC-MS resulted in increasing the correlation coefficient from an initial 0.93 to 0.97.[30] A further issue encountered related to the calibration curve for protein identification. In the first instance, problems with the curve indicated that the S3 and S5 standards had accidentally been switched, and the calibration curve had to be adjusted accordingly. Furthermore, one TIC from C2913 (sample 177.1, see appendix 9) included an unusual silane compound subsequently identified as deriving from the GC column itself.

The major issue experienced during GC-MS related to the pervasive presence of animal glue on all of the samples as a result of treatment at the museum during the 1920s (paper III) (Ebert 2018b, 105). While some samples indicated the possibility of egg being present, the extensive presence of animal glue makes it very difficult to be conclusive. Renewed sampling after cleaning an area on the object might help, though it is possible that the animal glue has penetrated into deeper layers. Otherwise, an additional method such as the use of antibody assays or proteinomics may be of help (Mazurek 2010, Mazurek et al. 2014).

30 Only the diluted run is included in the appendix for purposes of simplicity.

Image overleaf:

Torsken Virgin

4. Discussion and conclusion

The four papers included in this thesis build up consecutively, culminating in a final interdisciplinary paper at the end. I begin by looking at the history of research of late-medieval polychrome sculpture in Norway (paper I). Subsequently, I address technical construction details (paper II), before moving on to re-assess and qualify art historic attributions based on updated material studies (paper III). This is followed by an attempt to use analytical data to complement broader biographical narratives (paper IV). Out of necessity, the style and length of the individual papers varies significantly, in part due to different audiences and publication venues. While some articles discuss the methodology and results, the fourth article presents material data purely in its interpreted form. Therefore, the complete data underpinning the various case studies is included in the appendices for full transparency. For a brief overview, a summary of results is tabulated in appendix 10.

4.1 Revisiting the thesis' research aims

In the introduction to this thesis, I outlined my desire for a holistic approach to late-medieval sculpture in Norway. I here reassert the claim that we ought to take advantage of many of the skills employed by conservators, namely observation, examination, documentation, analysis, deduction, and interpretation, and combine them with contextual research. This is reflected by research theme 2, which seeks to clarify how techniques common to conservation studies may enrich material culture studies. It is crucial to employ frameworks for interpreting change and assessing significance, as the field of conservation needs "a commitment of expertise to issues of interpretation and education that can match the accomplishments of our technical work on cultural heritage sites"(Bluestone 2000, 67). In this manner, research theme 3 raises the possibility of employing an object biography approach as complementary theoretical framework in conservation studies, and seeks to underline what a conservator may offer that differs from object biographical approaches in other disciplines. One of my aims has been to link material investigations with comprehensive studies of treatment and display history and wider socio-historical contexts so as to come to broader interpretations of medieval sculpture in changing contexts over time. This aim is reflected in research theme 1. In addition to this broad theme, some of the smaller goals have involved detailed material studies, as well as examination and re-assessment of former workshop attributions, leading to updated knowledge about late-medieval sculpture in Norway, while cementing their value as a significant aspect of Norwegian cultural heritage (research theme 1).

The role of the conservator as mediator between the object and its audiences is of prime importance, as it demonstrates that there is significant value in communicating technical knowledge to varied audiences. Consequently, we should embrace the "inter-disciplinary character of the conservator's job" (Kirby Talley Jr. 1997, 279). According to Kirby Talley Jr. (1997, 279), "the conservator… is in the unhappy position of having chosen a profession which requires more than average competence in diverse disciplines". It may be argued that dipping into a broad variety of disciplines including art history, conservation science, museum studies and history, amongst others, could imply that one attempts too many things, with insufficient knowledge to fully do anything justice. While this could be seen as a downside, I suggest that we should instead take advantage of this breadth of knowledge, allowing us to communicate effectively across disciplines. Furthermore, material and technological analysis add depth and detail to the biographical approach, as set out in research themes 2 and 3, and thus the combination of material analysis with a contextual approach is in itself a significant contribution of the thesis.

While on the one hand material analysis has been important, one of the main aims of the thesis as delineated in research themes 1 and 3 has been to employ the object biographical approach to demonstrate the value of these objects within Norwegian cultural heritage narratives, as set out in Engelstad's introduction to his authoritative publication of 1936 (author's translation): "The entire work becomes a piece of Norwegian cultural history, even if only few of the works discussed herein were made in Norway. [The book] is organised topographically so as to emphasise the character of Norwegian cultural history. If we turn the case on its head, we can say that the book deals with a broad range of German and Netherlandish art history, while at the same time being an important aspect of Norwegian cultural history."[31] Consequently, I have demonstrated how these objects, despite mostly not having been produced in Norway, form a valid part of Norwegian cultural heritage by virtue of the lives they have lived.

4.2 Biographies carved in wood

In what manner then does the theoretical framework of object biographies relate to the individual papers in the thesis? Each case study sculpture offers a variety of approaches to object biographies that may be explored as considered relevant. Furthermore, the sculptures as a group act as a window on temporally and culturally specific changing understandings or "socially ascribed value" of late-medieval sculpture in Norway (Caple 2006, 10).

Paper I outlines the research status of late-medieval sculpture in Norway. While on the surface it might appear that this paper constitutes a simple literature review, it does in fact represent much more than that. Archival research as outlined in section 3.1.2 forms the backbone of paper I. By engaging with the history of collecting and display and publishing in this niche field of art

31 "Hele arbeidet blir derfor et stykke norsk kulturhistorie, selvom bare de færreste av de kunstverker som behandles, er laget her hjemme. Bortsett fra det store, ressonnerende kapitel I, er derfor de øvrige ordnet topografisk, nettopp for å understreke karakteren av *norsk* kulturhistorie. Setter vi saken på spissen kan vi si at boken omhandler en rekke områder innen tysk og nederlandsk *kunsthistorie*, som samtidig er blitt et viktig avsnitt av Norges *kulturhistorie*"(Engelstad 1936, 9).

historic study, I have examined and counterpointed varying approaches to medieval sculpture in Norway during the period of Norwegian nation building, from the 19th century and into the early 20th century. Wider social agendas and attitudes towards late-medieval times are explored, demonstrating how politics and history can be entangled with medieval sculpture. As attested to by Avrami, Mason and de la Torre (2000, 6), “heritage, at its core, is politicised and contested”. I have attempted to tease out the range of reasons for the ‘skewed’ Sverre Fehn display, wherein far more early-medieval sculptures have been exhibited compared to late-medieval sculpture. Consequently, shifting value judgements and interpretations relating to the late Middle Ages in Norway are described by virtue of the research history of late-medieval sculpture.

Paper II engages with a very specific angle, namely construction technique, and hence the making (or birth) of a sculpture. Methods of relevance to paper II include examination and documentation (section 3.1.1.), specialised imaging techniques described in section 3.2, as well as fibre identification (section 3.4.2) and GC-MS for glue identification (section 3.4.4). Papers for this publication were required to be concise, and therefore focused on a very specific topic, leaving little space for theoretical engagement. In the paper, I describe the technique of wainscot block construction, thus providing insight into the medieval carver’s technical skills and material knowledge. While the paper is technical in nature, examining a specific construction technique, it also acts as a window on medieval carving by providing a glimpse into the carver’s engagement with his material. Conscious choices were made by the sculptor in selecting wainscot, resulting in a block of wood that is technically harder to carve than green wood. Was the sculptor interested in longevity or did he choose his material specifically for producing export sculpture? Furthermore, I demonstrate that the technique appears to have developed in tandem in Germany, the Low Countries and Italy, pointing either towards cultural exchange and transfer of art technological knowledge or synchronic technical developments across Europe.

Paper III in the thesis re-examines joint altarpiece attribution of two sculptures. In doing so, I explore how conservation treatment history of the objects within the museum may have affected viewers’ perceptions and interpretation of the sculptures. All the methods outlined in chapter 3 are of relevance to paper III. After examining the material and technological choices made in painting and gilding the sculptures, their later life stages are explored, post-entry into the museum. This stands in contrast to paper II, where only the early life stages are addressed. The emphasis here is on the impact of conservation treatment or lack thereof, and how this affects the appearance of sculptures. This is a crucial part of the biographies of objects that have entered museum collections, though often downplayed or not widely acknowledged. The conclusion arrived at was that there is no direct link between the two sculptures.

Paper IV explores the parallel lives of two very similar sculptures, examining how their use and valuation has shifted across space and time. The full object biographical approach is employed in paper IV, with the sculptures compared from their point of creation up to their present state, making use of all the methods described in chapter 3. One sculpture is located in a museum setting while the other remains within its community, thus demonstrating two very different approaches to medieval sculpture. While the two sculptures would have begun life looking remarkably similar, their current appearance demonstrates their passage through time. The Norwegian sculpture retains its original polychromy, while the sculpture in Germany has been subjected to stripping off of the paint and gilding as a result of changing tastes. Furthermore, I reveal how a plaster copy of the museum sculpture can continue the social life of the sculpture in Torsken, much like the sculpture in Germany is integrated into a contemporary religious community that actively engages with it on a variety of levels.

In sum, the four papers demonstrate an interdisciplinary approach wherein material analysis and interpretation are linked with a range of social contexts throughout the sculptures' lives. Consequently, it has been demonstrated how a range of shifting values can be associated with medieval polychrome sculpture. The significance or value judgements attached to sculptures can directly impact their appearance and state of preservation, for example wherein a sculpture is stripped of its original polychromy or restored and put on display. In addition, the converse is true, with a sculpture's shifting significance being the result of its preservation and appearance.

4.3 The biographical approach in conservation

In light of the long timespan of medieval sculpture, one approach towards the objects of study comes from the perspective of object biographies, in order to provide the sculptures with a more complete context, interpreting and linking the material evidence with wider social narratives, outlined in research theme 3. As asserted by Miriam Clavir (2002, 54), "it is interpretation, the socially constructed meanings of objects, that give them their intrinsic value". However, it must be noted that this is only one of the many ways in which the material could have been studied and interpreted.

Given the status of late-medieval polychrome sculpture in Norway as set out in Paper I, it was decided that the biographical approach could offer insight into broader aspects such as socio-historical contexts. This may be considered tangential to traditional approaches in conservation studies, and not always relevant or necessary. However, in this study the outcome was to shed light on the complexities of provenance, and highlight my personal viewpoint that art historic provenance studies of such objects need not necessarily be of prime importance. With relation to research theme 1, it may be much more crucial how an object was used over the centuries rather than where and by whom it was made. Thus, as outlined in paper IV, whether the Torsken Virgin was made in Germany, Norway, or a combination of the two, is of lesser importance than how it has been valued and used over the centuries (Ebert 2018c). Of course, this is not to downplay the importance of research into provenance, but merely to act as a reflection of my personal research interests, while adding a new perspective that complements other approaches. Multiple approaches are valid, with the biographical approach being just one of many. However, the thesis has successfully demonstrated that this theoretical stance can be used to much effect within conservation studies, and deserves further consideration within the discipline.

Needless to say, the biographical approach also has its constraints. Object biographies quickly reach their limitations when dealing with objects of unknown provenance, for example. However, this need not be a hindrance, as Joanne Kirton (2016), amongst others, has successfully demonstrated that comparative studies can be used to situate monuments that are no longer in situ within wider frameworks of similar assemblages. In addition, the biographical approach is often better suited to older objects, as it is easier to demonstrate changes to the object's materiality and valuation over longer timespans. On the other hand, Annuska Derks' (2015) life history approach to the coal briquette in post-Đổi Mới Vietnam highlights societal changes over the past thirty years, a relatively short period when compared to medieval sculpture. Thus, when looking beyond the object biographies of individual objects and aiming for broader life histories, even short time frames can successfully be described in relation to materialities and societal interactions. Furthermore, the notion of object biographies has been critiqued, and alternative approaches offered, as outlined in section 2.1.

Conservation is in the unique position of being able to physically investigate "the secret life of objects" (Appelbaum 2018, 343) and gather material information that may reveal a hitherto unknown aspect about the past (research themes 2 and 3), shedding light on historical contexts, use, misuse, repurposing, degradation and much more. In my opinion, the object's life does not end but continues along a new trajectory upon entry to the museum: the object is conserved (or not), put on display (or not), used as didactic tool, for research, or kept in storage.[32] This point of view is also made by others, as for example Mark Hall's claim (2012, 85) that "museums are never a graveyard for material culture but institutions that support the continuing life stories of the objects they curate". In Dinah Eastop's (2006, 523) case study of a concealed doublet, (see section 2.2), dirt and creasing have been retained in order to demonstrate the doublet's historical significance as a concealed garment, giving it an important new role as didactic tool within the museum, while a replica continues the doublet's "active social life". The object certainly enters new spheres of social entanglement within a museum context.[33] In paper IV, this situation is mirrored by the plaster cast of the Torsken Virgin which continues the museum sculpture's life in parallel within Torsken community on Senja island (Ebert 2018c).

In fact, it may be worth seeing an object as palimpsest, and paying attention to the "social patina that accrues over time as an object moves from maker to user to collector to preserver to exhibitor" (Ames 1994, 99). Hence, objects are continually recontextualised, and the museum itself plays an important role in the life of the object. Ames (1994, 100) highlights "two levels of analysis: (1) the social history of the object from origin to current destination, including the changing meanings as the object is continually redefined along the way; and (2) the museum itself as layered object and machine for recontextualization or…objectification".

32 For an alternate view, see Theodor Adorno's claim (1955, 215) that museums are sepulchres of works of art and contain objects that are dying.

33 Refer to the work of Ian Hodder (2011, 2012, 2014) for a discussion of the idea of entanglement.

Given that as conservators we are implicitly involved in writing object biographies when composing condition and treatment reports, handling, treating and thereby arguably altering objects, what is to stop us from writing explicit object biographies? As noted in section 2.2, conservators are active agents in the biographies of objects entrusted to our care (Caple 2003, Eastop 2006). This is directly evident when undertaking conservation treatment such as cleaning or consolidation, which alters the physical nature and appearance of an object for the purpose of securing it for future generations (Avrami, Mason, and de la Torre 2000, 10). However, it is also implied in the study and scientific investigation of objects, as I have undertaken in the current project, since the act of studying and generating scientific data for a small group of objects lifts the objects of study above others that could instead have been investigated. As Miriam Clavir (2002, 27) asserts, "the cultural value of collections can be the product of a circular and self-fulfilling path in museums. Museums have the power to designate which objects have cultural value".

Similarly, attachment of cultural value is also mirrored in my decision to investigate one group of sculptures over another. This makes the objects of study more likely to become visible to a wider audience by virtue of publications and exhibitions (see section 1.4.2), thus creating new avenues for developing their narratives within the museum context. The choice that I made at the start of my research project in investigating certain case studies and leaving others aside has catapulted my objects of study onwards in their biographies, while the other sculptures which I initially considered but chose not to investigate further could be said to remain static at this point in time.

4.4 Conservation and material culture

As I have previously paraphrased, Engelstad "considered the late medieval collection outlined in his book to represent a piece of Norwegian cultural history, given the distribution of the objects in remote towns and villages, despite the fact that most were produced abroad" (Ebert 2018a, 146). The individual case studies and publications included in this thesis highlight the Norwegian aspect of the sculptures, demonstrating their relevance within wider discourses around material culture (see research theme 1).

As conservators, we have at our disposal a wealth of information that may be obtained by material investigations, using the objects of study as primary source material. This is addressed in research theme 2. Material culture studies is located at the crossroads of numerous disciplines, and conservation can contribute with studies of the materiality of material culture. There is much to be gained by undertaking interdisciplinary research, as interdisciplinarity "seeks to move forward to a fruitful dialogue by developing common ground between disciplines and often breaks new ground in the margins between the 'turfs' of existing fields" (Wicker 1999, 169). Out of necessity, this requires the use of a common language that avoids technical field-specific jargon. Of course, the downside is that detailed analysis, description of methods, and varying interpretations of scientific data often find little room for discussion in such interdisciplinary publications.

Publishing outside the narrow confines of the conservation field hones our communication skills and enables others to see the benefits of the conservator's approach. Thus, I see paper IV in this thesis as the culmination of what I have set out to do, providing an alternative and complementary approach to those more established within conservation studies, as suggested by research themes 2 and 3. Effective communication ensures that the work of conservators loses some of that cloak of secrecy that is occasionally still actively cultivated[34] and spread in popular culture and newspaper articles that deal with the often mysterious work of white coat-clad conservators sporting head loupes, for example. Certainly, communication skills have been highlighted by numerous authors over the years as warranting attention (see, for example, Wainwright 1990, 79, Staniforth et al. 1994, 223, Muñoz Viñas 2005, 164, Appelbaum 2008, 2010, 2018). As summed up by Jørgen Nordqvist (1997, 8) at the end of the roundtable discussion of the 1996 IIC Congress on Archaeological Conservation and its Consequences, "a good conservator is a communicating conservator".

While conservation is much more in the public eye some twenty years after this roundtable discussion, with almost every museum now mounting conservation exhibitions or undertaking conservation in situ within open galleries (Appelbaum 2018, 363), there remains work to be done in positioning conservation as a more outward-looking discipline. I believe that there is much more to outreach than 'behind the scenes' conservation-in-action. Despite numerous pushes towards interdisciplinarity, surprisingly few conservators actively publish in related disciplines such as art history, archaeology or material culture, using language easily understandable to others outside the field. As Barbara Appelbaum (2018, 361) asserts, "much of what [conservators] talk about is foreign to their listeners". Dinah Eastop (2006) is one of few conservators who has attempted to break into material culture studies, despite the fact that conservators are actively involved with material culture on a daily basis and have much to contribute to broader discussions. On a wider level, while "heritage conservation is truly a *multi*disciplinary endeavour", "*inter*disciplinary collaboration is not often achieved" within the cultural heritage sector (Avrami, Mason, and de la Torre 2000, 3). Consequently, my thesis also forms an argument for greater involvement between conservation and material culture studies, coming from the material perspective where conservators can contribute by clearly communicating results in non-technical terms.

As suggested in section 2.3, Jules David Prown's (1982) framework for material culture studies deserves greater attention in conservation studies, as it offers a solid framework for theoretical and methodological engagement with one's object of study. Using the object as primary source material is fundamental to conservation studies, and also underpins Prown's methodology

34 During my time as practicing conservator prior to undertaking PhD research, a fellow conservator recounted how a colleague with whom he had trained insisted on surrounding his workplace with jars and bottles filled with variously coloured liquids so as to emphasise the aura of mystery and secrecy that he cultivated.

(1982, 1) "based on the proposition that artifacts are primary data for the study of material culture, and, therefore, they can be used actively as evidence" for the "study of culture through artifacts" and thus for "narrating the past" (Pearce 1994b). Since objects "embody and reflect cultural beliefs", close study of objects sheds light on wider social and cultural matters (Prown 1982, 3). Importantly, value and significance judgements underpin much of contemporary theories of conservation (see Pye 2001, Muñoz Viñas 2005). Therefore, understanding how these can change over time is pertinent within conservation studies, not least when undertaking treatment-based decisions such as, for example, choosing to retain or remove the material evidence of "tears and stains" on a military uniform (Pearce 1994b, 20).

Thus, building bridges between conservation studies and allied disciplines such as art history, archaeology, material culture studies and many more is of utmost importance, as it broadens our tool kit and allows us to combine material studies with wider theoretical engagements on culture and society, thus "reconcile[ing] the material and socio-cultural dimensions of human activity" (Boivin 2008, 20). As Andrew Jones (2002, 66) points out, it is possible to combine materials science with material culture studies by looking at how "artefacts are socially and culturally constructed, while also taking into account the physical and mechanical construction of artefacts". Material culture studies by its very nature is interdisciplinary, and conservators should not shy away from engaging with broader discussions on society and culture, as conservation can effectively address the "serious flaw" described by Nicole Boivin (2008, 16, 20) as "the marginalisation of the material". Given that conservators directly deal with the material, be that in examining, treating or analysing and interpreting material evidence, the profession has much to contribute to broader cultural studies. It is hoped that this thesis may be seen as a small contribution towards "collaps[ing] these very dichotomies" of "mind and matter" by virtue of integrating scientific analysis with theoretical engagement (Boivin 2008, 23).

4.5 Facture – the making of the object: material findings and implications

The data gathered during material investigations and analysis of the individual case study sculptures has use far beyond the confines of the biographical approach. Systematic material investigations of late-medieval northern German polychrome sculptures are few and far between, as outlined in section 1.4. While broader art historic studies have been undertaken, additional detailed art technological and material studies are required so as to add to the corpus of existing material knowledge. This contributes to a more nuanced understanding of the technical differences between early- and late-medieval carving and polychromy, as well as regional differences during the later Middle Ages in northern Germany and beyond.

Full details of analytical results are included in the appendices. In addition, a summary of interpreted results was compiled for the case study sculptures belonging to the MCH collection (appendix 10). It was not considered feasible to include such a summary for the Schwanbeck Virgin, as no sampling could be undertaken in this case for cross-checking of the pXRF results. In presenting all of the results of my material investigations in the appendices, I am contributing to the existing body of knowledge on late-medieval polychrome sculpture. Such transparency allows other researchers to draw their own conclusions from the data instead of relying on my interpretation of the results. In addition, the ethical decision to undertake limited further sampling in addition to investigating archival samples can so be further justified (see chapter 3 for compliance with ethical guidelines). Since the remaining physical samples are stored in the sample archive of the MCH while the raw data is archived digitally, the material investigations undertaken are of use far beyond my own research aims in this thesis.

The two sculptures from Berg, as well as the Torsken and Schwanbeck Virgins were all carved in oak. Both locally grown and imported oak was commonly used in northern German centres of production, though there is also limited evidence of other woods being employed in addition. For example, walnut and limewood are known to have been used in a variety of northern German locations, despite the often-cited Lübeck guild rules of pre-1425 stipulating the sole use of oak for church furnishings and altarpieces (Wehrmann 1864, 327, Hasse 1976, note 8, Ulmann 1984, 107, Tångeberg 1986, 144, Bonsdorff 1993, 58). The 1375 guild rules of Hamburg mention the use of hardwoods such as walnut or pear in addition to oak (Lappenberg 1866, 315, Rüdinger 1874, 91, Bonsdorff 1993, 59), while in other regions softwoods such as pine could also be used in addition to oak, walnut or limewood, for example (Wallraf Richartz Museum, Fondation Corboud, and Doerner Institut der Bayerischen Staatsgemäldesammlungen 2014, 21). Thus, while the use of other types of wood makes it possible to exclude Lübeck as place of origin, conversely the use of oak cannot be used to determine provenance as it was widely used throughout Germany, the Low Countries and Scandinavia.

Dendrochronological investigations revealed the use of Southern Baltic wainscot for the St Anne sculpture from Berg (C2912), while the other sculptures could not be dated or dendro-provenanced (appendix 4) (Ebert 2017, 2018b). However, X-rays and CT scans of the Berg Bishop and Torsken Virgin indicated that the wood used had numerous defects such as knots, woodworm holes, splits and checks, and derived from relatively fast-growing trees (Ebert 2018c, b, 97). As discussed in papers II, III and IV, lower quality oak is often indicative of the use of regionally-grown wood as opposed to imported oak from the Baltic regions (see also Wallraf Richartz Museum, Fondation Corboud, and Doerner Institut der Bayerischen Staatsgemäldesammlungen 2014, 22). While the slow, even growth of Baltic oak results in wainscot boards of high quality (Ebert 2017, 4), the choice of support is not always down to the individual carver.

It has been demonstrated that quality of wood can vary widely, even within an individual artist's output, and many different factors may come into play such as wood being provided by the client, cost, availability, and other factors (Ulmann 1993, 226, Wallraf Richartz Museum, Fondation Corboud, and Doerner Institut der Bayerischen Staatsgemäldesammlungen 2014, 22). There is currently only one documented evidence of a sculptor having his own wood store, and this was Michel Erhart in Ulm (Ulmann 1984, 106). The use of Baltic wainscot implies "purposeful purchase of high-quality imported wainscot" for the production of St Anne, though whether this was dictated by the client or sculptor cannot be determined at this stage (Ebert 2017, 4).

During the late-medieval period, the most common carving technique employed individual blocks of wood for polychrome sculpture, as opposed to piecing together from many individual wooden pieces (Tångeberg 1986, 152). Of course, exceptions are what define the rule, and it is in this light that the Berg Bishop (C2913) as well as wainscot block construction employed for St Anne (C2912) ought to be seen. Tångeberg describes numerous sculptures which, much like the Bishop sculpture, consist of one main block with smaller additions. Certainly, complicated forms often necessitated the addition of smaller pieces of wood to the main block, while additional pieces of wood were commonly used for crown finials and hands, for example (Tångeberg 1986, 152).

It is possible that the sculptor of the Bishop figure realised on carving that an additional narrow vertical section of wood was necessary to accommodate the bishop's robes more realistically. Similarly, one could imagine that a piece of wood was added to the base to allow the sculpture to conform in height to other sculptures in a group. As outlined in the condition report (appendix 2), the hands, now lost, would likely also have consisted of separate pieces of wood. Availability of suitable wood is a crucial factor; therefore I hesitate to use such 'piecing together' as indicative of provenance, or to place too much emphasis on its interpretations. Of far greater interest is the manner in which such pieces are attached to the main block by means of wooden wedges and canvas strips. This reveals something about medieval craftsmanship and allows us a glimpse into something often hidden from view or inaccessible, even to the conservator.

A case where the manner of joining blocks is less visible, on the other hand, is the Schwanbeck Virgin. Wide assemblages often necessitated the joining of several blocks of wood vertically, with dowels occasionally incorporated into such joins (Tångeberg 1986, 153). Similarly, the Schwanbeck Virgin consists of two blocks of wood with a vertical join that was reinforced with three wooden dowels (Ebert 2018c, 5). The conservation treatment report from 1972 recorded these dowels during regluing of the open join (Spiller 1972), while evidence of additional sawn off dowels on the sculpture could indicate the former presence of further sculptural or architectural elements.

Wainscot block construction as evidenced in the St Anne sculpture highlights an intriguing medieval manufacturing technique worthy of further investigation (Ebert 2017). The case study has highlighted the medieval carver's attention to high quality raw materials despite the associated added difficulty of carving dry wood. In paper II, I describe parallels as well as differences to wainscot block construction employed in the Low Countries. In particular, it would appear that Netherlandish block constructed sculptures often employ nails for reinforcement, something that has so far not been observed on the German examples studied.

Investigations of the polychromy on the case study sculptures has also contributed to the body of knowledge on late-medieval sculpture, allowing for further material comparisons to be made in future. The type, composition (chalk and animal glue), manner of application and sanding down of the ground on the case study sculptures (Ebert 2018b, 99) appears to be fairly standard and in keeping with techniques commonly employed during the Middle Ages. Of interest is the localised use of a grey ground on the Virgin's crown on St Anne from Berg (Ebert 2018b, 99-100). This appears to have been employed as filler or cement for additional reinforcement of a potentially fragile area. As outlined in paper III, such grey grounds have so far only been observed on a small number of sculptures, and are worthy of further study.

The polychromy observed on the case study sculptures is fairly simple, with blues, reds and greens being the most common colours. Blue paint layers on the sculptures were consistently found to be composed of azurite bound in animal glue (Ebert 2018c, b, 104). The dark blue over light blue layering structure on St Anne was found to be of interest, given the common use of dark underlayers. However, Tångeberg and other authors have also observed and described dark over light layering systems (Tångeberg 1986, 240, Guillot de Suduiraut 1991, 215-6). Thus, the assumption that azurite was usually applied over grey or dark blue layers needs to be re-assessed based on further material studies and comparisons.

Greens and reds were commonly applied as layered systems in order to obtain brighter, stronger colours (Tångeberg 1986, 240). Green paint layers on the case study sculptures appear to consist of a mixture of mainly copper green and lead tin yellow bound in oil. A two- to three-layer structure was usually observed in this case. Red layering systems on St Anne, the Bishop and the Torsken Virgin varied somewhat. These red paint layers were found to consist of vermilion and red lead, occasionally with an upper layer of an unidentified organic red glaze (see appendix 8).

Investigations of the gilding on the sculptures revealed a number of interesting results. Overall, the gilding is relatively simple, with no ornate patterns or punchmarks having been employed. There is limited evidence on the Torsken Virgin of red glazes, possibly depicting gems, on the Virgin's gilded crown (see condition report, appendix 2). Oil gilding was employed for hair, and the base layer found to be yellowish-brown or beige in colour. Both silver (in the case of St Anne) and gold leaf (in the case of the Torsken Virgin) were identified in areas of oil gilding (appendix 8).

Of particular interest is the water gilding technique employed, as well as choice of bole in these instances. Analysis of the binding medium indicated the potential use of egg on the Bishop sculpture, while animal glue was identified on the other sculptures (Ebert 2018b, 102). Apart from one anomaly on the Bishop sculpture described in paper III, gold leaf was employed on all the case study sculptures. However, while a red bole was identified on the sculptures from Berg and Schwanbeck, the case was somewhat more complicated for the Torsken Virgin. Very thin washes of red bole could account for the trace amounts visible underneath the gilding on Christ's robe (Ebert 2018c, 8). However, no underlayer was identified on the samples taken from the Virgin's gilded robe, indicating the use of a ground-gilding technique more commonly associated with earlier periods in Germany, or with techniques in use in Scandinavia (Tångeberg 1986, 68, Kollandsrud 2006, 80). Implications of this for determination of provenance have been discussed in paper IV, though I refrain from making definitive conclusions as there are still extensive gaps in knowledge surrounding gilding techniques.

4.6 Limitations and avenues for further research

A selection of qualitative and quantitative research methods and techniques was employed during this study in order to undertake in-depth case study investigations covering material analysis, historical and contextual research, and examinations of values and significance in order to come to a broad interpretation of late-medieval polychrome sculpture in Norway. This research has also highlighted the need for further material and contextual studies of polychrome sculpture, so as to expand on the current body of knowledge.

As outlined in section 3, the methods employed in the current study are standard investigative techniques common to conservation studies. Thus, it has been possible to conclude that these techniques can successfully be employed in tracing object biographies, as posed in research theme 2. Raman spectroscopy would have been a useful complementary technique in situations where conclusive pigment identification could not be obtained, as in the case of Joseph's grey tunic on the Torsken Virgin (see paper IV). However, while Raman was attempted, issues with the laser equipment at the time meant that it could not be followed through within the timeframe available.

While dendrochronology is a potentially useful technique, particularly if used non-invasively (Bill et al. 2012), it has to be noted that not all wood can successfully be dated or provenanced, especially if only few tree rings are available for study, typically less than 50 rings (English Heritage 2004, 13). This was described and demonstrated in section 3.2.4, as several case study sculptures could not be compared to known site or master chronologies due to insufficient tree rings. Nevertheless, the associated CT scans provided other pertinent information such as the presence of defects, or width of rings being indicative of growth speed.

As discussed in section 3.4.4, the use of animal glue for consolidation treatment at the MCH during the early 20th century has rendered conclusive GC-MS evidence towards the use of animal glue in samples difficult, due to the ubiquitous presence of animal glue on most of the sculptures in the collection. Should it be necessary, additional techniques such as the use of antibody assays or proteinomics could be attempted (Mazurek 2010, Mazurek et al. 2014). GC-MS could be employed for analysing the types of wood glues used on medieval polychrome sculptures, as in the case of St Anne, where no evidence of casein glue was found, despite historical sources indicating that this was used preferentially over animal glue (Ebert 2017, 5).

Development of the wainscot block technique across Europe during the late Middle Ages is worthy of further study, as it highlights how little is actually known about the technique. Similarly constructed sculptures are surely hiding in museum storage elsewhere, waiting to be identified, mapped and examined. While some tentative differences between German and Netherlandish block constructed sculptures have been identified (see section 4.5 and paper II), a broad survey should be undertaken in order to reveal further examples of polychrome sculpture constructed using this particular technique. There are as yet too many unknown factors, and further study is necessary before we can conclusively determine why the technique was employed in particular cases, such as in the case of export art.

Systematic material studies of late-medieval sculptures from the MCH collection would contribute to re-evaluations of art historic attributions, reappraising some of Engelstad's conclusions while contributing to the wider field of polychrome sculpture by expanding our knowledge base. Further technical analysis of medieval sculpture is crucial and timely, given the limited data available at present. Such studies would be complementary to the host of recent art historical investigations, as outlined in section 1.4.3. For example, as described in section 4.5, further examples of grey fillers and grounds could be explored, allowing conclusions to be drawn about their significance. Similarly, organic glazes were not investigated in the present study, and techniques such as surface-enhanced resonance Raman scattering, for example, could be employed for the investigation of these materials (Leona 2009). A crucial area of study identified is the use of metal alloys and the composition of metal leaves used in gilding (paper III). Reconstructions and artificial ageing may highlight differences between degraded Zwischgold and gold leaf of lower purity consisting of alloys that may tarnish. In addition to this, further material studies on gilding are required, so as to investigate boles and manner of gilding, particularly ground-gilding, which remains understudied. Such studies would be highly beneficial in shedding light on shifts in material technology from the early- to the late-medieval period, for example.

4.7 Conclusion

In undertaking this study, I have contributed with updated material knowledge to broaden our understanding of late-medieval polychrome sculpture. In addition to this, I have demonstrated the benefits of examining wider socio-historical contexts and investigating object biographies as part of other valid conservation studies approaches. As part of this research, I have explored some of the changing attitudes towards late-medieval material, and demonstrated the importance of late-medieval polychrome sculpture within a contemporary Norwegian cultural heritage context. Given that "museums are embedded in the social, economic and political complexities of contemporary society" (Ames 1994, 98), conservators must not lose sight of changing values and significance, and how these may impact our objects of study, as well as our own approach towards objects (van Mensch 1990, 149).

"The whole work of a conservator is a constant sequence of interpretations" (Jedrzejewska 1976, 6), and we should take advantage of this skill, laying aside theories of objectivity and focusing instead on multiplicities of truth as well as the subjective and interpretative aspect underlying contemporary theories of conservation. Thus, throughout the thesis, I have highlighted the importance of the conservator's role as mediator in reading and giving meaning to material evidence by means of suitable modes of interpretation, and have demonstrated that the object biographical approach can successfully be used to develop narratives around polychrome sculptures.

Image overleaf:

Torsken Virgin

References

Adorno, Theodor. 1955. *Prismen: Kulturkritik und Gesellschaft*. Frankfurt a. M.: Suhrkamp.

Ainsworth, Maryan. 2005. From connoisseurship to technical art history: the evolution of the interdisciplinary study of art. *Conservation, The Getty Conservation Institute Newsletter* 20 (1): 4-10.

Akca, Devrim. 2012. 3D modeling of cultural heritage objects with a structured light system. *Mediterranean Archaeology and Archaeometry* 12 (1): 139-152.

Albrecht, Uwe, ed. 2005. *Corpus der mittelalterlichen Holzskulptur und Tafelmalerei in Schleswig-Holstein: Hansestadt Lübeck, St.Annen Museum*. Vol. 1. Kiel: Ludwig.

Albrecht, Uwe, ed. 2012. *Corpus der mittelalterlichen Holzskulptur und Tafelmalerei in Schleswig-Holstein: Hansestadt Lübeck: die Werke im Stadtgebiet*. Vol. 2. Kiel: Ludwig.

Albrecht, Uwe, ed. 2016. *Corpus der mittelalterlichen Holzskulptur und Tafelmalerei in Schleswig-Holstein: Stiftung Schleswig-Holsteinische Landesmuseen auf Schloss Gottorf, Schleswig, Archäologisches Landesmuseum, Landesmuseum für Kunst und Kulturgeschichte*. Vol. 3. Kiel: Ludwig.

Albrecht, Uwe, Jan von Bonsdorff, and Annette Henning, eds. 1994. *Figur und Raum: mittelalterliche Holzbildwerke im historischen und kunstgeographischen Kontext*. Berlin: Dietrich Reimer.

American Institute for Conservation of Historic and Artistic Works. 1998. "Code of ethics and guidelines for practice." Accessed 16.05.2018. http://www.conservation-us.org/our-organizations/association-(aic)/governance/code-of-ethics-and-guidelines-for-practice/code-of-ethics-and-guidelines-for-practice-(html)#.Wvv496SFPmE.

Ames, Michael. 1994. Cannibal tours, glass boxes and the politics of interpretation. In *Interpreting objects and collections*, ed. Susan M. Pearce, 98-106. London: Routledge.

Angermeier, Heinz. 1984. *Die Reichsreform 1410-1555: die Staatsproblematik in Deutschland zwischen Mittelalter und Gegenwart*. München: Verlag C.H. Beck.

Appadurai, Arjun. 1986, ed. *The social life of things: commodities in cultural perspective*. Cambridge: Cambridge University Press.

Appelbaum, Barbara. 2008. Conservation treatment and the custodian/conservator relationship. *CeROArt : Conservation* (2).

Appelbaum, Barbara. 2010. *Conservation treatment methodology*. New York: Barbara Appelbaum.

Appelbaum, Barbara. 2018. *Preserve, protect and defend: a practical guide to the care of collections*. New York: Barbara Appelbaum.

Artal-Isbrand, Paula, and Philip Klausmeyer. 2013. Evaluation of the relief line and the contour line on Greek red-figure vases using reflectance transformation imaging and three-dimensional laser scanning confocal microscopy. *Studies in Conservation* 58 (4): 338-359.

Avrami, Erica C., Randall Mason, and Marta de la Torre, eds. 2000. *Values and heritage conservation: research report*. Los Angeles: The Getty Conservation Institute.

Barbieri, Gabriella. 2007. The role of X-radiography in the documentation and investigation of an eighteenth century multi-layered stomacher. In *X-radiography of textiles, dress and related objects*, eds. Sonia O'Connor and Mary Brooks, 203-211. London: Elsevier Butterworth-Heinemann.

Bell, Suzanne, and Keith Morris. 2010. *An introduction to microscopy*. Boca Raton: CRC Press.

Bergfjord, Christian, and Bodil Holst. 2010. A procedure for identifying textile bast fibres using microscopy: flax, nettle/ramie, hemp and jute. *Ultramicroscopy* 110 (9): 1192-1197.

Bernaerts, Lars, Marco Caracciolo, Luc Herman, and Bart Vervaeck. 2014. The storied lives of non-human narrators. *Narrative* 22 (1): 68-93.

Bill, Jan, Aoife Daly, Øistein Johnsen, and Knut S. Dalen. 2012. DendroCT - dendrochronology without damage. *Dendrochronologia* 30 (3): 223-230.

Bjerregaard, Peter, ed. 2019. *Transformation: faith and sacred objects in the Middle Ages* Trondheim: Museumsforlaget.

Blackwell, Mark. 2004. The it-narrative in eighteenth-century England: animals and objects in circulation. *Literature Compass* 1 (1): 1-5.

Blackwell, Mark. 2007. *The secret life of things: animals, objects, and it-narratives in eighteenth-century England*, *The Bucknell studies in eighteenth-century literature and culture*. Lewisburg: Bucknell University Press.

Bluestone, Daniel. 2000. Challenges for heritage conservation and the role of research on values. In *Values and heritage conservation: research report*, eds. Erica C. Avrami, Randall Mason and Marta de la Torre, 65-67. Los Angeles: The Getty Conservation Institute.

Boivin, Nicole. 2004. Mind over matter? Collapsing the mind-matter dichotomy in material culture studies. In *Rethinking materiality: the engagement of mind with the material world*, eds. Elizabeth DeMarrais, Chris Gosden and Colin Renfrew, 63-71. Cambridge: McDonald Institute for Archaeological Research, University of Cambridge.

Boivin, Nicole. 2005. Comments on A. Jones, 'Archaeometry and materiality: Materials-based analysis in theory and practice', archaeometry, 46(3), 327-338, 2004, and reply - Comments I: Post-textual archaeology and archaeological science. *Archaeometry* 47: 175-179.

Boivin, Nicole. 2008. *Material cultures, material minds: the impact of things on human thought, society, and evolution*. Cambridge: Cambridge University Press.

Bonde, Niels, Ian Tyers, and Tomasz Wazny. 1997. Where does the timber come from? Dendrochronological evidence of timber trade in Northern Europe. In *Archaeological Sciences 1995*, eds. Anthony Sinclair, Elizabeth Slater and John Gowlett, 201-204. Oxford: Oxbox Books.

Bonsdorff, Jan von. 1993. *Kunstproduktion und Kunstverbreitung im Ostseeraum des Spätmittelalters*. Vol. 99, *Finska fornminnesföreningens tidskrift*. Helsinki: Suomen Muinaismuistoyhdistys.

Bonsdorff, Jan von. 2000. Spridningen av senmedeltida träskulptur I Nordeuropa - alternative forskningstrategier. *Collegium Medievale* 13: 185-201.

Boockmann, Hartmut. 1987. *Stauferzeit und spätes Mittelalter: Deutschland 1125-1517*, *Deutsche Geschichte in zehn Bänden*. Berlin: Siedler.

Bower, Nathan, Dusan Stulik, and Eric Doehne. 1994. A critical evaluation of the environmental scanning electron microscope for the analysis of paint fragments in art conservation. *Fresenius' Journal of Analytical Chemistry* 348 (5): 402-410.

Bridges, Thomas. 1771. *The adventures of a bank-note*. London: T. Davies.

Briggs, Asa. 1988. *Victorian things*. London: Batsford.

Bugge, Anders. 1933. Kunsten langs leden i Nord. *Foreningen til Norske Fortidsminnesmærkers Bevaring*: 1-52.

Burström, Nanouschka. 2014. Things in the eye of the beholder: a humanistic perspective on archaeological object biographies. *Norwegian Archaeological Review* 47 (1): 65-82.

Caple, Chris. 2003. *Conservation skills: judgement, method and decision making*. London: Routledge.

Caple, Chris. 2006. *Objects: reluctant witnesses to the past*. London: Routledge.

Carey, Annie. 1870. *Autobiographies of a lump of coal, a grain of salt, a drop of water, a bit of old iron, a piece of flint*. London: Cassell, Petter & Galpin.

Carey, Annie. 1873. *The history of a book*. London: Cassell, Petter & Galpin.

Catling, Dorothy, and John Grayson. 1998. *Identification of vegetable fibres*. London: Archetype.

Clavir, Miriam. 2002. *Preserving what is valued: museums, conservation, and First Nations*. Vancouver, B.C: UBC Press.

Colombini, Maria Perla, Alessia Andreotti, Ilaria Bonaduce, Francesca Modugno, and Erika Ribechini. 2010. Analytical strategies for characterizing organic paint media using gas chromatography/mass spectrometry. *Accounts of Chemical Research* 43: 715-727.

Colombini, Maria Perla, and Gwénaëlle Gautier. 2009. GC/MS in the characterisation of protein paint binders. In *Organic mass spectrometry in art and archaeology*, eds. Maria Perla Colombini and Francesca Modugno, 237-259. Chichester: Wiley & Sons.

Colombini, Maria Perla, and Francesca Modugno. 2009. Organic materials in art and archaeology. In *Organic mass spectrometry in art and archaeology*, eds. Maria Perla Colombini and Francesca Modugno, 3-36. Chichester: John Wiley & Sons.

Coventry, Francis. 1751. *The history of Pompey the Little: or, the life and adventures of a lap-dog*. London.

Cultural Heritage Imaging. 2002-2018a. "Photogrammetry." Accessed 31.05.2018. http://culturalheritageimaging.org/Technologies/Photogrammetry/.

Cultural Heritage Imaging. 2002-2018b. "Reflectance transformation imaging (RTI)." Accessed 23.05.2018. http://culturalheritageimaging.org/Technologies/RTI/.

Cultural Heritage Imaging. 2011. *Reflectance transformation imaging: guide to highlight image processing v1.4*.

Cultural Heritage Imaging. 2013a. *Reflectance transformation imaging: guide to highlight image capture v2.0*.

Cultural Heritage Imaging. 2013b. *Reflectance transformation imaging: guide to RTIViewer v1.1*.

Daly, Aoife. 2011. Dendro-geography - mapping the Northern European historic timber trade. In *Tree rings, art archaeology: proceedings of an international conference; Brussels, Royal Institute for Cultural Heritage, 10-12 February 2010*, ed. Pascale Fraiture, 107-123. Brussels: Institut Royal du Patrimoine Artistique.

Daly, Aoife. 2016. *Non-invasive dendrochronological analysis of four polychrome ecclesiastical sculptures from Troms, Norway*. Denmark: Dendro.dk. Report.

Daly, Aoife, and Noëlle L. W. Streeton. 2017. Non-invasive dendrochronology of late-medieval objects in Oslo: refinement of a technique and discoveries. *Applied Physics A: Materials Science and Processing* 123: 431.

Derks, Annuska. 2015. Fuelling change: a biography of the beehive coal briquette in post- Đổi

Mới Vietnam. *Journal of Material Culture* 20 (3): 331-349.

Derrick, Michele, Louis Souza, Tanya Kieslich, Henry Florsheim, and Dusan Stulik. 1994. Embedding paint cross-sections in polyester resins: problems and solutions. *Journal of the American Institute for Conservation* 33 (3): 227-245.

Díaz-Guardamino, Marta, Leonardo García Sanjuán, David Wheatley, and Víctor Rodríguez Zamora. 2015. RTI and the study of engraved rock art: A re-examination of the Iberian south-western stelae of Setefilla and Almadén de la Plata 2 (Seville, Spain). *Digital Applications in Archaeology and Cultural Heritage* 2 (2-3): 41-54.

Doehne, Eric. 2006. ESEM applications: from cultural heritage conservation to nano-behaviour. *Micro and Trace Analysis* 155 (1): 45-50.

Dudley, Sandra H., and Susan M. Pearce. 2012. *Narrating objects, collecting stories: essays in honour of professor Susan M. Pearce*. London: Routledge.

Eastop, Dinah. 2006. Conservation as material culture. In *Handbook of material culture*, eds. Christopher Tilley, Webb Keane, Susanne Küchler, Michael Rowlands and Patricia Spyer, 516-533. London: SAGE.

Ebert, Bettina. 2017. Composite wainscot block construction in medieval sculptures: a question of quality? In *ICOM-CC triennial conference preprints Copenhagen 4-8 September 2017. Linking past and future*, ed. Janet Bridgeland, art. 1703. Paris: International Council of Museums.

Ebert, Bettina. 2018a. A skewed balance? Examining the display and research history of the medieval collection at the Museum of Cultural History, University of Oslo. *Journal of the History of Collections* 30 (1): 139-151.

Ebert, Bettina. 2018b. Saintly relationships or grounds for divorce? An examination of workshop links between two medieval polychrome sculptures. *Journal of the Institute of Conservation* 41 (2): 95-112.

Ebert, Bettina. 2018c. Biographies carved in wood: turning points in the lives of two medieval Virgin sculptures. *Journal of Material Culture*. https://doi.org/10.1177/1359183518811355

Electron Microscopy Sciences. 2018. "Sputter coater principles." Accessed 14.08.2018. https://www.emsdiasum.com/microscopy/technical/datasheet/sputter_coating.aspx.

Engelstad, Eivind S. 1933. *Die hanseatische Kunst in Norwegen: stilkritische Studien*. Oslo: Det Norske videnskaps-akademi.

Engelstad, Eivind S. 1936. *Senmiddelalderens kunst i Norge ca. 1400-1535*. Oslo: Universitetets Oldsaksamling.

English Heritage. 2004. *Dendrochronology. Guidelines on producing and interpreting dendrochronological dates*: English Heritage.

Fett, Harry. 1909. *Norges kirker i middelalderen*. Kristiania: Norsk folkemuseum.

Fett, Harry. 1925. *Skulptur og malerkunst i middelalderen*. Vol. 1, *Norsk Kunsthistorie*. Oslo: Gyldendal Norsk Forlag.

Fett, Harry. 1938. *Hellig Olav: Norges evige konge*. Oslo: Gyldendal Norsk Forlag.

Fontijn, David Robert. 2002. "Sacrificial landscapes: cultural biographies of persons, objects and "natural" places in the bronze age of the southern Netherlands, c.2300-600 BC." PhD, University of Leiden.

Fried, Johannes. 1987. Deutsche Geschichte im früheren und hohen Mittelalter: Bemerkungen zu einigen neuen Gesamtdarstellungen. *Historische Zeitschrift* 245: 625-747.

Fründt, Edith. 1962. Der Junge-Altar aus der Nikolaikirche zu Stralsund. Ein Beitrag zum Problem der Werkstoffverwendung in der mittelalterlichen Plastik. *Forschungen und Berichte* 5: 25-30.

Fulbrook, Mary. 1990. *A concise history of Germany*, *Cambridge concise histories*. Cambridge: Cambridge University Press.

Gallardo, Francisco, Victoria Castro, and Pablo Miranda. 1999. Riders on the storm: rock art in the Atacama Desert (Northern Chile). *World Archaeology* 31 (2): 225-242.

Gettens, Rutherford J. 1932. A microsectioner for paint films. *Technical Studies in the Field of the Fine Arts* 1: 20-28.

Gettens, Rutherford J. 1936. The cross-sectioning of paint films. *Technical Studies in the Field of the Fine Arts* 5: 18.

Giorgi, Gianluca. 2009. Overview of mass spectrometric based techniques applied in the cultural heritage field. In *Organic mass spectrometry in art and archaeology*, eds. Maria Perla Colombini and Francesca Modugno, 37-74. Chichester: John Wiley & Sons.

Glycerine Producers Association. 1963. *Physical properties of glycerine and its solutions*. New York: Glycerine Producers Association.

Goldstein, Joseph I., Dale E. Newbury, Joseph R. Michael, Nicholas W. M. Ritchie, John Henry J. Scott, and David C. Joy. 2018. *Scanning electron microscopy and X-ray microanalysis*. 4th edition. New York: Springer.

Gosden, Chris, and Yvonne Marshall. 1999. The cultural biography of objects. *World Archaeology* 31 (2): 169-178.

Graeme, Earl, Basford Philip, Bischoff Alexander, Bowman Alan, Crowther Charles, Dahl Jacob, Hodgson Michael, Isaksen Leif, Kotoula Eleni, Martinez Kirk, Pagi Hembo, and E. Piquette Kathryn. 2011. "Reflectance transformation imaging systems for ancient documentary artefacts." In *Electronic Visualisation and the Arts*.

Graham, Chelsea Alene. 2012. "Applications of digitization to museum collections management, research and accessibility." MA, Archaeology and ancient history, Lunds universitet.

Guillot de Suduiraut, Sophie. 1991. *Sculptures allemandes de la fin du Moyen âge dans les collections publiques françaises: 1400-1530*. Paris: Editions de la Réunion des Musées Nationaux.

Guillot de Suduiraut, Sophie, ed. 1993. *Sculptures médiévales allemandes: conservation et restauraration*. Paris: La documentation Française.

Hall, Mark. 2012. Three stones, one landscape, many stories. In *Narrating objects, collecting stories*, eds. Sandra H. Dudley, Amy Jane Barnes, Jennifer Binnie, Julia Petrov and Jennifer Walklate, 85-102. London: Routledge.

Hamilakis, Yannis. 1999. Stories from exile: fragments from the cultural biography of the Parthenon (or 'Elgin') marbles. *World Archaeology* 31 (2): 303-320.

Haneca, Kristof, Tomasz Wazny, Joris Van Acker, and Hans Beeckman. 2005. Provenancing Baltic timber from art historical objects: success and limitations. *Journal of Archaeological Science* 32 (2): 261-271.

Hasse, Max. 1976. Maler, Bildschnitzer und Vergolder in den Zünften des späten Mittelalters. In *Jahrbuch der Hamburger Kunstsammlungen*, 31-42. Hamburg: Dr. Ernst Hauswedell & Co Verlag.

Haugan, Espen, and Bodil Holst. 2013. Determining the fibrillar orientation of bast fibres with polarized light microscopy: the modified Herzog test (red plate test) explained. *Journal of Microscopy* 252 (2): 159.

Hill, Kate, ed. 2012. *Museums and biographies: stories, objects, identities*. Woodbridge: Boydell Press.

Hodder, Ian. 2011. Human-thing entanglement: towards an integrated archaeological perspective. *The Journal of the Royal Anthropological Institute* 17 (1): 154-177.

Hodder, Ian. 2012. *Entangled: an archaeology of the relationships between humans and things*. Hoboken: Wiley.

Hodder, Ian. 2014. The entanglements of humans and things: a long-term view. *New Literary History: A Journal of Theory and Interpretation* 45 (1): 19-36.

Hoffmann, Miriam J. 2015. *Studien zur Lübecker Tafelmalerei von 1450-1520, Schleswig-Holsteinische Schriften zur Kunstgeschichte*. Kiel: Verlag Ludwig.

Hohler, Erla. 2017. Medieval wooden sculptures in Norway. *Collegium Medievale* 30: 33-84.

Holtorf, Cornelius. 2002. Notes on the life history of a pot sherd. *Journal of Material Culture* 7 (1): 49-71.

Holtorf, Cornelius. 2008. The life-history approach to monuments: an obituary? In *Gropar & monument - En vänbok till Dag Widholm*, ed. Joakim Goldhahn, 411-427. Solna: Intellecta DocuSys.

Hoskins, Janet. 1998. *Biographical objects: how things tell the stories of people's lives*. New York: Routledge.

Ingold, Tim. 2007a. Materials against materiality. *Archaeological Dialogues* 14 (1): 1-16.

Ingold, Tim. 2007b. Writing texts, reading materials. A response to my critics. *Archaeological Dialogues* 14 (1): 31-38.

Ivarsson, Magnus, and Sara Holmström. 2012. The Use of ESEM in geobiology. In *Scanning electron microscopy*, ed. Viacheslav Kazmiruk. London: IntechOpen.

Jedrzejewska, Hanna. 1976. *Ethics in conservation*. Stockholm: Kungl. Kunsthögskolan.

Jenkins, Ron. 1999. *X-ray fluorescence spectrometry*. 2nd edition. New York: John Wiley & Sons.

Jenkins, Ron. 2000. X-ray techniques: overview. In *Encyclopedia of analytical chemistry*, ed. R. A. Meyers, 13269-13288. Chichester: John Wiley & Sons.

Jenks, Stuart. 2013. Small is beautiful: why small hanseatic firms survived in the late Middle Ages. In *The Hanse in medieval and early modern Europe*, eds. Justyna Wubs-Mrozewicz and Stuart Jenks, 191-214. Leiden: Brill.

Johnstone, Charles. 1775. *Chrysal, or, the adventures of a guinea*. London.

Jones, Andrew. 2002. *Archaeological theory and scientific practice*. Cambridge: Cambridge University Press.

Jones, Andrew. 2004. Archaeometry and materiality: materials-based analysis in theory and practice. *Archaeometry* 46 (3): 327-338.

Jones, Andrew, Marta Díaz-Guardamino, and Rachel J. Crellin. 2016. From artefact biographies to 'multiple objects': a new analysis of the decorated plaques of the Irish Sea Region. *Norwegian Archaeological Review* 49 (2): 113-133.

Jones, Siân, and Sally Foster. 2008. Recovering the biography of the Hilton of Cadboll pictish cross-slab. In *A fragmented masterpiece: recovering the biography of the Hilton of*

Cadboll pictish cross-slab, eds. Heather James, Siân Jones, Sally Foster and Isobel Henderson. Edinburgh: Society of Antiquaries of Scotland.

Joy, Jody. 2009. Reinvigorating object biography: reproducing the drama of object lives. *World Archaeology* 41 (4): 540-556.

Joyce, Rosemary A. 2015. Things in motion: itineraries of Ulua marble vases. In *Things in motion: object itineraries in anthropological practice*, eds. Rosemary A. Joyce and Susan D. Gillespie, 21-38. Santa Fe: School for Advanced Research Press.

Joyce, Rosemary A., and Susan D. Gillespie, eds. 2015. *Things in motion: object itineraries in anthropological practice*, *School for Advanced Research Advanced Seminar series*. Santa Fe: School for Advanced Research Press.

Karasek, Francis W., and Ray E. Clement. 1988. *Basic gas chromatography - mass spectrometry*. New York: Elsevier.

Kausland, Kristin. 2016a. A fishy business: a late-medieval North German shrine attributed to Wilm Dedeke in Norway. In *Painting techniques, history, materials and studio practice, 5th international symposium, Rijksmuseum Amsterdam, 18-20 September 2013*, ed. Arie Wallert. Amsterdam: Rijksmuseum.

Kausland, Kristin. 2016b. Late medieval paintings in Norway - materials, techniques, origins. *Zeitschrift für Kunsttechnologie und Konservierung* 30 (2): 47-66.

Kausland, Kristin. 2017a. "Late medieval altarpieces in Norway - domestic, imported or a mixed enterprise? An art technological study of Northern German and Norwegian altarpiece production in the period 1460-1530." PhD, Conservation Studies, University of Oslo.

Kausland, Kristin. 2017b. Nailing it! The identification of northern Netherlandish altarpieces through common features in their methods of construction. In *ICOM-CC 18th Triennial Conference Preprints, Copenhagen, 4-8 September 2017*, ed. Janet Bridgeland, article 1704. Paris: International Council of Museums.

Kausland, Kristin. 2018. Dusting the "Dusk of the Dark Ages" - art technological illumination on late medieval altarpieces in Scandinavia. Norwegian Research Council.

Kempff, Margareta. 1994. *Attribueringarnas mångfald - Johannes Stenrat och Hans Hesse. Den senmedeltida verkstadens produktion*. Stockholm: Konstvetenskapliga institutionen.

Khandekar, Narayan. 2003. Preparation of cross-sections from easel paintings. *Studies in Conservation* 48 (Supplement-1): 52-64.

Kirby Talley Jr., Mansfield. 1997. Conservation, science and art: plum puddings, towels and some steam. *Museum Management and Curatorship* 15 (3): 271-283.

Kirton, Joanne. 2016. "Sculpture and place: a biographical approach to recontextualising Cheshire's early medieval stone sculpture." PhD, Archaeology, University of Chester.

Knüvener, Peter. 2011a. *Die spätmittelalterliche Skulptur und Malerei in der Mark Brandenburg*, *Forschungen und Beiträge zur Denkmalpflege im Land Brandenburg*. Worms: Wernersche Verlagsgesellschaft.

Knüvener, Peter. 2011b. *Mittelalterliche Kunst aus Berlin und Brandenburg im Stadtmuseum Berlin*. ed. Franziska Nentwig. Berlin: G+H Verlag.

Knüvener, Peter. 2015. *Die mittelalterlichen Kunstwerke des Johann-Friedrich-Danneil-Museums in Salzwedel: Sammlungskatalog*. Berlin: Hendrik Bäßler Verlag.

Kollandsrud, Kaja. 1994. Krusifiks fra Haug kirke. Undersøkelser og behandling. *Varia* 27.

Kollandsrud, Kaja. 2006. New light on the Virgin from Veldre, the Virgin from Østsinni and the crucifix from Tretten. In *Medieval painting in Northern Europe: techniques, analysis, art history*, eds. Jilleen M. Nadolny, Kaja Kollandsrud, Marie Louise Sauerberg and Tine Frøysaker, 76-90. London: Archetype Publications.

Kollandsrud, Kaja. 2018. "Evoking the Divine: The visual vocabulary of sacred polychrome wooden sculpture in Norway between 1100 and 1350." PhD, Department of Philosophy, Classics, History of Art and Ideas / Museum of Cultural History, University of Oslo.

Kopytoff, Igor. 1986. The cultural biography of things: commoditization as process. In *The social life of things*, ed. Arjun Appadurai, 64-91. Cambridge: Cambridge University Press.

Krohm, Hartmut, Uwe Albrecht, and Matthias Weniger. 2004. *Malerei und Skulptur des späten Mittelalters und der frühen Neuzeit in Norddeutschland : künstlerischer Austausch im Kulturraum zwischen Nordsee und Baltikum*. Wiesbaden: Dr. Ludwig Reichert Verlag.

Krohm, Hartmut, and Eike Oellermann. 1992. *Flügelaltäre des späten Mittelalters*. Berlin: Dietrich Reimer Verlag.

Kühlenthal, Michael, and Sadatoshi Miura, eds. 2004. *Historische Polychromie: Skulpturenfassung in Deutschland und Japan = Historical polychromy: polychrome sculpture in Germany and Japan*. München: Hirmer.

Lang, Janet, and Andrew Middleton. 2005. *Radiography of cultural material*. 2nd edition. Oxford: Elseview Butterworth-Heinemann.

Lappenberg, Johann Martin. 1866. Beiträge zur älteren Kunstgeschichte Hamburgs. *Zeitschrift des Vereines für Hamburgische Geschichte* 5: 224-366.

Laurie, Arthur Pillans. 1914. *The pigments and mediums of the Old Masters*. London: Macmillan.

Leigh, David, J. S. Altman, E. Black, A.-C. Brandt, Denis E. Cosgrove, Eric Doehne, E. Esteve-Coll, E.

Fiorentini, B. Goodey, C. Grimm, K. Krumbein, and Stefan Michalski. 1994. Group report: What are the responsibilities for cultural heritage and where do they lie? In *Durability and change: the science, responsibility, and cost of sustaining cultural heritage*, eds. Wolfgang E. Krumbein, Peter Brimblecombe, Denis E. Cosgrove and Sarah Staniforth, 269-286. Chichester: Wiley & Sons.

Leona, Marco. 2009. Microanalysis of organic pigments and glazes in polychrome works of art by surface-enhanced resonance Raman scattering. *Proceedings of the National Academy of Sciences of the United States of America* 106 (35): 14757-14762.

Lidén, Hans-Emil, Knut Berg, Peter Anker, Anne Wichstrøm, Marta Hoffmann, and Per Jonas Nordhagen. 1981. *Norges kunsthistorie: Høymiddelalder og Hansa-tid*. Vol. 2. Oslo: Gyldendal.

Lindemann, Steffen. 2016. *Holzskulpturen in Mecklenburg, von den Anfängen bis zur Mitte des 15. Jahrhunderts*. Schwerin: Heidberg.

Lluveras, Anna, Ilaria Bonaduce, Alessia Andreotti, and Maria Perla Colombini. 2010. GC/MS analytical procedure for the characterization of glycerolipids, natural waxes, terpenoid resins, proteinaceous and polysaccharide materials in the same paint microsample avoiding interferences from inorganic media. *Analytical chemistry* 82 (1): 376.

Lundanes, Elsa, Léon Reubsaet, and Tyge Greibrokk. 2014. *Chromatography: basic principles, sample preparations and related methods*. Weinheim: Wiley-VCH Verlag.

Malzbender, Tom, Dan Gelb, and Hans Wolters. 2001. Polynomial texture maps. *SIGGRAPH '01*: 519-528.

Mantler, Michael, and Manfred Schreiner. 2000. X-ray fluorescence spectrometry in art and archaeology. *X-Ray Spectrometry* 29 (1): 3-17.

Marshall, Yvonne, and Chris Gosden. 1999. The cultural biography of objects. *World Archaeology* 31 (2): 169-320.

Mazurek, Joy. 2010. Antibodies and art: characterization of albumen and gelatin on paper. *International Preservation News* 50: 17-20.

Mazurek, Joy, Marie Svoboda, Jeffrey Maish, Kazuki Kawahara, Takashi Fukakusa, and Yoko Taniguchi. 2014. Characterization of binding media in Egyptian Romano portraits using enzyme-linked immunosorbant assay and mass spectrometry. *e-Preservation Science* 11: 76-83.

McCrone, Walter. 1994. Polarized light microscopy in conservation: a personal perspective. *Journal of the American Institute for Conservation* 33 (2): 101-114.

McCrone, Walter, Lucy McCrone, and John Gustav Delly. 1995. *Polarized light microscopy*.

Chicago: McCrone Research Institute.

McGlinchey, Chris. 2012. Handheld XRF for the examination of paintings: proper use and limitations. In *Handheld XRF for art and archaeology*, eds. Aaron N. Shugar and Jennifer L. Mass, 130-158. Leuven: Leuven University Press.

Meeks, Nigel, Caroline Cartwright, Andrew Meek, and Aude Mongiatti, eds. 2012. *Historical technology, materials and conservation: SEM and microanalysis*. London: Archetype Publications.

Mills, John S. 1966. The gas chromatographic examination of paint media. Part I. Fatty acid composition and identification of dried oil films. *Studies in Conservation* 11 (2): 92-107.

Mills, John S., and Raymond White. 2006. *The organic chemistry of museum objects*. 2nd edition. Oxford: Butterworth Heinemann.

Moraht-Fromm, Anna, and Gerhard Weilandt. 2000. *Unter der Lupe: neue Forschungen zu Skulptur und Malerei des Hoch und Spätmittelalters: Festschrift für Hans Westhoff zum 60. Geburtstag*. Ulm: Süddeutsche Verlagsgesellschaft Jan Thorbecke Verlag.

Moreland, John. 1999. The world(s) of the cross. *World Archaeology* 31 (2): 194-213.

Morigi, Maria Pia, Franco Casali, Matteo Bettuzzi, Rosa Brancaccio, and V. D'Errico. 2010. Application of X-ray computed tomography to cultural heritage diagnostics. *Materials Science & Processing* 100 (3): 653-661.

Mudge, Mark, Tom Malzbender, Carla Shroer, and Marlin Lum. 2006. "New reflection transformation imaging methods for rock art and multiple-viewpoint display." VAST 2006: The 7th International Symposium on Virtual Reality, Archaeology and Intelligent Cultural Heritage, Nicosia, Cyprus, 2006.

Muñoz Viñas, Salvador. 2005. *Contemporary theory of conservation*. Oxford: Elsevier Butterworth-Heinemann.

Murphy, Douglas B., and Michael W. Davidson. 2013. *Fundamentals of light microscopy and electronic imaging*. 2nd edition. Hoboken: John Wiley & Sons, Inc.

Museum of Cultural History. 2018. "Saving Oseberg." Accessed 29.05.2018. http://www.khm.uio.no/english/research/projects/saving-oseberg/.

Myers, Fred, ed. 2001. *The empire of things: regimes of value and material culture*. Santa Fe: SAR Press.

National Center for Preservation Training and Technology. 2017. "Fiber reference image library." Accessed 08.08.2018. http://cameo.mfa.org/wiki/Fiber_Reference_Image_Library.

Newman, Sarah E. 2015. Applications of reflectance transformation imaging (RTI) to the study of bone surface modifications. *Journal of Archaeological Science* 53: 536-549.

Nipperdey, Thomas. 1990. *Deutsche Geschichte 1866-1918: Machtstaat vor der Demokratie*. Vol. 2. Munich: C. H. Beck.

Nordhagen, Per Jonas. 1994. Das Hanse-Problem in der norwegischen Kunstgeschichte. Der Zusammenbruch der Kunstproduktion in Norwegen im Spätmittelalter. In *Norwegen und die Hanse*, eds. Volker Henn and Arnved Nedkvitne. Frankfurt am Main: Peter Lang.

Nordqvist, Jørgen. 1997. Archaeological conservation and its consequences. *IIC Bulletin* (5): 1-8.

Oellermann, Eike. 2015. On the imitation of textile structures in late gothic polychromy and panel painting. In *Polychrome sculpture: meaning, form, conservation*, eds. Michele D. Marincola and Johannes Taubert, 54-63. Los Angeles: Getty Conservation Institute.

Olson, Roberta, Patricia Reilly, and Rupert Shepherd. 2006. *The biography of the object in late medieval and renaissance Italy*. Oxford: Blackwell Publishing.

Pavlidis, George, Anestis Koutsoudis, Fotis Arnaoutoglou, Vassilios Tsioukas, and Christodoulos Chamzas. 2007. Methods for 3D digitization of cultural heritage. *Journal of Cultural Heritage* 8 (1): 93-98.

Pawel, Daniela. 2014. The altarpiece from Vardø church, Finnmark: technological and art historical context. In *Paint and piety*, eds. Noëlle L. W. Streeton and Kaja Kollandsrud. London: Archetype.

Pearce, Susan M, ed. 1994a. *Interpreting objects and collections*, *Leicester readers in museum studies*. London: Routledge.

Pearce, Susan M. 1994b. Objects as meaning; or narrating the past. In *Interpreting objects and collections*, ed. Susan M. Pearce, 19-29. London: Routledge.

Peers, Laura. 1999. 'Many tender ties': the shifting contexts and meanings of the S BLACK bag. *World Archaeology* 31 (2): 288-302.

Pierce, Karisa, Jeremy Nadeau, and Robert Synovec. 2012. Data analysis methods. In *Gas chromatography*, ed. Colin F. Poole, 415-434. Oxford: Elsevier.

Plahter, Unn. 2004a. *Painted altar frontals of Norway 1250-1350: illustrations and drawings*. Vol. 3. London: Archetype.

Plahter, Unn. 2004b. *Painted altar frontals of Norway 1250-1350: materials and technique*. Vol. 2. London: Archetype.

Plesters, Joyce. 1954. The preparation and study of paint cross-sections. *The Museums Journal* 54: 97-101.

Plesters, Joyce. 1956. Cross-sections and chemical analysis of paint samples. *Studies in Conservation* 2 (3): 110-157.

Pollard, Mark, Catherine Batt, Ben Stern, and Suzanne Young. 2007. *Analytical chemistry in archaeology*, *Cambridge manuals in archaeology*. Cambridge: Cambridge University Press.

Poole, Colin F. 2012. *Gas chromatography*. 1st edition, *Handbooks in Separation Science*. Oxford: Elsevier.

Porter, Samantha T., Nadine Huber, Christian Hoyer, and Harald Floss. 2016. Portable and low-cost solutions to the imaging of Paleolithic art objects: a comparison of photogrammetry and reflectance transformation imaging. *Journal of Archaeological Science: Reports* 10: 859-863.

Porter, Samantha T., Morgan B. Roussel, and Marie Soressi. 2016. A simple photogrammetry rig for the reliable creation of 3D artifact models in the field. Lithic examples from the early upper Paleolithic sequence of Les Cottés (France). *Advances in Archaeological Practice* 4 (1): 71-86.

Pouyet, Emeline. 2014. "New methods for the preparation and analyses of paint samples from cultural heritage artifacts with combined hyperspectral techniques." PhD, Materials Science, Université de Grenoble.

Preuss, Peter, Kjeld Christensen, and Kurt Peters. 1991. The use of computer-tomographical X-ray scanning in dendrochronology. *Norwegian Archaeological Review* 24 (2): 123-130.

Price, T. Douglas, and James H. Burton. 2011. *An introduction to archaeological chemistry*. New York: Springer.

Prown, Jules David. 1982. Mind in matter: an introduction to material culture theory and method. *Winterthur Portfolio* 17 (1): 1-19.

Prown, Jules David. 2001. *Art as evidence: writings on art and material culture*. New Haven: Yale University Press.

Pye, Elisabeth. 2001. *Caring for the past: issues in conservation for archaeology and museums*. London: James & James.

Raehlmann, Eduard. 1910. Über die Maltechnik der Alten, mit besonderer Berücksichtigung der römisch-pompejanischen Wandmalerei, nebst einer Anleitung zur mikroskopischen Untersuchung der Kunstwerke. Berlin: Georg Reimer.

Rasche, Anja. 2013. *Studien zu Hermen Rode*. Petersberg: Michael Imhof Verlag.

Reimers, P., J. Riederer, J. Goebbels, and A. Kettschau. 1989. Dendrochronology by means of X-ray computed tomography (CT). In *Archaeometry: proceedings of the 25th international symposium*, ed. Y. Maniatis, 121-125. Amsterdam: Elsevier.

Reinhard, Wolfgang. 2004. *Probleme deutscher Geschichte 1495-1806: Reichsreform und Reformation 1495-1555*. ed. Bruno Gebhardt. 10th edition. Vol. 9, *Handbuch der deutschen Geschichte*. Stuttgart: Klett-Cotta.

Rief, Michael. 2011. "…dem maler, von dem brustbild ze malen am hirtzenhorn in der ratstuben…". Technologische Aspekte der Geweihleuchter. In *Artefakt und Naturwunder - Das Leuchterweibchen der Sammlung Ludwig. Katalog einer Ausstellung in der Ludwiggalerie Schloss Oberhausen 6. Februar bis 17. April 2011*, eds. Christine Vogt, Dagmar Preising and Michael Rief. Bielefeld: Kerber Verlag.

Riggins, Stephen Harold, ed. 1994. *The socialness of things: essays on the socio-semiotics of objects*. Berlin: Mouton de Gruyter.

Rochow, Theodore George, and Eugene George Rochow. 1978. *An introduction to microscopy by means of light, electrons, X-rays, or ultrasound*. New York: Plenum Press.

Rüdinger, Otto, ed. 1874. *Die ältesten Hamburgischen Zunftrollen und Brüderschaftsstatuten*. Hamburg: Lucas Gräfe.

Saunders, Nicholasj. 1999. Biographies of brilliance: pearls, transformations of matter and being, c. AD 1492. *World Archaeology* 31 (2): 243-257.

Schilling, Michael R. 1990. Analysis of drying oils by gas chromatography-mass spectrometry. *WAAC Annual Meeting*.

Schilling, Michael R. 2005. Paint media analysis. In *(Sackler NAS colloquium) Scientific examination of art: modern techniques in conservation and analysis*, ed. National Academy of Sciences, 186-205. Washington DC: The National Academies Press.

Schilling, Michael R., and Herant P. Khanjian. 1996a. Gas chromatographic analysis of amino acids as ethyl chloroformate derivatives. III. Identification of proteinaceous binding media by interpretation of amino acid composition data. In *ICOM-CC 11th Triennial Meeting Preprints, Edinburgh, 1-6 September 1996*, ed. Janet Bridgeland, 211-219. London: James and James.

Schilling, Michael R., and Herant P. Khanjian. 1996b. Gas chromatographic analysis of amino acids as ethyl chloroformate derivatives. Part 2, effects of pigments and accelerated aging on the identification of proteinaceous binding media. *Journal of the American Institute for Conservation* 35 (2): 123-144.

Schilling, Michael R., Herant P. Khanjian, and Louis Souza. 1996. Gas chromatographic analysis of amino acids as ethyl chloroformate derivatives I. Composition of proteins associated with objects of art and monuments. *Journal of the American Institute for Conservation* 35: 45-59.

Schreiner, Manfred, Bernadette Frühmann, Dubravka Jembrih-Simbürger, and R Linke. 2004. X-rays in art and archaeology: an overview. *Powder Diffraction* 19 (1): 3-11.

Schreiner, Manfred, Michael Melcher, and Katharina Uhlir. 2007. Scanning electron microscopy and energy dispersive analysis: applications in the field of cultural heritage. *Analytical and Bioanalytical Chemistry* 387 (3): 737-747.

Schrumpf, Fredrikke. 1999. "Senmiddelalderens treskulptur i Norge: Eivind S. Engelstads verk fra 1936, i et nytt lys." Hovedoppgave i kunsthistorie, Universitetet i Bergen.

Selzer, Stephan. 2010. *Die mittelalterliche Hanse*, *Geschichte kompakt*. Darmstadt: Wissenschaftliche Buchgesellschaft.

Seymour, Kate, ed. 2014a. "Polychrome sculpture: artistic tradition and construction techniques." Polychrome sculpture: artistic tradition and construction techniques. Proceedings ICOM-CC Interim Meeting, Working Group Sculpture, Polychromy, and Architectural Decoration, Glasgow 13-14, April 2012.

Seymour, Kate, ed. 2014b. "Polychrome sculpture: tool marks and construction techniques." Polychrome sculpture: tool marks and construction techniques. ICOM-CC Interim Meeting, Working Group Sculpture, Polychromy, and Architectural Decoration, Maastricht 24-25 October 2010.

Seymour, Kate, and Stefanie Litjens, eds. 2017. "Polychrome sculpture: decorative practice and artistic tradition." Polychrome sculpture: decorative practice and artistic tradition. ICOM-CC Interim Meeting, Working Group Sculpture, Polychromy, and Architectural Decoration, Tomar, 28-29 May, 2013.

Shanks, Michael. 1998. The life of an artifact in an interpretive archaeology. *Fennoscandia archaeologica* 15: 15-30.

Shugar, Aaron N., and Jennifer L. Mass, eds. 2012. *Handheld XRF for art and archaeology*. Vol. 3, *Studies in archaeological sciences*. Leuven: Leuven University Press.

Shugar, Aaron N., and P. Jane Sirois. 2012. Handheld XRF use in the identification of heavy metal pesticides in ethnographic collections. In *Handheld XRF for Art and Archaeology*, eds. Aaron N. Shugar and Jennifer L. Mass, 313-348. Leuven: Leuven University Press.

Smithsonian Institution. "About Smithsonian X 3D." Smithsonian Digitization Program Office, Accessed 29.05.2018. https://3d.si.edu/about.

Sobczyk, Joanna, Piotr FrAczek, MichaA Obarzanowski, Julio M. Hoyo-Melendez, and Aukasz Bratasz. 2014. Digital radiography (DR) and imaging analysis for evaluating the penetration and distribution of organic substances used in wood conservation. *Wood Science and Technology* 48 (5): 981.

Spiller, Wilfried. 1972. *Restaurierungsbericht*. Schwerin: Institut für Denkmalpflege.

Staniforth, Sarah, M. W. Ballard, E. N. Caner-Saltik, Rainer Drewello, I.-L. Eckmann, Wolfgang E. Krumbein, T. Padfield, M. M. Reddy, M. Schuller, S. Simon, L. Slavoshevskaya, N. H. Tennent, and W. Wolters. 1994. Group report: What are the appropriate strategies to evaluate change and to sustain cultural heritage? In *Durability and change: The science, responsibility, and cost of sustaining cultural heritage*, eds. Wolfgang E. Krumbein, Peter Brimblecombe, Daniel E. Cosgrove and Sarah Staniforth, 217-224. Chichester: Wiley & Sons.

Stelzner, Jörg, and Sebastian Million. 2015. X-ray computed tomography for the anatomical and dendrochronological analysis of archaeological wood. *Journal of Archaeological Science* 55: 188.

Streeton, Noëlle L. W. 2013. After the black death: painting and polychrome sculpture in Norway, 1350-1550. Norwegian Research Council.

Streeton, Noëlle L. W. 2017a. Decoding damages to late-medieval cult sculpture from Norwegian churches. In *ICOM-CC 18th Triennial Conference Preprints, Copenhagen, 4-8 September 2017*, ed. Janet Bridgeland, article 1708. Paris: International Council of Museums.

Streeton, Noëlle L. W. 2017b. Writing histories for late-medieval objects: the engagement of conservation with theoretical perspectives on material culture. *Studies in Conservation* 62 (7): 419-431.

Streeton, Noëlle L. W. 2018. Perspectives (old and new) on late medieval church art in Norway: questioning the hegemony of Lübeck workshops. *Scandinavian Studies* 90 (1): 50-77.

Summers, David. 1994. On the histories of artifacts (a range of critical perspectives) (the subject in/of art history). *The Art Bulletin* 76 (4): 590-592.

Suomela, Jenni A., Krista Vajanto, and Riikka Räisänen. 2017. Seeking nettle textiles – utilizing a combination of microscopic methods for fibre identification. *Studies in Conservation*: 1-11.

Taubert, Johannes. 1978. *Farbige Skulpturen: Bedeutung, Fassung, Restaurierung*. München: Callwey.

Taubert, Johannes, and Michele D. Marincola, eds. 2015. *Polychrome sculpture: meaning, form, conservation*. Los Angeles: Getty Conservation Institute.

Thiel, Bradley L. 2006. Imaging and microanalysis in environmental scanning electron microscopy. *Micro and Trace Analysis* 155 (1): 39-44.

Tilley, Christopher. 2007. Materiality in materials. *Archaeological Dialogues* 14 (1): 16-20.

Trentelman, Karen, Catherine Schmidt Patterson, and Nancy Turner. 2012. XRF analysis of manuscript illuminations. In *Handheld XRF for art and archaeology*, ed. A. Shugar and Jennifer L. Mass, 159-189. Leuven: Leuven University Press.

Trinkert, Julia. 2014. *Flügelretabel in Mecklenburg zwischen 1480 und 1540: Bestand, Verbreitung und Werkstattzusammenhänge*. Vol. 120, *Studien zur internationalen Architektur- und Kunstgeschichte*. Petersberg: Imhof.

Tythacott, Louise. 2011. *The lives of Chinese objects: Buddhism, imperialism and display*. Vol. 3, *Museums and collections*. New York: Berghahn.

Tångeberg, Peter. 1986. *Mittelalterliche Holzskulpturen und Altarschrein in Schweden: Studien zu Form, Material und Technik*. Stockholm: Almqvist & Wiksell International.

Tångeberg, Peter. 1993. *Das "Schöne Kruzifix" in Vadstena und Nussbaumholzskulpturen aus dem Deutschordensland*. Vol. 75, *Antikvariskt arkiv*. Stockholm: Kungl. vitterhets historie och antikvitets akademien.

Tångeberg, Peter. 2005. *Retabel und Altarschreine des 14. Jahrhunderts: Schwedische Altarausstattungen in ihrem europäischen Kontext*. Stockholm: Kungl. Vitterhets historie och antikvitets akademien.

Ulmann, Arnulf von. 1984. *Bildhauertechnik des Spätmittelalters und der Frührenaissance*. Darmstadt: Wissenschaftliche Buchgesellschaft.

Ulmann, Arnulf von. 1993. Über die Qualitätsbestimmung im Holzhandel. Ein Beitrag zur Materialgeschichte des ausgehenden Mittelalters. In *Sculptures médiévales allemandes: conservation et restauration*, ed. Sophie Guillot de Suduiraut, 225-232. Paris: La Documentation française.

United Kingdom Institute of Conservation. 1996. "Code of Ethics and Rules of Practice." Accessed 16.05.2018. https://icon.org.uk/what-is-conservation/resources.

van Mensch, Peter. 1990. Methodological museology; or, towards a theory of museum practice. In *Objects of Knowledge*, ed. Susan M. Pearce, 141-157. London: The Athlone Press.

van Saaze, Vivian. 2013. *Installation art and the museum: presentation and conservation of changing artworks*. Amsterdam: Amsterdam University Press.

von Achen, Henrik. 1994. Hanseatic art in late medieval Bergen. Import or local production? In *Bergen and the German Hansa*, ed. Ingvild Øye, 59-85. Bergen: Bryggens museum.

Voss, Johannes. 2004. Die Stralsunder Junge-Madonna: Ein Beitrag zur Entstehung des Retabels und zur Werkstoffgeschichte in Nordostdeutschland im 15. Jahrhundert. In *Malerei* *und Skulptur des späten Mittelalters und der frühen Neuzeit in Norddeutschland: Künstlerischer Austausch im Kulturraum zwischen Nordsee und Baltikum*, eds. Hartmut Krohm, Uwe Albrecht and Matthias Weniger, 68-88. Wiesbaden: Dr. Ludwig Reichert Verlag.

Wachowiak, Melvin J. 2004. Efficient new methods for embedding paint and varnish samples for microscopy. *Journal of the American Institute for Conservation* 43 (3): 205-226.

Wachowiak, Melvin J., and Basiliki Vicky Karas. 2009. 3D scanning and replication for museum and cultural heritage applications. *Journal of the American Institute for Conservation* 48 (2): 141-158.

Wagner, Kathrin. 2011. *Rostocker Retabelkunst im 15. Jahrhundert*. Kiel: Verlag Ludwig.

Wainwright, Ian N. M. 1990. Examination of paintings by physical and chemical methods. In *Shared responsibility: proceedings of a seminar for curators and conservators, National Gallery of Canada, Ottawa, Canada, 26, 27 and 28 October 1989*, eds. Barbara A. Ramsay-Jolicoeur, Ian N. M. Wainwright and National Gallery of Canada, 79-102. National Gallery of Canada.

Wallraf Richartz Museum, Fondation Corboud, and Doerner Institut der Bayerischen Staatsgemäldesammlungen. 2014. *Let the material talk: technology of late-medieval Cologne panel painting*, *Die Sprache des Materials*. London: Archetype.

Wazny, Tomasz. 2002. Baltic timber in Western Europe - an exciting dendrochronological question. *Dendrochronologia* 20 (3): 313-320.

Wehrmann, Carl Friedrich, ed. 1864. *Die älteren lübeckischen Zunftrollen*. Lübeck: F. Asschenfeldt.

White, Raymond, and Jo Kirby. 2006. Some observations on the binder and dyestuff of glaze paints in early European panel paintings. In *Medieval painting in Northern Europe: techniques, analysis, art history*, eds. Jilleen M. Nadolny, Kaja Kollandsrud, Marie Louise Sauerberg and Tine Frøysaker, 215-222. London: Archetype.

Whitley, James. 2002. Objects with attitude: biographical facts and fallacies in the study of late Bronze Age and early Iron Age warrior graves. *Cambridge Archaeological Journal* 12 (2): 217-232.

Wicker, Nancy L. 1999. Archaeology and art history: common ground for the new millennium. *Medieval Archaeology* 43 (1): 161-171.

Williams, Howard, Joanne Kirton, and Meggen Gondek. 2015. *Early medieval stone monuments: materiality, biography, landscape*, *Boydell Studies in Medieval Art and Architecture*. Woodbridge: The Boydell Press.

Wubs-Mrozewicz, Justyna. 2013. The Hanse in medieval an early modern Europe: an introduction. In *The Hanse in medieval and early modern Europe*, 1-35. Leiden: Brill.

Yonan, Michael. 2011. Toward a fusion of art history and material culture studies. *West 86th* 18 (2): 232-248.

Image overleaf:

Karlsøy St Sunniva and St Mary Magdalen

Photograph © Museum of Cultural History

PAPER I

Paper I

A skewed balance? Examining the display and research history of the medieval collection at the Museum of Cultural History, University of Oslo

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Paper II

Composite wainscot block construction in medieval sculptures: a question of quality?

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ICOM-CC
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SCULPTURE, POLYCHROMY, AND ARCHITECTURAL DECORATIONS

Composite wainscot block construction in medieval sculptures: A question of quality?

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KEYWORDS: late-medieval polychrome sculpture, construction techniques, wainscot, composite block, quality

ABSTRACT

In this contribution, a late-medieval technique for constructing polychrome wooden sculptures is discussed. This rare 'composite block' method employed blocks made from wainscot boards glued together. The technique is compared to the more common method of carving a solid block cut from a tree trunk, followed by hollowing out of the block to reduce the risk of cracking and splitting. The composite block technique is not widely known and has not yet been comprehensively studied. It merits further attention because it reveals the medieval carver's advanced technical skills, in-depth material knowledge and concern for quality. Development of the construction technique during the 15th century in Northern Europe is explored by means of a case study of one such sculpture from the Museum of Cultural History, Norway. Northern German, northern Netherlandish and Florentine composite block techniques are examined, pointing to parallels within art production both north and south of the Alps.

INTRODUCTION

Composite block sculptures have been described by a small number of researchers in Sweden, Germany, the Netherlands and Belgium (Rief 1998, Knüvener 2011 and 2015). The technique appears to have emerged around 1400, and interestingly has been observed across Europe. The presence of a group of similarly constructed sculptures in Florence in particular negates the divide often seen to exist between Northern European medieval art and early Renaissance Italian art.

The composite block is essentially a simple laminated wooden structure, and can be loosely compared to glued laminated timber (glulam) used in structural engineering, a material known for its inherent stability and strength (USDA 2010). Such composite block sculptures are characterised by high structural stability and generally consist of two, occasionally three or more wainscot boards glued together. The technique differs from block construction out of separate smaller pieces of wood, such as the sculptures from the high medieval period in Sweden described by Tångeberg (1986). Similarly, it differs from the addition of smaller pieces of wood to a single block due to the need for sculptural features extending outside the log dimensions. Instead, the composite block technique points to medieval woodworkers having a high level of material awareness and utilising their intimate knowledge of the material to create high-quality sculptures of optimum stability.

CASE STUDY

The late medieval sculpture of the *Virgin and Child with Saint Anne* (hereafter called *St Anne*), stylistically dated to the 1470s (Engelstad 1936, 55), is likely to have been imported from northern Germany to Norway (Figure 1). It was originally located in the remote church of Berg on Senja Island, Troms county, northern Norway, and entered the collection of the Museum of Cultural History (MCH), University of Oslo in 1862, together with an ambry and two other sculptures from the church.

The sculpture is constructed out of three wainscot boards, measuring 26 centimetres in width and ranging between 4 and 5 centimetres in thickness. The boards were glued together so that the top face of one was glued to the back face of the next, with grain direction aligned and parallel to the height of the sculpture. The gluing of the joins is so precise that the construction technique was not noticed during conservation treatment in the 1970s (Lindberg 1976). The sculpture has not been hollowed out on the back, something that was usually undertaken in order to reduce the

Table 1. Selection of known sculptures with composite block construction (Tångeberg 1986; Vereecke and Deveseleer 1995; Rief 1998; Olstad 2008, 2003, 2002; Knüvener 2011; Preising 2013; Preising and Rief 2013; Rief 2014, 2013; Knüvener 2015)

Sculpture	Provenance*	Date	Size+	Construction	Workshop
St Anne	Berg church, Senja, Troms, Norway	1470s–80s (d)	58 h 26.3 w 3.6 d	Three radial cut Baltic oak boards, wainscot, canvas patches	Northern Germany
St Anne	Schmolde, Prignitz, Germany	1480–90 (d)	45 h 19.5 w 9 d	Two Baltic oak boards, wainscot, canvas patches, large hole in base	Northern Germany
Four sculptures from an altarpiece: Sts Peter, Paul, John, Virgin	Järstad, Östergötland, Sweden	1410–30s (s)	49 h 15 w 7.5 d	Two radial cut oak boards, canvas and parchment patches, large hole in base	Northern Germany
12 apostles	Salzwedel Marienkirche, Germany	1420 (s)	44.5 h 14 w 10 d	Two radial cut oak boards, large hole in base	Northern Germany
Altarpiece (10 saints, two larger scenes)	Bodo, Dalarna, Sweden	1430s (s)	44 h	Two oak boards	Northern Germany
Apostle	Gothem, Gotland, Sweden	1450–1500 (s)	71 h	Two oak boards	Northern Germany
Three sculptures from an altarpiece: Virgin, St Olaf, St Michael	Leka church, Nord-Trøndelag, Norway	early 1500s (s)	62 h 28 w 15 d	Two radial cut oak boards	Utrecht, Netherlands
Three sculptures from an altarpiece: St Olaf and two bishops	Røst church, Nordland, Norway	early 1500s (s)	64 h 23 w 14 d	Two radial cut oak boards	Utrecht, Netherlands
Three sculptures from an altarpiece: Virgin, St Olaf, St Margaret	Grip church, Møre and Romsdal, Norway	1520–30 (s)	86 h 35 w 13 d	Radial cut oak, two boards for two sculptures, three boards for central sculpture	Utrecht, Netherlands
Three sculptures from an altarpiece: Virgin, St Stephen, St Catherine	Hadsel church, Nordland, Norway	1470s (d)	98.5 h 33 w 9.5 d	Three, four and five radial cut oak boards, (two widened with blocks glued to side), nails, canvas patches	Utrecht, Netherlands
Two sculptures from an altarpiece: Virgin and St John	Ørsta church, Møre and Romsdal, Norway	1520 (d)	c. 50 h	Two radial cut oak boards	Utrecht, Netherlands
St Dorothy	Suermont-Ludwig Museum (SLM), Aachen, Germany	1520–30 (d)	89 h 32 w 21 d	Four oak boards, three radial and one tangential cut, nails	Utrecht, Netherlands
St Mary Magdalen	Unna, Münster, Germany	1520–30 (s)	112 h 38 w 28 d	Five oak boards, nails and canvas patches	Utrecht, Netherlands
Female saint with book	Krakow National Museum, Poland	early 1500s (s)	86 h 35 w 23 d	Four oak boards, two inner radial cut, outer tangential cut, wooden nails through all boards via pre-drilled holes	Utrecht, Netherlands
Virgin and child on crescent moon	Catherine convent museum, Utrecht, Netherlands	1525–30 (s)	47 h 21.5 w 10 d	Two oak boards and one additional piece, nailed	Utrecht, Netherlands
St Anthony	SLM, Aachen, Germany	1520s (d)	57.5 h 66.5 w 21 d	Six Baltic oak boards, wainscot	Northern Netherlands
Virgin and child on crescent moon	SLM, Aachen, Germany	1510–50 (d)	58 h 24 w 12.5 d	Two radial cut Baltic oak boards, wainscot	Netherlands
Virgin and child	SLM, Aachen, Germany	1500 (d)	57 h 22 w 14 d	Two radial cut Baltic oak boards, wainscot	Netherlands
St Mary Magdalen	Rijksmuseum, Amsterdam	1520s (s)	64 h	Two oak boards	Brussels
St George and the dragon	Rijksmuseum, Amsterdam	early 1500s	52 h	Two oak boards	Mechelen
Virgin and child	Rijksmuseum, Amsterdam	early 1500s	39.5 h	Two oak boards	Antwerp, Brabant
Carved leaf pattern pedestal from an altarpiece	SLM, Aachen, Germany	1530–40 (d)	21 h 22 w 14.5 d	Three Baltic oak boards	Antwerp, Brabant
St Anne	Private collection, Netherlands	1510–20 (s)	95 h	Six oak boards	Antwerp, Brabant
St Gertrude and two lost male saints (same height)	SLM, Aachen, Germany	1470–80 (d)	76 h 32 w 20.5 d	Three radial cut Baltic oak boards, wainscot, nails	Antwerp, Brabant
Saints Anthony, Cornelius, Hubert and Quirnius	St Irmgardis chapel, Süchteln am Niederrhein, Germany	1520s (s)	62 h	Two oak boards	Antwerp, Brabant
Christ the Saviour	Monastery of Maria zum Frieden, Köln, Germany	1520s (s)	87 h	Several oak boards	Antwerp, Brabant
St Peter enthroned	SLM, Aachen, Germany	circa 1500 (d)	46.5 h 25.5 w 16.5 d	Three radial cut Baltic oak boards, wainscot	Brabant
Virgin and child	St Vincent of Soignies church, Belgium	circa 1500 (s)	106 h 35 w 25 d	Three oak boards attached to oak base with nails, central board hollowed out	Brabant
St John Evangelist	St Genevieve church, Oplinter, Belgium	late 1400s (s)	86 h	Three oak boards	Brabant
St Catherine	Breda Museum, Brabant	1500–25 (s)	61 h 25 w 14 d	Two oak boards	Brabant

* Where known, the previous location of sculptures is listed instead of the museum where they are currently located
+Size in cm (height × width × depth). Where sizes of sculptures within one altarpiece vary, the largest dimensions are given.

h = height   w = width   d = depth   (d) = dendrochronology dating   (s) = stylistic dating effects of cracking, as green wood dries over time. The boards must have been fully seasoned when glued, since gluing requires a low moisture content to be successful and long-lasting (USDA 2010).

Figure 1. *Virgin and Child with Saint Anne* (58 × 26.3 × 13.6 cm), Museum of Cultural History, University of Oslo

Norwegian art historian Eivind Engelstad linked the *St Anne* to one other sculpture from Berg church, a standing male saint identified as a *Bishop*, suggesting that they had previously belonged to the same altarpiece (Engelstad 1936) (Figure 2). However, the sculptures' material construction differs significantly, and technical investigations have resulted in a rejection of this hypothesis.[1] The *Bishop* is carved out of one piece of oak, with an additional narrow vertical section of wood added along the proper left side. The base consists of a separate piece of wood, and the back has been hollowed out. The *Bishop* sculpture is therefore not considered to have any relation to the subject of this paper.

Figure 2. *Bishop* (63 × 22 × 13.5 cm), Museum of Cultural History, University of Oslo

Photogrammetry was used to better illustrate the three-dimensional nature of the sculpture of *St Anne* (Figure 3). The 3D model was generated using Agisoft PhotoScan and uploaded to Sketchfab, where it can be viewed and rotated to gain a clearer understanding of the sculpture's construction.

Figure 3. 3D model of *St Anne:* https://skfb.ly/66O9w

CONSTRUCTION METHOD

The timber used to construct the *St Anne* sculpture would have been split radially from the pith with an axe, resulting in slightly wedge-shaped boards (Tångeberg 2000). The resulting radial cut of wood is, given the anisotropic behaviour of wood, dimensionally the most stable in terms of moisture response. Such boards are also known as wainscot, a term originating from the Low German term *Wagenschott*, referring to oak boards of a particular size cut radially by splitting (Grimm and Grimm 1854–1961). The dimensions of the *St Anne* and other composite sculptures generally fall within the dimensions of standard wainscot board sizes. These would not have exceeded 40 cm, given that they were split radially from trees with a 90-cm diameter (Ulmann 1993, 227; Rief 2005, 133). Apart from a few exceptions, such as the Hadsel composite group where two sculptures were widened with additional boards glued to either side (Olstad 2008), the width of the board is usually the limiting factor, resulting in medium-sized sculptures with a width of between 15 to 30 cm (Table 1).

The majority of workshops were generally not allowed to have their own wood store, and had to order sufficient wood once a commission was in place (Ulmann 1993, 226). Hence, the use of composite blocks cannot be attributed solely to a thrifty sculptor making do with what is left lying around the workshop and gluing leftover boards together to form a single block, although some such instances have also been identified by Rief (Oellers, Preising, and Schneider 1998, 59–62). Instead, it points to the purposeful purchase of high-quality imported wainscot for sculpture construction.

The boards are likely to have been planed prior to gluing in alternate growth ring directions, given the almost perfect join seen in the CT scan of the *St Anne* (Figure 4). A fine line of parallel marks on the base of the sculpture, seen on the front board only, can possibly be attributed to a workbench used to hold the timber in place during planing (Figure 5). These marks are different from the usual holes visible in the centre of the base, which are more likely to relate to the workbench used for carving. Saw marks on the base could indicate cutting of the excess from the glued boards, especially since the saw marks extend over the edges of the joins and outer boundaries of the sculpture. Enhanced visualisation of the tool marks was achieved with reflectance transformation imaging (RTI).

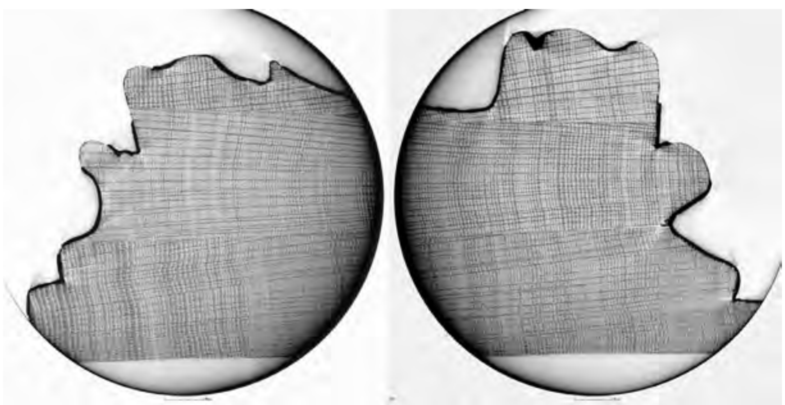

Figure 4. CT scans depicting virtual sections through *St Anne*

Figure 5. RTI still of the base of *St Anne*, showing tool and workbench marks, as well as board dimensions

The glue used to join the boards was analysed using gas chromatography/mass spectrometry (GC/MS) to identify whether animal glue or casein was used. Given the higher water resistance of casein lime glue over animal glue (Bye 1990, 145), it might be expected that material with improved moisture resistance was used for a sculpture destined for travel to Norway by sea. A two-step method was employed by Joy Mazurek at the Getty Conservation Institute, which involved initial quantification of oils, waxes and resins, followed by amino acid quantification and protein identification on the same sample (Schilling, Khanjian, and Souza 1996, Schilling 2005). The identification of proteins was accomplished by comparing the amino acids in the sample to those of standard reference materials using correlation coefficients, where a perfect match is a correlation coefficient of 1.0. Animal glue was identified in the sample based on a correlation coefficient of 0.999. This is interesting, given that both Cennino Cennini and Theophilus Presbyter suggest that casein was preferentially used when gluing wood, due to its greater strength and water resistance compared to animal glue. Cennini introduces his chapter on the preparation of casein glue by stating that ‘it is a glue used by workers in wood’ (Cennini and Thompson 1954, 68), while Theophilus indicates that casein is used to glue wooden panels together (Brepohl 1999, 64).

DENDROCHRONOLOGY

Non-invasive dendrochronology was undertaken by Aoife Daly. The sculptures were scanned at the Norwegian Geotechnical Institute using a Nikon Metrology XT H 225 LC industrial type computer tomography (CT) scanner with micron resolution. Using this method, over 3,000 x-rays are taken while the sculpture is rotated, and the resulting x-ray images are then compiled into a three-dimensional model that allows virtual cross sections (CT scans) of the sculpture to be viewed (Figure 4). As a result, tree rings can be measured non-destructively by CT scans (Bill et al. 2012, Daly 2016).

The three oak boards used in the construction of the *St Anne* were identified as timber from the Southern Baltic region based on tree-ring curve correlations with identified chronological standards (Daly 2016). The presence of sapwood on the back board provides an estimated felling date of 1471–85, while the other two boards covered tree-ring curves up to the years 1415 and 1422, indicating that they were felled after 1425 and 1432, respectively. Assuming that the three trees used for the boards were felled at a similar time (1471–85), the sculpture can be dated to the latter part of the 15th century (1471–1500), as the boards are likely to have been seasoned prior to use.

STRUCTURAL REINFORCEMENT

Often, canvas patches or parchment would be employed to cover board joins visible after carving was completed. A group of four composite sculptures examined in Sweden at the Historiska Museum, originally from Järstad, had both canvas and parchment covering some wooden joins. In the case of the *St Anne*, flax fibres were identified using polarised light microscopy (PLM), suggesting that linen canvas was used.

Investigation of the *St Anne* with x–radiography revealed the absence of any structural reinforcement, such as dowels and nails (Figure 6), as well as the straightness of the grain. Known composite block sculptures in northern Germany and Sweden date from the 15th century and usually do not incorporate any additional structural reinforcement other than the glued joins (Knüvener 2011 and 2015). However, composite sculptures thought to originate from the Netherlands are dated somewhat later, to around 1500 or the first part of the 16th century, in addition to often having metal or wooden nails for securing the boards together (Table 1) (Vereecke and Deveseleer 1995, Rief 1998, Olstad 2008, Preising 2013, Rief 2013 and 2014).

THE ITALIAN CONNECTION

An interesting point worth noting is the existence of the composite block technique in Florence from the second half of the 15th century to the 1520s (Stiberc 1989 and 2014). What, then, is to be made of this Italian technique?

Researchers in Florence have investigated a group of composite block sculptures that are constructed from boards in a remarkably similar manner to those from north of the Alps during this period (Stiberc 1989, Fidanza 2010 and 2011, Stiberc 2014). It would appear that during the first half of the 15th century, most sculptors working in Florence carved from solid wooden blocks, which often resulted in cracking and splitting. Given that they were less conversant with woodworking techniques and had greater familiarity with stone as a medium, they worked much like stone carvers would, steadily working the shape out of the block in relief (Ulmann 1984). To reduce the occurrence of splitting, blocks would be hollowed out in the same manner as previously described for the *Bishop* sculpture. However, greater emphasis was being placed on carving the human form, particularly nudes, in three dimensions rather than just frontally. Hollowing out in such cases is not ideal as it detracts from the three-dimensional nature of the sculpture. From the 1480s in Florence, it would appear that the composite block technique developed as a way to counteract this. In addition, sculptors working in the latter part of the 15th century were typically woodworkers by background rather than mainly stone masons, resulting in better awareness of wood technology. While these Italian composite block sculptures are not made from wainscot but from wood common to the region, such as linden or poplar, and there is as yet no evidence of a preference for radial cut boards, the use of dry boards glued together suggests a desire to take advantage of the properties of seasoned wood.

Figure 6. X-ray image of *St Anne*

Figure 7. Map showing regional distribution of known Netherlandish (blue) and northern German (orange) composite block sculptures

DISCUSSION

Rief (1998 and 2013) has previously discussed composite block sculptures originating from Utrecht, and suggests they would have been manufactured in workshops in coastal vicinities due to the use of wainscot, which would have been imported from the Baltic region. Rief argues that composite block sculptures were manufactured as export art, due to their superior stability over standard single block sculptures, which were more likely to respond to climactic changes. This could certainly apply to Netherlandish sculptures in Norway linked to the Utrecht workshop, as well as some northern German altarpieces in Sweden (Tångeberg 1986, Olstad 2002, Rief 2013), and the *St Anne* sculpture. However, why are there not significantly more imported sculptures in Norway and Sweden that are constructed in this manner? Similarly, the argument that they were manufactured for export cannot be used as an explanation for the existence of numerous sculptures with composite block construction in the Netherlands, the Low Countries and northern Germany, in the vicinity of their likely places of origin (Table 1). Nevertheless, by mapping known Netherlandish and northern German composite block sculptures, trade networks based around the North Sea and Baltic Sea, respectively, can be visualised (Figure 7).

Whether the use of the composite block technique developed independently in Florence, or whether a journeyman from Northern Europe led to its spread is of little consequence. What can be demonstrated is that there was an increased awareness of the properties of wood as a carving material, and that its inherent properties were being exploited by sculptors working in different regions of Europe during the 15th and early 16th centuries. The reasons behind the sculptor's choice of the more expensive and difficult composite block technique as yet evades thorough explanation and warrants further investigation.

CONCLUSION

Addressing a little known subject, this paper outlines a construction technique occasionally found in medieval sculpture from the 1400s. The composite block method of construction using wainscot boards highlights the medieval sculptor's extensive level of material awareness. While not as common as construction techniques involving a single tree trunk or several parts thereof, composite block sculptures have been identified in numerous European countries. Examples such as the *St Anne* sculpture are generally structurally stable and exhibit few cracks. As a result, the preconceived idea of single-block construction being indicative of high quality is yet again challenged (Rief 1998, 77). In addition, the use of boards in composite block construction has been observed in a number of sculptures in both Southern and Northern Europe, thereby contradicting the myth of a North/South divide in medieval European art.

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NOTES

[1] The research underlying this comparative study of the *St Anne* and *Bishop* sculptures will be published within the course of 2017.

REFERENCES

BILL, J., A. DALY, O. JOHNSEN, and K.S. DALEN. 2012. DendroCT – Dendrochronology without damage. *Dendrochronologia* 30 (3): 223–30 (doi: 10.1016/j.dendro.2011.11.002).

BREPOHL, E. 1999. *Theophilus Presbyter und das mittelalterliche Kunsthandwerk: Gesamtausgabe der Schrift de diversis artibus in zwei Bänden*, vol. 1. Köln: Böhlau Verlag.

BYE, C. 1990. Casein and mixed protein adhesives. In *Handbook of adhesives*, ed. I. Skeist, 135–52. New York: Chapman & Hall.

CENNINI, C. and D.V. THOMPSON. 1954. *The craftman's handbook: Il Libro dell' Arte*, transl. D.V. Thompson. New York: Dover Publications.

DALY, A. 2016. *Non-invasive dendrochronological analysis of four polychrome ecclesiastical sculptures from Troms, Norway*. Dendro.dk report.

ENGELSTAD, E.S. 1936. *Senmiddelalderens kunst i Norge ca. 1400–1535*. Oslo: Universitetets Oldsaksamling.

FIDANZA, G.B. 2010. Überlegungen zu Michelangelo als Holzbildhauer. *Wiener Jahrbuch für Kunstgeschichte* LIX: 49–64.

FIDANZA, G.B. 2011. Sistemi di assemblaggio e risultati formali: Alcuni casi seicenteschi. *Bollettino d'arte* 7.

GRIMM, W. and J. GRIMM. 1854–1961. Deutsches Wörterbuch von Jacob und Wilhelm Grimm. In *Universität Trier*. http://dwb.uni-trier.de/de/ (accessed 19 October 2016).

KNÜVENER, P. 2011. *Mittelalterliche Kunst aus Berlin und Brandenburg im Stadtmuseum Berlin*, Ed. F. Nentwig. Berlin: G+H Verlag.

KNÜVENER, P. 2015. *Die mittelalterlichen Kunstwerke des Johann-Friedrich-Danneil-Museums in Salzwedel: Sammlungskatalog*. Berlin: Hendrik Bäßler Verlag.

LINDBERG, H. 1976. Anna selv tredje, Berg kirke, Troms. C.nr. 2912. *Conservation treatment report*. Oslo: Universitetets Oldsaksamling.

OELLERS, A., D. PREISING, and U. SCHNEIDER. 1998. *In gotischer Gesellschaft: Spätmittelalterliche Skulpturen aus einer niederländischen Privatsammlung*. Köln: Wienand.

OLSTAD, T. 2002. Det gyldne hollandske alterskap i Leka kirke, Nord-Trøndelag. *NIKU publikasjoner* 120.

OLSTAD, T. 2003. Alterskapet i Grip stavkirke. Et 1700-talls alterskap fra middelalderen. In *NIKU Rapport* 5.

OLSTAD, T. 2008. Alterskapet i Hadsel kirke – Et alterskap fra senmiddelalderen attribuert til Lekagruppen. *NIKU Rapport* 21.

PREISING, D. 2013. Eine unbekannte Heiligenfigur aus Utrecht im Krakauer Nationalmuseum. *Papers of the National Museum in Krakow, New Series* VI: 101–20.

PREISING, D. and M. RIEF. 2013. *Mittelalterliche Bildwerke aus Utrecht 1430–1530*. Stuttgart: Belser.

RIEF, M. 1998. Blockverleimte spätgotische Holzskulpturen aus dem Gebiet der alten Niederlande. *Restauratorenblätter* 18: 77–84.

RIEF, M. 2005. Engraved marks on Baltic wainscot boards. In *Constructing Wooden Images: Proceedings of the Symposium on the Organization of Labour and Working Practices of Late Gothic Carved Altarpieces in the Low Countries: Brussels 25–26 October 2002*, eds. C. van de Velde, F. Verhaeghe, H. Beeckman, and J. Van Acker, 127–46. Brussels: VUB Brussels University Press.

RIEF, M. 2013. Die Technik der Utrechter Holzskulptur. Versuch eines Überblickes. In *Mittelalterliche Bildwerke aus Utrecht 1430–1530*, eds. M. Rief and D. Preising. Stuttgart: Belser Verlag.

RIEF, M. 2014. Going forensic. Art historical research of Northern late Gothic and Renaissance wooden sculptures based on in-depth analysis of materials and traces left by the carving process. In *Polychrome Sculpture: Tool Marks and Construction Techniques. Proceedings of the Interim Meeting of the ICOM-CC Sculpture, Polychromy, and Architectural Decoration Working Group, Maastricht 24–25 October 2010*, ed. K. Seymour, 34–40. Paris: ICOM-CC.

SCHILLING, M.R. 2005. Paint media analysis. In *Scientific examination of art: Modern techniques in conservation and analysis*, ed. National Academy of Sciences, 186–205. Washington DC: The National Academies Press.

SCHILLING, M.R., H.P. KHANJIAN, and L. SOUZA. 1996. Gas chromatographic analysis of amino acids as ethyl chloroformate derivatives I. Composition of proteins associated with objects of art and monuments. *Journal of the American Institute for Conservation* 35: 45–59.

STIBERC, P. 1989. Polychrome Holzskulpturen der Florentiner Renaissance. Beobachtungen zur bildhauerischen Technik. *Mitteilungen des Kunsthistorischen Institutes in Florenz* 33 (2): 205–28.

STIBERC, P. 2014. Wood crucifixes in late 15th century Florence – Innovations in construction techniques. First results from a research in progress. In *Polychrome Sculpture: Tool Marks and Construction Techniques. Proceedings of the Interim Meeting of the ICOM-CC Sculpture, Polychromy, and Architectural Decoration Working Group, Maastricht 24–25 October 2010*, ed. K. Seymour, 41–8. Paris: ICOM-CC.

TÅNGEBERG, P. 1986. *Mittelalterliche Holzskulpturen und Altarschrein in Schweden: Studien zu Form, Material und Technik*. Stockholm: Almqvist & Wiksell International.

TÅNGEBERG, P. 2000. Beobachtungen zu spätmittelalterlichen Holztechniken. In *Unter der Lupe: Neue Forschungen zu Skulptur und Malerei des Hoch und Spätmittelalters: Festschrift für Hans Westhoff zum 60. Geburtstag*, eds. A. Moraht-Fromm and G. Weilandt, 195–208. Ulm: Süddeutsche Verlagsgesellschaft Thorbecke.

ULMANN, A. VON. 1984. *Bildhauertechnik des Spätmittelalters und der Frührenaissance*. Darmstadt: Wissenschaftliche Buchgesellschaft.

ULMANN, A. VON. 1993. Über die Qualitätsbestimmung im Holzhandel. Ein Beitrag zur Materialgeschichte des ausgehenden Mittelalters. In *Sculptures médiévales allemandes: Conservation et restauration*, ed. S. Guillot de Suduiraut, 225–32. Paris: La Documentation française.

USDA, FOREST PRODUCTS LABORATORY. 2010. *Wood handbook: Wood as an engineering material*. Madison, Wisconsin: USDA.

VEREECKE, J. and J. DEVESELEER. 1995. Notre-dame à l'encrier. In *Dorures, brocarts et glacis: S.O.S. polychromies, Musée des arts anciens du Namurois, Namur, 27 October–31 December 1995*, ed. D. Allard, 87–9. Bruxelles: Fondation Roi Baudoin.

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Image overleaf:

Berg Bishop

Paper III

Saintly relationships or grounds for divorce? An examination of workshop links between two medieval polychrome sculptures

Journal of the Institute of Conservation, June 2018, volume 41, issue 2, pp. 95-112.

DOI: https://doi.org/10.1080/19455224.2018.1463923

Image overleaf:

Schwanbeck Virgin

Photograph by Stefan Pohlke

Paper IV

Biographies carved in wood: Turning points in the lives of two medieval Virgin sculptures

Journal of Material Culture, published online 21st November 2018

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Biographies carved in wood: Turning points in the lives of two medieval Virgin sculptures

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Abstract

By comparing two medieval polychrome sculptures of a combined enthroned Virgin and nativity scene, important and hitherto unnoticed stages in their object biographies can be described. Provenance and attribution are addressed by virtue of stylistic and material comparisons, and the sculptures' wider iconographic, social, historical and spatial contexts are outlined. The article demonstrates how conservation science investigations feed into knowledge regarding the sculptures' material composition, use, transformation and treatment histories. Thus, the applicability of the conservator's approach to examining objects and shedding light on wider historical contexts is outlined by virtue of this case study.

Keywords

conservation, Germany, medieval sculpture, Norway, object biography

Introduction

The following article compares two medieval polychrome sculptures of the same narrative type, one located in Germany and the other in Norway. I will demonstrate the rise and fall of their importance and valuation within their respective communities, and their remarkable survival through turbulent centuries. Thus, the case study takes the form of an object biography, highlighting aspects of the sculptures' passage through time. Their biographies begin at a similar point, from material construction and iconography, diverging afterwards.

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The Torsken Virgin (Figure 1), originating in Torsken on Senja Island, Troms, northern Norway, is a somewhat unusual medieval sculpture as it combines the enthroned Virgin, a common sculptural motif throughout the medieval period, with a nativity scene. The sculpture has traditionally been ascribed to the same German workshop as a similar sculpture originally from Schwanbeck, northern Germany, hereafter called the Schwanbeck Virgin (Figure 2). On both sculptures (Figures 1 and 2), the Virgin and Child are framed by Joseph looking at them from one side, and the two animals facing inwards from the other side. The Virgin is seated in an elevated position on a throne, and the Christ Child is standing on her right knee.

Figure 1. Torsken Virgin, 69 x 35.5 x 10.5 cm. © Photograph: Bettina Ebert.

Figure 2. Schwanbeck Virgin, 70.6 x 59.1 x 9.5 cm. © Photograph: Bettina Ebert.

An object biography approach to conservation studies

In this article, I employ an object biographical approach as starting point, underpinned with scientific evidence gathered from material investigations undertaken as part of conservation research into the sculptures. As such, I am bridging disciplines and demonstrating that conservation has much to offer to a wider audience interested in material culture studies. The use of object biographies is common practice in archaeology, and I will demonstrate what this affords as theoretical framework for conservation research, especially when investigating broader contexts and building narratives around the objects under investigation, the two Virgins in question.

Igor Kopytoff (1986) first suggested the value of writing 'biographies of things', and numerous articles (see Derks, 2015; Jones, 2005; Malkogeorgou, 2011) and books (Olson et al., 2006; Tythacott, 2011) employing this approach have since been written. In 1999, a special issue of the journal *World Archaeology* was dedicated to 'The Cultural Biography of Objects' (Marshall and Gosden, 1999). The articles in the issue highlighted the multitude of relationships between people and objects amidst a variety of approaches for the use of object biographies. As Gosden and Marshall (1999: 172) mention in the introductory article, 'at the heart of the notion of biography are questions about the links between people and things; about the ways meanings and values are accumulated and transformed.' This accumulation and transformation of meanings and values allocated to the two Virgin sculptures is also of particular interest to me in the current study.

Jody Joy (2009: 542) has clarified the difference between an object biography and a life history approach, wherein the latter seeks to address long-term changes, while an object biography usually explores social relations between people and individual objects. In addition, Joy sets out a clear methodology for relational object biographies that also underpins the approach used here. Instead of tracing a linear historical narrative from the object's birth, through life and subsequent death, there is value in looking at object biographies as relational, 'consisting of a series of connected jumps as the object becomes alive within certain clusters of social relationships and is inactive at other points in time and space' (p. 544). Going one step further, I combine this outlook with Andrew Jones's approach of exploring material culture and object biographies via materials science (see Jones, 2002, 2004), or conservation science in my case. Jones's work in particular is close to my heart, as he emphasizes 'the interwoven nature of the social and the material' (Jones, 2004: 331), and pushes for 'closer integration of analytically derived data with theoretical argument' (p. 334).

Conservators have a relationship with their objects of study that arguably goes beyond the approach of art historians, for example. A conservator's specialized and trained manner of seeing allows for significant data to be gleaned from minute paint flakes, tool marks, material composition and layer structures. Thus, the conservator builds a picture of the object's original and transformed appearance, while also interpreting causes of damage or degradation. This is a powerful tool when combined with the contextual approach as it significantly enriches discussions around the objects. Thus, I have chosen to examine the trajectories of the two sculptures' biographies at various points in time with the aim of highlighting important turning points within their respective lives as revealed by their historical, social and spatial contexts, and material investigations.

The *Hauptwerkstattmeister* of Lübeck: Current state of research

In the 1920s, German art historian Rolf Struck evaluated Lübeck altarpieces and sculptures, linking the Schwanbeck Virgin, dated to around 1430, to the workshop of what he called the *Hauptwerkstattmeister*, or main workshop of Lübeck (Struck, 1926: 228). Struck claimed that this workshop was responsible for the high altar of St Jakobi church and the now destroyed high altar of St Mary's church, Lübeck.[1] It is thought that the sculptures of these altarpieces were created in the same workshop as the sculptures of the former high altar of Minden Cathedral, known as the *Goldene Tafel*, or golden altarpiece, now housed at the Bode Museum in Berlin. The Schwanbeck Virgin can be tied to this workshop or its immediate vicinity by virtue of close stylistic similarities, an interpretation supported by several art historians (Lindemann, 2016: 442; Suckale and Krohm, 1992: 146).[2]

The Torsken Virgin has been described as German product of circa 1420–1430 by Norwegian art historians Anders Bugge (1933a: 20) and Eivind Engelstad (1933: 28, 1936: 306). Engelstad first noticed the striking similarity between the Torsken Virgin and the Schwanbeck Virgin (Engelstad, 1933: 27), and concluded that both were made by the same Lübeck workshop, Struck's *Hauptwerkstattmeister*.

These conclusions were drawn on stylistic comparisons common to an art historic approach. I will explore these conclusions by focusing on an object–biographical perspective combined with a conservation–technical investigation.

The beginning: Construction of the sculptures

The sculptures' 'birth', that is, their material construction will first be discussed, followed by the paint schemes, given that these represent their original appearance. After this initial stage, the sculptures' biographies diverge and follow different trajectories. This section deals with similarities and differences in the sculptures' construction and structure, factors which can be taken as evidence against joint workshop provenance.

Both sculptures are relatively thin reliefs; hence there was no need to hollow out the back as often undertaken on sculptures carved in the round. The Schwanbeck sculpture is 1.5 cm taller than Torsken. However, taking into account that the crown fleurons on the Schwanbeck Virgin have been reconstructed while they are lost on the Torsken Virgin, their height would originally have been almost exactly the same. The difference lies in their width, as the Schwanbeck Virgin, at 59 cm, is almost twice as wide as the Torsken Virgin.

This is the result of two tangentially sawn oak blocks joined together vertically for the Schwanbeck Virgin. The glued joint runs through the proper left edge of the Virgin's cloak and foreground, and was originally reinforced with three wooden dowels. While clearly visible in its present condition, the joint would not have been noticeable in the original painted state. Remnants of two sawn-off dowels are present on top of the throne at either side, and could indicate the former presence of additional vertical architectural elements. The majority of the sculpture is intact, with the most significant loss being the Virgin's left hand.

On Schwanbeck, the infant has placed his arms around his mother's neck; Joseph is cooking in the foreground. Joseph sits within the same plane as Mary, and therefore the image is that of a unified whole. This is despite Mary, who sits on a throne, having an ambiguous role as a figure of devotion herself. Joseph has a bowl in his lap and is stirring food within a long-handled pan cooking over a fire. This scene with Joseph cooking, while rarely seen nowadays, has some parallels in medieval art from the late 1300s to the 15th century (Schmidt, 1980), and will be discussed subsequently.

Structurally, the main difference between the sculptures is that Torsken has been carved out of one oak block as opposed to two. As a result of this material difference, the scene is compressed into a more vertical format, though one cannot say whether limited access to timber dictated this, or whether the sculptor made an aesthetic choice in altering the format. Thus, the animals appear as an afterthought underneath Mary's hemline, while Joseph is relegated to dwarf-like status. The space is used to lend overall importance to the Virgin, with the secondary players compressed underneath her voluminous gilded robes. Mary is regal in size, while Christ does not wrap his arms around her neck, instead pointing at a book in her hands. Thus, the mother and child relationship is also modified, and pushed further towards the enthroned Virgin and child iconography, which could support the theory that the sculptor made conscious choices to differentiate the sculpture from other extant versions.

On Torsken, a large knot is present in the wood underneath Joseph's left arm, while there are numerous cracks and splits. Joseph's left hand and spoon handle are missing, as well as some of the foreground. A large hole in the Virgin's chest passes through the sculpture, and is likely to be an original or secondary form of attachment within a shrine.

Figure 3. X-ray of Torsken Virgin. © Photograph: Bettina Ebert.

Indentations and losses in the paint surrounding this hole indicate that a tool was used to remove a nail which had fixed the sculpture in its shrine. Numerous canvas patches are present underneath the ground layer to reduce the possibility of cracks in the support becoming visible in the paint layers. In addition to extensive woodworm tunnelling, most of these features can be seen in an X-radiograph of the sculpture (Figure 3). Dendrochronology of the wood was unsuccessful as insufficient tree rings were present; however, the quality of oak suggests the use of local or regional wood rather than imported timber, indicating that the sculptor was limited in his access to first-rate timber, a factor that could also have affected the sculpture's narrower format.

The verticality of Torsken was noted by Engelstad in his comparison to Schwanbeck, calling Torsken 'condensed and simplified' (Engelstad, 1933: 28), a fact that I must agree with. The carving is less refined and detailed, leading to a more rustic, simple appearance. Notable, however, is the close similarity between the carving of the folds in the Virgin's robe, which could indicate pre-existing visual knowledge of the Schwanbeck sculpture by the sculptor of the Torsken Virgin, or the use of a model/pattern book, woodcut or print as basis for both sculptures. One could even suggest that a famous sculpture existed on the basis of which others, including Torsken and Schwanbeck, were subsequently modelled, or that the Schwanbeck Virgin was the original model. The use of pattern books, prints and models for paintings and sculptures has been demonstrated as standard practice during the late medieval period (Haastrup, 1982: 90; Kausland, 2017; Kempff, 1994a: 28, 1994b: 181; Knüvener, 2011: 14; Wrapson, 2015: 170).

The paint scheme

This section continues with the theme of the sculptures' birth by looking at the paint schemes employed. I undertook pigment and media analysis using a combination of visual observation, portable X-ray fluorescence, microscopy, gas chromatography – mass spectrometry and scanning electron microscopy coupled with energy dispersive spectroscopy. When combined, these techniques allowed me to draw conclusions about the overall paint schemes and to make detailed comparisons of the pigments, media and layering systems employed, despite the sculptures' current appearance being dissimilar.

The original paint and gilding has largely been preserved on the Torsken Virgin. A glue-based chalk ground was applied on the wooden structure and overlying canvas patches prior to paint application. A discoloured glue isolation layer is located on top of the ground, generally present underneath oil-based paint to reduce soaking in of the paint medium (Plahter, 2014: 305). Joseph wears red stockings and a red hood painted in oil-bound paint consisting of vermilion, red lead and chalk. His tunic is an unusual blue-grey and consists of a two-layer oil-based structure, with a thin pale brown layer of lead white and earth pigments underneath a blue-grey layer that could consist of lead white together with a combination of organic pigments such as indigo or bone black, and traces of earth pigments. The green landscape is likely to consist of lead tin yellow and copper green pigments bound in oil. The inner lining of the Virgin's robe consists of glue-bound azurite, resulting in a matte appearance that contrasts with the gilding, while the carnations are oil-bound and painted in lead white tinted with vermilion.

Only isolated small paint flakes are left on the Schwanbeck Virgin and the paint scheme was reconstructed from close visual observation of remaining paint. It was found to correlate closely with the Torsken Virgin. Joseph was dressed in a grey tunic, although it was not possible to identify the original colour of his hood or stockings. The inner lining of the Virgin's cloak was blue, and the presence of copper indicates azurite. Carnations were painted with lead white tinted with vermilion. The throne on both sculptures was brownish-purple, while the donkey was grey and the ox red. The landscape on Schwanbeck was green, while remnants on the cooking implements indicate that the food inside both bowls was light blue, and the stones or logs of the fire source dark red.

Gold was used extensively on both sculptures, with the Virgin's crown, hair, dress and robe as well as Jesus's robe being gilded. I identified a red layer underneath the gilding on the Schwanbeck Virgin, and the presence of iron implied the use of a bole preparatory layer, in keeping with standard practice in northern Germany during the 15th century (Brachert and Kobler, 1981: 855; Nadolny, 2006: 156). Evidence of such a bole layer on Torsken was inconclusive, as it could only be found in trace amounts on Christ's robe. What is certain is that the Virgin's robe was ground-gilded, with the gold leaf applied directly on the white ground as opposed to being applied over bole. This technique was used in northern Europe in the early medieval period (Tångeberg, 1986: 68), while gilding was commonly applied over a red bole from around 1400 onwards (Kausland, 2017: 89; Tångeberg, 1986: 223). In Scandinavia, ground-gilding or the presence of extremely thin washes of bole was common well into the late medieval period (Kollandsrud, 2006: 80; Tångeberg, 1986: 223). Thus, it is reasonable to conclude that the gilding on Torsken could have been applied in a Norwegian context.

Much like the carving, the paint schemes are remarkably similar on both sculptures, further supporting the theory that the sculptures were based on a joint model. The gilding techniques described above could act as evidence for local Norwegian manufacture of the Torsken Virgin as opposed to being imported from northern Germany, as claimed by Engelstad. It is also feasible that the sculpture was carved in Germany, with paint and gilding applied in Norway. However, technical knowledge about art production in coastal German centres other than Lübeck is under-researched, and further work is needed before the use of ground-gilding allows the ruling out of German provenance for the Torsken Virgin.

The motif: Joseph cooking

Given the unusual combined imagery of the enthroned Virgin, nativity and Joseph cooking on both sculptures, it is worth examining them to determine whether it derives from a known German or Scandinavian model that could place the sculptures within a wider art historical context or provide clues on provenance.

The iconography of Joseph cooking porridge first appears in the late 14th century (Schmidt, 1980: 144). This scene occasionally incorporates further scenes from the nativity, such as the adoration by the magi, or shepherds (Pietzner, 2012). The standard imagery usually incorporates Joseph cooking porridge in a long-handled pan over a fire, and stirring with a wooden spoon. A good comparison is the Niederwildungen altarpiece dated 1404 (Figure 4), or the circa 1410–1415 altar in St Catherine Convent museum, Utrecht (Figure 5). According to Leopold Schmidt (1980: 151), the scene is almost solely found depicted from circa 1370 to 1450 in northwest Germany, although I have come across a few carved scenes of a later date. One of the few portrayals within a carved altarpiece rather than a painting is the Buxheim altarpiece dated to around 1510, which was carved in southern Germany (Figure 6).

Figure 4. Niederwildungen altar, circa 1404, detail of wings depicting the Nativity. © The Yorck Project, Conrad von Soest [public domain], via Wikimedia Commons.

Walter Pötzl traced the occurrence of Joseph in medieval calendars, pointing to an increased prevalence during the 14th century. He notes that the attribute of *nutritoris Domini* (*Ernährer*, provider for Jesus) occurs more frequently during that period (Pötzl, 2014: 79). This coincides with Joseph cooking in painted depictions, and could have resulted from the desire to emphasize the homely. Schmidt (1980: 162) has concluded that the scene of Joseph cooking porridge for his newborn son was a known scene in Christmas plays, as evident in a version of such a play where Joseph tells Mary, ‘I koch dem Kind a Müasela,/Und warm dabei sei Windela’ (my translation: ‘I will cook a porridge for the child, and warm shall be his diaper’). This correlates with the emphasis on Joseph’s role as provider for his son, or *nutritoris Domini*. A number of miniatures from Books of Hours of the late 1300s and early 1400s are also listed by Pötzl (2014), wherein Joseph is cooking or depicted near cooking utensils.

Figure 5. Utrecht altar, circa 1410–1415, detail of inner wing depicting the Nativity. © Museum Catharijneconvent, Utrecht.

Gertrud Schiller (1966: 86, 90) discusses changes to iconography of the nativity throughout the centuries, and confirms that the 14th century saw increased portrayals of Joseph going about his homely duties, and that this probably resulted from Joseph's portrayal in Christmas plays. These were popular throughout German-speaking regions from the late medieval period onwards, with versions of such plays still in use even now. While few medieval plays have survived in written form, it is thought that numerous later plays and Christmas songs from the 17th and 18th centuries have their origins in older versions dating to the Middle Ages (Möller, 2006; Weinhold, 1875). Some of these also mention Joseph cooking. One such play, from Vordernberg in the Austrian Alps, is based on an earlier medieval version (Weinhold, 1875: 134). Herein, on Mary's proposal to Joseph to light a fire and cook for his newborn, Joseph responds:

> Yes, yes Mary, soon./ …/ We have very little flour and semolina./ If only God were not to desert us!/…Give him this porridge;/ I believe the child will be hungry. (my translation, Weinhold, 1875: 152)[3]

Figure 6. Buxheim altar, circa 1510. © Museum Ulm, Bernd Kegler.

Another Austrian play, transcribed by Benedict Edelpöck in 1535–1536, includes this scene:

> Mary, ‘Go, Joseph! Cook some porridge./…go and prepare the food for him./’
>
> Joseph, ‘I am going, look after the child with diligence meanwhile./ I will try my best/ to cook a porridge as best I can;/ …./ The semolina is nice and quite good/ but the milk is clotting.’ (my translation, Weinhold, 1875: 213–214)[4]

The comical role allocated to Joseph in his awkwardness as cook for his newborn son was often found in medieval Christmas plays, whether as cook (Vogt, 1899: 21) or when attempting to light a fire (Weinhold, 1875: 212). It is particularly the comical role as cook that Schmidt (1980: 158) claims is addressed by medieval theologian Johannes Eck, when he urges in the *Ingolstädter Pfarrbuch*, or parish book of 1535, that Joseph should no longer be depicted as such in plays to avoid making fun of the Church during the Reformation period.

Thus, the scene of Joseph cooking was a familiar scene during the late Middle Ages in German-speaking regions, waning somewhat during subsequent centuries, and now appearing unusual to modern eyes, even though Joseph may be considered the medieval archetype of modern man. This anchors the Schwanbeck Virgin within a German iconographic context, while such a scene depicted in the Torsken Virgin is rather more curious. A particularly German theme has been appropriated, although altered somewhat, perhaps to suit Norwegian tastes by placing more emphasis on the enthroned Virgin. While, in Schwanbeck, the Virgin looks both at Jesus and Joseph, thus linking the nativity scene with the iconography of the enthroned Virgin, this is not the case in Torsken. In addition, Jesus does not have his arms around his mother's neck, instead pointing at the book in her hand, which further changes the homely family scene.

As a Nordic example, although without the nativity scene, Swedish art historian Aina Trotzig mentions that over 30 versions of the enthroned Virgin with Christ standing in her lap exist in Sweden (Trotzig, 2004). In Norway, while there are many enthroned Virgin and Child sculptures from the early medieval period, very few exist from the late medieval period, and even less with Christ standing in his mother's lap. The few nativities extant in Norwegian medieval art show no parallels with the scene of Joseph cooking, either in early or late medieval imagery (Engelstad, 1936: 160–161; Hohler et al., 2004: 45). Thus, it is best to consider the Torsken sculpture in isolation in this instance, rather than as part of a standard trope.

To conclude, material evidence gathered from conservation studies of the sculptures has allowed me to reconstruct their original appearance, whilst highlighting differences in construction and gilding. Both material evidence and iconography situate the Schwanbeck Virgin firmly within German production centres, with ties to the Lübeck *Hauptwerkstattmeister*. The question of German versus Norwegian manufacture, or 'birth', of Torsken has been addressed, although evidence does not clearly point in either direction. Ground-gilding could support the theory of a Norwegian paint scheme, while the narrower format and changes to iconography could indicate adjustments made specifically for a Norwegian market, be that in a German or Norwegian workshop. It would nevertheless appear likely that the sculptures were based on a joint model, or that the Torsken Virgin was fashioned after the Schwanbeck sculpture.

The Schwanbeck Virgin's early life

Until the 1970s, the sculpture was located in Schwanbeck, northern Germany, in a chapel dedicated to St George, patron saint of lepers (Figure 7) and attached to the local *Siechenhaus* (leprosarium, poor house) which stood opposite (Figure 8). The *Siechenhaus* was founded in the 13th century by the bishops of Ratzeburg, functioning first as leprosarium and subsequently as poor house from 1441 (Ende, 2000: 126). The chapel was erected at some stage during the 15th century, as noted on the surviving stone charter (Krüger, 1934: 332).[5] The first written mention of the chapel dates to 1504, when the chapel was confirmed by bishop Johannes von Parkentin (1479–1511) as having received a donation from two Lübeck citizens for a benefice 'in capella St. Georgii pauperum Christi videlicet leprosorum prope Lütke Dartzowe' (Krüger, 1934: 330).

Figure 7. St George chapel, Schwanbeck. Reproduced courtesy of Stefan Pohlke.

Figure 8. The *Siechenhaus* across the road from the chapel. Reproduced courtesy of Stefan Pohlke.

The Schwanbeck chapel was a small rectangular brick structure with a chancel at the eastern end formed by three sides of an octagon (Krüger, 1934: 331).[6] The surviving book of accounts does not list the sculpture, so it is likely to have arrived in the chapel prior to 1599, when the accounts first begin (Anonymous, 1599–1855). Much like other chapel contents, such as the pulpit which came from a church in Herrnburg in 1676, or the altarpiece which originated from a church in Schönberg in 1683, the Virgin sculpture was perhaps donated to the chapel during the 15th or 16th centuries. However, since the dates of chapel construction and sculpture overlap, it is also possible that the Schwanbeck Virgin was made specifically for the chapel. Given the sculpture's amalgam of the Virgin enthroned and nativity scene, and the cult of the Virgin Mary during the late medieval period, it is possible that the sculpture was gifted to act as an object of devotion and prayer for those in need at the *Siechenhaus*.

The Schwanbeck Virgin's historical context

The sculpture is currently housed in St Nikolai church, Dassow, just beyond Schwanbeck (Figure 9). Dassow is a small town located between Lübeck and Wismar, on the shores of the Dassow See, a bay leading into the Baltic. The location in what was the former German Democratic Republic (DDR) was what led to the relocation of the sculpture and sealed the fate of the medieval chapel within which it was located.

Figure 9. St Nikolai church, Dassow. © Bettina Ebert.

The sculpture remained in Schwanbeck until the early 1970s, when political reasons led to the chapel's destruction. During the 1950s and 60s, the border between the DDR and the Federal Republic of Germany was increasingly fortified to stop people fleeing the DDR for the West (Ritter and Lapp, 2006: 55). Therefore, the border along the edges of Dassow See was turned into a *Sperrgebiet*, or restricted zone, in 1952 (Schwark et al., 2011: 75).[7] Both Schwanbeck and Dassow were located within this zone, severely restricting access to the area (Figure 10). The chapel itself was only 100 metres from the border. A watch tower was constructed some metres from the *Siechenhaus* (Figure 11), and in 1966 a further fence was raised, creating the mined *Todesstreifen*, or death strip.

Figure 10. Map of former border within Germany. © Kalimedia Verlag, reproduced courtesy of Stephan Hormes.

Figure 11. Watch tower. © Bettina Ebert.

In December 1969, the church authorities in Schwerin wrote to the *Institut für Denkmalpflege* (IfD, Institute for Preservation of Built Heritage), requesting financial help for restoration of the chapel, as the local congregation apparently showed little interest (Ende, 2000: 128). Although not granted, the IfD offered to restore individual items such as the sculpture. By 1971, all objects of value from the chapel were relocated to Dassow, while the altarpiece was returned to Schönberg. The Schwanbeck Virgin was sent to the IfD in summer 1971, and conserved between 1971 and June 1972, prior to installation in Dassow church. As part of conservation treatment, the two oak blocks were rejoined and the sculpture cleaned (Spiller, 1972). The missing crown finials were reconstructed, and the sculpture was placed in a protective box frame prior to being sent to Dassow.

In the meantime, in early 1972, the regional authorities decided to tear down the dilapidated schoolhouse that had stood beside the *Siechenhaus* (Pohlke, 2018: 49, note 190).[8] Demolition of the chapel was also requested, since it was located within a 500-metre no-go zone at the border. Reasons cited included the poor state of preservation and, more importantly, it was claimed that the chapel could serve as a hiding place for people attempting to flee the DDR (Ende, 2000: 128).[9] Head of the church authorities in Wismar, Christoph Pentz, responded that demolition would not be granted without combined approval of the church authorities and the IfD (Ende, 2000: 128–129). A site visit by the IfD confirmed that the chapel was in good condition apart from minor damages (Figure 12). An independent report reiterated the chapel's regional historic importance, and reminded the authorities of its listed status (p. 129). However, this could not save the chapel from destruction. In the summer of 1972, vandalism caused further deterioration, as reported by the local pastor. Given that the chapel was located within the 500-metre no-go zone, a heavily fortified area patrolled by border guards, it is now thought that systematic vandalism was ordered by the authorities (p. 130). As a result, the chapel was blown up on 10 January 1973. Nowadays, a few gravestones and a handful of bricks and parts of the foundations are all that is left of the medieval chapel (Figures 13a, 13b).

Figure 12. View of the inside of the chapel in 1972, prior to destruction. The sculpture would have hung on the southern wall, to the right. Reproduced courtesy of Stefan Pohlke.

(a) (b)

Figure 13. (a) Site of the former chapel. © Bettina Ebert; (b) Remaining foundations. © Stefan Pohlke.

The Schwanbeck Virgin's later years

The Schwanbeck Virgin probably kept its medieval painted aspect until the 19th century, when physical removal or stripping of paint and gilding occurred, leading to its altered appearance. As a result of the almost complete absence of paint, the wooden support takes centre stage, best described using the German term *Holzsichtigkeit*, or visibility of the wood.

A preference for form over colour in the aesthetic appreciation of medieval wooden sculpture led to stripping of countless sculptures throughout Europe. Since bare wood was considered aesthetically more pleasing and authentic at that time, sculptures were dipped in lye baths or scrubbed and scraped with metal implements, which left their mark on the wooden supports (Portsteffen and Müller, 2002: 179). It was erroneously thought that classical Roman sculptures were originally unpainted (Göbel, 2005: 324), leading to a rise in popularity of material authenticity – according to which, the carved support was thought to be more crucial to an appreciation of the sculpture than the combined effect of carving and colour. Scrape marks are visible in a number of places on the Schwanbeck Virgin, leading me to conclude that the sculpture was stripped with the aid of metal tools such as rasps or metal brushes, instead of being dipped in lye.

Amateur restorations are present in the form of metallic paint applied to the Virgin's crown and belt on the Schwanbeck sculpture. They were noted as present in the condition report written during the 1970s (Spiller, 1972), while I identified the metallic paint as a modern copper and zinc alloy 'gold bronze' paint on the basis of its elemental composition. Such paints have been in use since the late 19th century (Gettens and Stout, 1966), indicating that it must have been applied between the end of the 19th century and 1972.

By fast-forwarding into the 21st century, we observe changes in the local congregation in Dassow. The community was previously said to have shown little interest in Schwanbeck chapel or its contents (Ende, 2000: 128), which could be attributed to living near the tightly controlled border of Eastern Germany, within a Communist society where control and spying on the population were the norm. The current situation, as experienced by myself over several visits, is significantly different. Donations enabled the community to print a booklet about St Nikolai church, which also provides a brief history of St George's Chapel and the inventory transferred to Dassow (Poley, nd). There is significant appreciation of the Schwanbeck Virgin within the congregation, as I have witnessed in numerous informal discussions with individuals belonging to the community. This is despite the sculpture's iconography with the enthroned Virgin being distinctly Catholic in nature, while having pride of place in a Protestant church.

While the sculpture was still located in the box frame in 2015, it was removed by the congregation at some stage during the subsequent year, prior to being attached directly to the church wall. The sculpture has hung in a variety of positions in the church, and can currently be viewed on the eastern wall, next to the stone charter of Schwanbeck chapel. A stele commemorating Schwanbeck *Siechenhaus* and chapel was inaugurated in July 2018, while local historian Stefan Pohlke has gathered an extensive selection of literature and photographs about the sculpture, Schwanbeck chapel and St Nikolai church on the church's website (Pohlke, 2016).

The Torsken Virgin's early life

The Torsken Virgin can be traced to Torsken church on Senja island, northern Norway (Figure 14). While the earliest written account of Torsken church dates to 1589 (Trædal, 2008: 428), the region's importance in the medieval fishing industry implies that it is highly likely that a church was already present from the early to mid 1400s. The fishermen of Torsken are said to have built a church during the first half of the 15th century (Berg, 2014: 65; Brox, 1959: 330; Mikalsen, 2002: 8), at the height of the fishery's prosperity. This coincides with the stylistic date of the sculpture, and could indicate that it was commissioned specifically for the church. It is highly likely that the Virgin was one of the main elements in the medieval church, together with a magnificent crucifix dating to around 1500.

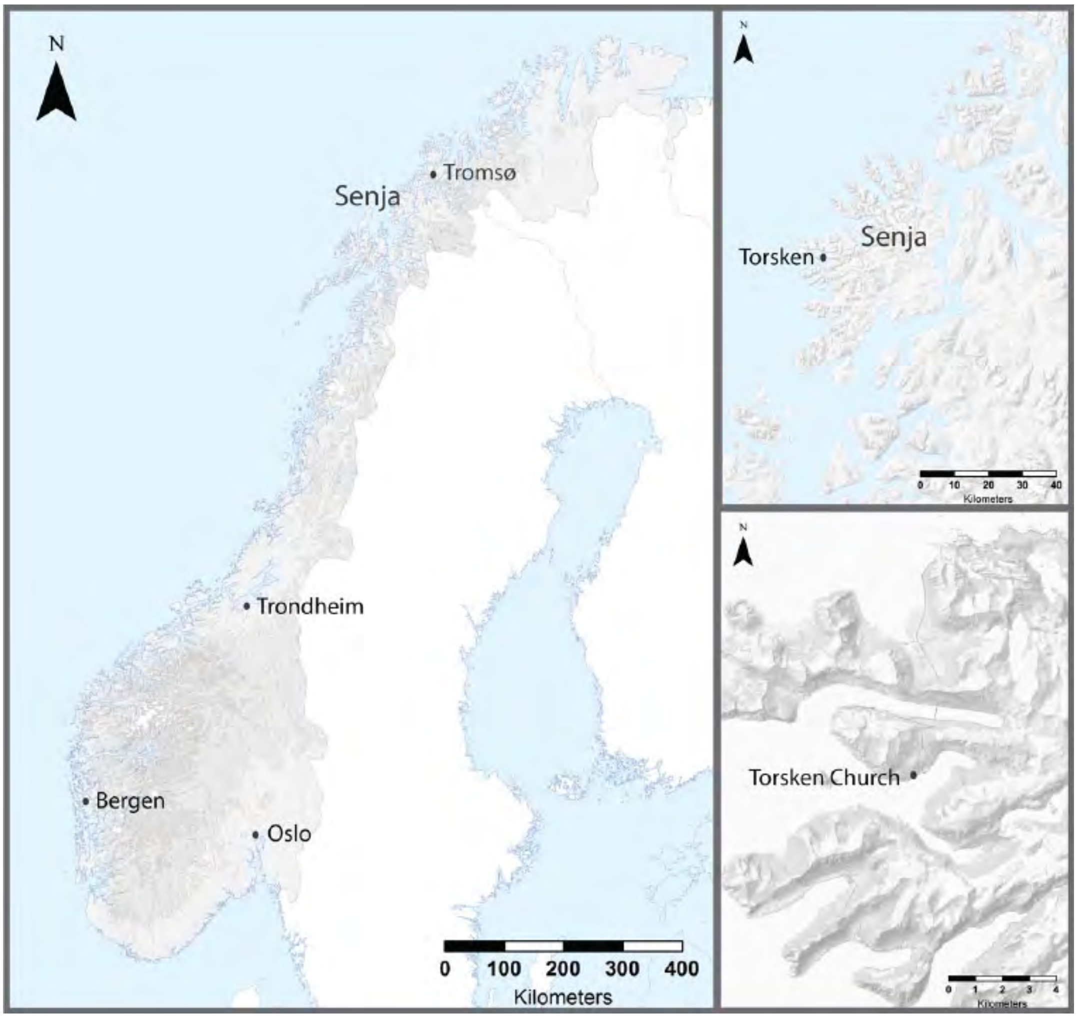

Figure 14. Location of Torsken on Senja, northern Norway. © Rebecca Cannell.

The medieval church would have been relatively small, and thus would probably have had just one main altar. It is certainly possible that the Virgin had stood on the altar in the chancel, and that the crucifix had hung over the threshold to the nave. Visual examination of the sculpture's preservation state reveals patterns of usage. A large burn mark on the Virgin's right knee (Figure 15) suggests devotion employing candles in proximity to the sculpture, and could support the theory that the sculpture was placed on the altar. In a survey of 1770, the medieval church was described as being in very poor condition, and was torn down in 1780 (Trædal, 2008: 429).

Figure 15. Burn mark on Torsken Virgin. © Bettina Ebert.

The church that now stands in Torsken was built between 1780 and 1784, a short distance from the previous location, and is a cruciform wood-panelled building with a small tower (Figure 16). In 1782, the nearby chapel of Gryllefjord was torn down and the church bells sent to Torsken (Munch, 1998: 67); thus, one cannot say for sure whether the Virgin was originally destined for Torsken church or elsewhere on Senja as it is known that medieval inventory was moved between churches in the region in numerous cases.[10] It is known that church furnishings, including sculptures, remained in Norwegian churches in outlying areas well after the Reformation, at least into the 17th century (Amundsen, 2014: 75). An inventory from 1785 of the new church in Torsken did not include either the crucifix or the sculpture (Brox, 1965: 188), although they were possibly stored elsewhere.

Figure 16. Torsken church and environment. © Bettina Ebert.

Catholic sculptures were not systematically destroyed in Norway but largely survived the Reformation period with minor losses, unlike in many parts of Europe, where iconoclasm led to widespread destruction of Catholic imagery.[11] Nevertheless, many medieval objects were relegated to distant memory and stored away in attics, and their places taken by Protestant altarpieces.

The Torsken Virgin's historical context

The fishing town takes its name from a nearby mountain that was supposedly shaped like the skeleton of a cod fish (Brox, 1959: 327).[12] Torsken farmstead is mentioned as early as 1306 in written sources (Brox, 1965: 68); historic documents indicate that the farm tenants regularly exported stockfish and other fishery products to Bergen (p. 70). Torsken had its heyday in the Middle Ages, when fishermen from all over northern Norway came to catch cod in winter and early spring, using Torsken as their seasonal base. The importance of stockfish to the Norwegian economy is such that, by the late Middle Ages, farmers used stockfish to pay landowners rent, which subsequently formed the basis of the taxation system.

While it is likely that the Black Death led to temporary population decline on the western coast of Senja much as elsewhere, archaeological finds attest to the region's continued affluence and trade with Hanseatic merchants via Bergen. For example, archaeological finds include a silver spoon from Lübeck, German 15th-century ointment jars and German ceramics dated between 1250 and 1400 (pp. 82–83). However, unlike the nearby village of Gryllefjord, Torsken had no permanent residents from the time of the arrival of the plague in 1349 until the 16th century (p. 87). Instead, Torsken was used as seasonal place of residence only during the cod fishing season.

During the 1500s, the value of stockfish decreased when compared to the cost of flour, with double the weight of stockfish required to purchase flour by the end of the century (p. 92). Arthur Brox suggests that the advent of the Reformation in Europe played a role in this as fish was no longer as valuable a commodity as previously. Certainly, Catholics consumed a lot of fish during fasting time and on feast days, which was no longer a requirement in the Protestant church. However, the English fishing trade and navy rose to importance during the 16th century and could also have affected the Norwegian fishing industry. British dried salted cod, *klippfisk*, was sold throughout Catholic Portugal, Spain and the Mediterranean (Fagan, 2008: 120–125).

In the early 1600s, the yearly catch in Torsken lay between 3000 and 5000 *våg* of stockfish, while the annual catch in 1694 consisted of only 400 to 500 *våg* (Brox, 1959: 331).[13] Seasonal influxes of fishermen decreased as fishermen began fishing further north, in Finnmark (Brox, 1965: 124). By the 18th century, the fishing industry had declined significantly, although Torsken never completely stopped being used as a fishery, both by the local population and fishermen who travelled from elsewhere. In the 19th century, cod was caught near further outlying islands and, by the 1890s, the town of Gryllefjord increased in importance as the industry changed (Brox, 1959: 332). Nevertheless, with governmental help in the 1930s (Johnsen, 2002), fisheries and a shrimpery were built in Torsken, thus guaranteeing the town's continued survival.

The Torsken Virgin's later years

In the 1860s, medieval church inventory was auctioned off throughout Norway, and the Torsken Virgin was acquired by the Museum of Cultural History (MCH) in Oslo in 1861. Somewhat later, in 1866, the wooden roof tiles of Torsken church were replaced with slate during renovations (Munch, 1998: 61). It is possible that the sculpture's sale was necessary to fund such renovations. Nevertheless, given that the move from church to museum coincided with the sale of medieval sculptures all over Norway, one can assume that the congregation's interest in Catholic objects was at an all-time low. This situates the sculpture within the larger-scale social history of polychrome sculpture and church furnishings in post-Reformation Norway.

However, interest in the medieval inventory of Torsken church increased in the 20th century. The medieval crucifix was found in the attic by bishop Berggrav in the 1930s (Brox, 1965: 99).[14] It was sent to *Riksantikvaren* (Directorate for Cultural Heritage) for restoration prior to being reinstalled on the altar in Torsken church in 1967 (Figures 17 and 18) (Munch, 1998: 64). The Christ figure has nail holes on the chest, indicating that a reliquary container was previously attached. Intriguingly, a relic was found hidden below the chin, consisting of bone fragment in a pouch, together with a Latin inscription on parchment reading *Ligno domini*, referring to fragments of the holy cross (Hauglid, 1949: 64; Liepe, 2015: 263). This was the first relic found in Norway, and Hauglid noted that it would not originally have been integral to the sculpture since the holes on Christ's chest were not contemporary to construction. Instead, Hauglid plausibly hypothesized that a pilgrim could have brought the relic to Torsken, and that it was placed within the container on Christ's chest in Norway. Hauglid (1949: 64) concluded that the relic was hidden for safe-keeping under the chin after the Reformation. Thus, in this instance, a trained eye was able to decipher material evidence, offering an insight into the wider context of Catholic objects in post-Reformation Norway.

The Torsken Virgin was restored at the MCH in 1923, when Louis Smestad undertook treatment with isinglass vapour and glue water on large portions of the medieval collection (Kollandsrud, 1994: 93; Smestad, 1922–1926). While oil-based painted areas are solidly attached as a result of this treatment, it is likely that liberal use of moisture led to damages to the gilding and blue lining of the Virgin's robe as glue-bound layers partially dissolved. Gilding, paint and ground subsequently moved under gravity prior to hardening in the wrong position. In addition, pooling of ground and gilding is visible in hollows of the Virgin's robe, leading to a visually confusing mixture of materials.

An archival photo of the sculpture on display in the museum indicates that it was exhibited from 1946 until 1971 as part of the medieval exhibition installed by curator Gerhard Fischer. Subsequently, in 1976, the sculpture was conserved again, undergoing consolidation and cleaning. In keeping with standard conservation treatment approaches at the museum, no attempt was made to reconstruct the crown finials in the manner of the Schwanbeck Virgin.

Increased interest within the Torsken congregation can be demonstrated by the fact that a plaster cast of the Torsken Virgin was made in 1977 and now hangs in the chancel

Figure 17. Crucifix in Torsken church. © Bettina Ebert.

Figure 18. Interior of Torsken church in 2016, with crucifix on altar and plaster copy of the Virgin on the northern wall. © Bettina Ebert.

(Figures 18 and 19) (Munch, 1998: 63). Interestingly, the Virgin's gilded robe was turned into a white and gold robe, indicating that the copyist confused remnants of white ground for white paint. Thus, the sculpture, by virtue of its alter ego the plaster replica, once again plays a role in the religious life of the congregation, albeit in a painted state that the original never existed in.

Figure 19. Plaster copy of Torsken Virgin. © Bettina Ebert.

Conclusion: Object biographies of two medieval Virgin sculptures

While the Schwanbeck Virgin can be linked to German workshop practice in the immediate milieu of the Lübeck *Hauptwerkstattmeister*, the Torsken Virgin's provenance is less clear-cut. Iconographic and material evidence indicates that both sculptures were either based on a joint model, or that the Torsken sculpture was fashioned after the Schwanbeck sculpture. This could have occurred in Germany, Norway or a combination of the two, as indicated by the use of ground-gilding, a narrower format and iconographic adjustments.

Furthermore, the two sculptures, while originally very similar, have led disparate histories. These differing trajectories have resulted in two dissimilar yet multivalent objects. While Torsken has become a museum object, the Schwanbeck Virgin has moved from the medieval chapel as place of worship to another sacred space, St Nikolai church in Dassow, thus remaining an active religious agent by virtue of its role as devotional sculpture. The sculpture arguably plays a less potent role now in its Protestant home compared to its medieval placement in a Catholic chapel attached to a *Siechenhaus*, where the poor and outcast of society offered their prayers; nevertheless, it retains its sacred qualities.

In addition, the Schwanbeck Virgin stands as a symbol of defiance to the former Communist authorities, having survived the razing of the chapel in 1972. Thus, the sculpture has been inscribed with additional levels of meaning, and it is this accumulated agency that may add to its status as a focal point for the local congregation. Furthermore, the sculpture has an art-historic role as a link in the chain of attributions for the *Goldene Tafel*, associated altarpieces and sculptures.

Wealth from trade with stockfish and trade links with German-speaking regions via the Hanse and Bergen are some reasons why the northern Norwegian coast has a plethora of medieval sculpture. With its arrival in Torsken on Senja in the late Middle Ages, the Torsken Virgin, in addition to its religious function, took on a further attribute as marker of the fishing community's wealth. The importance of the fishing trade for communities in north-west Norway is evident in the strong trade networks via Bergen and the Hanseatic merchants. It is highly likely that the sculpture found its way to Torsken via Bergen by virtue of these trade links or the existence of craftsmen in or around Bergen. Today, the continued presence of the medieval crucifix and the plaster replica of the Virgin in the church, together with chandeliers and other church furnishings, act as reminders of the coast's former wealth.

The Reformation was more drawn-out in remote regions of Norway but certainly, after the 17th century, Catholic imagery lost most of its significance to the newly Protestant population. Therefore, religious sculptures that had lost their agency turned into objects that could be modified, stored away, sold or given to newly established museums throughout the country.

Archival photos and conservation reports highlight the Torsken Virgin's passage into the museum, where its exhibition history reveals a shift in role from religious object of devotion to work of art. The majority of museums exhibiting religious objects do so in a variety of approaches, showing the objects as fine or decorative art, or by employing an archaeological or anthropological approach (Paine, 2000). As an archaeological museum, the MCH falls within these traditions, combining a traditional archaeological display of medieval everyday objects with an aesthetic and fine-art approach whereby sculptures are displayed as individual works of art (Ebert, 2018).

However a museum chooses to address the sacred in religious art, I believe it is not possible to completely deny an object its religious agency since so much is due to interactions between the individual viewer and the object itself, as well as the 'intangible, inexpressible dimension of religion' (Arthur, 2000: 7). Nevertheless, in becoming a museum accession, the Torsken Virgin has taken on additional roles while having shed some of its former ones. As historian Ivan Gaskell puts it, 'once a sacred object has been removed to a secular space, its sacred qualities are often compromised' (Gaskell, 2003:

150). This means that the sculpture's main function as an object of devotion is now somewhat overshadowed by its artistic, educational and historical values. Nevertheless, the Torsken Virgin has been repatriated to Senja by means of a replica plaster cast now residing in the church, while the original sculpture remains at the museum. Thus, even though the community's authentic Virgin is now arguably a work of art in addition to being a religious object, the replica has itself become part of Torsken's material culture and the community's cultural heritage.

The conservation of religious objects can be fraught with complications, as often seen with sacred objects from indigenous cultures or non-Christian religions (Maunder, 2000). In much the same way, modern conservation approaches at the MCH aim to preserve devotional evidence, such as the presence of candle wax drips or grime from repeated devotional touching. An insensitive approach could remove such usage evidence, resulting in the erasure of phases in the object's biography. For example, the stripping of the Schwanbeck Virgin's paint and gilding has completely altered the sculpture's appearance, leaving it in a state where its former aspect has been rendered inaccessible to the majority of viewers. The sculpture now stands as evidence of historic tastes that have shifted over time. Only the conservator can now reconstruct the original polychromy by closely examining remaining paint flakes, and therefore unlock this crucial phase in the sculpture's object biography.

By virtue of their divergent environments, histories and contexts, the two sculptures demonstrate different ways of keeping objects of value alive. The historical, social and spatial contexts described highlight the multitude of values that can be assigned to an individual object. Meanings and values associated with the sculptures have accumulated and transformed over time, some receding while others gain importance. While the Schwanbeck Virgin has accumulated agency through the centuries, the Torsken Virgin has lost some of its significance with a shift from sacred to secular in its museum context, becoming a work of art. Nevertheless, the Torsken Virgin has been reinvented in the guise of a plaster replica that now takes on some of the sculpture's religious significance.

The two case studies have highlighted the importance of the conservator's mode of seeing and interpreting visual evidence, and have demonstrated the potential of conservation science in generating novel information that can shed light on object interpretation. When tied to a contextual perspective, the conservator's toolbox allows for a multi-faceted approach whereby a variety of meanings can be teased out from minute evidence inaccessible to other viewers.

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I would like to thank the Dassow congregation for the warm welcome, access to the Schwanbeck Virgin and, in particular, Stefan Pohlke for generously sharing information and friendship. Thanks to the Museum of Cultural History in Oslo for granting access to the Torsken Virgin and museum archives. I would like to extend my thanks to my PhD supervisors Professor Lotte Hedeager and Michael Rief, as well as archaeologist colleagues for invaluable feedback on the draft manuscript. Thanks to Duncan Slarke for guidance with X-ray imaging and to Calin Stendal for technical support with SEM-EDS. Many thanks to Joy Mazurek for generously sharing her knowledge and skills with GC/MS and to Tom Learner and the Getty Conservation Institute for hosting me.

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Notes

1. This relationship has not been entirely clarified by modern art historical research, probably due in part to the fact that the high altar of St Mary's was destroyed during World War II, with only some isolated architectural elements preserved. Differences between the architectural elements of the altar shrines could indicate that these originate in different regions of Germany, such as Lüneburg in Lower Saxony, or Westphalia, as opposed to Lübeck, although there is consensus on the Lübeck origin of the sculptures (see Albrecht, 2012; Ludwig and Krohm, 1992; Richter, 2014, 2015).
2. In fact, the sculpture was shown in Berlin between 1992 and 1993 in an exhibition about the *Goldene Tafel* and related sculptures.
3. 'Ja ja Maria, wol alsbald./ …/ Wir haben gar wenig Mel und Grieß./ Wenn uns doch Gott nit gar verließ!/… Nimm hin, gib ihm das Müeselein;/ ich glaub das Kind wird hungrig sein.'
4. Mary, 'Joseph, gee! Koch ein müeselein./…lauf hin, und richt im zue die speis./'

   Joseph, 'Ich gee, pfleg du des kinds mit fleiß./ Mit nichten will ich underlan,/ ain mues zu kochen wie ichs kann;/…Der grieß ist schön und ziemlich guet;/ aber die milch mir grinnen thuet.'

5. MCCCC can be deciphered on the charter, although the remaining numerals are illegible. It is likely that this points to a date in the 1400s, despite not being written MCD.
6. The Schwanbeck chapel is very similar in construction to another chapel attached to a leprosarium outside Lübeck, in Klein Grönau. The Grönau chapel was built in 1409 and, given the strong architectural similarity between the chapels, one can assume that they were built by the same master builder (see Hagen, nd; Siechenaus (Klein Grönau), 2018).
7. Excerpt from the 'Polizeiverordnung über die Einführung einer besonderen Ordnung an der Demarkationslinie', 26 May 1952:

   §1: Die entlang der Demarkationslinie zwischen der Deutschen Demokratischen Republik und Westdeutschland festgelegte Sperrzone umfasst einen 10 m breiten Kontrollstreifen unmittelbar an der Demarkationslinie, anschließend einen etwa 500 m breiten Schutzstreifen unmittelbar an der Demarkationslinie und dann eine etwa 5 km breite Sperrzone. (Ritter and Lapp, 2006).

8. As early as 1948, the border police had appropriated the *Siechenhaus* and the adjacent schoolhouse. During that period, the *Siechenhaus* rapidly deteriorated, and was torn down in 1952 with approval from the IfD.
9. Sie befindet sich in einem Territorium, das vollkommen von jeder Bevölkerungsbewegung … frei ist und Anziehungspunkt für Personen sein kann, die sich unter Mißachtung der Grenzordnung dort aufhalten können. Außerdem hinterläßt der ungepflegte bauliche Zustand der Kapelle bei den Transitreisenden nicht gerade den besten Eindruck … auf Grund des baufälligen Zustandes und der Gewährung von Ordnung und Sicherheit an der Staatsgrenze, die Kapelle ebenfalls bis 30.6.1972 abzubrechen. (Ende, 2000: 126–138)
10. Anders Bugge (1933b: 1–52) makes the claim, although unsubstantiated, that the sculpture was originally housed in a church in Medfjordvær.
11. The *Beeldenstorm* in the Low Countries, or *Bildersturm* in Germany during the 16th century,

led to a significant loss of Catholic cultural heritage. Medieval sculptures originating from those regions are largely preserved in Norway, thus being of value far beyond the shores of Norway as objects of cultural heritage and as research material.

12. *Torsken* literally means 'cod' in Norwegian.
13. 1 *våg* of stockfish = 18.52 kg (see Aakvik, 2008; Berg, 2014: 61–71).
14. Only the crucified Christ figure was found, and a new crucifix was constructed for placement on the altar.

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References

Aakvik T (2008) *Mynt, mål, vekt og landskyld*. Available at: http://www.aagskardet.com/garder/index2.php?option=com_content&do_pdf=1&id=23 (accessed 24 October 2018).

Albrecht U (2012) *Corpus der mittelalterlichen Holzskulptur und Tafelmalerei in Schleswig-Holstein: Band 2: Hansestadt Lübeck: die Werke im Stadtgebiet*. Kiel: Ludwig.

Amundsen AB (2014) Reformed church interiors in southern Norway, 1537–1700. In: Hansen LI et al. (eds) *The Protracted Reformation in Northern Norway*. Stamsund: Orkana Akademisk, 73–92.

Anonymous (1599–1855) Des Armen- oder Siechenhauses für Dassow Rechenbuch.

Arthur C (2000) Exhibiting the sacred. In: Paine C (ed.) *Godly Things: Museums, Objects and Religion*. London: Leicester University Press, 1–27.

Berg SH (2014) The canonry of Trondenes: A jewel in the Nidaros crown. In: Hansen LI et al. (eds) *The Protracted Reformation in Northern Norway*. Stamsund: Orkana Akademisk, 61–71.

Brachert T and Kobler F (1981) Fassung von Bildwerken. In: Wirth K-A, Kunstgeschichte Zf (eds) *Reallexikon zur deutschen Kunstgeschichte*, Vol. 7. Munich: C.H. Beck'schen Verlagsbuchhandlung.

Brox A (1959) *Berg og Torsken bygdebok: 1: Gardshistoria*, Tromsø.

Brox A (1965) *Berg og Torsken bygdebok: 2: Bygdehistoria*, Tromsø.

Bugge A (1933a) *Kirkebygninger og deres udstyr: Norge*. Stockholm: Bonnier.

Bugge A (1933b) Kunsten langs leden i Nord. *Foreningen til Norske Fortidsminnesmærkers Bevaring*: 1–52.

Derks A (2015) Fuelling change: A biography of the beehive coal briquette in post-Đổi Mới Vietnam. *Journal of Material Culture* 20: 331–349.

Ebert B (2018) A skewed balance? Examining the display and research history of the medieval collection at the Museum of Cultural History, University of Oslo. *Journal of the History of Collections* 30: 139–151.

Ende H (2000) Die Kapelle des Siechenhauses in Schwanbeck bei Dassow. *Mecklenburgia Sacra, Jahrbuch für Mecklenburgische Kirchengeschichte* 3: 126–138.

Engelstad ES (1933) *Die hanseatische Kunst in Norwegen: stilkritische Studien*. Oslo: Det Norske videnskaps-akademi.

Engelstad ES (1936) *Senmiddelalderens kunst i Norge ca. 1400–1535*. Oslo: Universitetets Oldsaksamling.

Fagan B (2008) *Fish on Friday: Feasting, Fasting and the Discovery of the New World*. Sydney: Accessible Publishing Systems.

Gaskell I (2003) Sacred to profane and back again. In: McClellan A (ed.) *Art and its Public: Museum Studies at the Millennium*. Malden: Blackwell, 149–164.

Gettens R and Stout G (1966) *Painting Materials, a Short Encyclopaedia*, New York: Dover Publications.

Göbel R (2005) Zur Geschichte der Abnahme von Skulpturenfassungen. *Zeitschrift für Kunsttechnologie und Konservierung* 19: 323–355.

Gosden C and Marshall Y (1999) The cultural biography of objects. *World Archaeology* 31: 169–178.

Haastrup U (1982) The use of graphic models in Claus Berg's workshop. In: Bjarnhof S, Thomsen V (eds) Polykrom skulptur og maleri på træ. Copenhagen: Nordisk Ministerråd, 90–93.

Hagen J (nd) *Die Kapelle und das 'Siechenhaus' von Klein Grönau*. Available at: https://www.cvjm-luebeck.de/hotel-hostel/jugendheim-klein-gr%C3%B6nau/zur-geschichte/.

Hauglid R (1949) Krusifikset og relikvien: en nyfunnet kristusfigur i Torsken kirke. *Foreningen til Norske Fortidsminnesmærkers Bevaring*: 63–68.

Hohler E, Morgan N and Wichstrøm A (2004) *Painted Altar Frontals of Norway 1250–1350* Vol. 1: *Artists, Styles and Iconography*. London: Archetype, in association with Kulturhistorisk museum, Universitetet i Oslo.

Johnsen JP (2002) Fiskeren som forsvant? En studie av avfolking, overbefolking og endrinsprosesser i norsk fiskerinæring. *Norges fiskerihøgskole*. Tromsø: Universitetet i Tromsø.

Jones A (2002) *Archaeological Theory and Scientific Practice*, Cambridge: Cambridge University Press.

Jones A (2004) Archaeometry and materiality: Materials-based analysis in theory and practice. *Archaeometry* 46: 327–338.

Jones S (2005) 'That stone was born here and that's where it belongs': Hilton of Cadboll and the negotiation of identity, ownership and belonging. In: Foster S, Cross M (eds) *Able Minds and Practised Hands: Scotland's Early Medieval Sculpture in the 21st Century*. Leeds: Society for Medieval Archaeology, 37–54.

Joy J (2009) Reinvigorating object biography: Reproducing the drama of object lives. *World Archaeology* 41: 540–556.

Kausland K (2017) Late medieval altarpieces in Norway – domestic, imported or a mixed enterprise? An art technological study of Northern German and Norwegian altarpiece production in the period 1460–1530. *Conservation Studies*. Oslo: University of Oslo Press.

Kempff M (1994a) *Attribueringarnas mångfald – Johannes Stenrat och Hans Hesse. Den senmedeltida verkstadens produktion*, Stockholm: Konstvetenskapliga institutionen.

Kempff M (1994b) The Stenrat workshop – the cause of renewed efforts: Problems and resources of the art history medievalist. In: Albrecht U, Bonsdorff Jv (eds) *Figur und Raum. Mittelalterliche Holzbildwerke im historischen und kunstgeographischen Kontext*. Berlin: Dietrich Reimer Verlag, 178–183.

Knüvener P (2011) *Die spätmittelalterliche Skulptur und Malerei in der Mark Brandenburg*, Worms: Wernersche Verlagsgesellschaft.

Kollandsrud K (1994) Krusifiks fra Haug kirke. Undersøkelser og behandling. *Varia* 27.

Kollandsrud K (2006) New light on the Virgin from Veldre, the Virgin from Østsinni and the crucifix from Tretten. In: Nadolny JM et al. (eds) *Medieval Painting in Northern Europe: Techniques, Analysis, Art History*. London: Archetype Publications, 76–90.

Kopytoff I (1986) The cultural biography of things: Commoditization as process. In: Appadurai A (ed.) *The Social Life of Things*. Cambridge: Cambridge University Press, 64–91.

Krüger G (1934) *Kunst- und Geschichts-Denkmäler des Freistaates Mecklenburg-Strelitz. Band 2: Das Land Ratzeburg*. Neubrandenburg: Brückner.

Liepe L (2015) Det befolkade rummet: Relikfyndet från Torsken kyrka. *Nordlit* 36: 261–274.

Lindemann S (2016) *Holzskulpturen in Mecklenburg, Von den Anfängen bis zur Mitte des 15. Jahrhunderts*. Schwerin: Heidberg.

Ludwig SR and Krohm H (1992) *Die Goldene Tafel aus dem Mindener Dom*. Berlin: Mann.

Malkogeorgou T (2011) Folding, stitching, turning: Putting conservation into perspective. *Journal of Material Culture* 16: 441–455.

Marshall Y and Gosden C (1999) The cultural biography of objects. *World Archaeology* 31: 169–320.

Maunder M (2000) The conservation of sacred objects. In: Paine C (ed.) *Godly Things: Museums, Objects and Religion*. London: Leicester University Press, 197–209.

Mikalsen O (2002) Torsken kirke. *Yttersia – Menighetsbladet for Berg og Torsken* 57: 8–9.

Munch JS (1998) Kirker på Senja og i Senja prosti. *Årbok for Senja* 27: 60–90.

Möller I. (2006) Ziehvater Joseph vom Statisten zum Hauptakteur. *Mecklenburg Magazin, Regionalbeilage der SVZ und der NNN*. 2.

Nadolny JM. (2006) All that's burnished isn't bole: Reflections on medieval water gilding. Part 1: Early medieval to 1300. In: Nadolny JM et al. (eds) *Medieval Techniques in Northern Europe: Techniques, Analysis, Art History*. London: Archetype Publications, 148–162.

Olson R, Reilly P and Shepherd R (2006) *The Biography of the Object in Late Medieval and Renaissance Italy*. Oxford: Blackwell Publishing.

Paine C (2000) Religion in London's museums. In: Paine C (ed.) *Godly Things: Museums, Objects and Religion*. London: Leicester University Press, 151–170.

Pietzner C (2012) Der 'kleine Friedberger Altar' im Hessischen Landsmuseum Darmstadt – eine kunsttechnologische Studie. *Restaurierung, Kunsttechnologie und Konservierungswissenschaft*. Technische Universität München.

Plahter U (2014) Norwegian art technology in the twelfth and thirteenth centuries: Materials and techniques in a European context. *Zeitschrift für Kunsttechnologie und Konservierung* 28: 298–332.

Pohlke S (2016) *Aus der Geschichte*. Available at: http://www.kirche-mv.de/Aus-der-Geschichte.7785.0.html

Pohlke S (2018) Chronik des Kirchspiels zu Dassow 1898–2012. Dassow: Evangelisch-Lutherische Kirchengemeinde Dassow.

Poley M (nd) *Evangelisch Lutherische Kirche St. Nikolai zu Dassow*. Dassow: ev. luth. Kirchengemeinde Dassow.

Portsteffen H and Müller A (2002) Das Problem der Holzsichtigkeit aus restauratorischer Sicht. In: Königfeld P (ed.) *Das holzsichtige Kunstwerk: zur Restaurierung des Münstermann-Altarretabels in Rodenkirchen/Wesermarsch*. Hameln: Niemeyer, 178–183.

Pötzl W (2014) Die Aktivitäten des (heiligen) Joseph im gotischen Weihnachtsbild. Kalendarien, Legenden, mündliche Überlieferungen, Lieder sowie Spiele und ihre Rezeption im Bild. *Bayerisches Jahrbuch für Volkskunde*: 71–119.

Richter JF (2014) Das mittelalterliche Hochaltarretabel der Lübecker Marienkirche. *Zeitschrift für Lübeckische Geschichte* 94.

Richter JF (2015) Das Hochaltarretabel der Lübecker Marienkirche. Rekonstruktion und künstlerischer Kontext. In: Nürnberger U, Albrecht U (eds) *Palmarum 1942: Neue Forschungen zu zerstörten Werken mittelalterlicher Holzskulptur und Tafelmalerei aus der Lübecker St. Marienkirche*. Kiel: Verlag Ludwig, 73–96.

Ritter J and Lapp PJ (2006) *Die Grenze: Ein deutsches Bauwerk*. Berlin: Ch. Links Verlag.

Schiller G (1966) *Ikonographie der christlichen Kunst*. Gütersloh: Gütersloher Verlagshaus G. Mohn.

Schmidt L (1980) 'Sankt Joseph kocht ein Müselein' Zur Kindlbreiszene in der Weihnachtskunst des Mittelalters. *Europäische Sachkultur des Mittelalters: Gedenkschrift aus Anlass des zehnjährigen Bestehens des Instituts für mittelalterliche Realienkunde Österreichs*. Vienna, 143–166.

Schwark T, Schmiechen-Ackermann D and Hauptmeyer C-H (2011) *Grenzziehungen – Grenzerfahrungen – Grenzüberschreitungen. Die innerdeutsche Grenze 1945–1990*, Darmstadt: Wissenschaftliche Buchgesellschaft.

Siechenhaus (Klein Grönau) (2018) Available at: https://de.wikipedia.org/wiki/Siechenhaus_(Klein_Gr%C3%B6nau) (accessed 24 October 2018).

Smestad L (1922–1926) Prepareringen av Middelalderlige malerier. Oslo: Museum of Cultural History.

Spiller W (1972) Restaurierungsbericht. Schwerin: Institut für Denkmalpflege.

Struck R (1926) Materialien zur lübeckischen Kunstgeschichte. *Zeitschrift des Vereins für Lübeckische Geschichte und Altertumskunde* XXIII.

Suckale R and Krohm H (1992) *Die Goldene Tafel aus dem Mindener Dom*. Berlin: Mann.

Trotzig A (2004) The iconography of the enthroned Virgin with the Christ Child standing in her lap. In: Kaspersen S (ed.) *Images of Cult and Devotion: Function and Reception of Christian Images in Medieval and Post-Medieval Europe*. Copenhagen: Museum Tusculanum Press, 245–253.

Trædal V (2008) Kirkesteder og kirkebygninger i Troms og Finnmark før 1800. Tromsø: Universitetet i Tromsø.

Tythacott L (2011) *The Lives of Chinese Objects: Buddhism, Imperialism and Display*. New York: Berghahn.

Tångeberg P (1986) *Mittelalterliche Holzskulpturen und Altarschrein in Schweden: Studien zu Form, Material und Technik*. Stockholm: Almqvist & Wiksell International.

Vogt F (1899) Eine Auffürung Schlesischer Weihnachtsspiele. *Mitteilungen der Schlesischen Gesellschaft für Volkskunde* VI: 17–25.

Weinhold K (1875) *Weihnacht-spiele und Lieder aus Süddeutschland und Schlesien*. Vienna: Wilhelm Braumüller.

Wrapson LJ (2015) A medieval context for the artistic production of painted surfaces in England. Evidence from East Anglia c.1400–1540. In: Cooper T et al. (eds) *Painting in Britain 1500–1630: Production, Influences, and Patronage*. London: Oxford University Press, British Academy, 166–175.

Author biography

Bettina Ebert has submitted her PhD in Conservation Studies at the University of Oslo in Norway. Her research project focuses on case studies of late medieval polychrome sculptures originally from churches in Troms county, northern Norway. An object biography perspective is employed in the thesis to add context to material investigations. Bettina has a Master in Conservation from Northumbria University, UK. From 2009 to 2015, she was employed as paintings conservator and collections manager for Asiarta Foundation and Witness Collection in Southeast Asia. Her previous fields of research and publication include Vietnamese lacquer and modern Asian art.

Biographies carved in wood

Reconstructing narratives for medieval polychrome sculptures

Volume II of II

Bettina Ebert

Thesis for the degree of philosophiae doctor (PhD)

UiO : **Department of Archaeology, Conservation and History**
University of Oslo

2018

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Figure 16: Front view Schwanbeck Virgin

Figure 17: Back view Schwanbeck Virgin

Figure 18: Side, top and base view of Schwanbeck Virgin

Appendix 2: Condition reports

CONDITION REPORT WITH TREATMENT HISTORY

Object/title: St. Anne with Virgin and Christ

Date (c.): 1470s

Type: Sculpture

Dimensions: 58.0 x 26.3 x 13.6 cm

Inventory no.: **C2912**

Location: MCH conservation studio

Examined by: Bettina Ebert

Examination date: 14.09.2015

Short description

Solid heavy sculpture, St. Anne seated, with remnants of Christ's feet on her right knee, and the Virgin Mary sitting on her left knee pointing at a book

Provenance & acquisition date

1862 from Berg church, Senja, Troms, medieval diocese of Nidaros

Could come either from Berg itself or from Medfjordvær, as the inventory was sent to Berg after Mefjordvær was decommissioned

Was placed inside C2911 previously, but sculpture is not related to this

Literature

Nicolaysen 1862, Fett 1909, Nicolaissen 1915, Bugge 1933, Engelstad 1936, Trædal 2008

Exhibition history

1890, 1904

Other documentation

Erla Hohler MCH late medieval catalogue, and MCH condition and treatment report

http://www.unimus.no/arkeologi/forskning/index_katalog.php?museum=khm&id=3151&museumsnr=C2912

2912. *Helgenbillede* af Træ, 22" høit, malet med Vandfarve paa sædvanlig Maade. Forestiller en kvindelig Helgen i siddende Stilling; paa hendes venstre Knæ sidder en mindre kvindelig Skikkelse, kronet og pegende paa et Sted i en opslagen Bog, som hun holder foran sig. Paa det andet Knæ har staaet en Barnefigur, hvoraf nu kun Fødderne er tilbage. Vi har her altsaa formodentlig St. Anna, den hellige Jomfrus Moder, fremstillet efter Sædvane med Maria og Kristus.

Comments

Hohler's catalogue mentions that altar cabinet C2911 could have come from Ibestad church instead of Berg. Numerous church historians mention that Berg inventory could also have come from Mefjordvær, while there is no mention of Ibestad in their records, suggesting that there is no direct link with Ibestad.

TREATMENT HISTORY

Documentation

Treatment January/February 1923 by Louis Smestad, inspected 1975, treatment report by Håkan Lindberg 1974-76

Examined November 1991, when dirt was removed with brush and vacuum

Treatment notes

Smestad: Consolidation with isinglass vapour (*hus blas-inndampning*), cleaning with glue water (*limvannet*)

Lindberg: Sculpture was consolidated with wax using heated spatula and infrared heat, excess wax removed with white spirit. Paint layers were cleaned with soap and water while gilding was cleaned with a mixture of acetone and white spirit. Retouching of bare ground and losses, varnished with a matte MS2A wax varnish and Paraloid B72. The bare wood on the head was bleached with oxalic acid to blend more with the head covering.

Current condition

Paint solidly attached, extent of retouching during last conservation treatment makes it difficult to establish extent of ground without closer examination. Carnations are the most well preserved, red dress looks uneven due to retouching, blue and green are the least well preserved colours. Gilding in good condition despite losses

Support in excellent condition apart from one loss on the base and most of Christ apart from his feet

SUPPORT

Wood species Oak	**Dimensions** 58.0 x 26.3 x 13.6 cm
Number of blocks Three boards (wainscot?) glued together prior to carving to create the wooden block All boards on average 4.5 cm thick, though width varies, see drawing	**Grain direction** Vertical The radial lines of each board go in alternate directions at a slight angle to one another. Bottom board as seen on verso has some sapwood present, seen as lighter section at right edge.
Joins Boards glued together	**Open joins** One minimal gap on the base between bottom and middle boards
Structural alterations Missing section at base could possibly relate to a later alteration or placement of sculpture within a shrine	**Insect damage** None, excellent condition

Holes and cavities	**Losses**
One drill hole in the blue lining of Anne's robe at the proper right side, immediately behind where Christ would have been located. This could be a support mechanism for Christ and extends through to verso. One hole in Anne's red robe which was possibly linked to attachment to shrine or altar. On verso, five nail holes with a square profile ending in a point somewhere within the support, all located almost exactly along a vertical line along the centre of the sculpture, measured from the bottom at the following distances: 6 cm, 21.5 cm, 32.5 cm, 47.5 cm and 55 cm. A further indentation on verso could be a nail hole, but this is unclear. It is located between the two uppermost nail holes, 50.5 cm from the bottom. A small hole is also located on the verso near the top.	Entire Christ child apart from his feet (these are broken off with rough edges rather than cut wilfully), parts of Anne's hand supporting Christ, Christ's right big toe, crown fleurons on Mary's crown, though some remainders are present, loss on verso of Anne's head An additional section of the base, located at the proper right side below the throne is missing, 2.3 x 2.3 cm x depth It is unclear if this narrow section of wood was attached prior to paint application, or if it formed part of an adjacent structure that slotted into this sculpture. There are glue remnants in the area as well as some ground, which indicates it might be a later structure. It is unlikely to have been contemporary to gluing the boards together.
Cracks	**Concealed knots/joints**
Some radial cracks and checks in middle board visible on the base. One split within the bottom board visible on verso, extending from proper left side of base upwards, located circa 5 cm from edge and circa 22 cm long	Textile strips present on some areas related to board joins, such as on Anne's head, as well as on other areas possibly considered more fragile (book)

Preparation of wood
Sizing not visible, possibly due to conservation treatment with wax
Verso
Flat, planed down smoothly with almost no toolmarks visible (planed with a flat blade)
Construction marks
Saw marks on the base that extend across all three boards, indicating that they were glued together prior to levelling of base. Plane marks on verso visible in raking light. Regularly spaced small parallel indentations on the base visible in the top boad, as from a tool with "teeth". These are likely to be from attachment of the board during planing, rather than from attachment of the joined block. Some deeper indentations on the base are related to normal block attachment during carving. The carving appears very finished, with few tool marks visible. The most obvious tool marks on the sculpture are on the Virgin's crown, from a shallow gouge used to make the hollow shapes of the crown. Some cut marks, particularly around Christ's feet and near the Virgin's hands and arms, which would have been hidden by the ground layer. Hair has been created with a V-shaped gouge partly into the wood and the ground layer. On verso, there are two areas with pinpoint indentations in one line, as from saw teeth or a similar tool. Indentations from plier edges, in the shape of two pointed triangles sitting base to base with tips pointing outwards, located at central hole on verso, probably related to nail removal. Parallel scrape mark lines at centre of verso.
Other observations
Profile of throne is different on the left and right sides, eyes are carved into the support, rather than just created with the ground and paint layer

GROUND	
Colour White	**Thickness** Of varying thickness
Texture Rough ground with large inclusions on Virgin's crown	**Manipulation** Tools used to create fur texture in the ground, as well as carved hair
Losses Extensive uneven losses	**Intermediate layers** Not visible
Other observations Unusual layer underlying white ground and canvas on Virgin's crown requires further examination. This is a gritty grey base layer which may have acted as a putty or filler to even out differences in the wood where the joins resulted from crown finials and the presence of one of the board joins	

GILDING	
Metal Gold	**Application type** Anne's robe: poliment gilded, burnished, with bole present Virgin's hair possibly mordant gilded over a dark brown base colour, though most of the gold has been abraded
Surface coating Uncoated	**Losses** More extensive on forward facing areas, better preserved on the sides
Decoration None visible	**Condition** Minor abrasion, otherwise well preserved
Bole Red, appears uneven with darker and lighter areas	**Other observations** Some straight and curved indentations could imply a pattern, though they are probably unintentional. One drip mark damage, with parts of the gilding lost

POLYCHROMY
Overall impressions Carnations in good condition, while other colours are more damaged or lost
Medium Appears oil-bound apart from blue, which could be proteinaceous
Build-up of layers Red dress is composed of several layers, at least two but possibly more, with an orange base, light bright red, and darker glaze on top in some areas, with much of the darker top layer lost Fur was painted after the red dress as it overlaps the red. On the throne, blue was applied on top of the brown areas

Methods Pink highlights on skin painted wet in wet, while glazes were used on red dress, throne employs a marble effect based on different brown colours applied in large brush strokes, eyes and carnation are very fine and detailed
Textures, tool marks Some minimal brushmarks visible on forehead, eyebrows created with tool (end of brush?) which has left indentations in the underlying skin colour, subsequently the brown colour was stippled on with a dry brush
Pentimenti Possibly bole present underneath Virgin's blue dress, which could suggest change of plan from gilding to painting (no red visible underneath blue robe lining), some gilding is present underneath the brown of the throne on the proper right side, but not on the other side
Overpaint Watercolour retouching in the form of fine vertical strokes on all areas of exposed ground to make these less visible: blue and red used on dresses, brown on gilded areas
Surface deposits/accretions Minimal coating of dust, particularly in crevices
Paint losses Extensive losses to Virgin, particularly her dress, parts of her face and right hand. Losses to the red dress are not as extensive but nevertheless many, with a lot of abrasion or loss of the top paint layer. Head scarf is very damaged, with few paint remnants
Other observations Painted with mostly solid blocks of colour, very fine facial details, some use of decorative borders on textiles

DESCRIPTION
Flesh tones Very light pinkish tone, cheeks have circular highlights, darker pink highlights on chin, neck and underneath eyes, nostrils are dark red, lips are bright red with darker modelling and details Knuckles are highlighted with darker pink, dimples created by making hollows in the ground layer, fingernails are light blue, with red outlines created using two brush strokes
Textiles Anne wears red dress with grey fur trim around neckline and sleeves, and a gilded cape with blue lining, as well as white head cover with a red pattern Virgin's blue dress has a gilded border at the base and neckline separated from the blue with a thin white line
Landscape Green base, brown throne with some areas painted blue
Eyes Anne: blue iris darker on the outside, the whites consist of the flesh tone, pupil was painted on top of the blue, bottom lid and corners of eyes painted in fine red lines, dark brown top lid with very fine eyelashes painted into the slightly wet skin colour, lighter brown eyebrows stippled

DRAWINGS

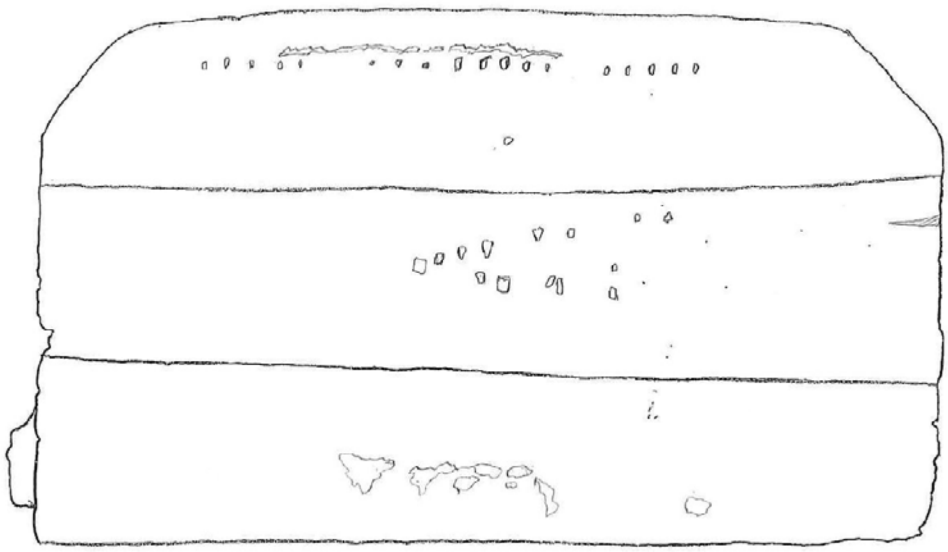


Figure 19: Indentations in the base

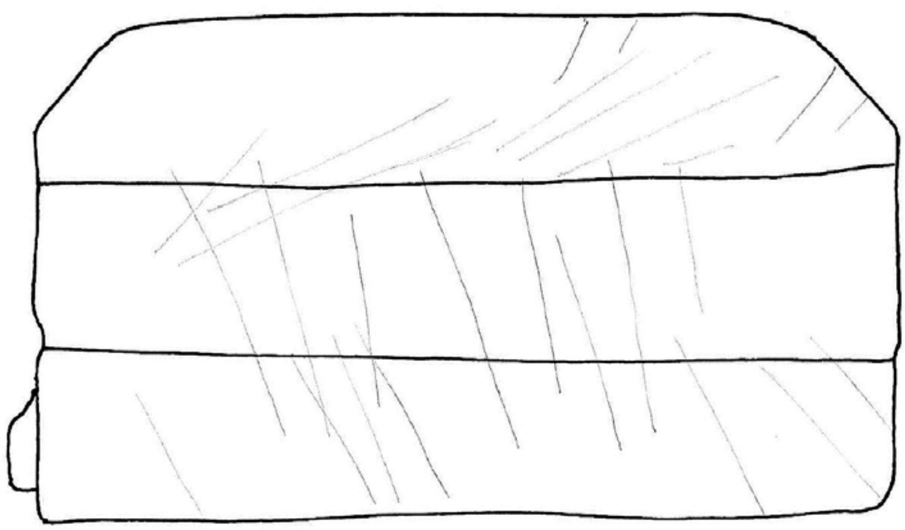


Figure 20: Saw marks on base

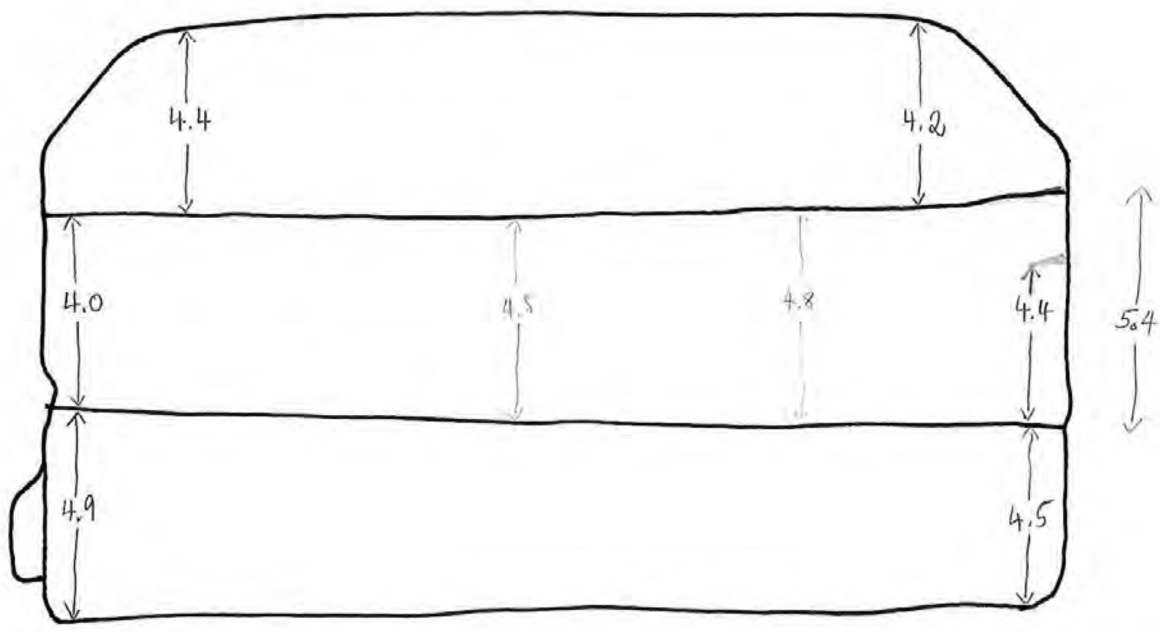


Figure 21: Base measurements

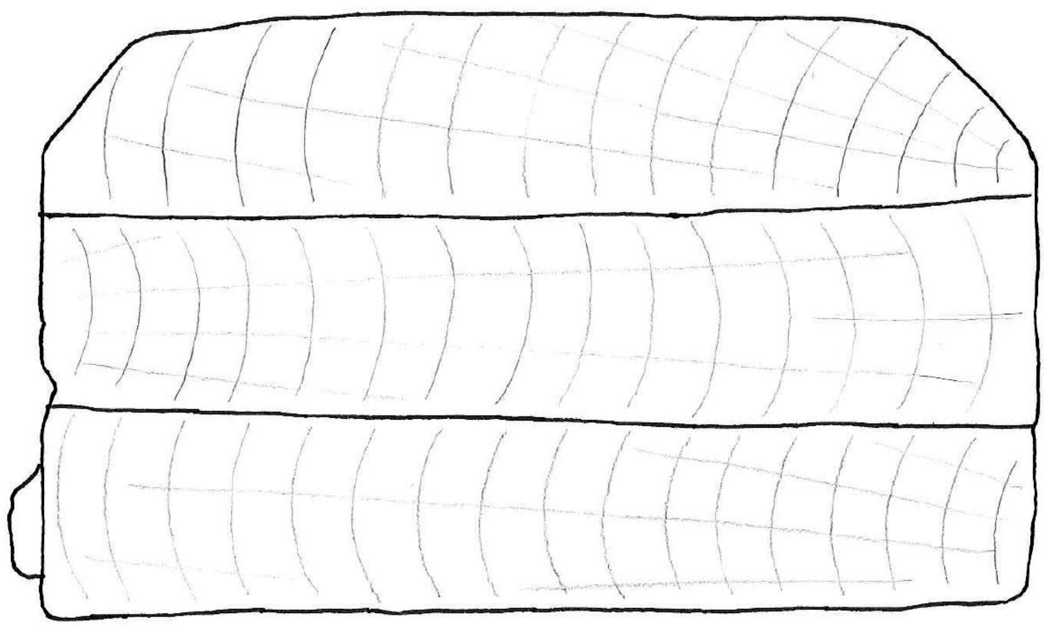


Figure 22: Direction of growth rings as seen on base

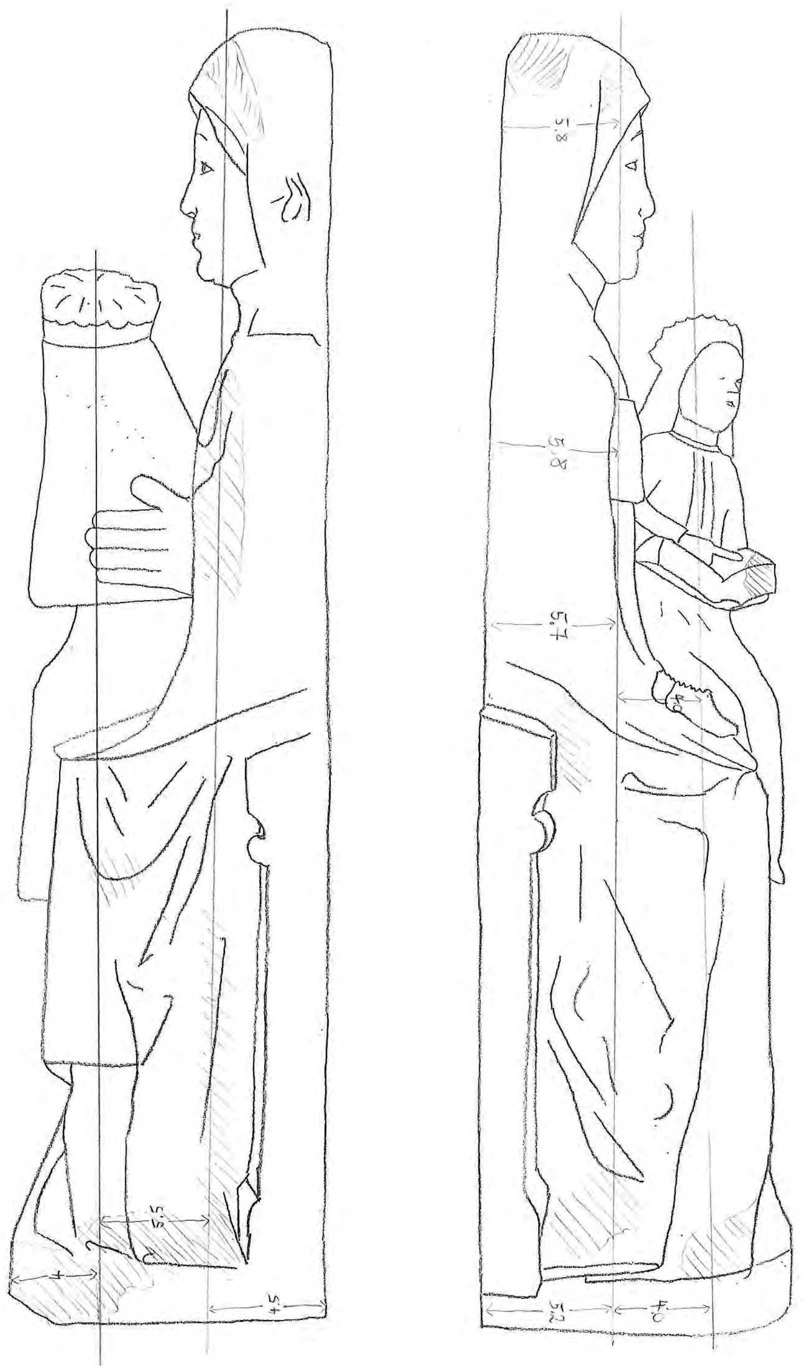


Figure 23: Profile view, with hatching to mark fabric patches

CONDITION REPORT WITH TREATMENT HISTORY	
Object/title: Bishop Date (c.): 1470s (stylistic dating) Type: Sculpture Dimensions: 63.0 x 22.0 x 13.5 cm Inventory no.: **C2913** Location: MCH studio Examined by: Bettina Ebert Examination date: 21.10.2015	
Short description Hollowed out sculpture of standing male saint with bishop's mitre at his feet, both arms lost	
Provenance & acquisition date 1862 from Berg church, Senja, Troms, medieval diocese of Nidaros Could come either from Berg itself or from Medfjordvær, as the inventory was sent to Berg after Mefjordvær was decommissioned	
Literature Bugge 1933, Engelstad 1936	
Exhibition history Pre-1979 installation, as seen in archival exhibition photos	
Other documentation Erla Hohler MCH late medieval catalogue http://www.unimus.no/arkeologi/forskning/index_katalog.php?museum=khm&id=3152&museumsnr=C2913 **2913.** *Helgenbillede* af Træ, 1 Alen høit, af samme Slags Arbeide; forestiller en Helgen i Biskopsdragt, uvist hvilken, da intet Attribut findes; begge Armene er nemlig afbrukne og borte. Hele Figuren, men især Ansigtet, er usædvanlig godt skaaret.	

TREATMENT HISTORY
Documentation Treatment 1923 by Smestad, inspected 1975 and 1981 (*kartotek* with brief condition notes) An old photo shows fabric at base hanging off, therefore sculpture must have been treated
Treatment notes Smestad: Consolidation with isinglass vapour (*hus blas-inndampning*), cleaning with glue water (*limvannet*)
Current condition No overpaint, carnation well preserved, some green on base and red on hat as well as brown hair preserved, blue lining of robe severely deteriorated. Gilding relatively well preserved, most losses located on cloak above proper right arm Support in good condition despite loss of both hands

SUPPORT	
Wood species Oak	**Dimensions** 63.0 x 22.0 x 13.5 cm
Number of blocks Three – base is a separate piece with variable thickness ranging from 1.8 to 2 cm, perhaps indicating that the main block was not flat Main body consists of one block, with a small section of wood added to the proper left side	**Grain direction** Main body and additional piece: vertical Base: horizontal grain
Joins It is unclear how the base is attached, whether glued, or if dowels are present Additional section probably attached with glue, patched over with canvas	**Open joins** Small gap between base and body on verso Join with the attached piece along the saint's proper left side (shoulder and cape) is open (visible on CT scan) and was fixed with small wooden wedges and fabric patches
Structural alterations Possibility that separate base was attached for added height or stability/straightness. This was added during construction (prior to canvas, ground and paint application) Small wooden wedges inserted into the join on the verso	**Insect damage** Very minor, only one or two insect holes visible

Construction marks	Preparation of wood
Chisel marks on verso from hollowing out, one nail hole at base (rectangular in shape) Top of mitre was shaped with a gouge	Blackened drips and brush marks on verso likely to be sizing applied on the wooden support prior to ground application
Verso	**Losses**
Hollowed out apart from head, circa 8-9 cm wide and 4.5 cm deep	Both arms, hole plug is missing, saint appears to only have one foot, smaller losses such as front-most section of cloak
Cracks	**Concealed knots/joints**
One horizontal split on the base at the right side, numerous small checks within the hollowed out verso One split on verso of ear from the plug hole downwards	Extensive use of canvas to cover fragile areas as well as reinforce attached wood: On red cap, visible on front of drapery through losses, extensively present on base, numerous on the left cloak

Holes and cavities
Plug hole is 9 cm deep. One hole in the neck at the proper left side One nail hole in base, at an angle to hold the sculpture in the altar / shrine (diameter circa 1 cm). Four small holes with diameter of ca. 0.7 cm Two holes at left at height of the left arm, only one of which extends through to the front. Possibility that the second hole which is full of dust was initially placed but at the wrong angle, resulting in the need for a second hole One hole at back on the left towards the base of the cloak, which also does not extend through to the front: unclear what the nature of that hole is One eyelet screw attached to verso at centre of neck and one deep hole 3.5 cm below that which could perhaps be an initial screw location
Other observations
Unclear why a hole goes through the arm – was the hand a separate piece of wood? If so, why was it not just attached with a dowel? Fibrous pulp deposits with embedded fibre or hair on verso: unclear nature or purpose of these

GROUND	
Colour	**Thickness**
White	Very thick

Texture	**Manipulation**
Numerous pits and pockmarks, crumbly in areas	Small parallel scrape marks on the robe and other areas from preparation tool Forehead has worry lines carved into ground
Losses Mostly on mitre, one small area on chest, large parts of pedestal and inner robe lining	**Intermediate layers** Not visible
Other observations Some areas appear crumbly as if partially dissolved (perhaps from 1923 treatment) Ground layer extends to the verso on the cap and is covered in red paint, but does not appear to have been scraped flat, hence appearing bubbly or lumpy (good evidence of ground layer appearance prior to smoothing)	

GILDING	
Metal Gold	**Application type** Poliment gilded over red bole, burnished
Surface coating Uncoated	**Losses** Extensive losses on mitre, localised losses along exposed areas (abraded), extensive larger scale losses on proper right shoulder and drapery
Decoration None	**Condition** Extensive abrasion, one area of corrosion at proper right side, this could be from a metal leaf of different composition from the rest
Bole Very thin layer of red bole, lost or abraded in many areas	**Other observations** Numerous candle wax drips on proper left shoulder, mitre and other areas, these are different colours and ages, indicating longer-term devotion

POLYCHROMY
Overall impressions Carnations well preserved, otherwise extensive losses to polychromy
Medium Appears oil-bound apart from blue, which could be proteinaceous

Build-up of layers Eyes and lips are relatively complex, with many layers and details. Red appears to have single layer stratigraphy Blue lining may have employed a grey underlayer, only minimal blue is left in the folds
Methods Skin tones painted wet in wet with reddish modelling, freely painted with extensive detail in face
Textures, tool marks None obvious
Overpaint None
Surface deposits/accretions Dark accretions on exposed edges, in left corner of eye and within hollows, numerous candle drips in white and natural wax colour
Paint losses Losses on proper left cheek, bottom lip, front and top of red cap, green landscape, central decoration on mitre, nose tip worn off, very few remnants to blue lining, underdress appears to be completely gone, leaving only the ground
Other observations Accretions consisting of fibrous pulp on proper right side of cap similar to those present on verso

DESCRIPTION
Flesh tones Pinkish, ruddy, lips are dark red over an orange red layer and darker red in the middle (three red tones), cheeks and chin are darker
Textiles Gilded robe has a blue lining, though mostly grey remnants of underlayer are left, mitre is gilded but a central stripe may have been painted (orange?) Red cap, gilded robe has black neckline, underdress might have been light red
Landscape Green base
Eyes Grey iris, black pupils, pinkish inner eye with white highlights, upper lid black while lower lid is pink, pink highlights in creases and corners of eyes as well as within the upper eyelid, eyebrows are light brown with some fine dark strokes on top

CONDITION REPORT WITH TREATMENT HISTORY

Object/title: Enthroned Virgin with nativity Date (c.): 1420s? (stylistic dating) Type: Sculpture Dimensions: 69,0 x 35,5 x 10,5 cm Inventory no.: **C2686** Location: MCH studio Examined by: Bettina Ebert Examination date: 19.08.2015	

Short description

Combination of enthroned Virgin and nativity: Christ child standing on Virgin's knee and pointing at a book, with smaller Joseph below, cooking in a pot over fire, with donkey and ox at side

Provenance & acquisition date

Torsken church, Troms, medieval diocese of Nidaros, acquired 1861

Literature

Nicolaysen 1862, Nicolaissen 1915, Bugge 1932, Engelstad 1933 and 1936, Trædal 2008

Exhibition history

Located in the pre-1979 medieval exhibition (church-room B 2), as seen in two archival photos from post-WWII exhibition arrangement by Gerhard Fischer (1948)

Other documentation

Erla Hohler MCH late medieval catalogue, MCH condition and treatment report

http://www.unimus.no/arkeologi/forskning/index_katalog.php?museum=khm&id=2925&museumsnr=C2686

Et Mariabillede af Træ, 1 Alen 2 Tr. høit. Maria er fremstillet i siddene Stilling; Kristusbarnet staar paa hendes Knæ og læser i en Bog, som hun holder frem for det. Ved Marias Fødder sees paa den ene Side en siddende mandlig Figur i simpel Dragt; paa den anden stikke to Hoveder af Dyr, som det synes Sauer, frem under Marias Fødder og drikke af en Krybbe. Imellem den siddene mandlige Figur og Krybben sees en Gjenstand, hvis Betydningen ikke skjønnes. Forgyldningen og Malingen har været anbrakte paa den ved slige middelalderske Træbilleder sædvanlige Maade, idet en Kridtgrund er lagt over et Behæk af fint Læred.
Billedet har været bevaret i Thorskens Annexkirke, Senjen og Tromsø Fogderi, Finnmarkens Amt.

TREATMENT HISTORY
Documentation Treatment 1923 by Louis Smestad, inspected 1975, treatment report from November 1976 by Grete Gundhus (nødkonservert), inspected 1991
Treatment notes Smestad: consolidation with isinglass vapour (*hus blas-inndampning*), cleaning with glue water (*limvannet*) Gundhus: overall cleaning and emergency conservation treatment, loose paint flakes consolidated with Plexisol in white spirit (1:3), surface dirt removed with water or “wux” and organic solvents (white spirit and acetone), depending on nature of the underlying layer (wux = white spirit : xylol: deionized detergent U9 1:1:5%)
Current condition Paint relatively well-preserved on Joseph and carnations, otherwise many losses, no overpaint present. Gilding well-preserved on Christ child, though with extensive losses to Virgin’s robe

SUPPORT	
Wood species Oak	**Dimensions** 69.0 x 35.5 x 10.5 cm (largest depth measured at Joseph’s hood)
Number of blocks One	**Grain direction** Vertical
Joins No joins, but one splintered/broken off dowel present at centre of verso	**Open joins** None
Structural alterations None	**Insect damage** Some isolated worm holes on recto, more holes visible on verso
Holes and cavities Two large holes passing through entire sculpture, diameter circa 1 cm on recto, possibly for attachment within altar/shrine. One hole is located below the Virgin’s neck, the other is beside the knot near Joseph’s outstretched arm. The lower hole ends in a square shape on verso, as from a nail that was inserted from recto. The upper exit hole on verso is somewhat larger. Rectangular indentation from metal spike at top of Virgin’s head, possibly to hold sculpture in position on workbench during carving.	**Losses** Spoon handle and Joseph’s left hand are missing. Joseph’s missing hand may have been glued on as no dowel is present, and glue remnants are visible Large piece of foreground beside Joseph has split off and is missing, probably the result of a deep crack in the wood. Two small losses to Virgin’s cloak All four crown fleurons missing. Glue remnants are present in the crown, as if fleurons were glued in position

<table>
<tr><td>Two small holes present on verso towards left and right edges respectively, these do not appear to extend through to the recto

Three modern screw eyelets present on verso, one at Virgin’s neck and two further down towards base</td><td>Remnants of wood from one of the missing fleurons is present within one of the frontal crown indentations, as well as some canvas fibres

Loss on sculpture’s proper left profile side, resulting in a concave hollow circa 1 cm in depth, possibly contemporary to construction since brown coating is present in that area (see below)</td></tr>
<tr><td>Cracks

Extensive cracking present, with checks and splits along the direction of the medullary rays, particularly visible on base and top, the majority of cracking visible on recto and verso of the sculpture is located on the proper right side, especially around the knot area

One crack along Mary’s forehead, while Jesus’s hands have split from the arms

One knot below Joseph’s outstretched arm, with associated cracking</td><td>Concealed knots/joints

Fabric visible in many areas covering the support prior to ground application, for example on Christ child’s back, right hand and back of head, on Joseph’s nose, right hand and hood, on Mary’s chest and crown, on Mary’s robe (on the folds that drape down from her left knee)</td></tr>
<tr><td colspan="2">Preparation of wood

Profile sides appear to be coated with a thin dark brown layer that exhibits some cracking and flaking, drip marks on verso at right as well as stains at bottom likely to consist of the same dark brown coating, possibly sizing of wood</td></tr>
<tr><td colspan="2">Verso

Relatively flat, accession number painted on verso in orange paint</td></tr>
<tr><td colspan="2">Construction marks

Gouge marks on back of sculpture, with a maximum width of 9 cm. Long parallel cut marks present on base. Christ’s ear is made from two shallow indentations with a boring tool

Fine parallel hatch marks at back of Virgin’s neck in the support and adjacent ground layer, possibly file marks from preparation of the ground - these are also visible on the base below Joseph’s feet

Carving has been left relatively rough, for example on the pot handle, and final shape was probably adjusted using the ground layer</td></tr>
<tr><td colspan="2">Other observations

Burn mark probably from candle on Virgin’s proper right knee/robe. Further burn mark on side of sculpture adjacent to Joseph’s hood

Glue is visible in the crack on Joseph’s hood. Remnants of facing paper fibres on Mary’s crown and hair from conservation treatment

One nail is present at the proper left edge of the base, inserted at an angle from the side

Sculpture does not stand straight when placed upright, but is angled somewhat to the back (see profile photos)</td></tr>
</table>

GROUND

Colour	**Thickness**
White	Of varying thickness, two distinct layers visible in areas. Ground is much thicker on gilded areas
Texture An underlying thinner and smoother layer with an upper thicker layer that is coarser, difference of ground layers is particularly visible in the Virgin's cloak Some pitting of the top ground layer	**Manipulation** Scrape marks from smoothing of ground visible on back of Virgin's neck and on base below Joseph's feet Some lines are visible on the Virgin's robe where outlines or marks were scratched into the ground prior to gilding Hair strands have been carved with a tool into the thick ground
Losses More extensive losses in foreground towards base, thin remnants present in many areas In the foreground and protruding points large areas of wood are fully exposed with total ground loss	**Intermediate layers** Some unpainted areas are present, it appears as if not all ground is covered with paint in areas that are hard to access or not very visible during frontal viewing eg. bottom of Virgin's shoes, back of Joseph's leg. These areas are beige or light brown in appearance, indicative of a discoloured glue isolation layer Dark brown drips and brush marks seen on verso (described above) likely to relate to glue isolation layer

Other observations

Ground on the Virgin's cloak is particularly thick, gritty and messy in some areas, containing embedded fibres. There are some gold particles mixed into these areas, as if these are dislodged flakes floating around which have migrated during consolidation

Some of the insect flight holes have ground inside them, suggesting that they were possibly present before ground and paint layers were applied

GILDING

Metal	**Application type**
Gold	Virgin's robe and crown, Christ's robe: Poliment gilded and burnished Hair: Mordant gilded over light brown base colour
Surface coating Possibly red glaze remnants on parts of crown	**Losses** Extensive losses on Virgin's robe while Christ's robe, gilding of hair and crown is better preserved

Decoration	Condition
None visible	Best-preserved on hair and Christ's robe, extensive abrasion in many areas of robes and high points of hair, possibly dark dirt layer present on crown
Bole	**Other observations**
Brown mordant on hair Appears ground-gilded, possibly a very thin pinkish bole present in some areas, visible on some areas of Virgin's cloak and Christ's robe	Some areas of the Virgin's cloak appear to have ground present on top of gilding – likely to be result of extensive use of moisture during consolidation, which has shifted some material

POLYCHROMY

Overall impressions

Majority of sculpture was gilded, with paint present on Joseph and carnations as well as the background and animals, paint layers mostly well-preserved

Medium

Appears oil-bound apart from blue robe lining, which could be proteinaceous

Build-up of layers

Gilding was applied prior to paint application

Layering technique used in the painting of the Virgin's throne to create different colours. Joseph's cloak appears to have been applied with two paint layers, possibly brown and overlying blue, otherwise most colours are just one paint colour or layer

Skin tones on Christ were applied prior to the red robe lining due to visible paint overlaps. Skin tones were applied in two layers: initial application of a warm pink tone, and a cooler tone on top of this containing more white, which gives a bluish cast. This is quite visible in Jesus's face, where this top paint layer is particularly visible on back of neck and around the ear

Methods

Quite thin and opaque paint layers, not much detail overall, cheek highlights have been painted wet in wet, other details like eyes and eyebrows painted subsequently once underlayers were dry, whites of the eyes have been applied more thickly

Some paint has been applied directly on the wood, without a ground layer (red on top of Virgin's head, one area on Joseph's cloak behind his arm)

Textures, tool marks

Brushmarks visible in some areas

Overpaint

None

Surface deposits / accretions Numerous black spots and accretions present on Virgin's face and neck, more concentrated on the proper left side (also mentioned in 1976 treatment report) Resinous remnants on Joseph's neck, some resinous or waxy remnants also present on back of sculpture. Black surface deposits on gilding on proper left side of Virgin's hair and crown. Dust, dirt and debris scattered in hollows of the sculpture, with a white accretion above Joseph's left shoulder
Paint losses Majority of green paint is lost, foreground paint lost, animals have extensive losses, blue robe lining has extensive losses, Joseph's feet and legs as well as the back of his cloak have many paint losses
Other observations Damages to paint and ground in the form of indentations on the Virgin's neck could relate to pressure from a tool during removal of nail holding the sculpture in position in shrine/altarpiece, losses around the hole also relate to this damage Virgin has scrape marks on the forehead Distinct appearance resulting from contrast between matte paint and gilded areas – perhaps related to Joseph's status (not seen as a saint in that period)? Resinous glossy remnants present on verso, particularly at top left, smaller spots also on recto of sculpture such as Joseph's chin, thicker drips have cracked, these remnants fluoresce bright green and appear to relate to conservation treatment history Green fluorescence of exposed fabric which appears to have been impregnated with consolidant, as well as stained areas on the Virgin's hair where facing paper fibres are present, some cracks also appear to have been strengthened with the same material

DESCRIPTION
Flesh tones Light pink skin with dark pink/reddish cheeks, lips and neck shading, Joseph has darker skin tones with a grey beard, nose tip is darker pink, while nostrils are same colour as lips. Fingernails outlined in brown at base and a darker brown at finger tips
Textiles Virgin's robe is gilded with blue lining, while Christ's robe is gilded with red lining. Blue lining of Virgin's cloak mostly bright blue, while in the hollow below arm supporting Christ, darker blue is visible. Necklines and sleeve edges have a thin black trim. Joseph wears a red hood with green lining and red leggings, a grey cloak and black shoes. Joseph's grey cloak appears to consist of a blue layer over a brown layer, resulting in grey.
Landscape Green background mostly lost, the Virgin's throne has a pink and purple pattern, the donkey is grey while the ox is painted red, and a dark red pot stands on dark red stones or coals
Eyes Mary has blue irises, Joseph's are brown. Black pupils and brown eyelids, eyebrows painted as thin lines.

CONDITION REPORT WITH TREATMENT HISTORY

Object/title: Enthroned Virgin with nativity, Schwanbeck Virgin

Date (c.): 1410-1430 (stylistic dating)

Type: Sculpture

Dimensions: 70.6 x 59.1 x 9.5 cm

Location: Evangelisch Lutherische Kirche St. Nikolai zu Dassow, Germany

Examined by: Bettina Ebert

Examination date: 1.11.2015

Short description

Combination of enthroned Virgin and nativity: Christ child standing on Virgin's knee, nativity scene with Joseph cooking in the foreground, as well as ox and donkey in the manger to one side

Provenance & acquisition date

Siechenhaus Kapelle, Schwanbeck, relocated to Dassow in 1972 after destruction of chapel

Literature

Struck 1926, Engelstad 1933, Trost 1990, Krohm & Suckale 1992, Voss 2007, church leaflet, online historical information gathered by church congregation

Exhibition history

Die Goldene Tafel aus dem Mindener Dom, late 1992 - early 1993 at Staatliche Museen Preußischer Kulturbesitz (SMPK), Berlin

TREATMENT HISTORY

Documentation

Conservation treatment report from Schwerin Landesdenkmalamt by Wilfried Spiller, 1971-72

Sculpture had split along the join between the two wooden pieces, gap contained reddish brown filler and crown and belt had been painted with copper paint.

Treatment notes

Surface dirt removal, removal of copper paint and gap filler. Wood re-glued with animal glue. Minor losses and insect flight holes filled with wood filler. Large rust stain on Virgin's robe reduced with Cyanex I and II. Missing crown finials reconstructed. Protective oak box frame constructed.

Current condition
Sculpture was stripped, very minor paint flakes present in hidden crevices upon detailed examination, gold paint remnants on crown and belt likely to be later overpaint

SUPPORT	
Wood species Oak	**Dimensions** 70.6 x 59.1 x 9.5 cm
Number of blocks Two, left block is wider (37.1 cm), right block circa 22 cm, vertical join running through the edge of the Virgin's cloak	**Grain direction** Vertical for both blocks, both appear to be flatsawn boards
Joins Glued along vertical join, brown filler along the join is remnant from prior restoration treatment. Three original wooden dowels present along the join according to treatment report. Plug in Virgin's cloak/elbow could be a dowel joining/connecting the two blocks? A broken off dowel present in Virgin's proper left arm, as well as another one in the cloak directly above	**Open joins** Gap between the two blocks has opened slightly at base Slight concave warp when viewed from the base
Structural alterations Two large and one small dowel on top of the throne at either side have been neatly sawn off, saw scrape marks visible on the wood. Dowel more clearly visible at proper right side. Sawed off dowels could indicate additional architectural element Replacement crown finials have been glued in position, some brown filler present, same as along the vertical join	**Insect damage** Some isolated insect holes visible on the sculpture itself, more extensive tunnelling from woodworm on verso behind Joseph, as well as woodworm damage on top of crown and on verso at left edge, sculpture feels quite hollow when tapped
Holes and cavities Hole in base of smaller right block filled with a lighter material, appears newer than original	**Losses** Virgin's proper left arm, top of wooden spoon, Joseph's nose, donkey's tip of the proper right ear, ox tip of proper left horn
Cracks Some cracks in throne between Joseph and the Virgin, as well as some checks on the base, in the larger left block	**Concealed knots/joints** None visible, though large wooden plug present in Virgin's neck at proper left side, 2,2 cm diameter, could have been location of a knot

Preparation of wood Not noticeable, possibly due to stripping of sculpture
Verso Flat, three modern screw holes on verso from attachment to wooden box. Appears very dark as if stained (previously covered in boat varnish according to 1971 condition report)
Construction marks Some chisel or axe marks on verso (deep straight cuts, not curved). Saw or axe marks on base, from the join towards the right only (left block base is smooth), perhaps to adjust the height of the right block to match the left base
Other observations One sawn-off old nail on verso, located at height of 43 cm from the base. Some scratch marks on wood surface as of scraping during stripping treatment, wax remnants present on verso. One chunk on Christ's outreached arm could perhaps point to placement of Virgin's missing left arm Pieces of cork attached to base so that sculpture stands straight in its box

GROUND	
Colour White	**Thickness** Appears very thin underneath green remnants
Texture Insufficient amount left to observe details	**Manipulation** Insufficient amount left to observe details
Losses Very extensive due to stripping treatment	**Intermediate layers** Not visible
Other observations None	

GILDING	
Metal Gold	**Application type** Likely to be poliment gilded and burnished on robes due to presence of red bole remnants on top of ground remnants in Virgin's cloak folds Hair likely mordant gilded
Bole Red	**Condition** Almost all gone

Other observations
Some original remnants inside Christ's left arm crook as well as on his robe Non-original gold paint visible on crown as well as Virgin's belt (has filled wood pores and covers losses in the support, no ground underneath)

POLYCHROMY
Overall impressions Stripped, but paint remnants appear to correlate with Torsken Virgin
Medium Insufficient remnants to determine medium used
Overpaint Small bright red paint speck on Joseph looks as if it has no ground layer and could be non-original
Paint losses Extensive, stripped apart from some minor remnants in hard to access spots
Other observations Some red marks present on base as well as along the join, likely to be non-original. Some sparkling crystals on bottom of Joseph's proper right hand

DESCRIPTION
Flesh tones Paint remnants on Christ's right ear, Virgin red lips, some pink on hands, Virgin's neck, base of foot, Virgin's ear. Joseph's face appears pink
Textiles Virgin has gilded robe with blue lining, remnants of both at central edge of robe Joseph's stockings possibly white, while cloak is dark blue or grey
Landscape Green visible on base behind the pot and spoon, light blue present in both bowls, red paint specks on the flames, bowl in Joseph's lap has an off-white colour, not clear if ground or paint Remnants on throne and manger indicate reddish/pink/purple appearance

DRAWINGS

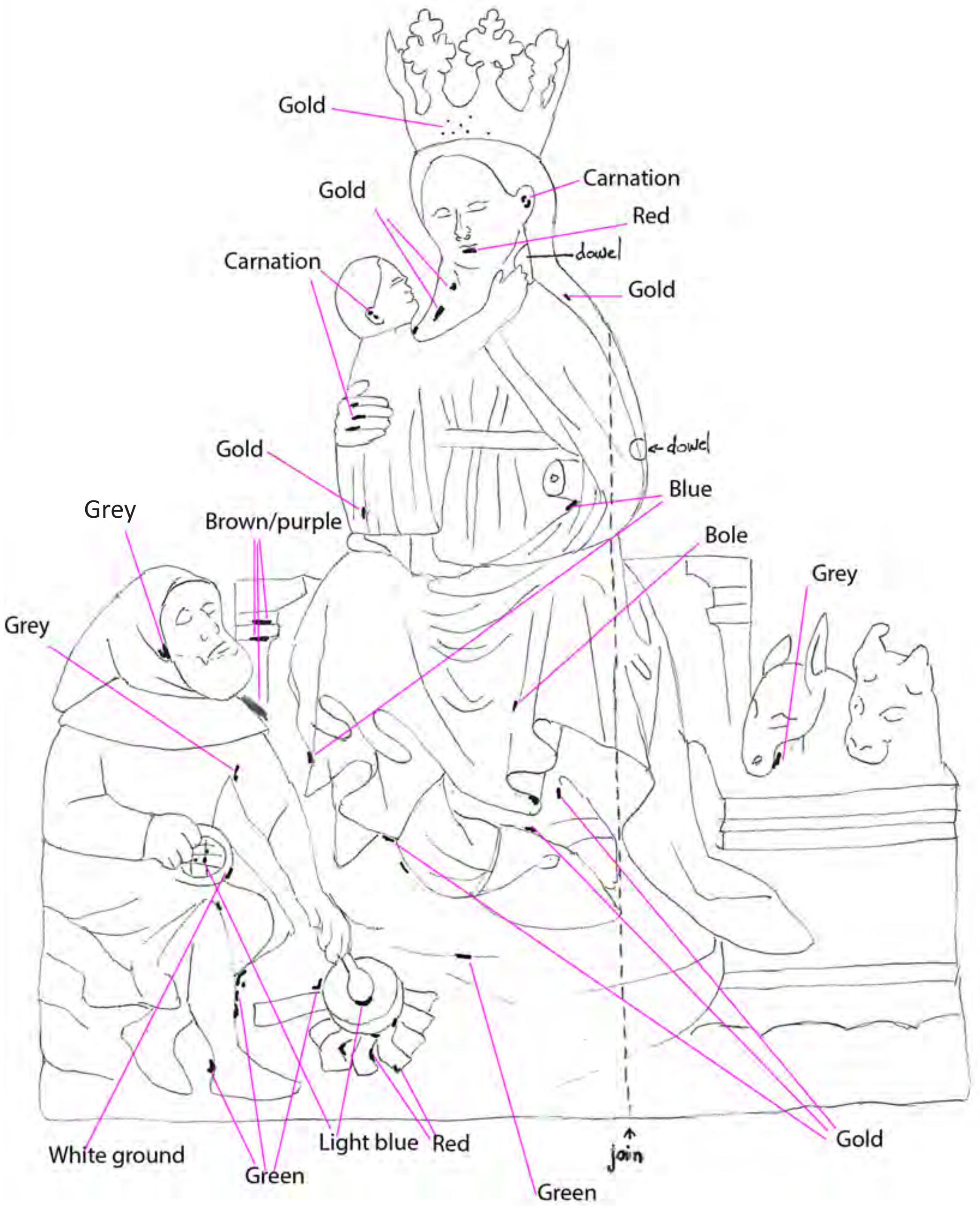


Figure 24: Paint remnants

Appendix 3: X-ray imaging

Figure 25: X-ray of C2912

Figure 26: X-ray of C2913

Figure 27: X-ray of C2686

Appendix 4: Dendrochronology

dendro.dk report 43 : 2016

1st July 2016

Non-invasive dendrochronological analysis of four polychrome ecclesiastical sculptures from Troms, Norway.

Aoife Daly, Ph.D.

Dendro.dk report 43 : 2016
Commissioned by Bettina Ebert, Department of Archaeology, Conservation and History (IAKH), University of Oslo. In collaboration with Noëlle Streeton of the research project 'After the Black Death: Painting and Polychrome Sculpture in Norway, 1350-1550', the Centre for Art Technological Studies and Conservation (CATS), Statens Museum for Kunst, Copenhagen and the Norwegian Geotechnical Institute (NGI), Oslo.

Fig. 1. Sculpture C2686 Madonna and nativity from Torsken church standing in the CT-scanner at NGI, Ullevål, Oslo (photo Bettina Ebert).

Non-invasive dendrochronological analysis has proved successful in recent years, both through CT-scanning of oak objects and through analysis of exposed tree-rings on objects, when possible (Bill et al 2012, Daly & Streeton forthcoming). Following success with applying the CT-scanning method to polychrome sculpture, four oak sculptures from Troms, Norway have been subjected to the method. This report outlines the results of the analysis.

The four sculptures, which are the subject of a phd study by Bettina Ebert, are Madonna and nativity (C2686) from Torsken church, Senja island, Troms, Female saint (C3124) from Karlsøy church, Karlsøy island, Troms, St Anne with Virgin and child (C2912) and St Bernhard (C2913) both from Berg church, Senja island, Troms, all now part of the collections at the Museum of Cultural History, University of Oslo.

In order to obtain tree-ring measurements for analysis the four sculptures have been CT-scanned at the facility at the Norwegian Geotechnical Institute. The objects are placed upright on a wooden stand (kindly lent by Jan Bill, UiO), and positioned in the scanner in such a way as to optimise the resolution and to enable the maximum number of tree-rings to be visible (fig. 1). The object rotates slowly so that a total of 3142 X-ray images are compiled into a 3D model through the object. Virtual cross-sections of the object (fig. 2) can then be extracted for tree-ring measurement. Measuring was carried out from these images using the program Able Image Analyser, and for the analysis and the calculation of the *t*-value ("*t*-test"), the programs "DENDRO" (Tyers, 1997) and "CROS" (Baillie & Pilcher, 1973) are used. An extensive network of master and site chronologies for Northern Europe were consulted to find the dating for the tree-ring series.

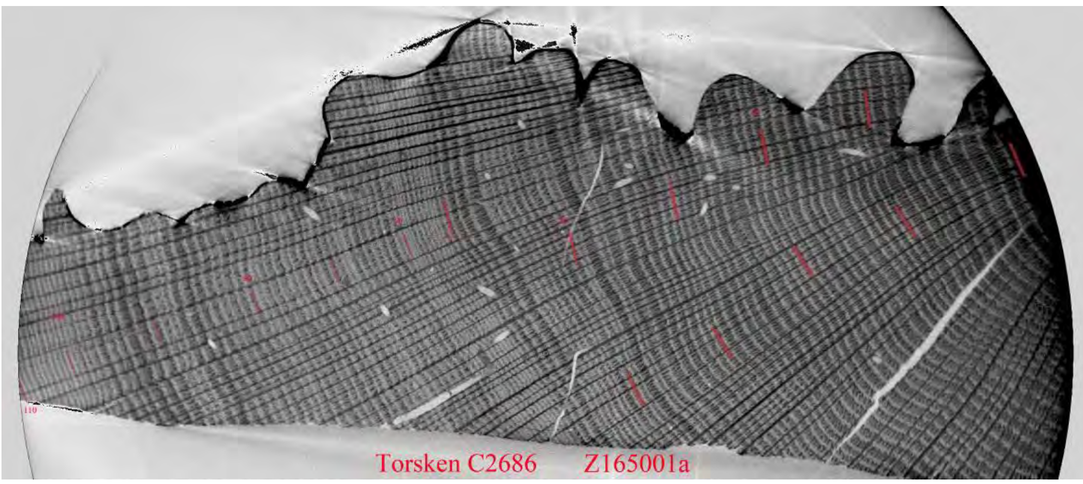


Fig. 2. C2686 Madonna and nativity from Torsken church. A virtual section through the sculpture clearly shows the oak tree-rings (image produced at NGI, Oslo; markings Aoife Daly).

C2912 St Anne, with Virgin and child from Berg church, Senja island, Troms

The sculpture of St. Anne from Berg church (fig. 3) is made of three oak pieces placed together vertically. It was possible to mount the sculpture on the wooden stand (fig. 4) and it was tied with cotton tape and placed in the CT-scanner (fig. 5). Due to the relatively broad width of the sculpture it was decided to scan the object in two halves, in order to attain a view of the maximum number of rings, from innermost to outermost (fig. 5). It is clear from the virtual section (fig. 6) that three wood elements are present, and a view of the full number of tree-rings is only lacking from the back element of the object.

Fig. 3. C2912 St Anne, with Virgin and child from Berg church, Senja island, Troms (photo Aoife Daly).

Fig. 4. C2912 St Anne, with Virgin and child from Berg church, Senja island, Troms. The sculpture is mounted upright in preparation for scanning (photo Aoife Daly).

Fig. 5. C2912 St Anne, with Virgin and child from Berg church, Senja island, Troms. The sculpture is positioned in the CT-scanner for X-ray (photo Aoife Daly).

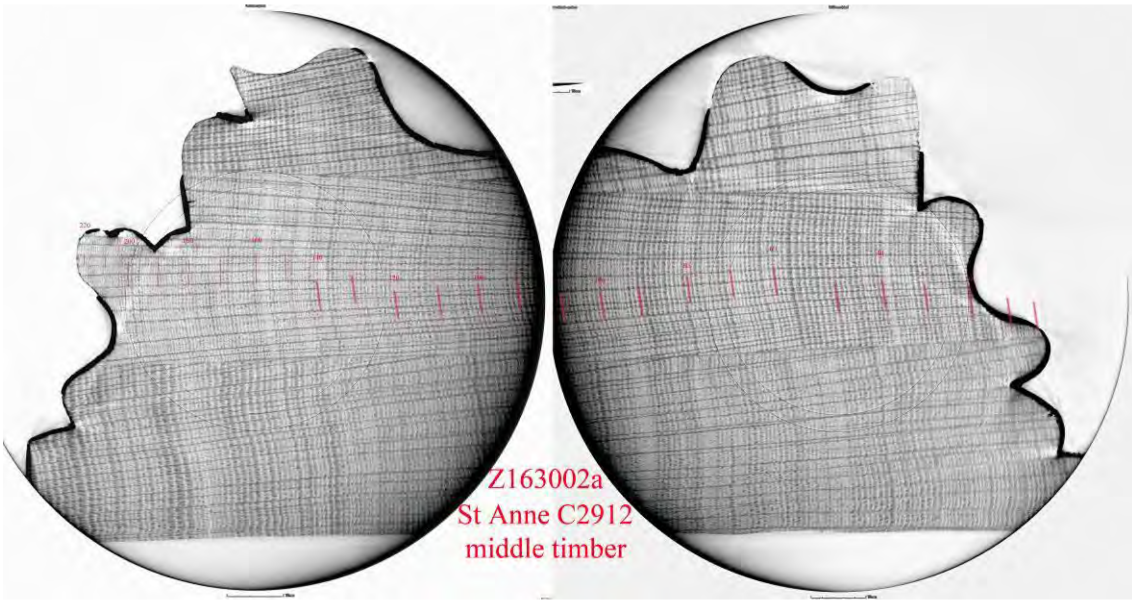


Fig. 6. C2912 St Anne, with Virgin and child from Berg church, Senja island, Troms. View of two virtual sections through the sculpture, from the CT scanner (image produced at NGI, Oslo; markings Aoife Daly).

The front timber
The wooden element at the front of the sculpture contains 138 tree-rings, with only heartwood observed. The tree-ring curve from this element covers the period AD 1278-1415. Allowing for missing sapwood, the tree used for this element was felled after AD 1425 (see fig. 7).

The middle timber
The wood for the middle piece is from a very slow-grown tree, with an average annual growth rate of just 1,05 mm per year (fig. 8). The middle element contains 223 tree-rings and its tree-ring curve covers the period AD 1200-1422. No sapwood was observed on this element. The tree used for this part was felled after AD 1432 (fig. 7).

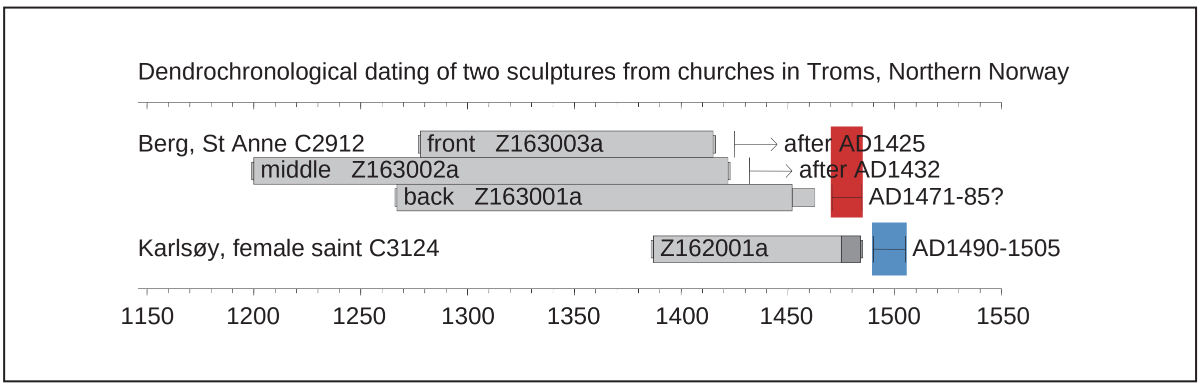


Fig. 7. Two sculptures from Troms, Norway. The diagram illustrates the chronological position of the dated wood elements. The red shading indicates the dating for the felling of the trees used for the St. Anne sculpture. The blue shading indicates the felling dating for the tree used for the Karlsøy sculpture (illustration Aoife Daly).

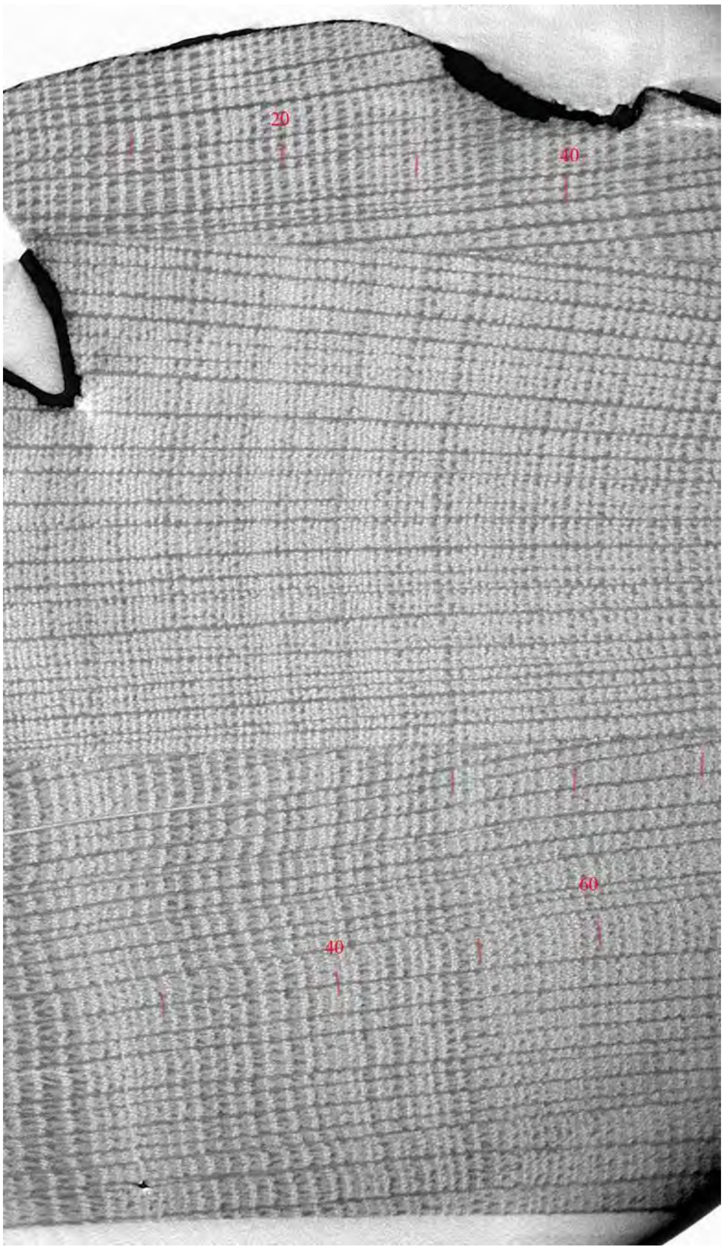


Fig. 8. C2912 St Anne, with Virgin and child from Berg church, Senja island, Troms. The oak tree-rings of the three wood elements used to make the sculpture are clearly visible, enabling non-invasive dendrochronological analysis (image produced at NGI, Oslo; markings Aoife Daly).

The back timber
From the CT imagery it was possible to count and measure 186 tree-rings on the back wood element. The resulting tree-ring curve covers the period AD 1267-1452. As mentioned above however, the CT-scan imagery did not cover the full width of this part. Approximately 10 heartwood rings are present but not measured outermost, and observations of the sculpture surface suggest that a little sapwood is also present, but due to varnish, this could not be conclusively confirmed (fig. 9). The estimated dating for the felling of the tree used for the back wood part, can be placed at c. AD 1471-85 (marked with red in fig. 7).

As the trees for the wood elements that make up the sculpture probably grew in the Baltic region (see below) a sapwood statistic for Northern Poland is used. Here oak trees have an average of 15 sapwood years (-6 +9) (Wazny 1990)).

If it is assumed that the three trees used for the making if the St. Anne sculpture were felled at the same time, then this felling would have taken place **around AD 1471-85**.

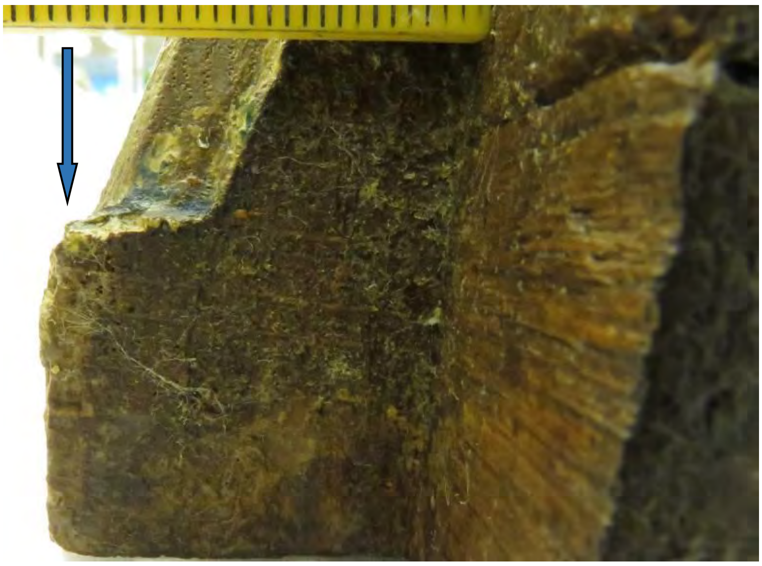


Fig. 9. C2912 St Anne, with Virgin and child from Berg church, Senja island, Troms. Sapwood might be preserved on the outermost edge of the back wood element (arrow) (image Aoife Daly).

Provenance
The tree-ring curves from the front and middle wood elements cross-match with each other, achieving a correlation of t = 5,19 so these two are averaged to an average curve (Z163M001) which is 223 years long. The tree-ring curve for the back element is dating independently of the other two. In table 1 the correlation values (*t*-values) between the tree-ring curves and a selection of Northern European chronologies are shown. All the elements for the sculpture are dating with Southern Baltic oak tree-ring datasets but the back element might be from a tree that grew in a different area to the trees for the middle and front elements within this vast region.
As many of the Baltic tree-ring chronologies are built from oak that was exported to Western Europe, it has not as yet been possible to say where, precisely, that these trees grew in the extensive Southern Baltic region. It is possible to distinguish between different groups of the Southern Baltic timber, (named Baltic 1, Baltic 2 and Baltic 3 (Hillam & Tyers 1995)) and these groups most probably represent forests in different areas within the region.

Filenames	-	-	St. Anne Berg back Z163001a	St. Anne Berg mid & front Z163M001	
-	start	dates	AD1267	AD1200	
-	dates	end	AD1452	AD1422	
Master chronologies					
0M040004	AD1156	AD1597	4,94	6,98	**Baltic 1** 64 timbers (Hillam & Tyers 1995)
PP122M01	AD1006	AD1359	1,61	5,05	Elblag 114 timbers (Wazny pers comm revised Daly 2007)
Baltic oak for artworks					
Z103009&10	AD1290	AD1488	3,50	8,23	Slagen altertavle Norge right wing bottom relief (Daly 2013d)
Z0800039	AD1275	AD1512	2,01	7,20	Private painting Moneylenders plank 3 (Daly 2011b; Daly & Läänelaid 2012)
Z099103a	AD1328	AD1478	0,97	4,60	KMS sp 739 Portrait of 27-year-old man (Daly 2013c)
HEADSx11	AD1304	AD1521	4,62	4,35	Stirling heads Baltic (Crone pers comm)
Z0700019	AD1238	AD1436	5,66	2,56	Bouts Madonna with child (Daly 2011a)
Z103M tracer	AD1348	AD1495	5,27	3,30	Slagen altertavle Norway tracery 4 timbers (Daly 2013d)
Shipwrecks and cargo of Baltic oak					
Z054m001	AD1235	AD1448	3,26	8,07	Ostsee VII planks 5 timbers (Daly 2010)
0075M00120	AD1113	AD1463	6,06	6,05	Vejdyb ship 16 timbers (Daly 1997b & unpubl)
02070169	AD1200	AD1390	0,74	5,47	Dokøen Copenhagen ship 3 (Eriksen 2002)
0075M00420	AD1247	AD1455	2,54	5,02	Vejdyb ship 4 timbers (Daly 1997b & unpubl)
02071059	AD1201	AD1412	6,27	3,63	Dokøen Copenhagen ship 2 (Eriksen 2001)
se613m01	AD1197	AD1464	5,86	2,51	Hull Blaydes Staithe 3 timbers (Tyers pers comm)
Z084007a	AD1338	AD1435	5,53	3,37	Skaftö wreck barrel head (Daly 2013b)
Z084M002	AD1152	AD1438	4,25	3,15	Skaftö wreck barrel 11 timbers (Daly 2013b)

Table 1. C2912 St Anne, with Virgin and child from Berg church, Senja island, Troms. Result of the correlation between the tree-ring curves for the sculpture and diverse Northern European site and master chronologies. The source of the chronologies is given. The grey tone highlights the high *t*-values.

C2913 St Bernhard from Berg church, Senja island, Troms (fig. 10)
From the CT-scanning it is clear that the sculpture of St. Bernhard from Berg church was made using two wood pieces – a larger, fast-grown piece and a smaller very slow-grown piece (fig. 11). The larger piece contains 91 tree-rings, with an average growth rate of just under 1,5 mm per year. The smaller piece contains 77 rings, with an average growth of just 0,77 mm per year. Neither of the tree-ring curves from the two elements that make up the St. Bernhard sculpture could be dated.

Fig. 10. C2913 St Bernhard from Berg church, Senja island, Troms is positioned in the CT-scanner at NGI (photo Bettina Ebert).

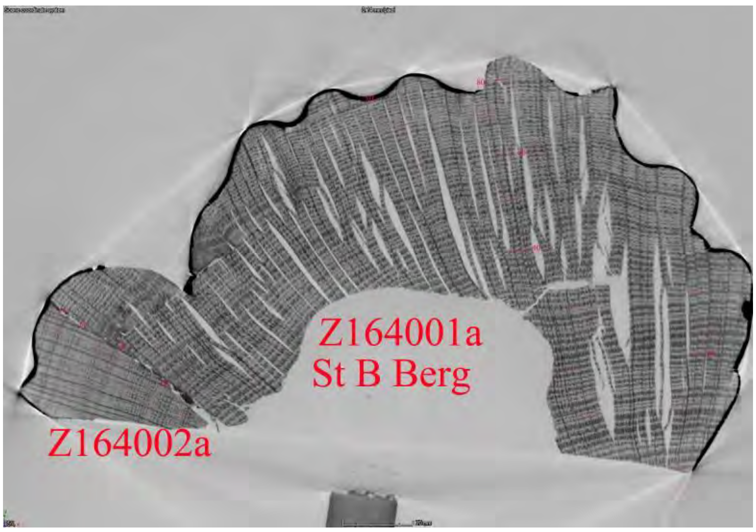


Fig. 11. C2913 St Bernhard from Berg church, Senja island, Troms. The virtual section through the sculpture (image produced at NGI, Oslo; markings Aoife Daly).

C3124 Female saint from Karlsøy church, Karlsøy island, Troms (fig. 12)
The sculpture of the saint from Karlsøy church is made from a single oak piece. Sapwood is clearly visible on the sculpture (fig. 13) and this sapwood is also clear in the virtual section achieved from the CT-scanning, visible as lighter density wood at the outermost rings (fig. 14).

The tree-ring curve from the sculpture contains 98 measured tree-rings of which nine are sapwood rings. The tree-ring curve covers the period AD 1387-1484. Allowing for missing sapwood the felling date for the tree used for this sculpture can be placed at AD 1490-1505. As the tree used grew in the northern German region (see below), a sapwood statistic for Northern Germany is used. Here oaks have an average of c. 20 sapwood years (-5+10) (Hollstein 1980).

Fig. 12. C3124 Female saint from Karlsøy church, Karlsøy island, Troms. The sculpture is positioned upright in the CT-scanner (photo Aoife Daly).


Fig. 13. C3124 Female saint from Karlsøy church, Karlsøy island, Troms. Sapwood is preserved on the sculpture (photo Aoife Daly).

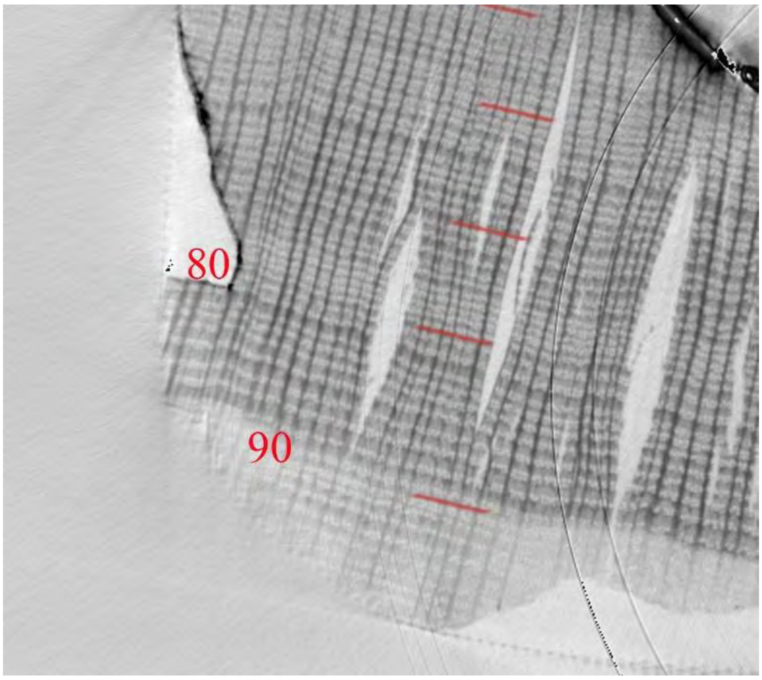


Fig. 14. C3124 Female saint from Karlsøy church, Karlsøy island, Troms. Sapwood preserved on the sculpture is clearly visible in the virtual section (image produced at NGI, Oslo; markings Aoife Daly).

Provenance

In table 2 the correlation values (*t*-values) between the tree-ring curve from the Karlsøy sculpture and a selection of Northern European chronologies are shown. It achieves highest correlation with a master chronology for Lübeck and with a site chronology from Niendorf in Schleswig-Holstein. The sculpture can have been made from an oak that grew in the Lübeck hinterland.

Filenames	-	-	Karlsøy Z162001a	
-	start	dates	AD1387	
-	dates	end	AD1484	
Master chronologies				
DM100008	AD457	AD1723	8,40	Lübeck (Hamburg Uni)
DM100007	AD1080	AD1967	5,84	Hamburg (Hamburg Uni)
DM200005	AD915	AD1873	5,77	Niedersachsen Nord (Göttingen Uni)
Site chronologies				
H112UM01	AD1391	AD1543	**10,20**	Niendorf Dörpstraat 6 timbers (Hamburg Uni revised Daly 2007)
H11HHM01	AD1379	AD1531	7,61	HL Langer Lohberg 14 timbers (Hamburg Uni revised Daly 2007)
H110GM01	AD1386	AD1511	7,60	Behlendorf Seestr 10 timbers (Hamburg Uni revised Daly 2007)
H11I0M01	AD1423	AD1541	6,43	HL Engelswisch 4 timbers (Hamburg Uni revised Daly 2007)
H11IXM01	AD1394	AD1539	6,12	HL Tuenkenhagen 6 timbers (Hamburg Uni revised Daly 2007)
H11IWM01	AD1389	AD1571	6,10	HL Gr.Petersgrube 15 timbers (Hamburg Uni revised Daly 2007)
H110AM01	AD1397	AD1506	5,95	Behlendorf Seestr. 6 timbers (Hamburg Uni revised Daly 2007)
H11HAM01	AD1385	AD1561	5,95	HL Fischergrube 18 4 timbers (Hamburg Uni revised Daly 2007)
H113MM01	AD1419	AD1507	5,84	Waltersdorf Windber 4 timbers (Hamburg Uni revised Daly 2007)
H11H8M01	AD1387	AD1460	5,76	HL Mengstr. 12 timbers (Hamburg Uni revised Daly 2007)
H114LM01	AD1362	AD1443	5,70	Eutin Kirche 15 timbers (Hamburg Uni revised Daly 2007)
H11AIM01	AD1375	AD1449	5,63	Ratzeburg Domkloste 16 timbers (Hamburg Uni revised Daly 2007)
HO121M01	AD1354	AD1486	5,63	Grossmist Dorfstr. 6 timbers (Hamburg Uni revised Daly 2007)
G330FZ01	AD1385	AD1681	5,62	Stadthagen 13 timbers (Göttingen Uni revised Daly 2007)
Oak for artworks				
Z104101&10	AD1369	AD1470	8,02	Skjervøy sculptures Virgin & Olav same tree CT (Daly & Streeton forthcoming)
Shipwrecks and cargos				
00651m07lub	AD1386	AD1586	6,43	Copenhagen ship B&W1 2 timbers (Daly 1997a; 2007)
Z093M001	AD1420	AD1614	5,92	Vasa barrels 7 timbers (Daly 2013a)

Table 2. C3124 Female saint from Karlsøy church, Karlsøy island, Troms. Result of the correlation between the tree-ring curve for the sculpture and diverse Northern European site and master chronologies. The source of the chronologies is given. The grey tone highlights the high *t*-values.

C2686 Madonna and nativity from Torsken church, Senja island, Troms (fig. 15)

The Madonna from Torsken church is made from a single oak piece (fig. 15). It was CT scanned with a view to attaining a view of as many rings as possible, while at the same time achieving a sufficient resolution, but due to the wide base of this sculpture, not all rings contained in it are imaged (fig. 2). Confident measurements of an uninterrupted tree-ring series of 115 years in length were made, but it remains as yet not possible to date this piece.

Fig. 15. C2686 Madonna and nativity from Torsken church, Senja island, Troms placed upright for scanning (photo Bettina Ebert).

Discussion

It has previously been shown that CT scanning as a non-invasive technique for dendrochronological analysis is a very viable technique, when suitable equipment and settings are used (Bill et al 2012; Daly & Streeton forthcoming). In the case of this study the images produced for tree-ring analysis were in most cases of a clarity that allowed confident reliable tree-ring measurement, resulting in successful dating of two of the four objects. The exception to this is the St Bernhard from Berg church. The imagery allowed confident measurement of the main timber in the sculpture, but the small additional timber contains quite narrow rings (average growth 0.77 mm) and this proved difficult to measure. That, in combination with the fact that each piece on the St Bernhard sculpture contain relatively few rings (91 and 77 respectively), has meant that that analysis has not produced a dating. In terms of the wood used for the two dated sculptures, the initial examination and the resulting dating and provenance results all indicate that

these two are quite different from each other. The St Anne from Berg is sculpted from three finely-grained oak blocks placed together. They were probably joined after the wood was seasoned, given that the joins are still tightly shut (fig. 8). All three timbers are from oaks that grew in the Southern Baltic region, and due to possible sapwood observed, the felling of these trees can be placed at c. AD 1471-85. It is a period where we see extensive trade of Baltic timber to western Europe, so the provenance of the wood does not indicate where the sculpture might have been made.
The results from the sculpture from Karlsøy church are quite different. The single oak timber used for the sculpture is from a faster-grown tree (average ring width 1.57 mm) and a large portion of sapwood has been allowed to remain. The tree used for this sculpture grew in the Lübeck hinterland and was felled in c. AD 1490-1505. For this sculpture the dendrochronological analysis might allow us to suggest that the sculpture was made in a Lübeck workshop, and was shipped to Norway as a finished piece.

Literature

Baillie, M.G.L. and Pilcher, J.R., 1973. A simple crossdating program for tree-ring research. *Tree-Ring Bulletin* 33, 7-14.

Bill, J., Dalen, K.S., Daly, A. og Johnsen, Ø., 2012. Dendro CT – dendrochronology without damage. *Dendrochronologia* 30 (2012) 223–230.

Daly, A., 1997a. Dendrokronologisk undersøgelse af tømmer fra ‘B&W grunden’, Strandgade 3A, Christianshavn, tidligere Grønnegaard Havn. II: Skibsvrag mm. *Naturvidenskabelige Undersøgelser rapport nr.* 1997: 5, København.

Daly, A., 1997b. Dendrokronologisk undersøgelse af skibsvrag fra Vejdyb udfor Hals, Aalborg Amt. *Nationalmuseets Naturvidenskabelige Undersøgelser* rapport 1997 : 12, Copenhagen.

Daly, A., 2007. *Timber, Trade and Tree-rings. A dendrochronological analysis of structural oak timber in Northern Europe, c. AD 1000 to c. AD 1650*. Ph.D. thesis submitted February 2007, University of Southern Denmark.

Daly, A., 2010. Ostsee VII Fpl 92, Meklenburg-Vorpommern, Germany. *dendro.dk rapport* nr. 2010 : 35

Daly, A., 2011a. Dieric Bouts, Madonna and Child. *dendro.dk rapport* 2011 : 20, Copenhagen.

Daly, A., 2011b. Dendrochronological analysis of a painting on an oak panel, Christ Driving the Moneylenders from the Temple. *Chronology, Culture and Archaeology* Report 05 (2011). University College Dublin.

Daly, A., 2013a. Dendrochronological analysis of samples from timbers and cargo from the Vasa, Stockholm, Sweden – a case study. *Chronology, Culture and Archaeology report* 13, University College Dublin.

Daly, A., 2013b. Barrels from the Skaftö shipwreck. *Dendro.dk rapport nr*. 2013 : 4, Copenhagen.

Daly, A., 2013c. Dendrochronological analysis of oak panel supports for painting “Portrait of 27 year old man” by a master of the 1540s, KMS sp 739 *CATS dendro report* 1, Copenhagen.

Daly, A., 2013d. Dendrochronological analysis of altarpiece from Slagen church, Norway, C2124. *CATS dendro report* 2, Copenhagen
Daly, A & Läänelaid, A., 2012. The dendrochronological dating of three paintings in the style of Bosch/Bruegel. in E. Hermens (ed.) *On the Trail of Bosch and Bruegel: Four Paintings under Magnification*. Archetype Publications/SMK.
Daly, A., & Streeton, N., forthcoming. Non-invasive dendrochronology of late-medieval objects in Oslo: refinement of a technique and discoveries. Submitted to *Applied Physics A*, June 2016.
Eriksen O.H., 2001. Dendrokronologisk undersøgelse af tømmer fra skibsvrag fundet på Dokøen, København. *Nationalmuseets Naturvidenskabelige Undersøgelser* rapport 2001 : 23, Copenhagen.
Hillam, J. and Tyers, I., 1995. Reliability and repeatability in dendrochronological analysis: tests using the Fletcher archive of panel-painting data. *Archaeometry* 37, p. 395-405.
Hollstein, E. 1980. *Mitteleuropäische Eichenchronologie*. Trierer Grabungen und Forschungen 11. Mainz am Rhein.
Tyers, I.G., 1997. Dendro for Windows Program Guide, *ARCUS Report* 340, Sheffield.
Wazny, T., 1990. *Aufbau und Anwendung der Dendrochronologie für Eichenholz in Polen*. PhD Thesis. Universität Hamburg, pp. 213.

Catalogue

Filename	sample title and number	rings	start yr.	end yr.	pith	sapwood	bark?	Conversion	extra end	Average ring width (mm.)	Interpretation / felling
C2912 St Anne, with Virgin and child from Berg church, Senja island, Troms											
Z163001a	St Anne sculpture C2912 timber 1 back CT scan QUSP	186	AD1267	AD1452	G	yes?	N	O	H10	1,43	AD1471-85?
Z163002a	St Anne sculpture C2912 timber 2 middle CT scan QUSP	223	AD1200	AD1422	G	0	N	O	H1	1,05	after AD1432
Z163003a	St Anne sculpture C2912 timber 3 front CT scan QUSP	138	AD1278	AD1415	G	0	N	O	H1	1,36	after AD1425
C2913 St Bernhard from Berg church, Senja island, Troms											
Z1640019	St B Berg sculpture C2913 timber 1 main piece CT scan QUSP	91			G	0	N	O	H1	1,49	undated
Z164002a	St B Berg sculpture C2913 timber 2 side piece CT scan QUSP	77			G	0	N	O	H1	0,77	undated
C3124 Female saint from Karlsøy church, Karlsøy island, Troms											
Z162001a	Karlsøy sculpture C3124 CT scan QUSP	98	AD1387	AD1484	G	9	N	O	S1	1,57	AD1490-1505
C2686 Madonna and nativity from Torsken church, Senja island, Troms											
Z1650018	Torsken sculpture C2686 CT scan QUSP	115			G	0	N	O	H1	2,12	undated
Conversion: R = radial split plank, T = tangential plank, W = whole timber, S = squared whole timber, H = half timber, Q = quarter timber, O = other conversion. Pith: C = centre, V = less than 5 rings, F = 5 – 10 rings, G = greater than 10 rings.											
Aoife Daly, Ph.D.	1st July 2016										

AOIFE DALY, Ph.d.

Appendix 5: Portable XRF interpretation

Record of analysis: Portable X-ray fluorescence (pXRF)

BERG ST ANNE, C2912		
Analyst	**Location**	**Date**
Bettina Ebert	Frederiksgate 3, MCH conservation studio	07.10.2015

In the interpretation, elements thought to derive from instrument contributions are not listed subsequently after their first mention, unless count rates are higher than expected solely from instrument contribution. Elements are listed in order of concentration (though note that the heaviest elements result in the highest concentration).

Spectra are archived at the MCH and available upon request.

Sample map

Site no.	Reading no.	Spot size (mm)	Sample region	Spot photo	Element identification	Interpretation, comments
0	167	3	Foam back-ground spectrum		Ag, W, Ni, Mo, Cu, Fe, Al	Ag – X-ray tube target Mo, Al, Cu, Fe – filters W – shutter and small spot collimator Ni – SDD casing Very low count rates, generally below 30 counts/second
1	451	3	Forehead		Pb, Ca, Sr	Pb – lead white Ca, Sr – chalk ground (Sr often associated with chalk in deposits)
2	452	3	Cheek		Pb, Ca, Hg, S, Sr	Pb – lead white Ca, Sr – chalk ground (Sr often associated with chalk in deposits) Hg, S – vermilion
3	453	3	Veil		Ca, Sr	Ca, Sr – chalk ground (Sr often associated with chalk in deposits), chalk possibly also used as upper paint layer
4	454	3	Light red		Hg, Ca, Sr, S, Si	Hg, S – vermilion Ca, Sr – chalk ground (Sr often associated with chalk in deposits) Si – contaminant or trace element in chalk
5	455	3	Dark red		Hg, S, Ca, Sr	Hg, S – vermilion Ca, Sr – chalk ground (Sr often associated with chalk in deposits) Likely organic glaze accounting for difference in colour to site 4
6	456	3	Throne		Pb, Ca, Sr, Cu, Fe, P	Pb – lead white or red lead Ca, Sr – chalk ground (Sr often associated with chalk in deposits) Cu – copper green particles Fe – earth pigment such as ochre P – bone black or trace element
7	457	3	Gold		Ca, Au, Fe, Si, Sr	Ca, Sr – chalk ground (Sr often associated with chalk in deposits) Fe, Si – bole Au – gold leaf
8	458	3	Blue dress		Ca, Cu, Ba, Sr	Ca, Sr – chalk ground (Sr often associated with chalk in deposits) Cu – azurite Ba – possibly from 1970s retouching
9	459	3	Green base		Cu, Pb, Ca, Sn, Sr, Fe	Cu – copper green Pb, Sn – lead tin yellow Ca, Sr – chalk ground (Sr often associated with chalk in deposits) Fe – perhaps iron oxide particles, contaminant or trace element
10	460	3	Wood (back-ground)		Ca, Pb, Cu, Fe	Similar to site 9 but significantly lower count rates, perhaps trace amounts of green from pedestal

Record of analysis: Portable X-ray fluorescence (pXRF)

BERG, BISHOP, C2913		
Analyst	**Location**	**Date**
Bettina Ebert	Frederiksgate 3, MCH conservation studio	05.02.2017
Elements deriving from instrument contributions are not listed subsequently, unless count rates are higher than expected solely from instrument contribution. Elements are listed in order of concentration (though note that the heaviest elements result in the highest concentration). Spectra are archived at the MCH and available upon request.		

Sample map

Site no.	Reading no.	Spot size (mm)	Sample region	Spot photo	Element identification	Interpretation, comments
0	167	3	Foam back-ground spectrum		Ag, W, Ni, Mo, Cu, Fe, Al	Ag – X-ray tube target Mo, Al, Cu, Fe – filters W – shutter and small spot collimator Ni – SDD casing Very low count rates, generally below 30 counts/second
1	180	3	Gold		Ca, Au, Sr, Fe, Si	Ca, Sr – chalk ground (Sr often associated with chalk in deposits) Fe, Si – bole Au – gold leaf
2	182	3	Gold		Ca, Au, Sr, Fe, Si	Ca, Sr – chalk ground (Sr often associated with chalk in deposits) Fe, Si – bole Au – gold leaf
3	184	3	Gold		Ca, Au, Sr, Fe, Si	Ca, Sr – chalk ground (Sr often associated with chalk in deposits) Fe, Si – bole Au – gold leaf
4	185	3	Gold (dis-coloured)		Ca, Ag, Au, Sr, Fe, Si, S	Ca, Sr – chalk ground (Sr often associated with chalk in deposits) Fe, Si – bole Au – gold leaf (lower count rate compared to sample sites 1-3) Ag – present as alloy within gold leaf (count rate higher than background spectrum scan) S – deterioration product related to silver
5	186	3	Blue lining		Ca, Sr, Cu, Pb	Ca, Sr – chalk ground (Sr often associated with chalk in deposits) Cu – possibly azurite Pb – unclear, extremely low count rates Very low count rates, well below 10 counts/second for all elements apart from calcium, due to limited access from curvature of carving, resulting in air gap
6	187	3	Wood (back-ground)		Ca, Pb, Fe, Cu	Very low count rates overall, apart from the low range readings
7	188	3	Wood (back-ground)		Pb, Ca, Fe, Cu	Higher count rates for lead compared to reading 187 Very low count rates overall, apart from the low range readings
8	189	3	Green pedestal		Pb, Cu, Sn, Ca, Fe, Sr	Ca, Sr – chalk ground (Sr often associated with chalk in deposits) Pb, Sn – lead tin yellow, also possibly lead white Cu – copper green Fe – perhaps iron oxide particles, contaminant or trace element

Site no.	Reading no.	Spot size (mm)	Sample region	Spot photo	Element identification	Interpretation, comments
9	191	3	Green pedestal		Pb, Cu, Sn, Ca, Fe, Sr	Ca, Sr – chalk ground (Sr often associated with chalk in deposits) Pb, Sn – lead tin yellow, also possibly lead white Cu – copper green Fe – perhaps iron oxide particles, contaminant or trace element
10	192	3	Green pedestal		Pb, Cu, Sn, Ca, Fe, Sr	Ca, Sr – chalk ground (Sr often associated with chalk in deposits) Pb, Sn – lead tin yellow, also possibly lead white Cu – copper green Fe – perhaps iron oxide particles, contaminant or trace element
11	193	3	Lining		Ca, Sr, Pb, Cu, Fe, P, Si, Al	Ca, Sr – chalk ground (Sr often associated with chalk in deposits) Cu – possibly azurite (conclusion based on blue remnants elsewhere on lining) Fe, Si, Al – possibly bole (from adjacent gilding?) P – trace element
12	195	3	Lining		Ca, Sr, Pb, Cu, Fe, P, Si, Al	Ca, Sr – chalk ground (Sr often associated with chalk in deposits) Cu – possibly azurite (conclusion based on blue remnants elsewhere on lining) Fe, Si, Al – possibly bole (adjacent gilding?) Higher count rate for Cu compared to reading 193 P – trace element
13	196	3	Lips		Hg, Pb, Ca, Sr, S	Hg, S – vermilion Pb – red lead (underlayer beneath vermilion) or lead white (from skin tones) Higher Hg count rate compared to reading 197 Ca, Sr – chalk ground (Sr often associated with chalk in deposits)
14	197	3	Hat		Hg, Ca, Sr, S	Hg, S – vermilion Ca, Sr – chalk ground (Sr often associated with chalk in deposits) No lead, higher calcium count rate compared to reading 196 (perhaps organic glaze with chalk substrate over the vermilion?)
15	199	3	Face		Pb, Ca	Pb – lead white and possibly red lead Ca – chalk ground

Site no.	Reading no.	Spot size (mm)	Sample region	Spot photo	Element identification	Interpretation, comments
16	202	3	Hair		Pb, Fe, Ca, Sr	Pb – lead white Fe – iron oxide brown Ca, Sr – chalk ground (Sr often associated with chalk in deposits)

Record of analysis: Portable X-ray fluorescence (pXRF)

TORSKEN VIRGIN, C2686		
Analyst	**Location**	**Date**
Bettina Ebert	Frederiksgate 3, MCH conservation studio	30.09.15 and 02.10.15
Elements deriving from instrument contributions are not listed subsequently, unless count rates are higher than expected solely from instrument contribution. Elements are listed in order of concentration (though note that the heaviest elements result in the highest concentration). Spectra are archived at the MCH and available upon request.		

Sample map

Site no.	Reading no.	Spot size (mm)	Sample region	Spot photo	Element identification	Interpretation, comments
0	167	3	Foam back-ground spectrum		Ag, W, Ni, Mo, Cu, Fe, Al	Ag – X-ray tube target Mo, Al, Cu, Fe – filters W – shutter and small spot collimator Ni – SDD casing Very low count rates, generally below 30 counts/second
1	433	8	Grey cloak (Joseph)		Pb, Sr, Fe, Ca	Ca, Sr – chalk ground (Sr often associated with chalk in deposits) Pb – perhaps lead white Fe – earth pigments or iron oxides
2	434	8	Wood (reference) on manger		Ca, Fe, Pb, Si	Ca – chalk ground Fe, Pb, Si – pigment traces Low count rates for all elements
3	435	8	Virgin's gilded robe (proper left elbow area)		Au, Ca, Fe, Sr, Si	Au – gold leaf Ca, Sr – chalk ground (Sr often associated with chalk in deposits) Fe, Si – bole? (extremely low count rates)
4	436	8	Red on Joseph's leggings		Ca, Hg, S, Pb, Sr	Ca, Sr – chalk ground (Sr often associated with chalk in deposits) Hg, S – vermilion Pb – lead white or red lead
5	439	8	Green landscape below Virgin's feet		Pb, Sn, Fe, Cu, Sr, Ca	Pb, Sn – lead tin yellow Ca, Sr – chalk ground (Sr often associated with chalk in deposits) Cu – copper green Fe – terre verte, trace impurity or iron oxide
6	440	8	Blue lining of Virgin's cloak		Ca, Cu, Sr	Ca, Sr – chalk ground (Sr often associated with chalk in deposits) Cu – azurite
7	441	8	Forehead of Virgin		Pb, Ca, Fe, Sr	Pb – lead white Ca, Sr – chalk ground (Sr often associated with chalk in deposits) Fe – trace element or contaminant
8	442	8	Cheek of Virgin		Pb, Hg, S, Ca	Pb – lead white Hg, S – vermilion Ca – chalk ground
9	443	3	Red glaze on gilded crown		Au, Ca, Sr, Si	Au – gold leaf Ca, Sr – chalk ground (Sr often associated with chalk in deposits) Si – trace element (very low count rates) Organic red glaze

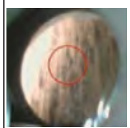
Site no.	Reading no.	Spot size (mm)	Sample region	Spot photo	Element identification	Interpretation, comments
10	444	3	Gilded crown		Au, Ca, Fe, Sr, Si, Cl	Au – gold leaf Ca, Sr – chalk ground (Sr often associated with chalk in deposits) Fe – bole, dirt or impurity Si – trace element (very low count rates) Cl – dirt or trace element
11	445	8	Exposed ground on Virgin's elbow		Ca, Sr, Si	Ca, Sr – chalk ground (Sr often associated with chalk in deposits) Si – trace element (very low count rates)
12	446	3	Throne at proper left side		Pb, Ca, Fe, Sr	Pb – red lead or lead white Ca, Sr – chalk ground (Sr often associated with chalk in deposits) Fe – iron oxide
13	447	3	Virgin's gilded hair		Pb, Au, Ca, Fe	Pb – mordant Au – gold leaf Ca – chalk ground Fe – iron oxide
14	448	3	Cooking pot		Ca, Fe, Hg, S, Pb, Cl	Ca – chalk ground Hg, S – vermilion Pb – lead white or red lead Fe – iron oxide Cl – dirt or trace element

Record of analysis: Portable X-ray fluorescence (pXRF)

SCHWANBECK VIRGIN, DASSOW		
Analyst	**Location**	**Date**
Bettina Ebert	St Nikolai church, Dassow, Germany	21.08.2016
Elements deriving from instrument contributions are not listed subsequently, unless count rates are higher than expected solely from instrument contribution. Elements are listed in order of concentration (though note that the heaviest elements result in the highest concentration). Spectra are archived at the MCH and available upon request.		

Sample map

Appendix 5: Portable XRF interpretation

Site no.	Reading no.	Spot size (mm)	Sample region	Spot photo	Element identification	Interpretation, comments
0	167	3	Foam back-ground spectrum		Ag, W, Ni, Mo, Cu, Fe, Al	Ag – X-ray tube target Mo, Al, Cu, Fe – filters W – shutter and small spot collimator Ni – SDD casing Very low count rates, generally below 30 counts/second
1	594	3	Virgin's robe (back-ground spectrum)		Ca, Fe, Pb, Au, Mn, Si	Ca – chalk ground Fe, Si – bole Au – gilding Pb –lead white or red lead Mn – possibly umber Very low count rates for Fe, Si and Mn, extremely low count rates for Au
2	595	3	Grass (back-ground spectrum)		Ca, Fe, Pb	Ca – chalk ground Fe – iron oxide Pb – lead white Very low count rates for Fe and Pb
3	596	3	Joseph's stocking (back-ground spectrum)		Ca, Fe, Pb, Mn	Ca – chalk ground Fe – iron oxide Pb – lead white Mn – possibly umber Very low count rates for Fe, Pb and Mn
4	597	3	Green landscape below Virgin's feet		Ca, Pb, Fe, Mn, Cu?	Ca – chalk ground Fe – iron oxide Pb – possibly lead white Mn – possibly umber Cu – possibly copper green Very low count rates for Fe, Pb and Mn Insufficient information gained from spectrum to provide any conclusions (extremely low count rates, hence not possible to conclusively confirm elements)
5	598	3	Porridge		Ca, Pb, Fe, Mn, Cu?, Ba?	Ca – chalk ground Fe – iron oxide Pb – possibly lead white Mn – possibly umber Cu – possibly azurite Ba – unclear Insufficient information gained from spectrum to provide conclusions (extremely low count rates, hence not possible to conclusively confirm presence of certain elements)

Site no.	Reading no.	Spot size (mm)	Sample region	Spot photo	Element identification	Interpretation, comments
6	599	3	Blue lining of Virgin's robe		Ca, Pb, Fe, Cu, Mn, Si, Au?, Ba?, Sr?	Ca, Sr – chalk ground (Sr often associated with chalk in deposits) Cu – azurite Pb – possibly lead white Fe, Si – possibly bole Au – gold leaf Mn – possibly umber Ba - unclear Insufficient information gained from spectrum to provide conclusions (extremely low count rates, hence not possible to conclusively confirm presence of certain elements)
7	600	3	Virgin's gilded robe		Ca, Pb, Fe, Au, Mn	Ca – chalk ground Pb – possibly lead white Fe – possibly bole Au – gold leaf Mn – possibly umber
8	601	3	Christ's gilded robe		Ca, Pb, Au, Fe, Sr, Si	Ca, Sr – chalk ground (Sr often associated with chalk in deposits) Pb – possibly lead white Fe, Si – possibly bole Au – gold leaf
9	602	3	Virgin's red lips		Ca, Fe, Pb, Ti, Mn, Si, Au?, Ba?	Ca – chalk ground Pb – possibly red lead Fe, Si, Ti – iron oxide or bole (Ti found in conjunction with Fe-containing pigment) Mn – possibly umber Au – gold leaf Ba – unclear
10	603	3	Gold on Virgin's crown		Ca, Cu, Zn, Fe, Pb, Ti, Cr	Ca – possibly chalk ground Cu, Zn – modern Cu/Zn alloy "gold bronze" paint Fe – possibly bole Pb – possibly lead white Ti, Cr – possibly component of modern bronze paint
11	604	3	Blue lining of robe		Ca, Cu, Pb, Sr	Ca, Sr – chalk ground (Sr often associated with chalk in deposits) Cu – azurite Pb – possibly lead white (low count rates)
12	605	3	Virgin's hair		Ca, Fe, Pb, Au, Mn, Si, Ba, Sr?	Ca, Sr – chalk ground (Sr often associated with chalk in deposits) Pb – possibly lead white Au – gold leaf Mn – possibly umber Fe, Si – possibly bole Ba - unclear

Site no.	Reading no.	Spot size (mm)	Sample region	Spot photo	Element identification	Interpretation, comments
13	606	3	Joseph’s grey cloak		Ca, Pb, Fe	Ca – chalk ground Pb – lead white Fe – iron oxide
14	607	3	Throne at proper right side		Ca	Insufficient count rates due to distance of target from sample site
15	608	3	Virgin’s hand		Ca, Pb, Fe, Hg, S, Ba, Sr	Ca, Sr – chalk ground (Sr often associated with chalk in deposits) Pb –lead white Fe – iron oxide Hg, S – vermilion Ba - unclear
16	609	3	Top of crown (red)		Pb, Ca, Fe, Hg, S	Pb – red lead Hg, S – vermilion Fe – iron oxide Ca – possibly chalk

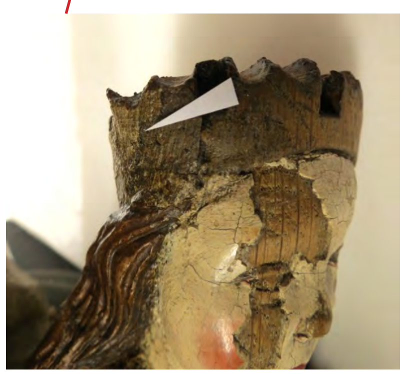
Appendix 6: Sampling

Object: Berg St Anne	**Researcher:** Håkan Lindberg
Inv. no./Collection: C2912 MCH	**Sampling date:** 1970s
Sampling sites	**Description**
L59.1	Blue hem of Virgin's dress
L59.2	Green base of sculpture
L59.3	St Anne's red dress
L59.4	Red border of headscarf
L59.5	Virgin's hair
L59.6	Throne
L59.7	St Anne's neck
L59.8	St Anne's gilded robe

Object: Berg St Anne	**Researcher:** Bettina Ebert
Inv. no./Collection: C2912 MCH	**Sampling date:** 12.07.2016
Sampling sites	**Description**
L59.9	Verso canvas fibre
L59.10	Virgin’s crown, grey ground

L59.9

L59.10



Object: Berg St Anne	**Researcher:** Bettina Ebert
Inv. no./Collection: C2912 MCH	**Sampling date:** 12.07.2016
Sampling sites	**Description**
L59.11	Glue from between boards

L59.11

Object: Berg Bishop	**Researcher:** Bettina Ebert
Inv. no./Collection: C2913 MCH	**Sampling date:** 06.08.2016
Sampling sites	**Description**
L177.1	Red base of mitre
L177.2	Green base
L177.3	Gilded robe

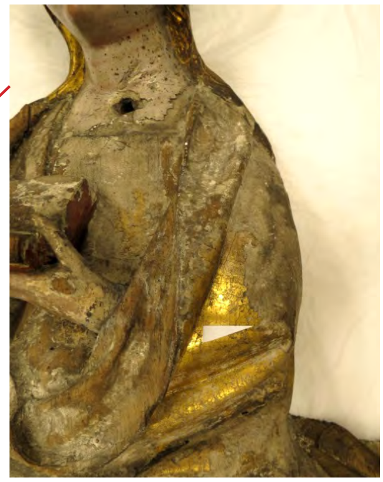
Object: Berg Bishop	**Researcher:** Bettina Ebert
Inv. no./Collection: C2913 MCH	**Sampling date:** 06.08.2016
Sampling sites	**Description**
L177.4	Verso accretion
L177.5	Verso canvas fibre

L177.4

L177.5

Object: Torsken Virgin	**Researcher:** Bettina Ebert
Inv. no./Collection: C2686 MCH	**Sampling date:** 13.07.2016
Sampling sites	**Description**
L178.1	Joseph's red stockings
L178.2	Joseph's grey robe
L178.3	Virgin's gilded robe

L178.3

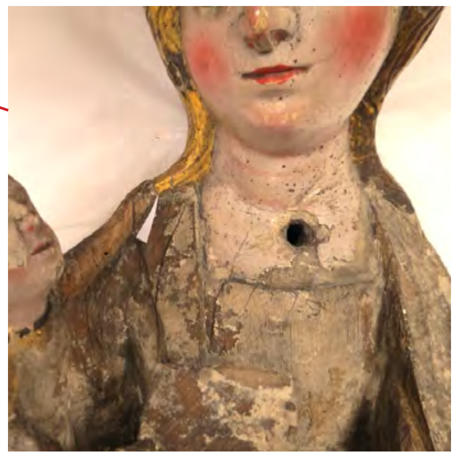


L178.2

L178.1

Object: Torsken Virgin	**Researcher:** Bettina Ebert
Inv. no./Collection: C2686 MCH	**Sampling date:** 13.07.2016
Sampling sites	**Description**
L178.4	Jesus' gilded robe
L178.5	Virgin's gilded hair
L178.6	Virgin's gilded crown

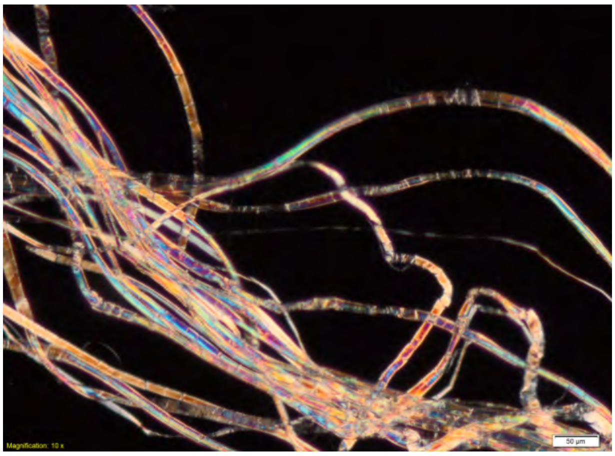
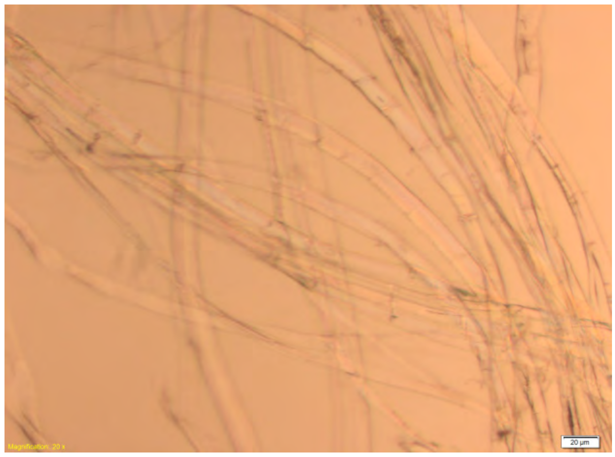
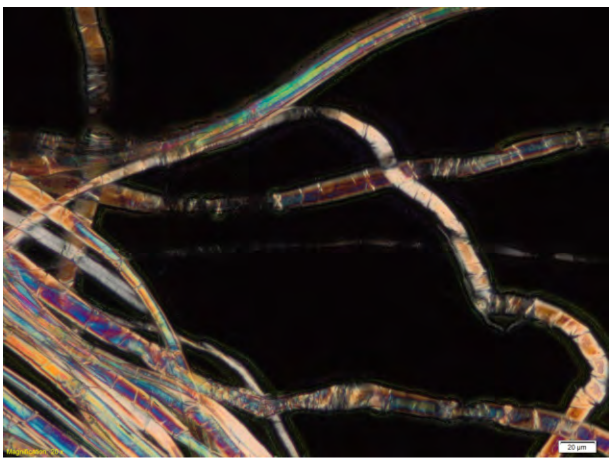
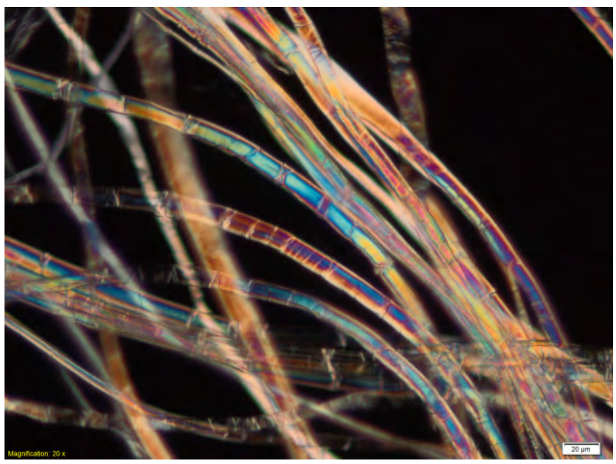
L178.6

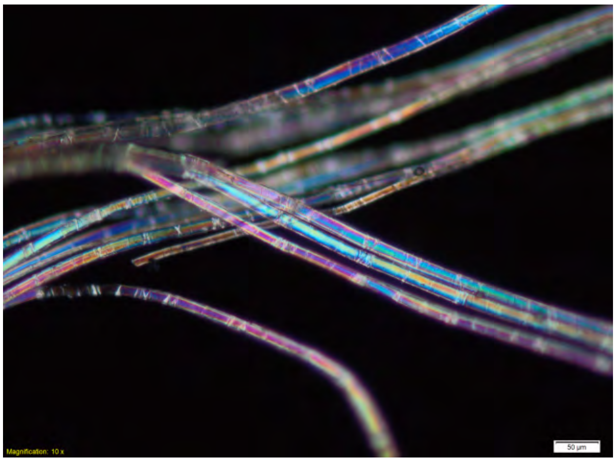
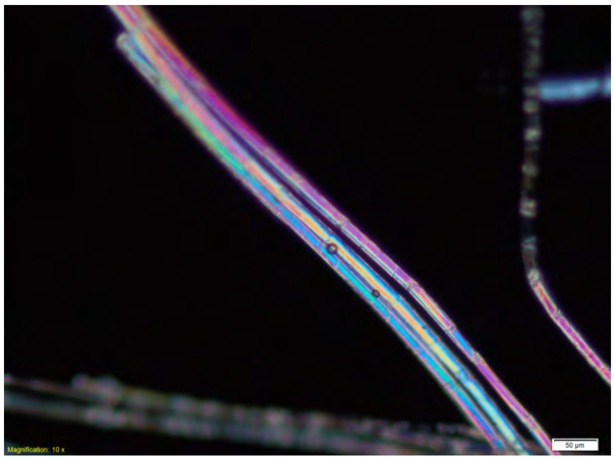
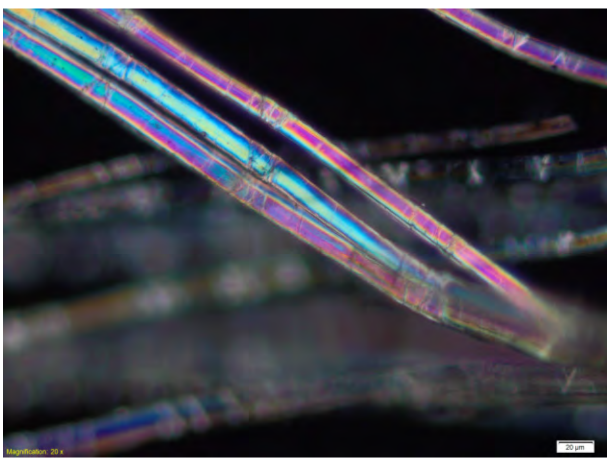
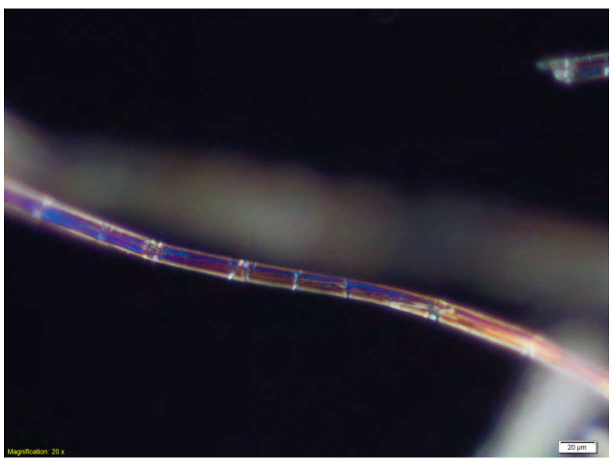


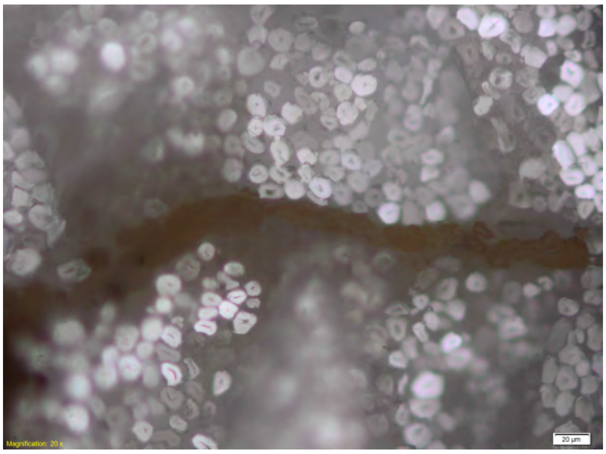
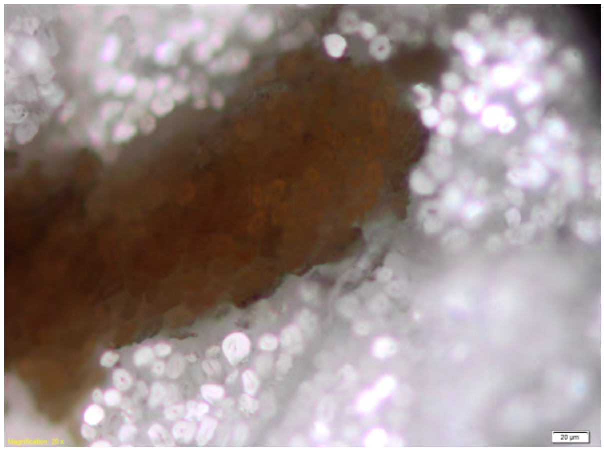
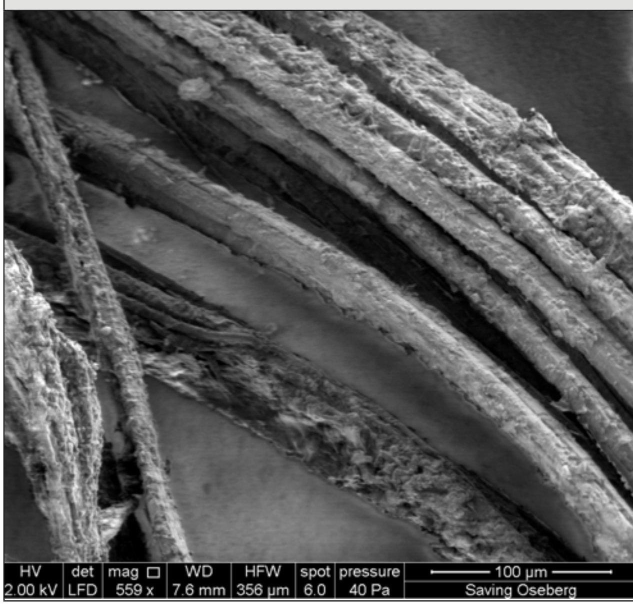
L178.5

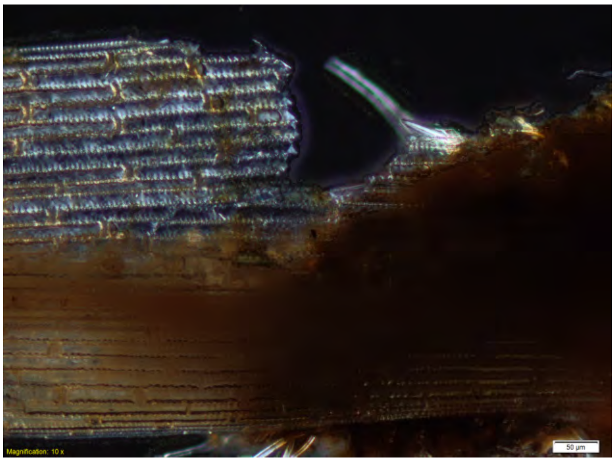
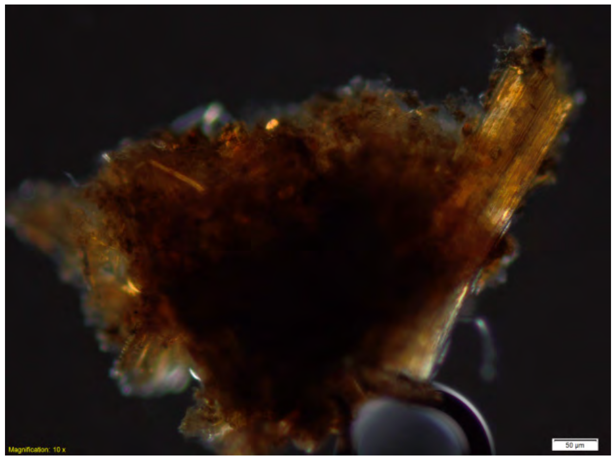
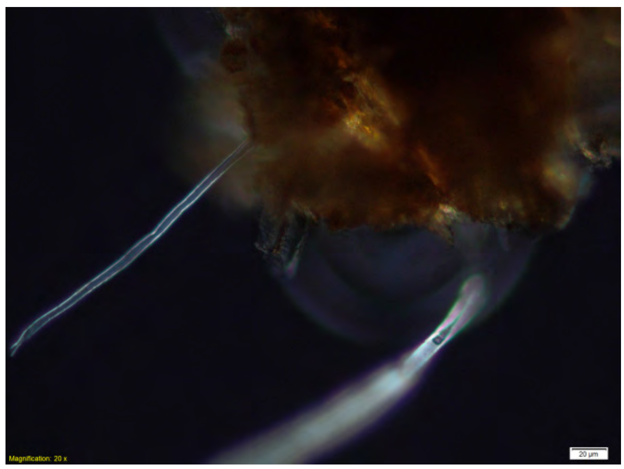
L178.4

Appendix 7: Light microscopy

Object: Berg St Anne	**Researcher:** Bettina Ebert
Inv. no./Collection: C2912 MCH	**Lab no.:** L59.9
Sample location: Canvas fibre from verso, top of head of sculpture	
Research question: What type of canvas fibre was used for the patches? Does it compare to those used for C2913 Bishop?	
Embedding material: 70% glycerine in water used as temporary embedding material for individual fibre identification by PLM	
Crossed polars × 10 obj magnification	**Vis × 20 obj magnification**
	
Crossed polars × 20 obj magnification	**Crossed polars × 20 obj magnification**
	
Description	**Interpretation**
Long straight fibres gathered in bundles. In crossed polars, nodes (transverse dislocations) are clearly visible. Some fibres are almost completely extinguished when rotated, while intense birefringence colours are visible. Thin lumen and thick cell walls.	Likely flax or a related bast fibre such as hemp or jute.

Object: Berg Bishop	**Researcher:** Bettina Ebert
Inv. no./Collection: C2913 MCH	**Lab no.:** L177.5
Sample location: Canvas fibre from verso, along the upper join between main sculpture and additional piece of wood	
Research question: What type of canvas fibre was used for the patches? Does it compare to those used for C2912?	
Embedding material: 70% glycerine in water used as temporary embedding material for individual fibre identification by PLM, fibre bundle sandwiched between cotton fibres and cut with razor for cross-section examination	
Crossed polars × 10 obj magnification	**Crossed polars × 10 obj magnification**
	
Crossed polars × 20 obj magnification	**Crossed polars × 20 obj magnification**
	

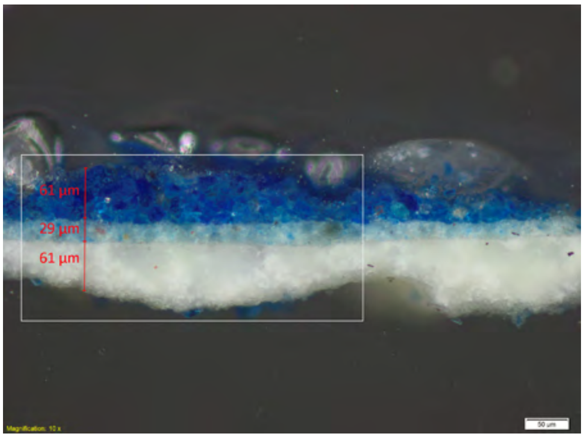
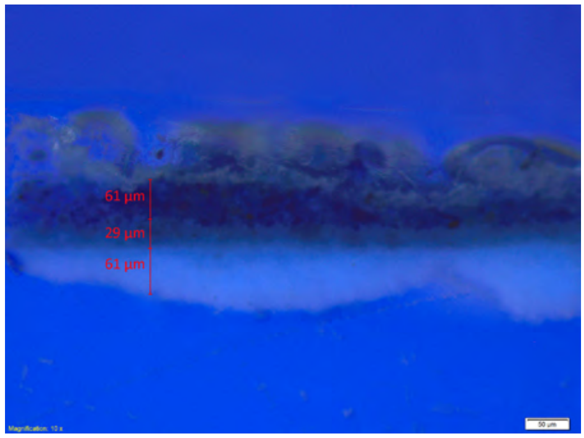
Vis x 20 obj magnification	Vis x 20 obj magnification
	
Description	**Interpretation**
Long straight fibres gathered in bundles. In crossed polars, nodes (transverse dislocations) are clearly visible. Some fibres are almost completely extinguished when rotated while intense birefringence colours are visible. Thin lumen and thick cell walls visible in cross section.	Likely flax or a related bast fibre such as hemp or jute.
Secondary electron image of a fibre bundle	**Interpretation**
	Surface morphology was examined with SEM to determine if any characteristic features can be identified for conclusive fibre identification. However, the SEM image did not provide more information that would point towards flax as a fibre.

Object: Berg Bishop	**Researcher:** Bettina Ebert
Inv. no./Collection: C2913 MCH	**Lab no.:** L177.4
Sample location: Accretion from verso, to the left of central screw hole and below eyelet screw	
Research question: What is the nature of the accretion? Is it possible to determine its source, whether it derives from construction of the sculpture, storage or conservation treatment?	
Vis × 10 obj magnification	**Vis × 10 obj magnification**
	
Vis × 20 obj magnification	**Vis × 20 obj magnification**
	
Description	**Interpretation**
Wood cells and a variety of fibrous material compacted together	Possibly material from animal nesting, storage or packing prior to museum accessioning

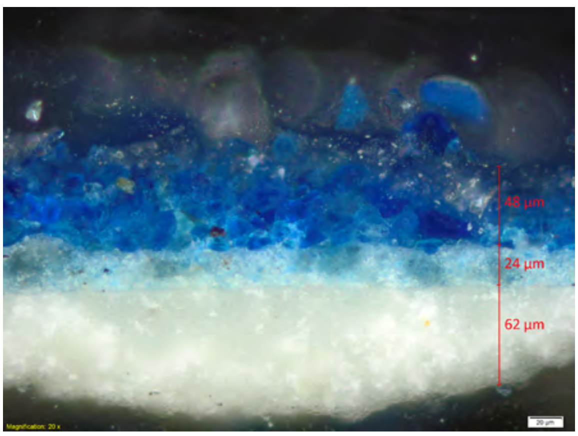
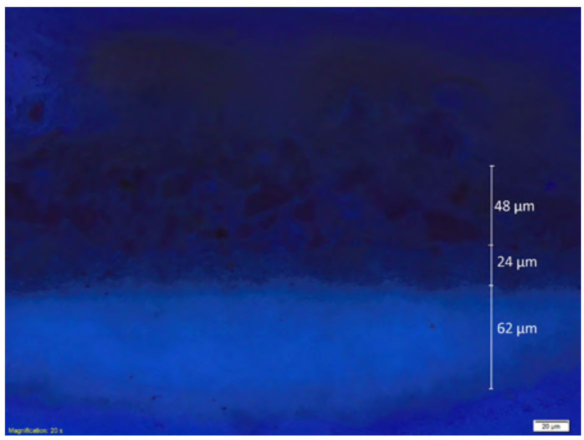
Appendix 8: Cross-section and SEM-EDS interpretation

Sample details	
Object: Berg St Anne	**Researcher:** Bettina Ebert
Inv. no./Collection: C2912 MCH	**Lab no.:** L59.2016.1
Sampling date: 1970s	**Embedding date:** 2016
Research question: What type of pigments and layer structure were used in the blue paint layers?	
Embedding material: EasySection/Technovit ® 2000 LC resin and varnish	
Layer thickness measurements taken in a representative area are marked on images. Layers are numbered consecutively from the ground up. EDS spectra and detailed elemental maps are archived at the MCH and available upon request.	
Sample location: Blue dress of the Virgin, as marked on archival photograph	

Cross-section

VIS × 10 obj magnification	UV × 10 obj magnification
	

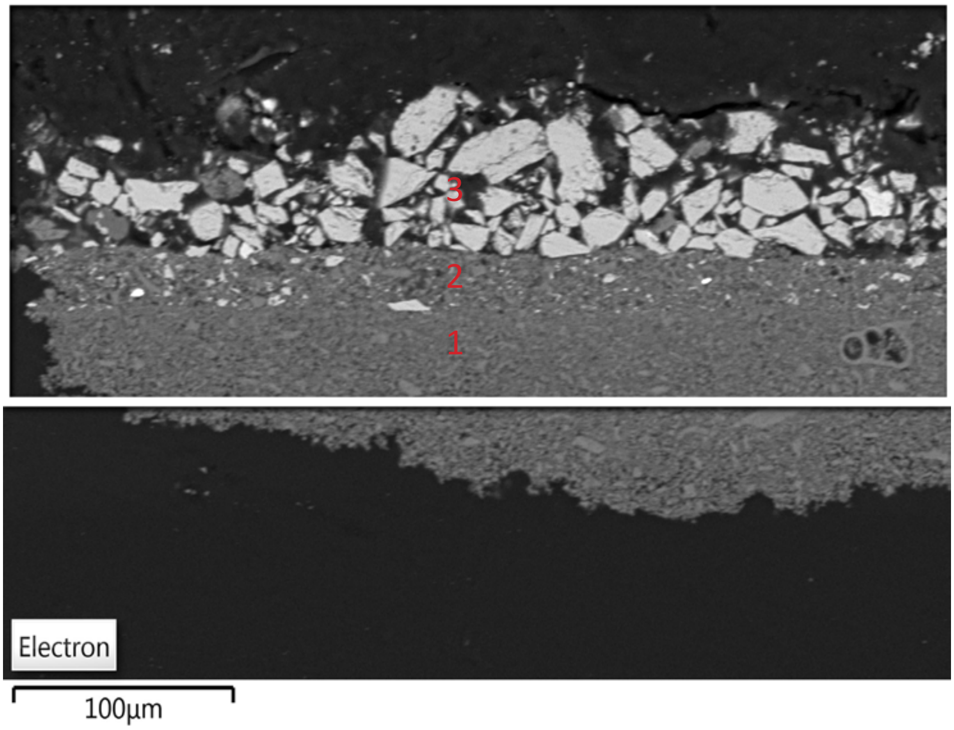
Layer	Thickness (µm)	Description
3	61	Dark blue paint layer of varying thickness
2	29	Light blue thin layer of uniform thickness, with finely ground blue particles and white
1	61	White ground

VIS × 20 obj magnification	UV × 20 obj magnification
	

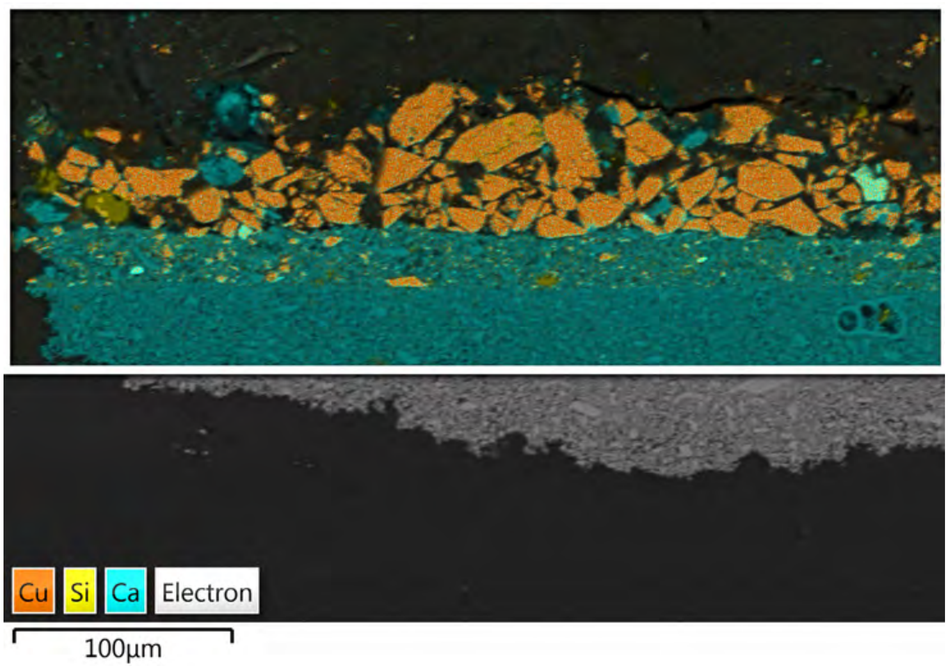
Layer	Thickness (µm)	Description
3	48	Dark blue paint layer, isolated traces of brown and yellow pigment particles
2	24	Light blue thin layer with finely ground blue particles and white, isolated traces of red and brown particles
1	62	White ground, isolated traces of yellow and brown pigment particles

SEM-EDS

Backscattered electron image



False colour layered EDS image



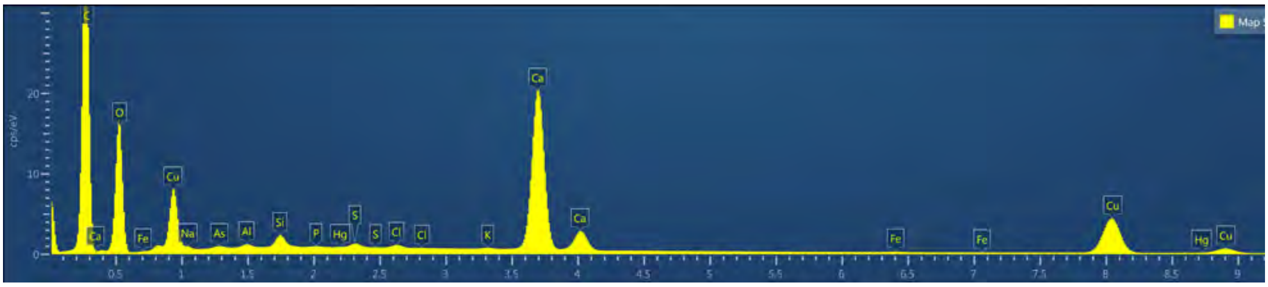
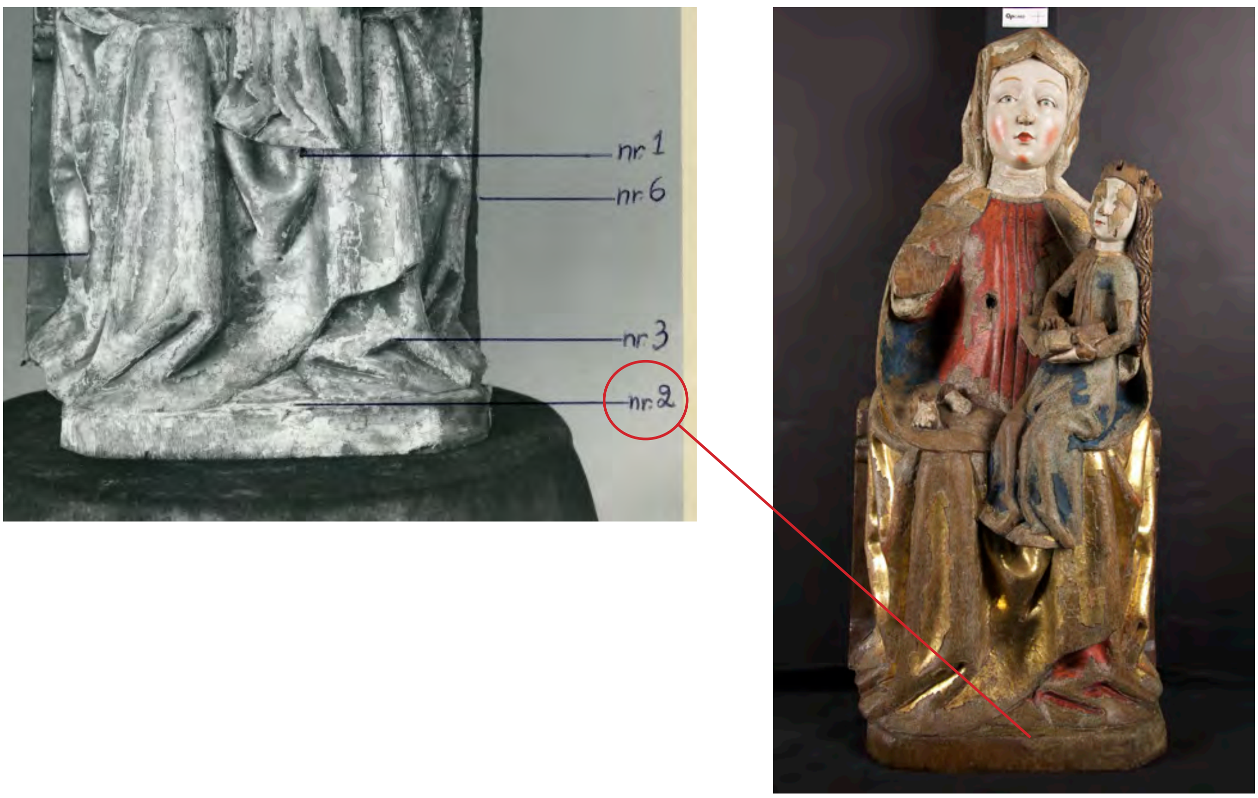


Figure 28: L59.1 EDS spectrum

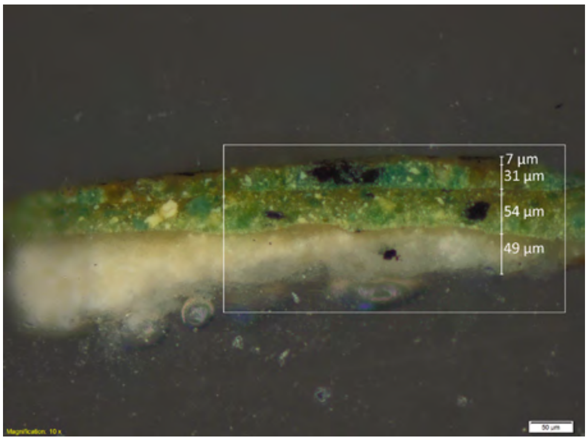
Layer	Major component	Minor component	Interpretation
3	Cu	Ca, Cl, K, Si, Fe, As, S	Azurite, with isolated chalk particles, some silicates, iron oxide and orpiment or realgar
2	Cu, Ca	Cl, K, Si, Fe, S, As	Azurite and chalk mixture, some iron oxide and silicates, and orpiment or realgar
1	Ca	Cl, K	Chalk

Sample details	
Object: Berg St Anne	**Researcher:** Bettina Ebert
Inv. no./Collection: C2912 MCH	**Lab no.:** L59.2016.2
Sampling date: 1970s	**Embedding date:** 2016
Research question: What type of pigments and layer structure were used in the green paint layers? How does it compare to the green used in the sculpture of the bishop C2913?	
Embedding material: EasySection/Technovit ® 2000 LC resin and varnish	
Layer thickness measurements taken in a representative area are marked on images. Layers are numbered consecutively from the ground up. EDS spectra and detailed elemental maps are archived at the MCH and available upon request.	
Sample location: Green base of sculpture, as marked on archival photograph	



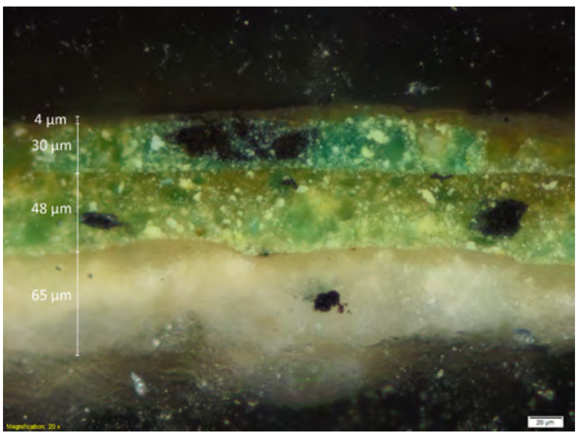
Cross-section

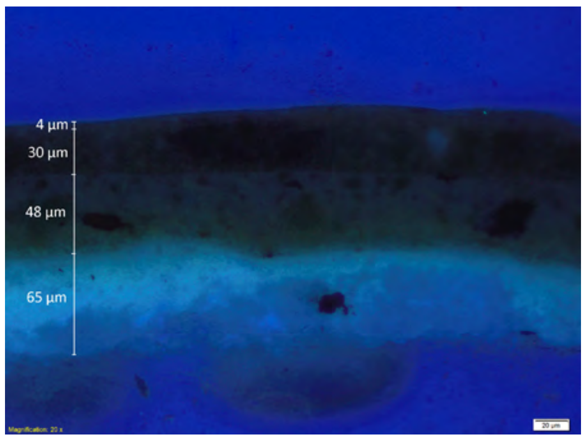
VIS × 10 obj magnification	UV × 10 obj magnification



Layer	Thickness (µm)	Description
4	7	Brown-green upper layer
3	31	Blue-green paint layer with blue-green and pale yellow particles, isolated large black pigment particles
2	54	Blue-green paint layer, brown-green towards the top, isolated large black pigment particles
1	49	White ground with milky fluorescence, darker towards the top, isolated large black pigment particles

VIS × 20 obj magnification	UV × 20 obj magnification

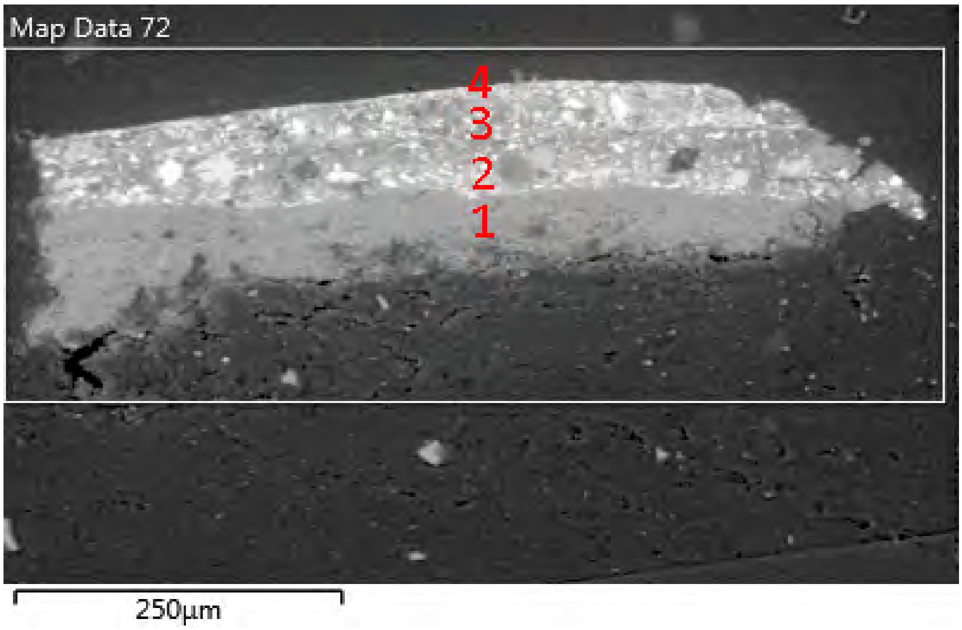




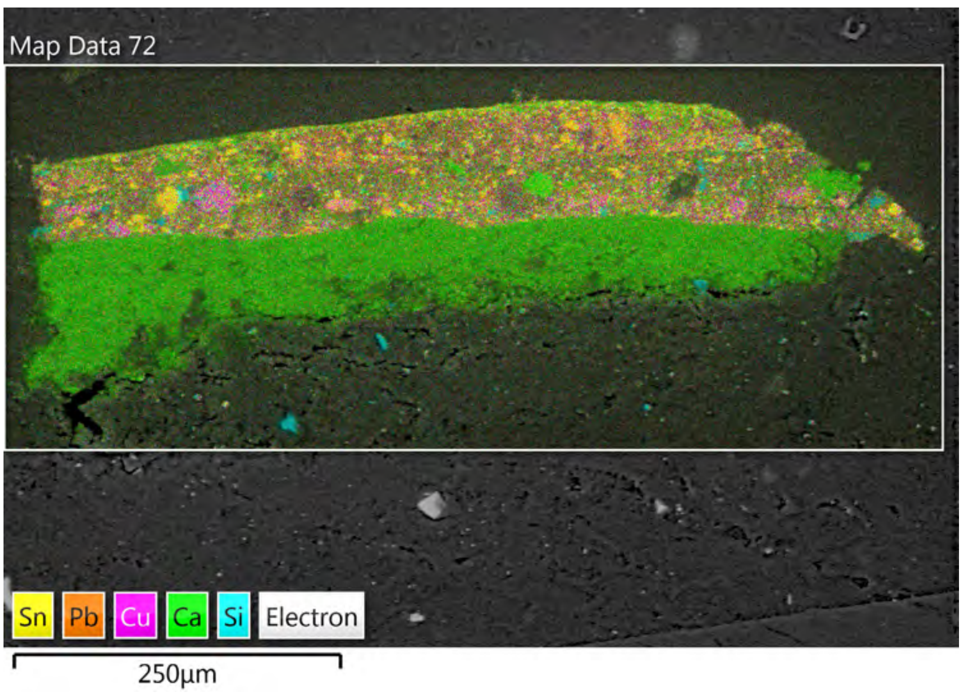
Layer	Thickness (µm)	Description
4	4	Brown-green upper layer
3	30	Blue-green paint layer with large and small blue-green particles, pale yellow particles of varying size, and isolated large black pigment particles
2	48	Blue-green paint layer with large and small blue-green particles, pale yellow particles of varying size, and isolated large black pigment particles
1	65	White ground with milky fluorescence, darker towards the top, isolated large black pigment particles

SEM-EDS

Backscattered electron image



False colour layered EDS image



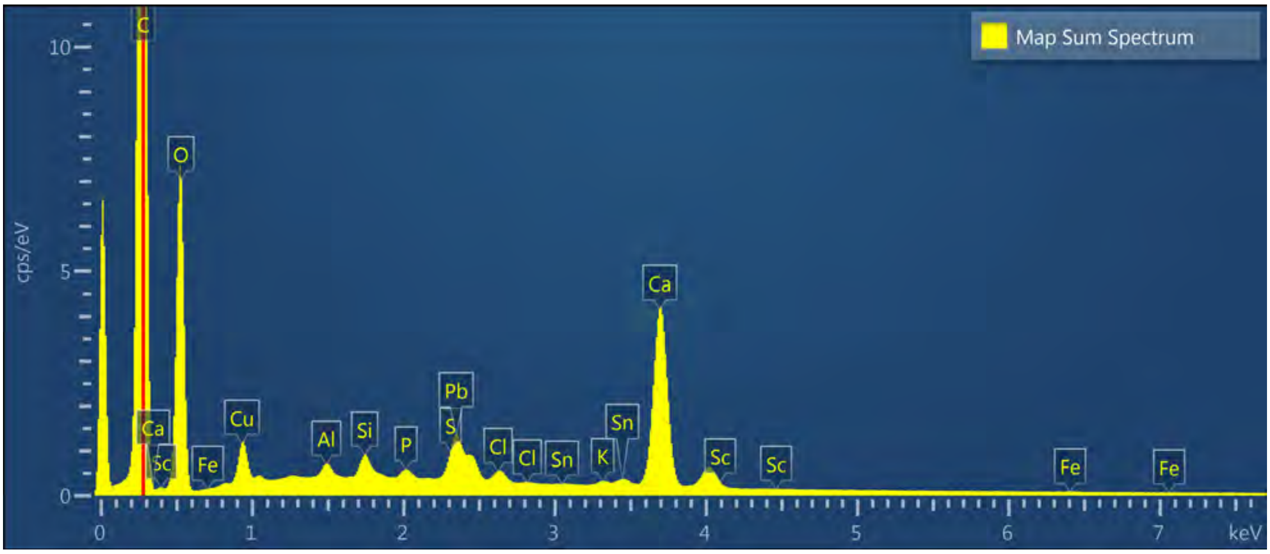
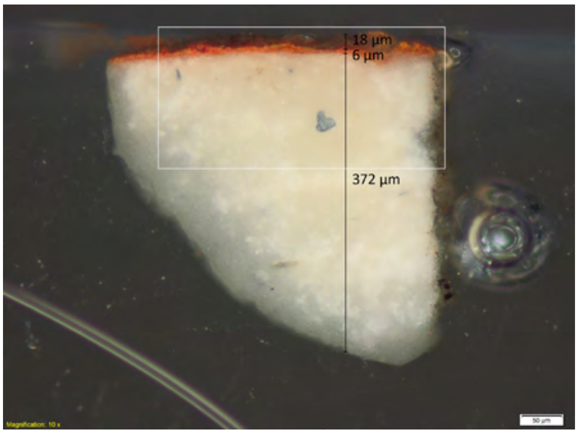
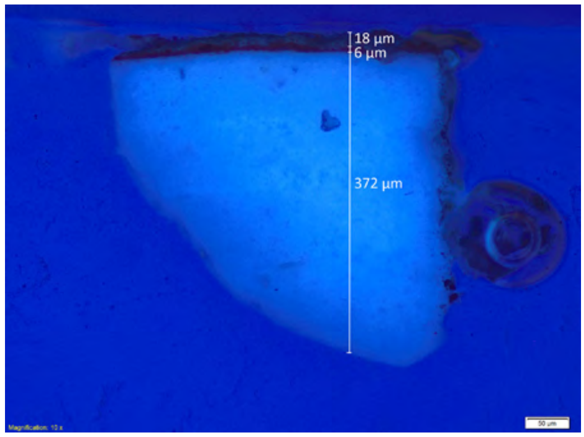


Figure 29: L59.2 EDS spectrum

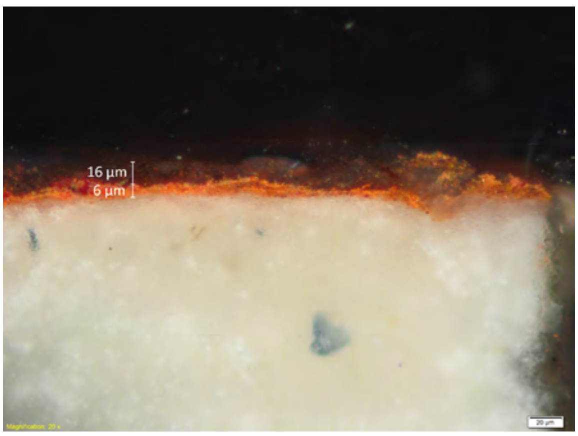
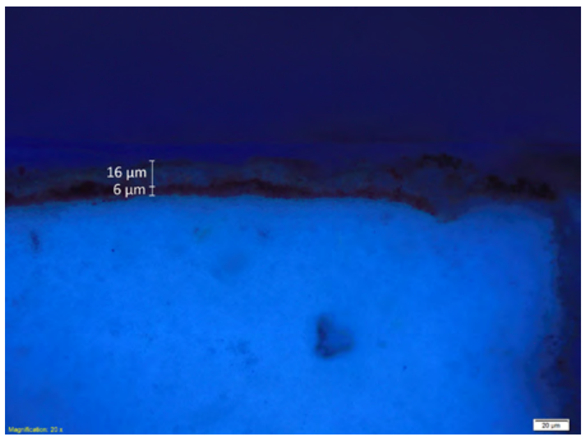
Layer	Major component	Minor component	Interpretation
4	Cu, Ca, Sn	Ca, K, P, Pb, Cl	Copper resinate glaze (?) with some lead tin yellow
3	Pb, Sn, Cu	Ca, K, S, Si	Lead tin yellow and copper green (verdigris?)
2	Pb, Sn, Cu	Ca, K, P, Si, S	Lead tin yellow and copper green (verdigris?)
1	Ca	K, P	Chalk ground

Sample details	
Object: Berg St Anne	**Researcher:** Bettina Ebert
Inv. no./Collection: C2912 MCH	**Lab no.:** L59.2016.3
Sampling date: 1970s	**Embedding date:** 2016
Research question: What type of pigments and layer structure were used in the red paint layers? How does it compare to the red used in the sculpture of the bishop C2913?	
Embedding material: EasySection/Technovit ® 2000 LC resin and varnish	
Layer thickness measurements taken in a representative area are marked on images. Layers are numbered consecutively from the ground up. EDS spectra and detailed elemental maps are archived at the MCH and available upon request.	
Sample location: Red dress, proper left side, as marked on archival photograph	

Cross-section

VIS × 10 obj magnification	UV × 10 obj magnification
	

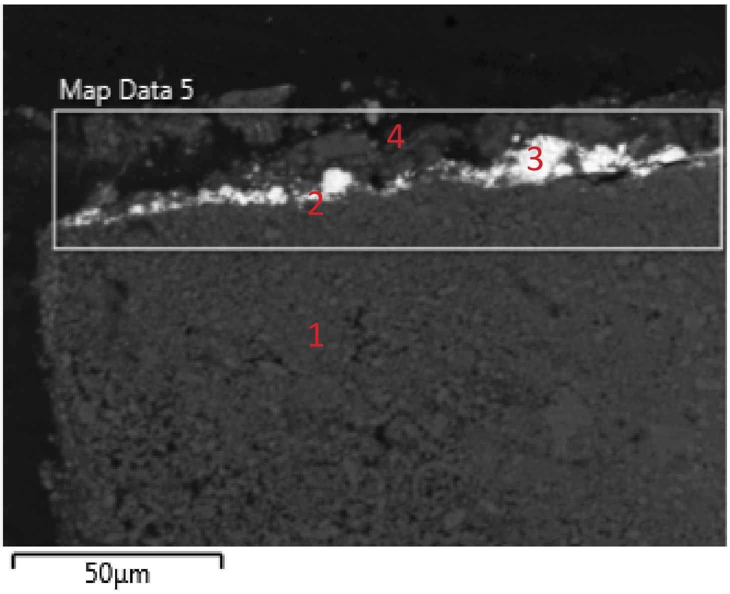
Layer	Thickness (µm)	Description
3	18	Dark red semi-transparent layer, organic glaze likely
2	6	Thin bright orange-red paint layer
1	372	Thick white ground with some small dark particles

VIS × 20 obj magnification	UV × 20 obj magnification
	

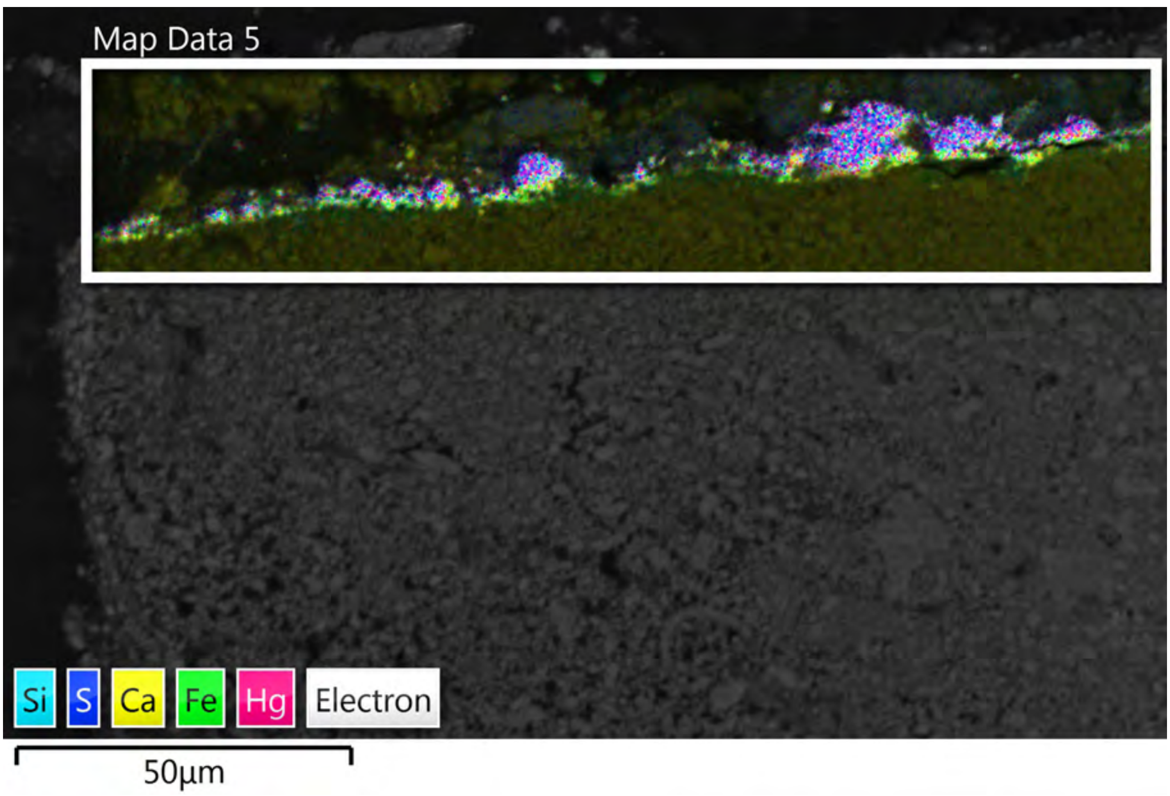
Layer	Thickness (µm)	Description
4	16	Dark red semi-transparent layer, fluorescent in UV, organic glaze likely
3	6	Bright orange-red paint layer of relatively uniform thickness, some larger red particles
2	<1	Only visible in SEM layered image
1	372	Thick white ground, traces of other particles

SEM-EDS

Backscattered electron image



False colour layered EDS image



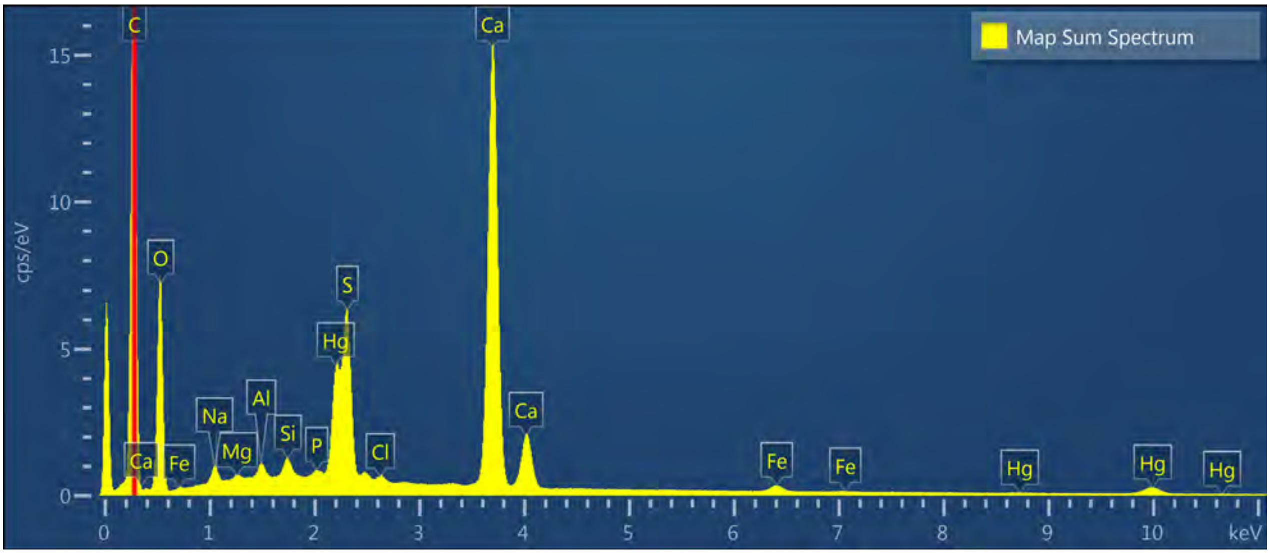
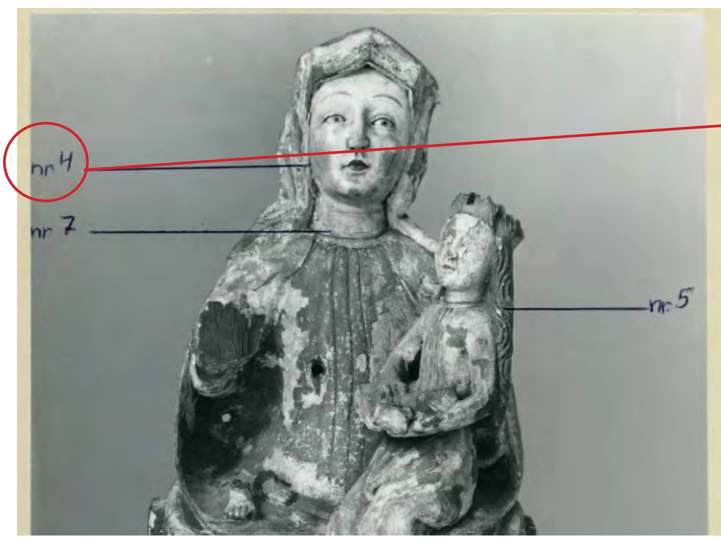


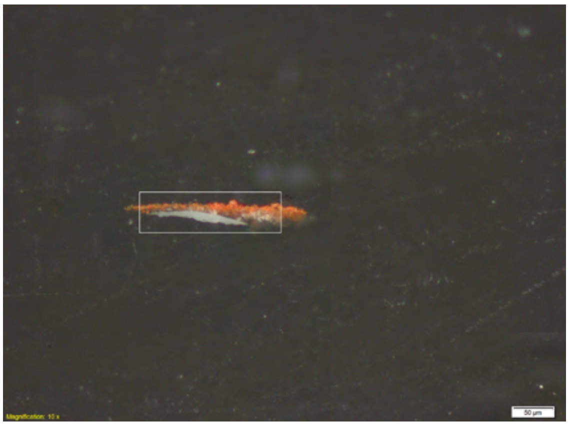
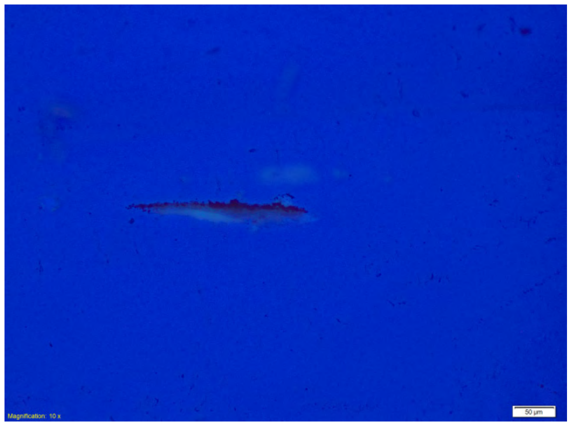
Figure 30: L59.3 EDS spectrum

Layer	Major component	Minor component	Interpretation
4	Ca	Mg, Na, S, Si, Al	No obvious colouring matter present as main component, likely organic red glaze precipitated onto calcium
3	Hg, S	Ca, Mg, Na, Si, Al, Fe	Vermilion
2	Fe	Al, Si	Bole from adjacent gilded areas
1	Ca	Al, Si	Chalk ground

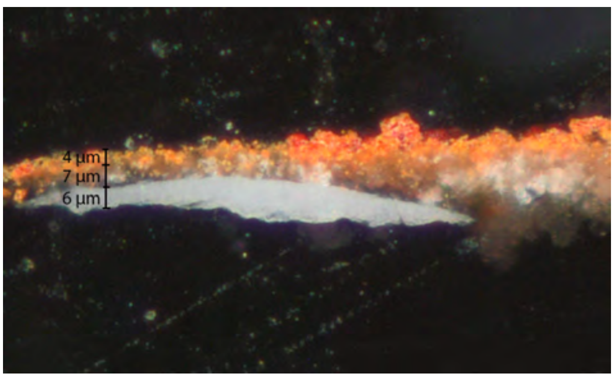
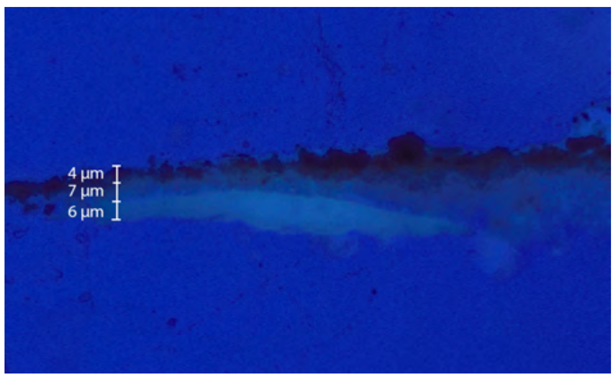
Sample details	
Object: Berg St Anne	**Researcher:** Bettina Ebert
Inv. no./Collection: C2912 MCH	**Lab no.:** L59.2016.4
Sampling date: 1970s	**Embedding date:** 2016
Research question: What type of pigments are present in the red paint layers?	
Embedding material: EasySection/Technovit ® 2000 LC resin and varnish	
Layer thickness measurements taken in a representative area are marked on images. Layers are numbered consecutively from the ground up. EDS spectra and detailed elemental maps are archived at the MCH and available upon request.	
Sample location: Red border of St Anne's headscarf, as marked on archival photograph	



Cross-section

VIS × 10 obj magnification	UV × 10 obj magnification
	

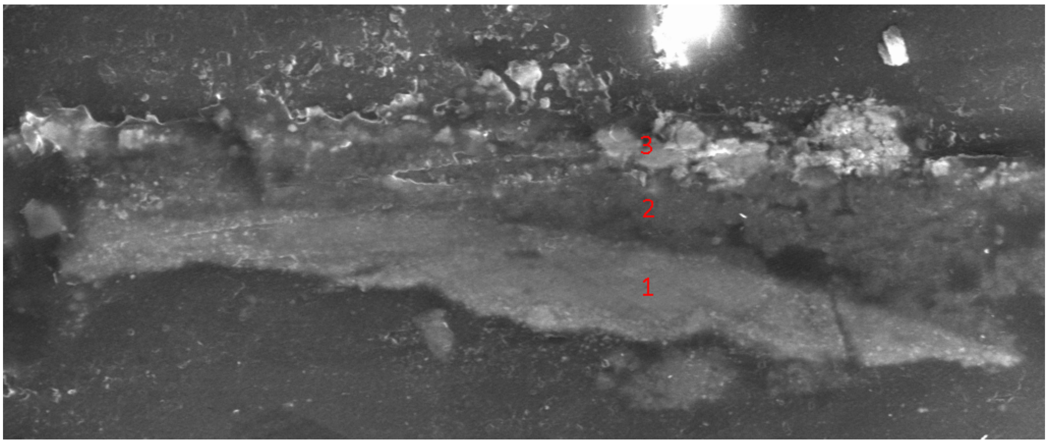
Layer	Description
3	Bright orange-red layer
2	Thin transparent layer
1	Thin white ground

VIS × 20 obj magnification	UV × 20 obj magnification
	

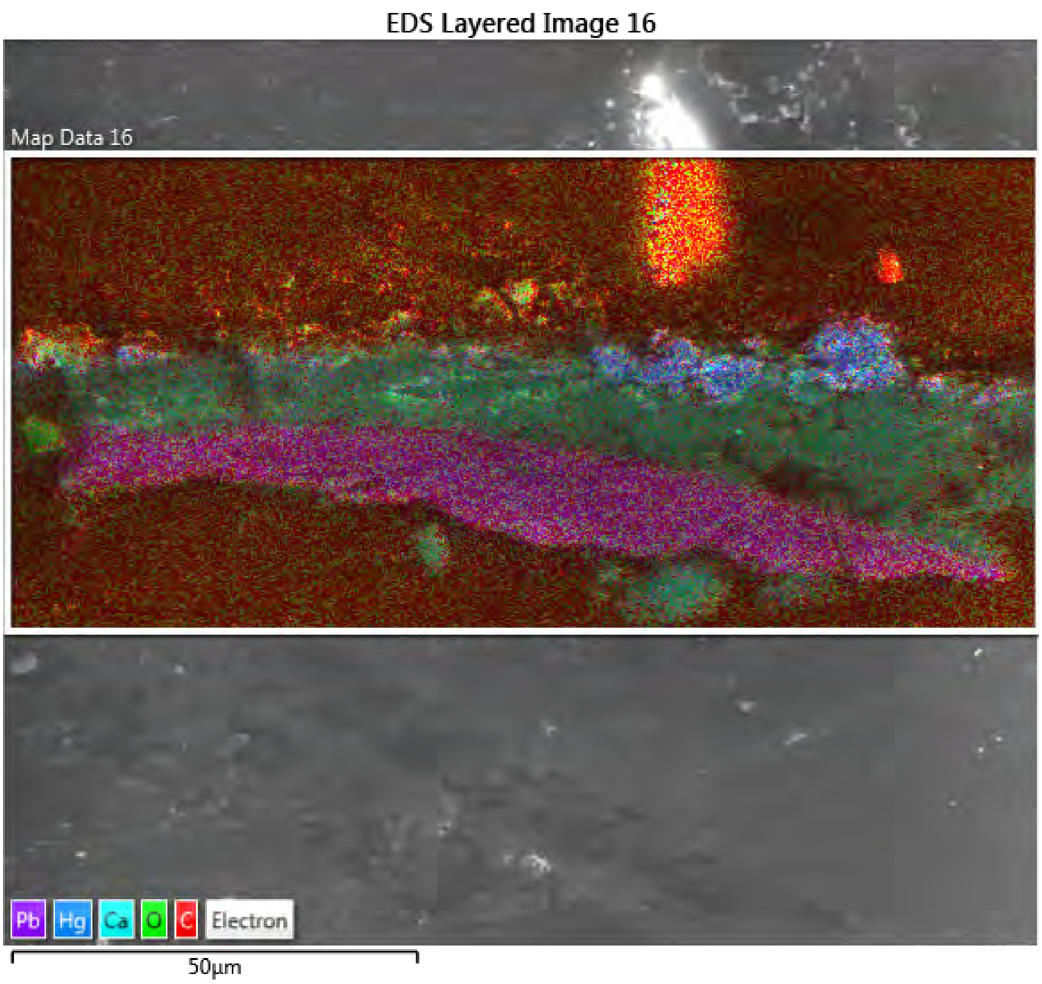
Layer	Thickness (µm)	Description
3	4	Bright orange-red layer
2	7	Transparent layer with some white particles, somewhat fluorescent in UV
1	6	Dense thin white layer, fluorescent in UV

SEM-EDS

Backscattered electron image



False colour layered EDS image



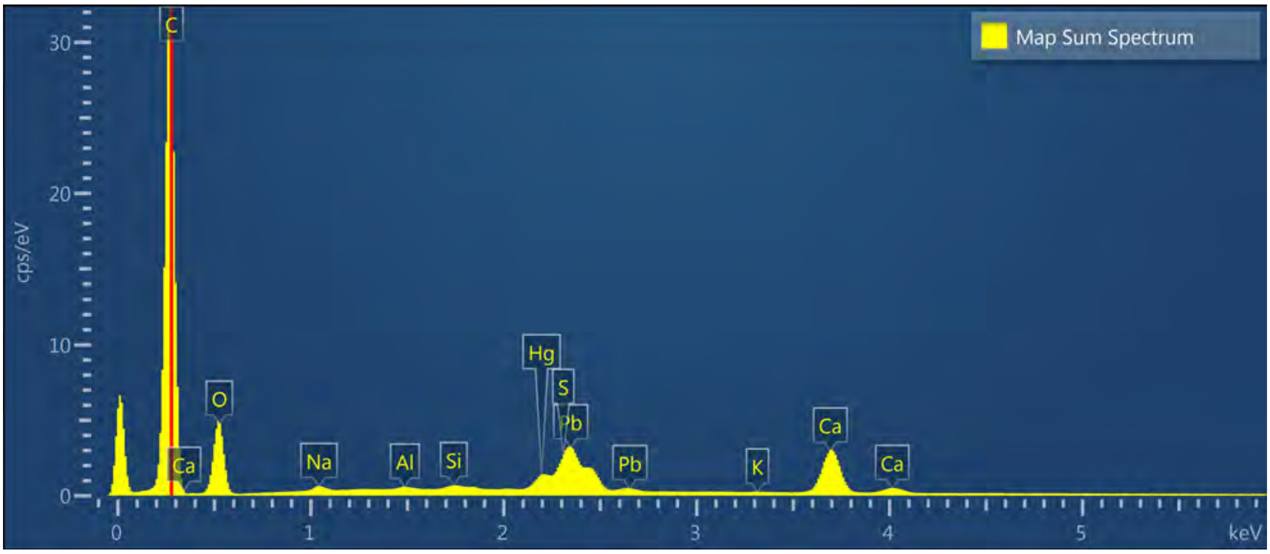
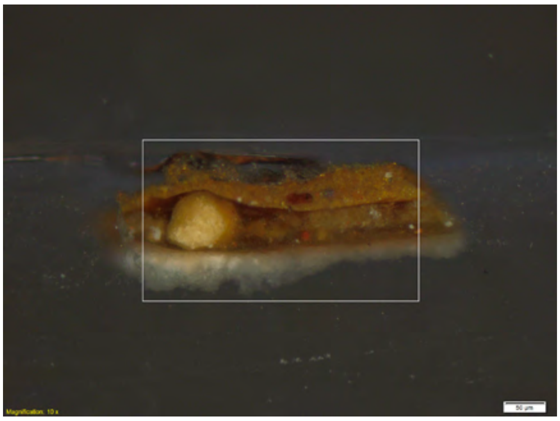
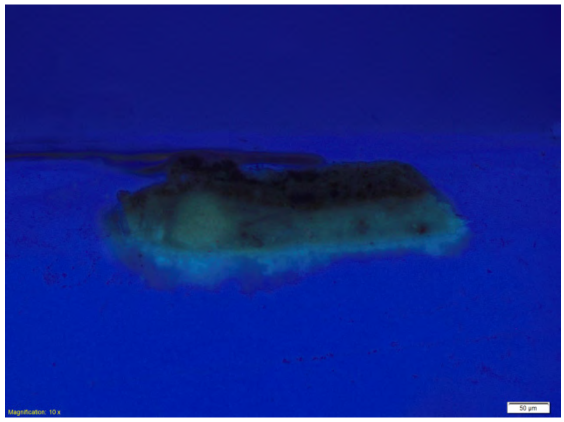


Figure 31: L59.4 EDS spectrum

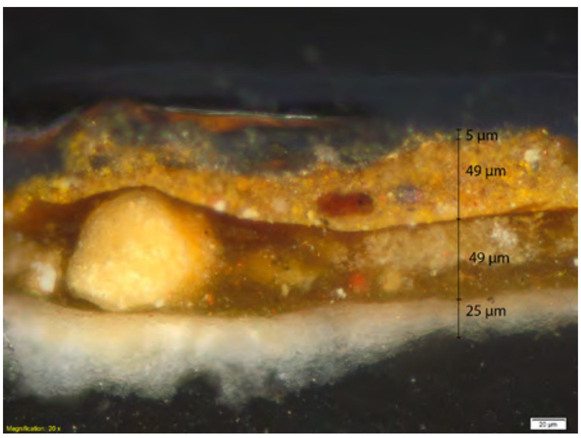
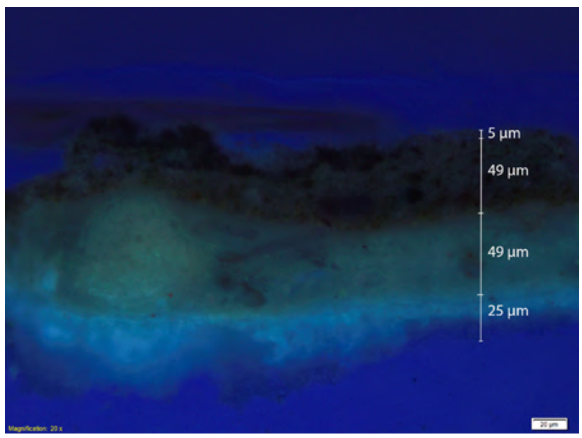
Layer	Major component	Minor component	Interpretation
3	Hg, S	Na, Pb	Vermilion, with traces of lead white
2	Ca	Na, Al, Si	Organic red (?) lake precipitated on calcium, traces of alumino-silicates or alum
1	Pb	S, Na	Likely lead white base layer rather than ground

Sample details	
Object: Berg St Anne	**Researcher:** Bettina Ebert
Inv. no./Collection: C2912 MCH	**Lab no.:** L59.2016.5
Sampling date: 1970s	**Embedding date:** 2016
Research question: What type of metal leaf is used for the gilding? What pigment or mordant is present underneath the gilding?	
Embedding material: EasySection/Technovit ® 2000 LC resin and varnish	
Layer thickness measurements taken in a representative area are marked on images. Layers are numbered consecutively from the ground up. EDS spectra and detailed elemental maps are archived at the MCH and available upon request.	
Sample location: Virgin's gilded hair, proper left side, as marked on archival photograph	

Cross-section

VIS × 10 obj magnification	UV × 10 obj magnification
	

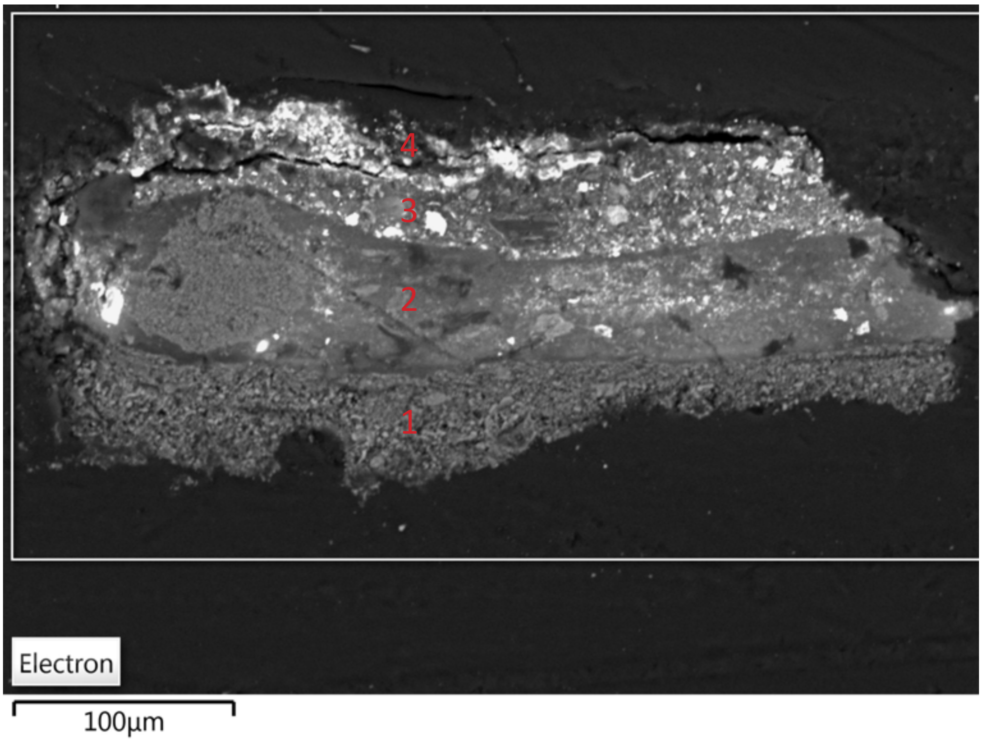
Layer	Description
4	Thin grey layer
3	Beige layer with some larger pigment particles
2	Thick brown layer, fluorescent in UV
1	Thin white ground, fluorescent in UV

VIS × 20 obj magnification	UV × 20 obj magnification
	

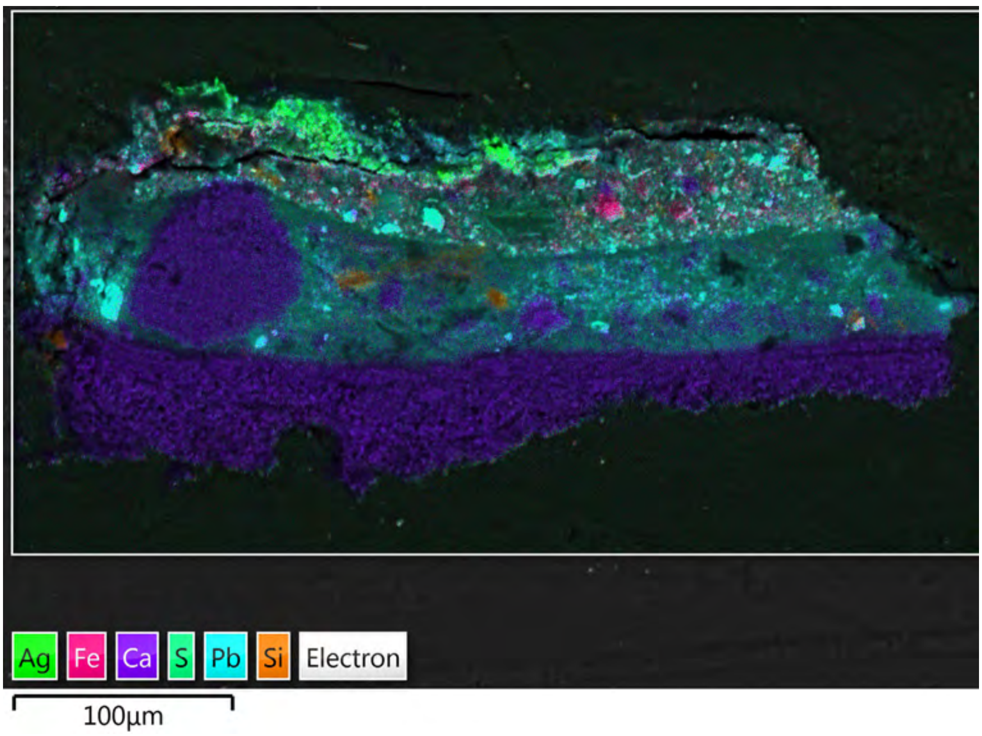
Layer	Thickness (µm)	Description
4	5	Dark grey layer of varying thickness
3	49	Beige paint layer with small pigment particles, some larger white and reddish particles
2	49	Thick brown fluorescent layer, likely resinous, pigment particles of varying size and type
1	25	White ground, fluorescent in UV

SEM-EDS

Backscattered electron image



False colour layered EDS image



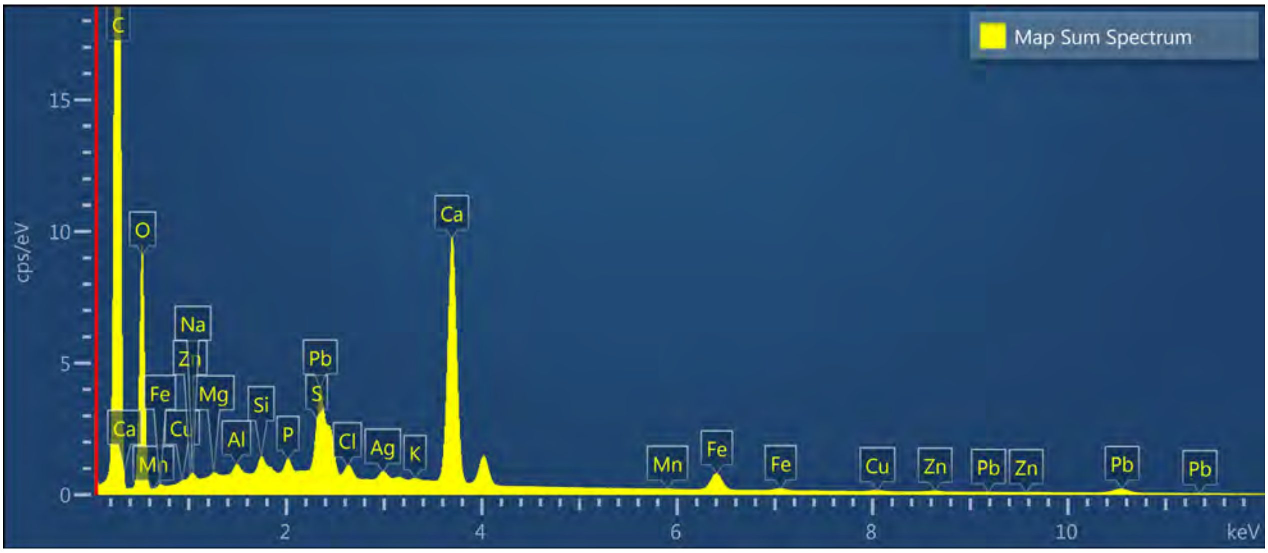
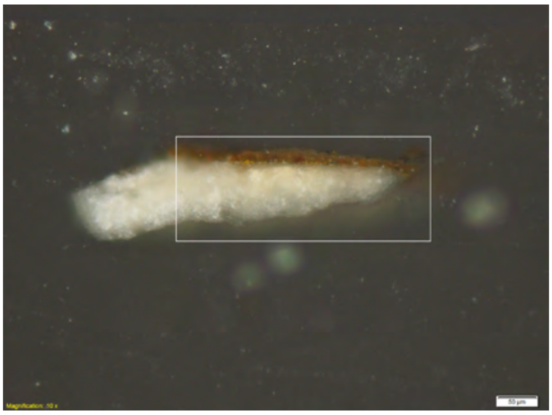
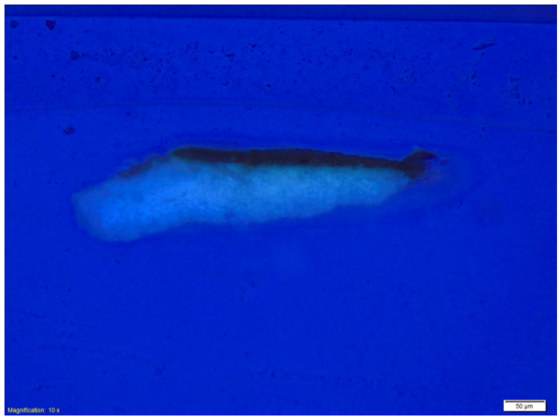


Figure 32: L59.5 EDS spectrum

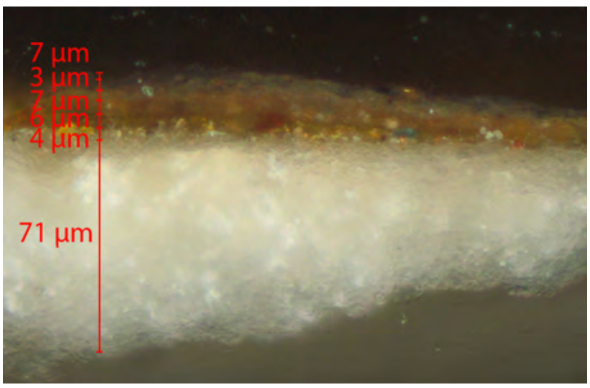
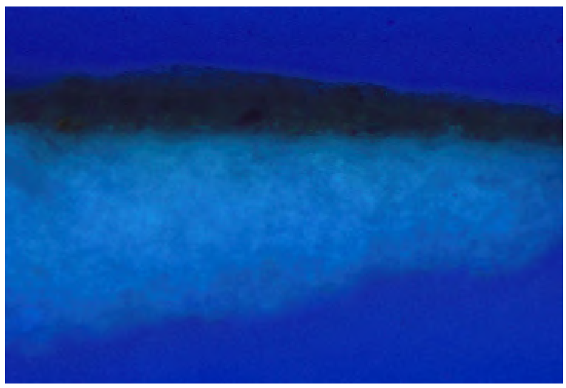
Layer	Major component	Minor component	Interpretation
4	Ag, Cl	S, Na, P	Silver, silver chloride and silver sulphide degradation products
3	Fe, Pb, S	Na, Al, Si, Zn, Mg, P, Cu	Mainly ochre, with lead white aggregates and traces of other pigments
2	Pb, P	Ca, S, Mg, Cu, Si, Na, Al	Resinous mordant, with chalk and lead white aggregates
1	Ca	Na	Chalk ground

Sample details	
Object: Berg St Anne	**Researcher:** Bettina Ebert
Inv. no./Collection: C2912 MCH	**Lab no.:** L59.2016.6
Sampling date: 1970s	**Embedding date:** 2016
Research question: What type of pigments are present in the brown layer?	
Embedding material: EasySection/Technovit ® 2000 LC resin and varnish	
Layer thickness measurements taken in a representative area are marked on images. Layers are numbered consecutively from the ground up. EDS spectra and detailed elemental maps are archived at the MCH and available upon request.	
Sample location: St Anne's throne, proper left side, as marked on archival photograph	

Cross-section

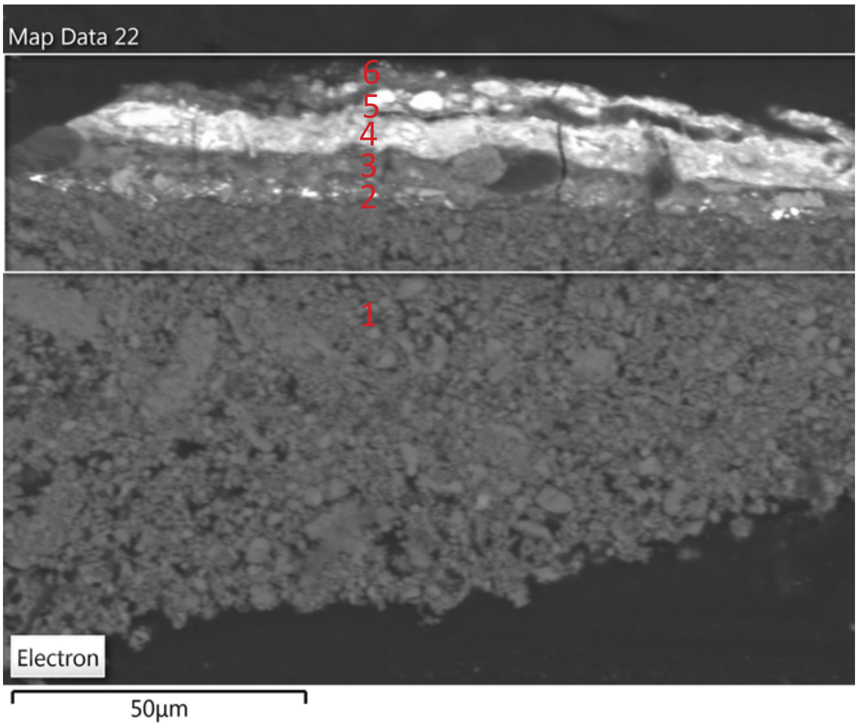
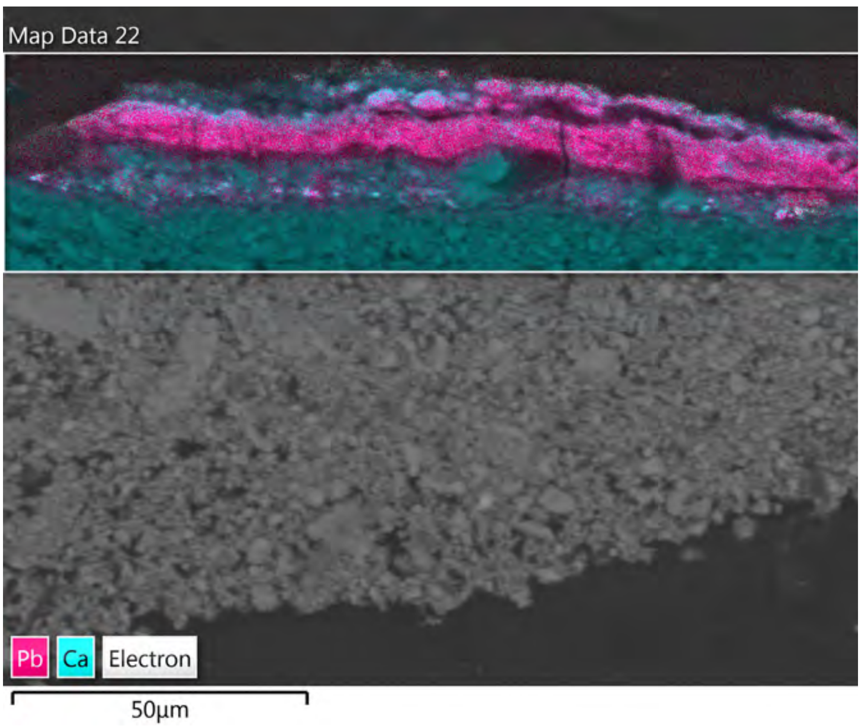
VIS × 10 obj magnification	UV × 10 obj magnification
	

Layer	Description
2	Brown layer, appears to consist of several thin layers
1	White ground

VIS × 20 obj magnification	UV × 20 obj magnification
	

Layer	Thickness (µm)	Description
6	7	Pale brown layer
5	3	Pale brown layer
4	7	Brown layer
3	6	Brown layer with some larger white pigment particles
2	4	Pale beige thin layer with traces of blue, red and yellow particles
1	71	White ground, fluorescent in UV

SEM-EDS

Backscattered electron image

False colour layered EDS image


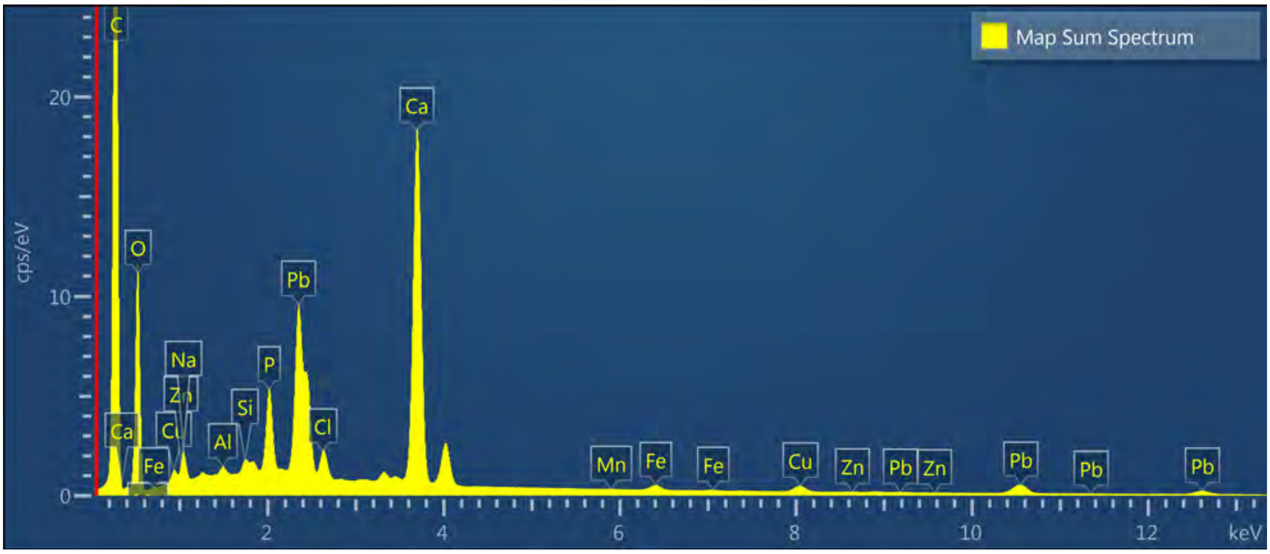
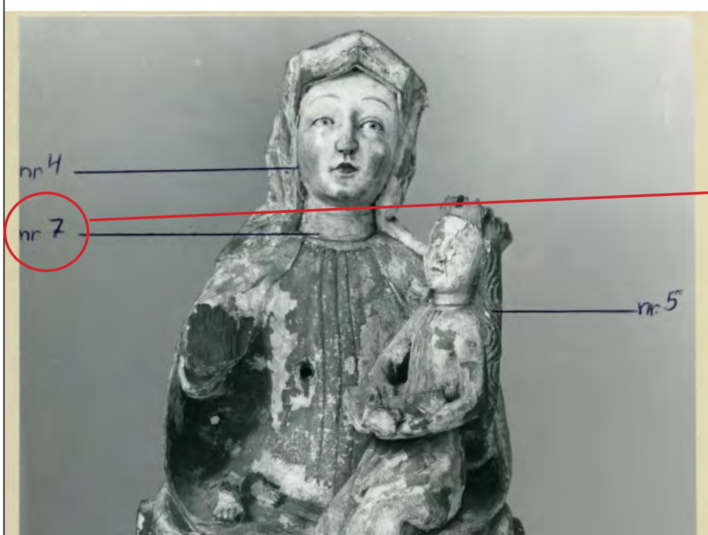


Figure 33: L59.6 EDS spectrum

Layer	Major component	Minor component	Interpretation
6	Pb	P, Cl, Ca, Al, Na	Mixture of organic black pigment (bone black?), lead white and earth pigments
5	Pb	P, Cl, Ca, Al, Si, Na, Mg	Mixture of organic black pigment (bone black?), lead white and earth pigments
4	Pb	P, Cl, Al, Na, Mg	Mixture of organic black pigment (bone black?), lead white and earth pigments
3	Ca	Pb, P, Cl, Al, Na	Chalk, earth pigments, traces of other pigments
2	Pb	Ca, Fe, Cu, Al, Na	Mixture of organic black pigment (bone black?), lead white and earth pigments
1	Ca		Chalk ground

<table>
<tr><th colspan="2">Sample details</th></tr>
<tr><td>Object: Berg St Anne</td><td>Researcher: Bettina Ebert</td></tr>
<tr><td>Inv. no./Collection: C2912 MCH</td><td>Lab no.: L59.7</td></tr>
<tr><td>Sampling date: 1970s</td><td>Embedding date: 1970s</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td colspan="2">Research question: What pigments are present in the white layer?</td></tr>
<tr><td colspan="2">Embedding material: Two perspex blocks with sample sandwiched in between using an unknown resin</td></tr>
<tr><td colspan="2">Layer thickness measurements taken in a representative area are marked on images. Layers are numbered consecutively from the ground up.
EDS spectra and detailed elemental maps are archived at the MCH and available upon request.</td></tr>
<tr><td colspan="2">Sample location: St Anne’s neck, proper right side near neckline of dress, as marked on archival photograph


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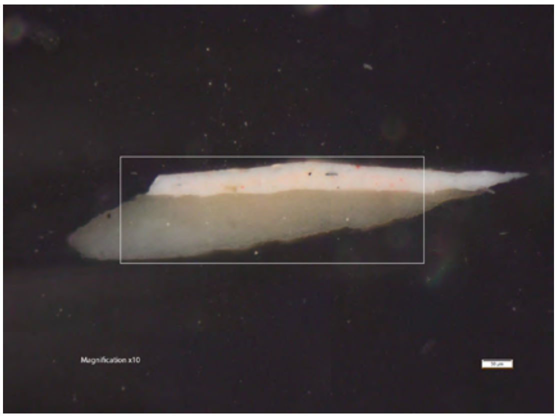
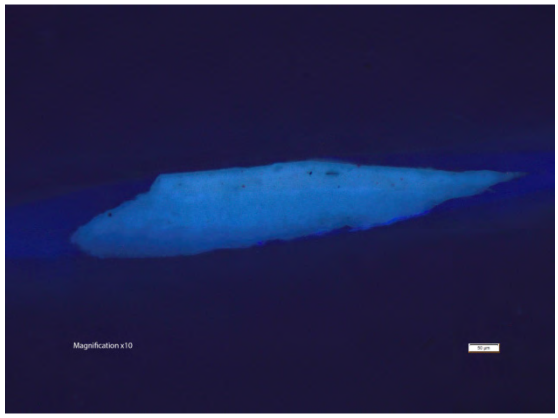
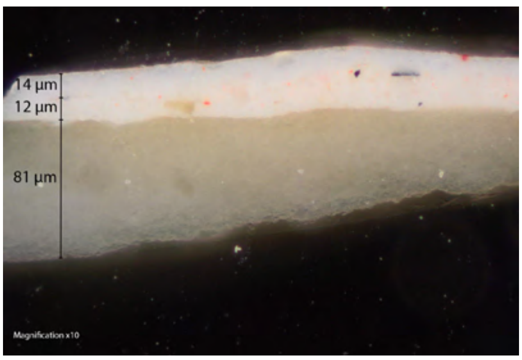
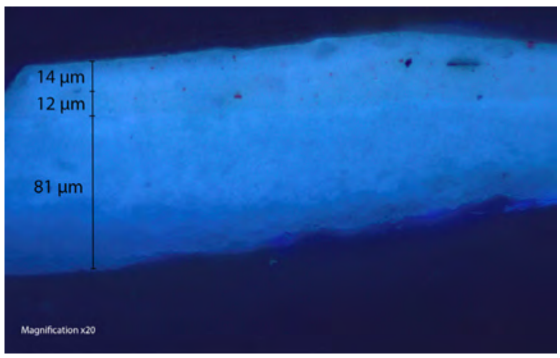
Cross-section

VIS × 10 obj magnification	UV × 10 obj magnification
	

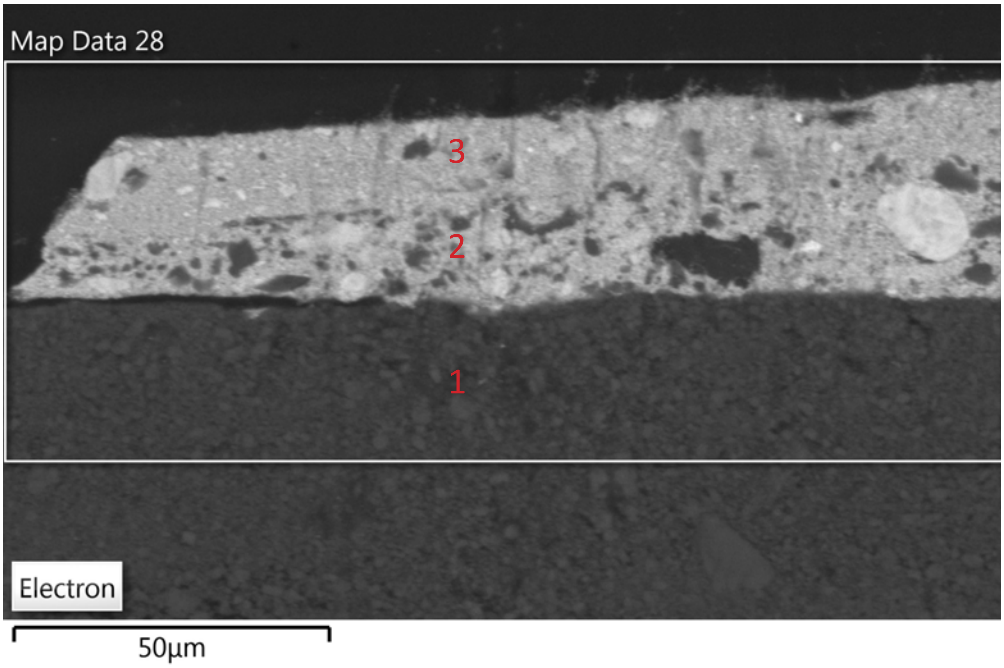
Layer	Description
3	White paint layer
2	Pinkish white paint layer
1	White ground

VIS × 20 obj magnification	UV × 20 obj magnification
	

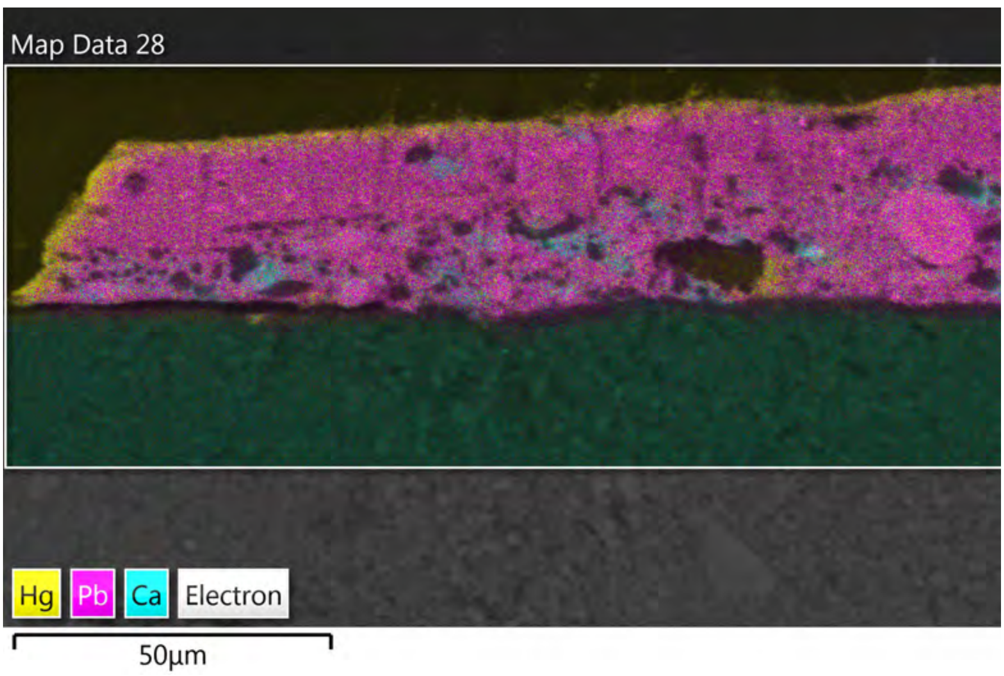
Layer	Thickness (µm)	Description
3	14	White paint layer, fluorescent in UV
2	12	Pinkish white paint layer, fluorescent in UV, some dark pigment particles
1	81	White ground, fluorescent in UV

SEM-EDS

Backscattered electron image



False colour layered EDS image



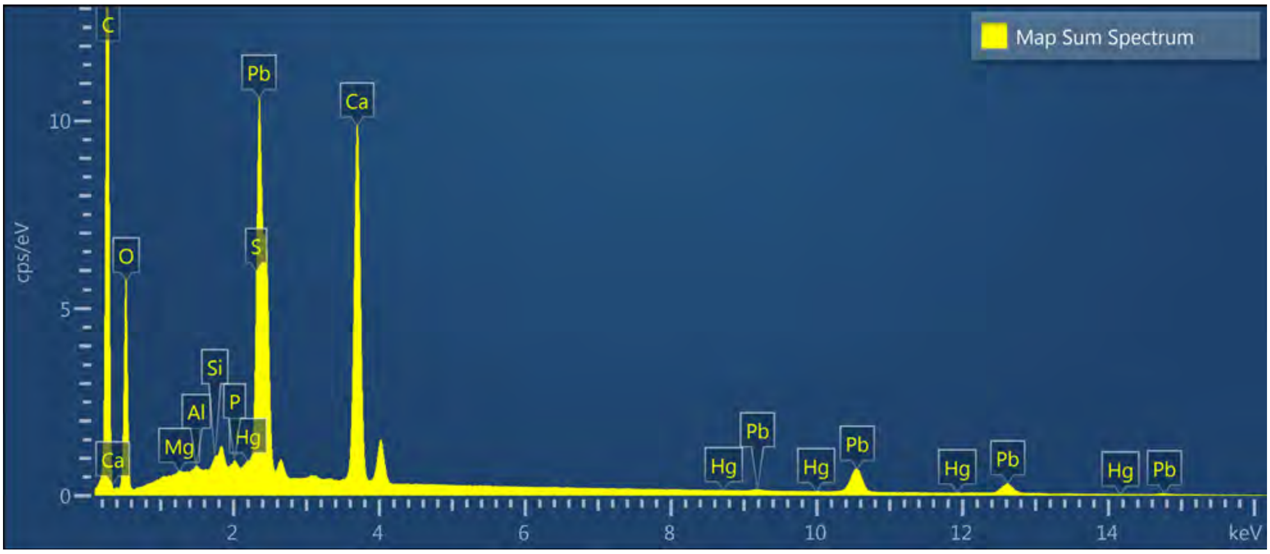
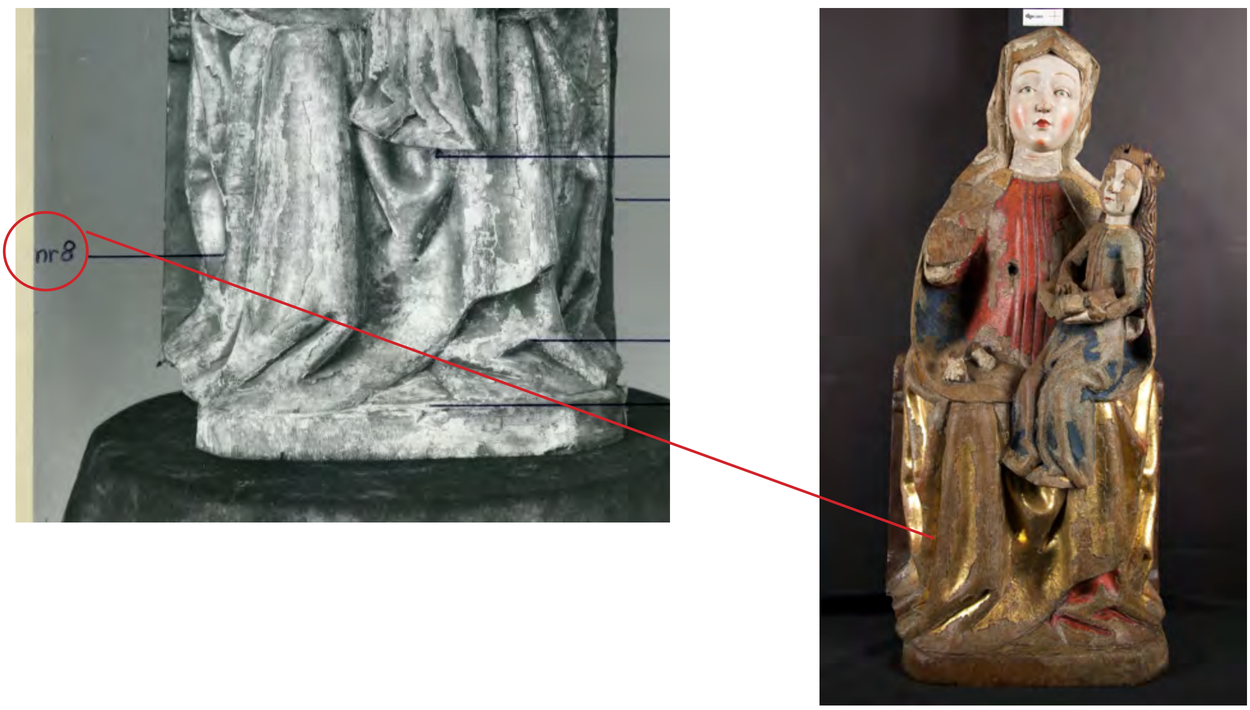


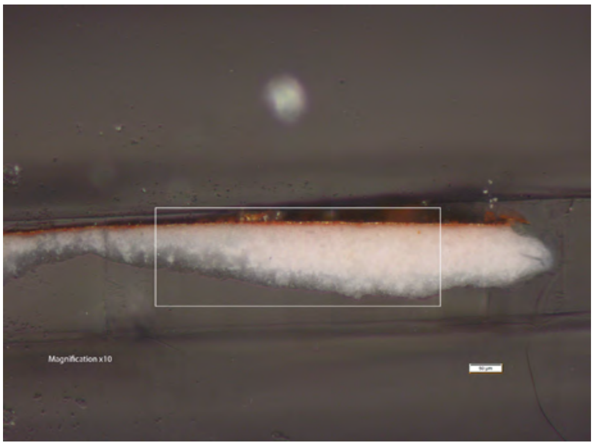
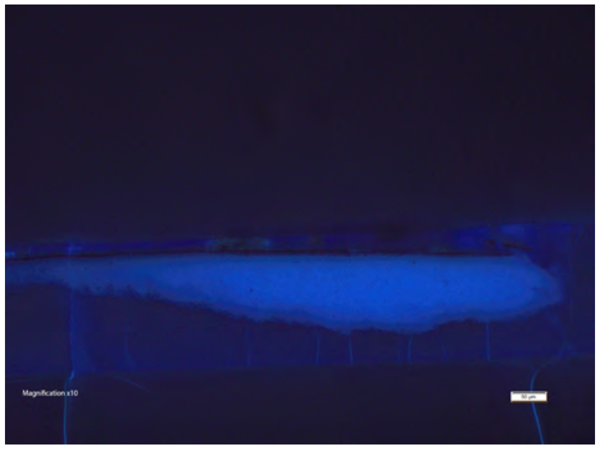
Figure 34: L59.7 EDS spectrum

Layer	Major component	Minor component	Interpretation
3	Pb	S, Hg, P, Si	Lead white, with some vermilion
2	Pb	Ca, S, Hg, P, Si	Lead white, vermilion, chalk
1	Ca		Chalk ground

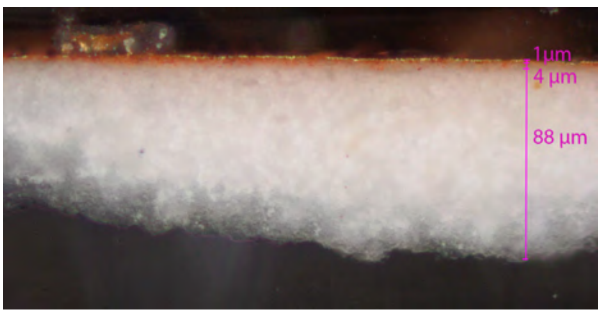
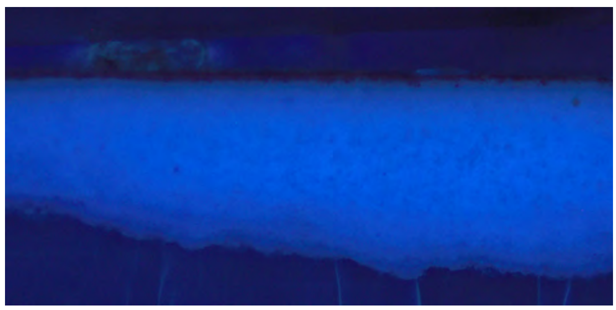
Sample details	
Object: Berg St Anne	**Researcher:** Bettina Ebert
Inv. no./Collection: C2912 MCH	**Lab no.:** L59.8
Sampling date: 1970s	**Embedding date:** 1970s
Research question: How does the gilding structure compare to that of Bishop C2913 in terms of composition and technique?	
Embedding material: Two perspex blocks with sample sandwiched in between using an unknown resin	
Layer thickness measurements taken in a representative area are marked on images. Layers are numbered consecutively from the ground up. EDS spectra and detailed elemental maps are archived at the MCH and available upon request.	
Sample location: Gilding from St Anne's robe, proper right side, as marked on archival photograph	



Cross-section

VIS × 10 obj magnification	UV × 10 obj magnification
	

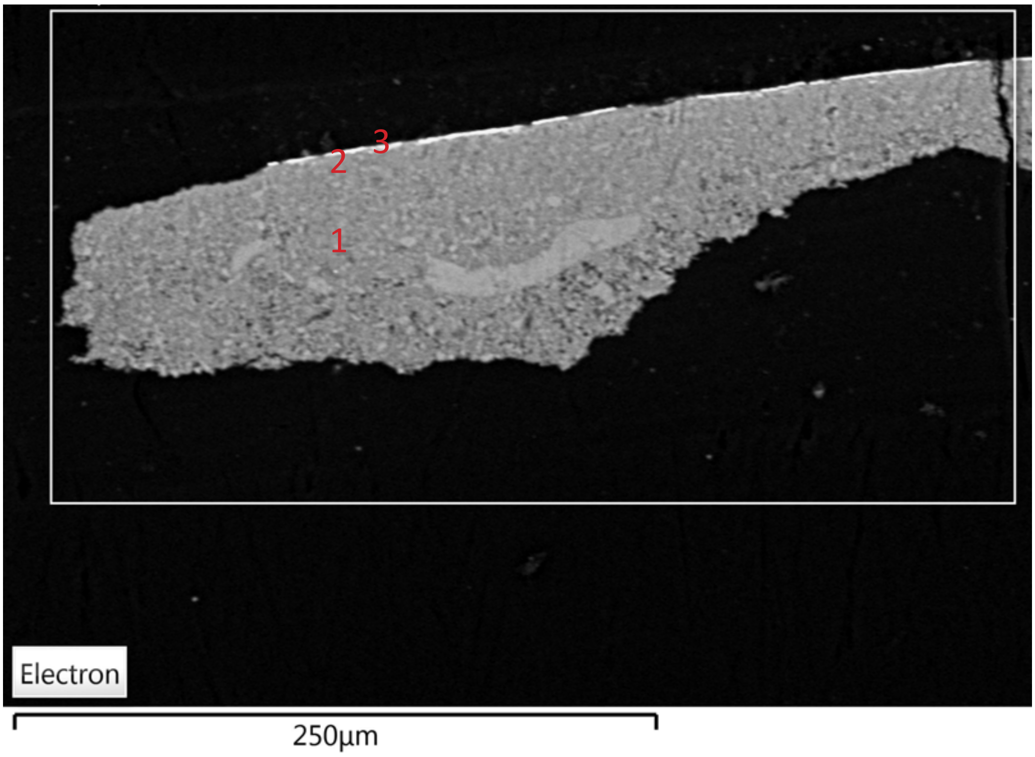
Layer	Description
3	Gold leaf
2	Red bole
1	White ground

VIS × 20 obj magnification	UV × 20 obj magnification
	

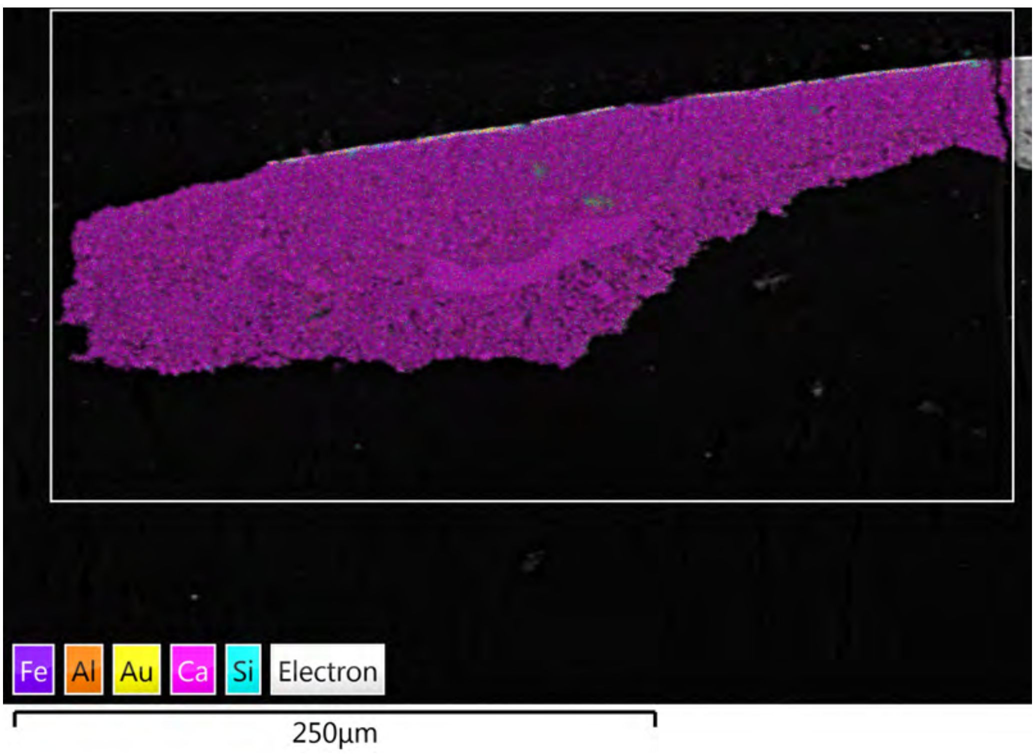
Layer	Thickness (µm)	Description
3	1	Gold leaf
2	4	Red bole
1	88	White ground, fluorescent in UV

SEM-EDS

Backscattered electron image



False colour layered EDS image



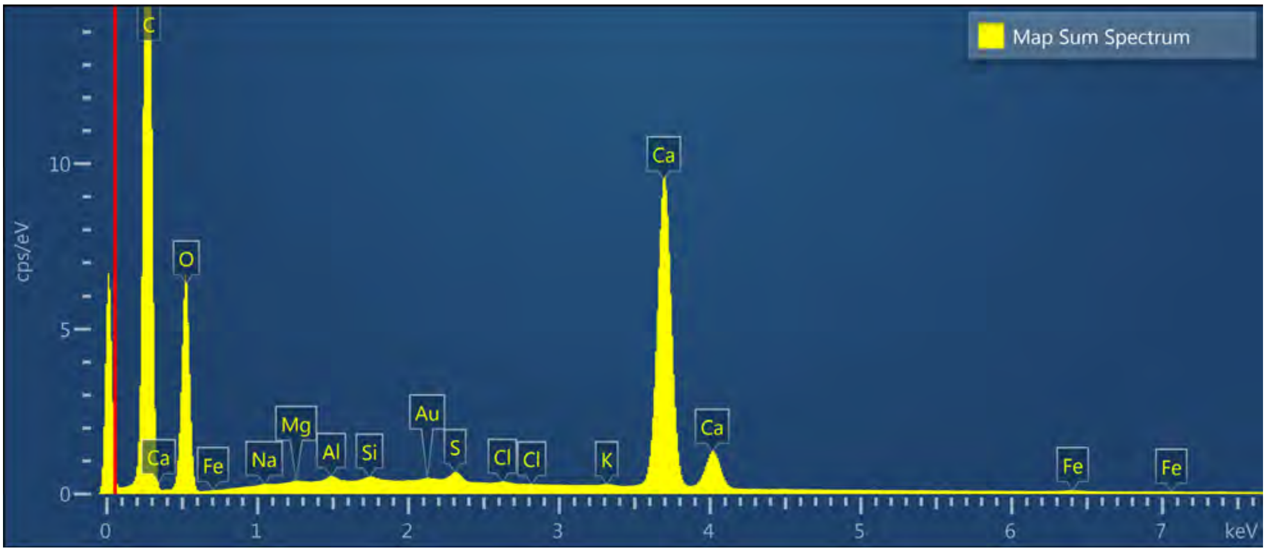
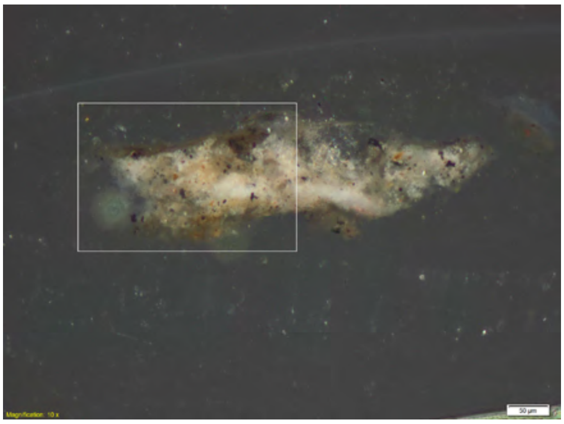
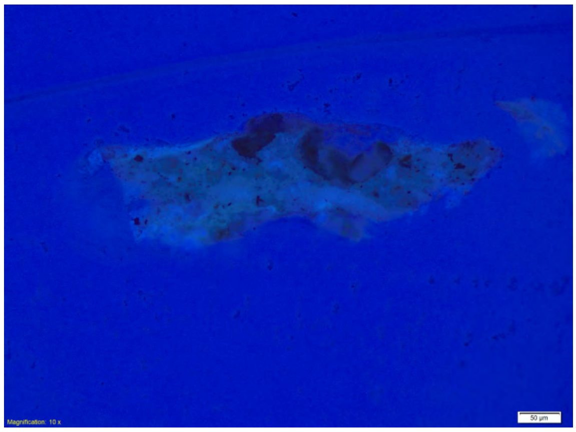


Figure 35: L59.8 EDS spectrum

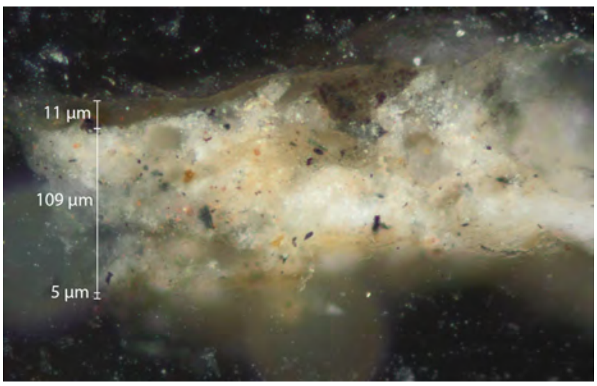
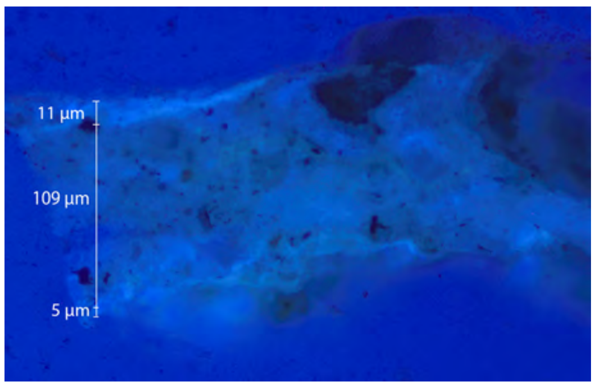
Layer	Major component	Minor component	Interpretation
3	Au	Ag, P, S	Gold leaf
2	Fe	Si, Al, Mg, Na, P, Ca, K	Ferrous alumino-silicate (bole)
1	Ca	Na, Mg, Al, K, Si	Chalk ground

Sample details	
Object: Berg St Anne	**Researcher:** Bettina Ebert
Inv. no./Collection: C2912 MCH	**Lab no.:** L59.10
Sampling date: 2016	**Embedding date:** 2016
Research question: What type of preparatory layer was used underneath the Virgin's crown? How does it differ from the usual white ground present elsewhere? What is the nature and purpose of this layer, and what is it composed of?	
Embedding material: EasySection/Technovit ® 2000 LC resin and varnish	
Layer thickness measurements taken in a representative area are marked on images. Layers are numbered consecutively from the ground up. EDS spectra and detailed elemental maps are archived at the MCH and available upon request.	
Sample location: Ground sample from Virgin's crown, proper right side of head	

Cross-section

VIS × 10 obj magnification	UV × 10 obj magnification
	

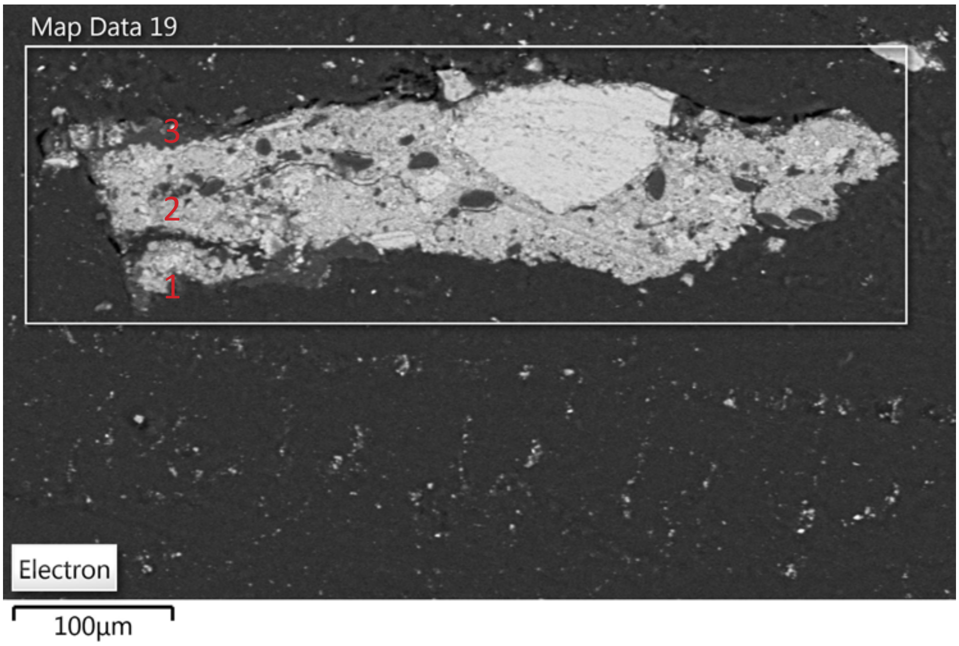
Layer	Description
3	Thin brown layer
2	White layer with dark pigment particles (grey ground)
1	Thin brown layer

VIS × 20 obj magnification	UV × 20 obj magnification
	

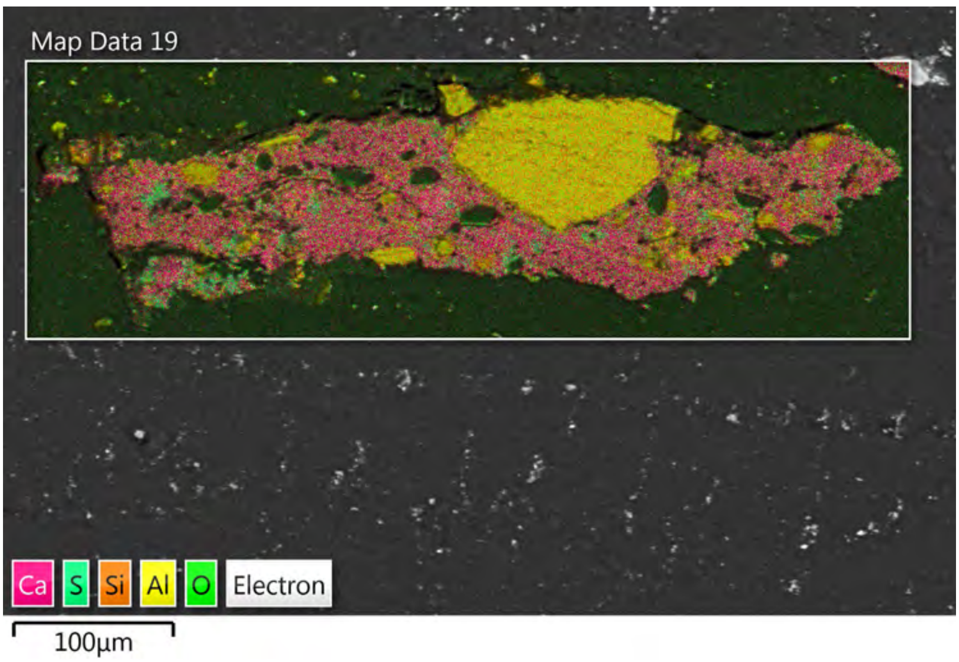
Layer	Thickness (µm)	Description
3	11	Brown layer, no obvious pigment particles, fluorescent in UV
2	109	White layer with brown and black pigment particles (grey ground)
1	5	Thin brown layer, fluorescent in UV

SEM-EDS

Backscattered electron image



False colour layered EDS image



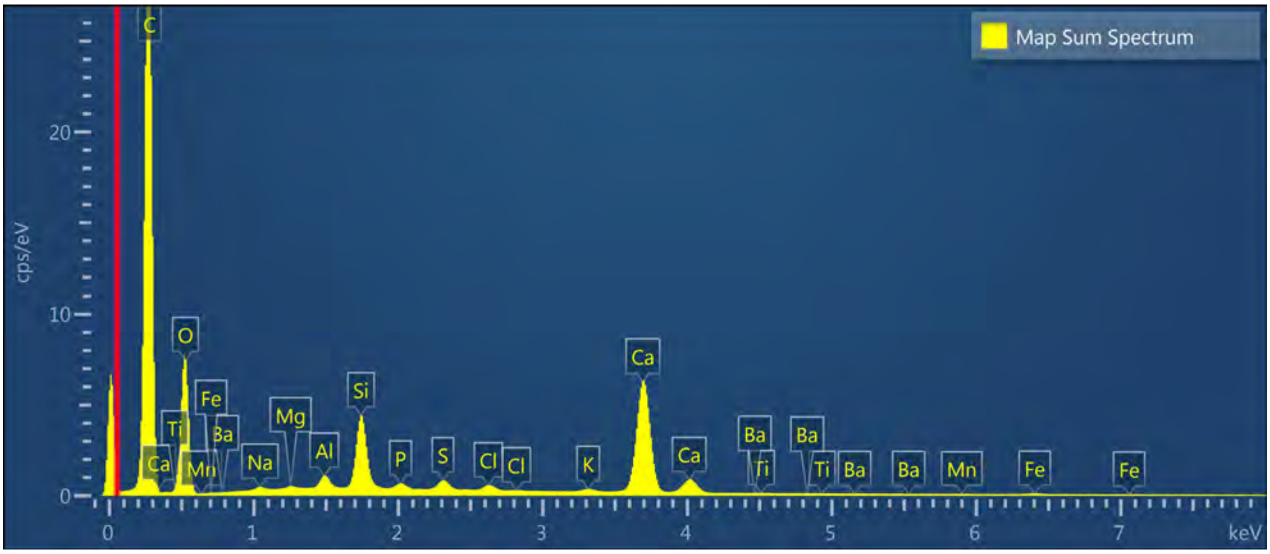
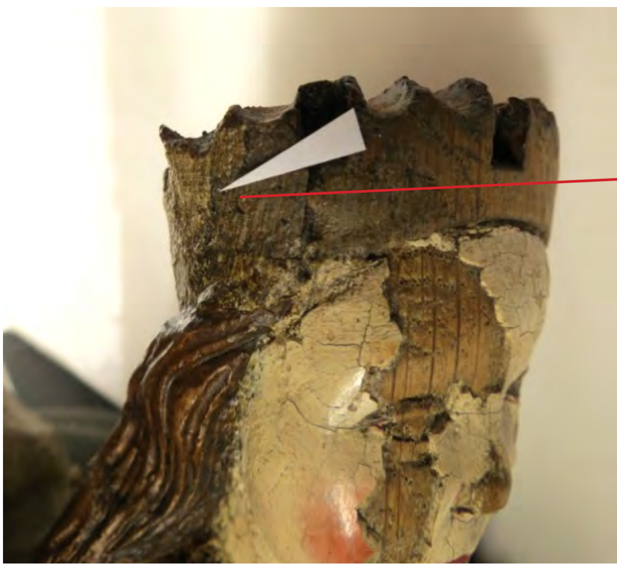


Figure 36: L59.10 EDS spectrum

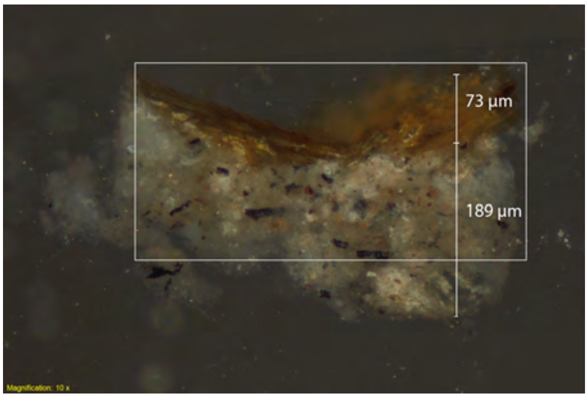
Layer	Major component	Minor component	Interpretation
3	C,O	Al, Si	Organic layer (glue)
2	Ca, Al, Si	K, Na, Mg, Cl, S, P	Chalk, alumino-silicates, organic black pigment (bone black?)
1	C, O	Al, Si	Organic layer (glue)

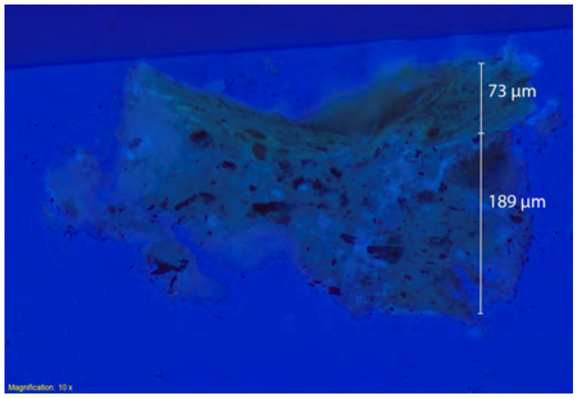
Sample details	
Object: Berg St Anne	**Researcher:** Bettina Ebert
Inv. no./Collection: C2912 MCH	**Lab no.:** L59.10A
Sampling date: 2016	**Embedding date:** 2016
Research question: What type of preparatory layer was used underneath the Virgin's crown? How does it differ from the usual white ground present elsewhere? What is the nature and purpose of this layer, and what is it composed of?	
Embedding material: EasySection/Technovit ® 2000 LC resin and varnish	
Layer thickness measurements taken in a representative area are marked on images. Layers are numbered consecutively from the ground up. EDS spectra and detailed elemental maps are archived at the MCH and available upon request.	
Sample location: Ground sample from Virgin's crown, proper right side of head	



Cross-section

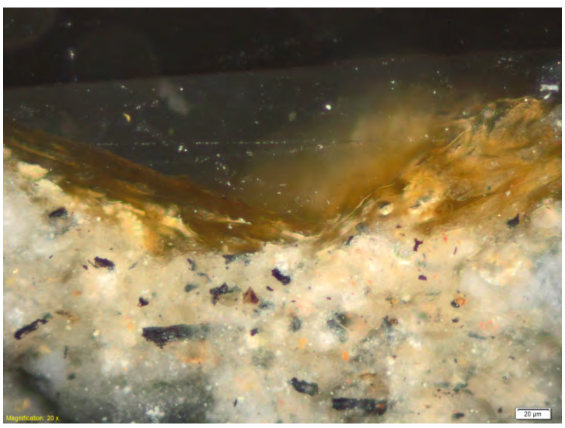
VIS × 10 obj magnification	UV × 10 obj magnification

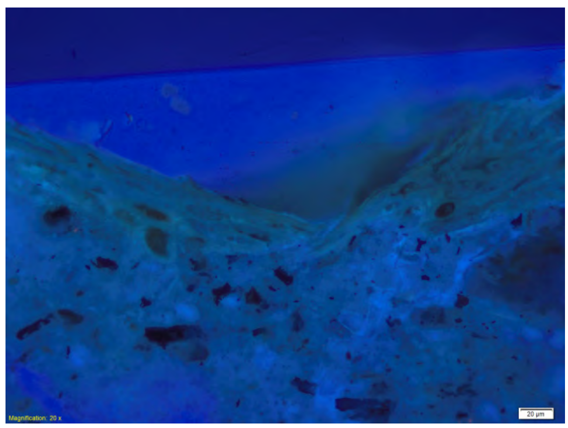




Layer	Thickness (µm)	Description
2	73	Brown layer
1	189	Grey layer with white and black pigment particles

VIS × 20 obj magnification	UV × 20 obj magnification

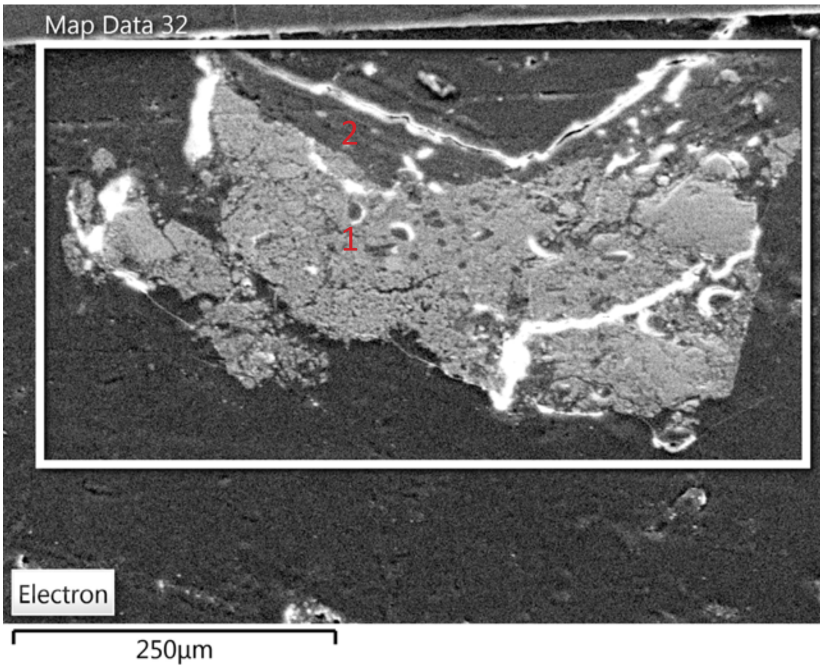




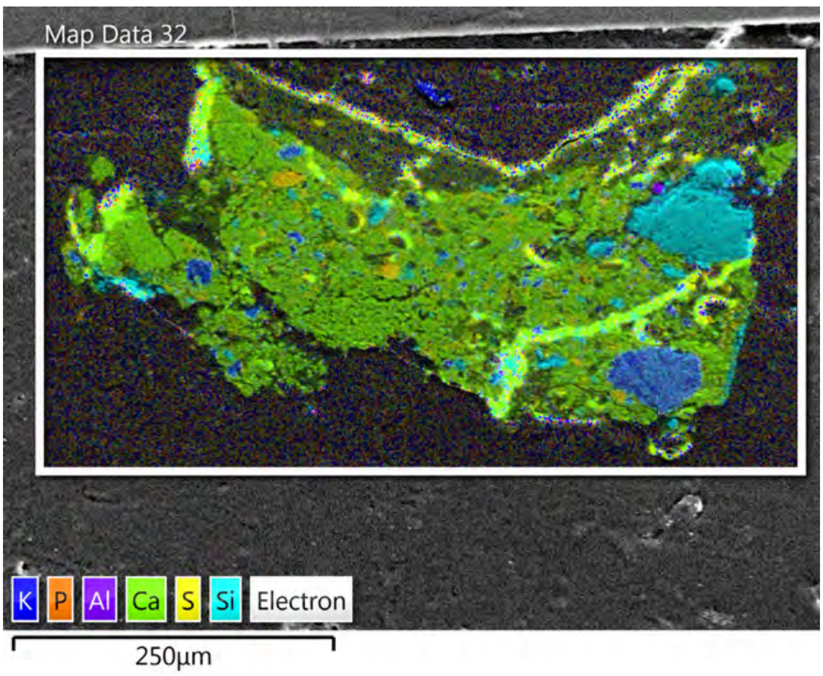
Layer	Description
2	Brown layer, no obvious pigment particles
1	Grey layer, reddish pigment particles, large black pigment particles

SEM-EDS

Backscattered electron image



False colour layered EDS image



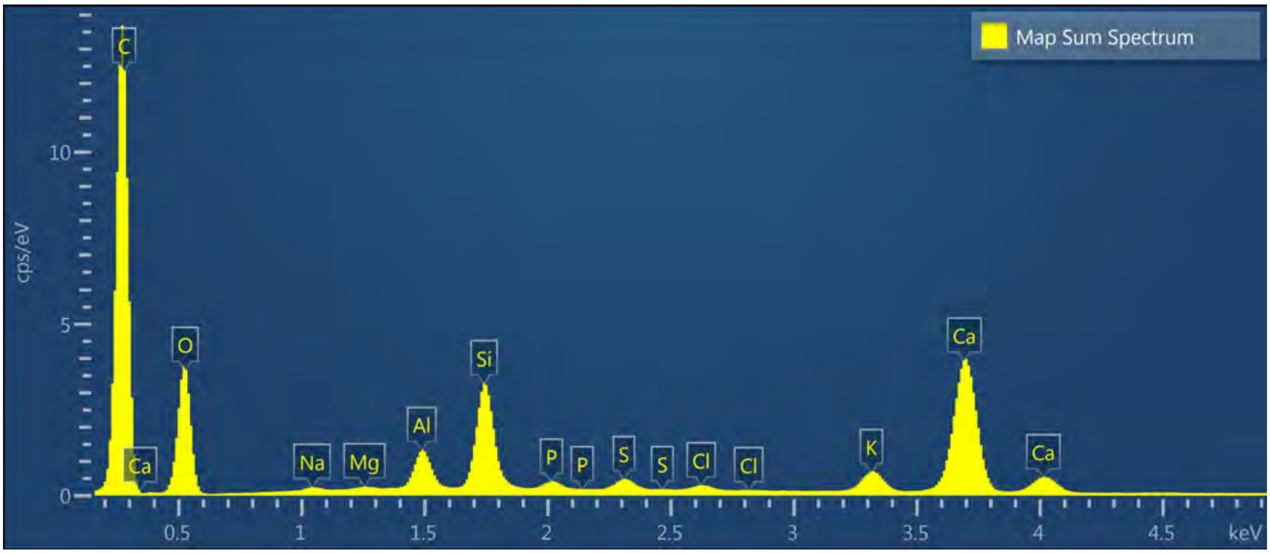


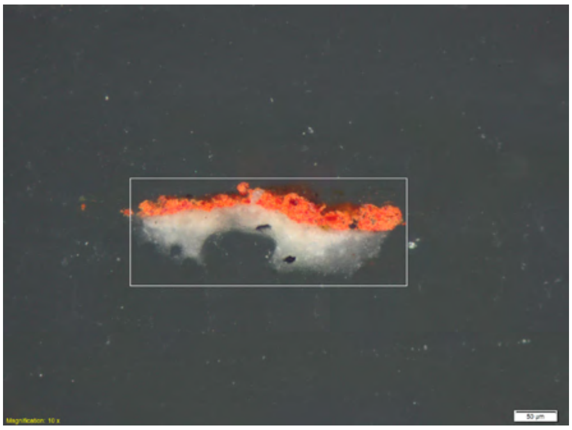
Figure 37: L59.10A EDS spectrum

Layer	Major component	Minor component	Interpretation
2	C, O	Cl, K, Mg, Na	Organic layer (glue)
1	Ca, Si	Fe, Al, S, P, Na, Mg, Cl, K	Chalk, quartz or other silicates, organic black pigment (charcoal black?), ochre

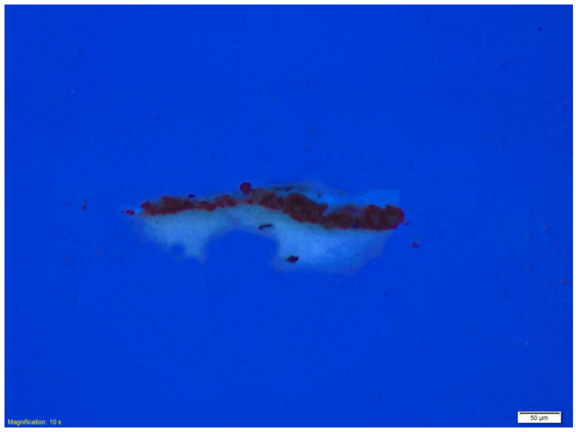
Sample details	
Object: Berg Bishop	**Researcher:** Bettina Ebert
Inv. no./Collection: C2913 MCH	**Lab no.:** L177.1
Sampling date: 2016	**Embedding date:** 2016
Research question: Pigments used, layer structure, particle size and distribution are to be examined and compared to C2912 St Anne to test hypothesis whether sculptures are from same workshop	
Embedding material: EasySection/Technovit ® 2000 LC resin and varnish	
Layer thickness measurements taken in a representative area are marked on images. Layers are numbered consecutively from the ground up. EDS spectra and detailed elemental maps are archived at the MCH and available upon request.	
Sample location: Red base of bishop's mitre	

Cross-section

VIS × 10 obj magnification

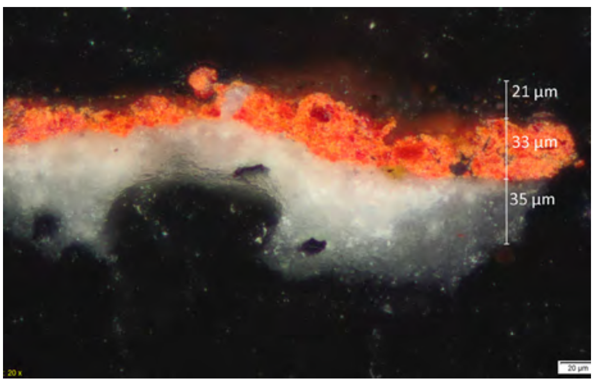


UV × 10 obj magnification

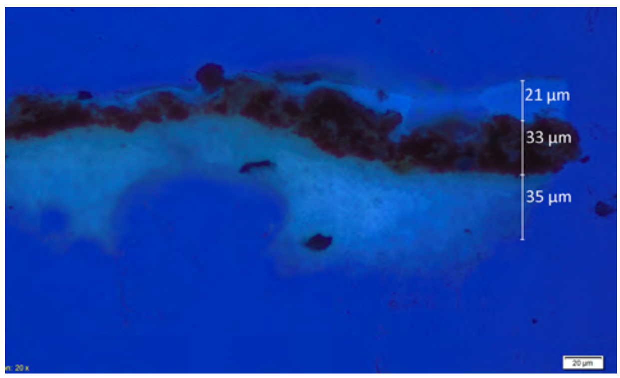


Layer	Description
3	Fluorescent upper layer
2	Red paint layer
1	White ground

VIS × 20 obj magnification



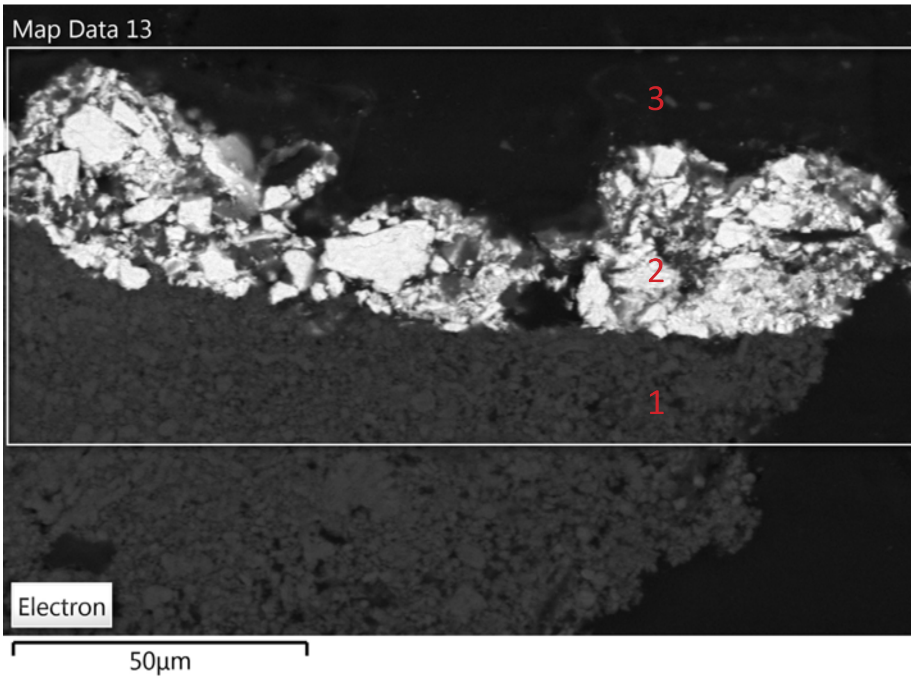
UV × 20 obj magnification



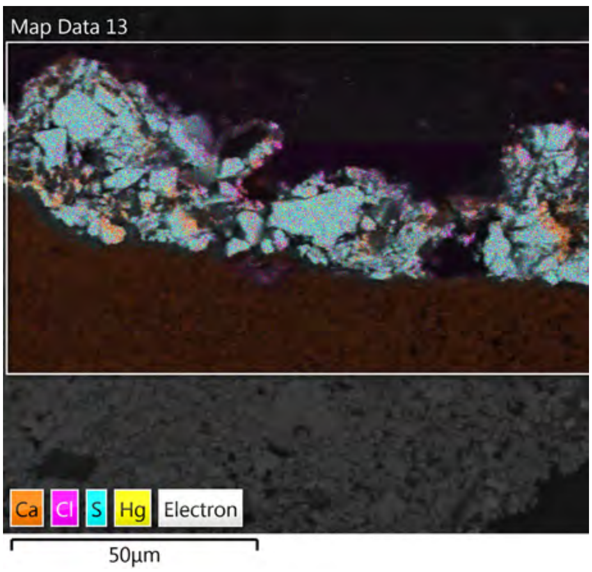
Layer	Thickness (µm)	Description
3	21	Fluorescent unpigmented layer, likely later surface coating or consolidant
2	33	Red paint layer with dark red and orange pigment particles
1	35	White ground with some large dark particles

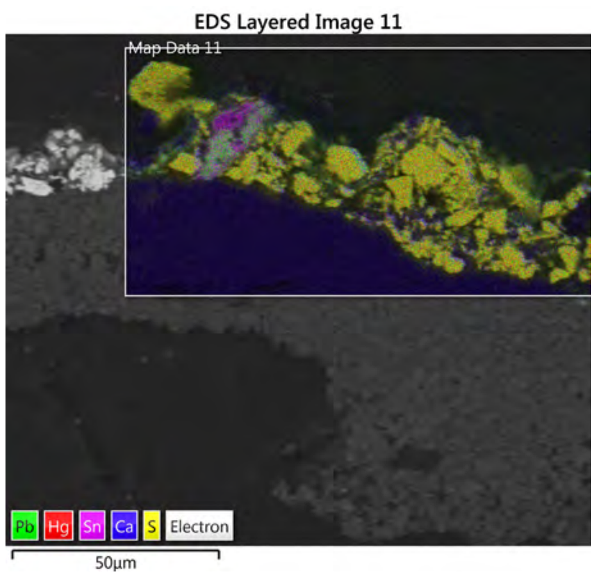
SEM-EDS

Backscattered electron image



False colour layered EDS images





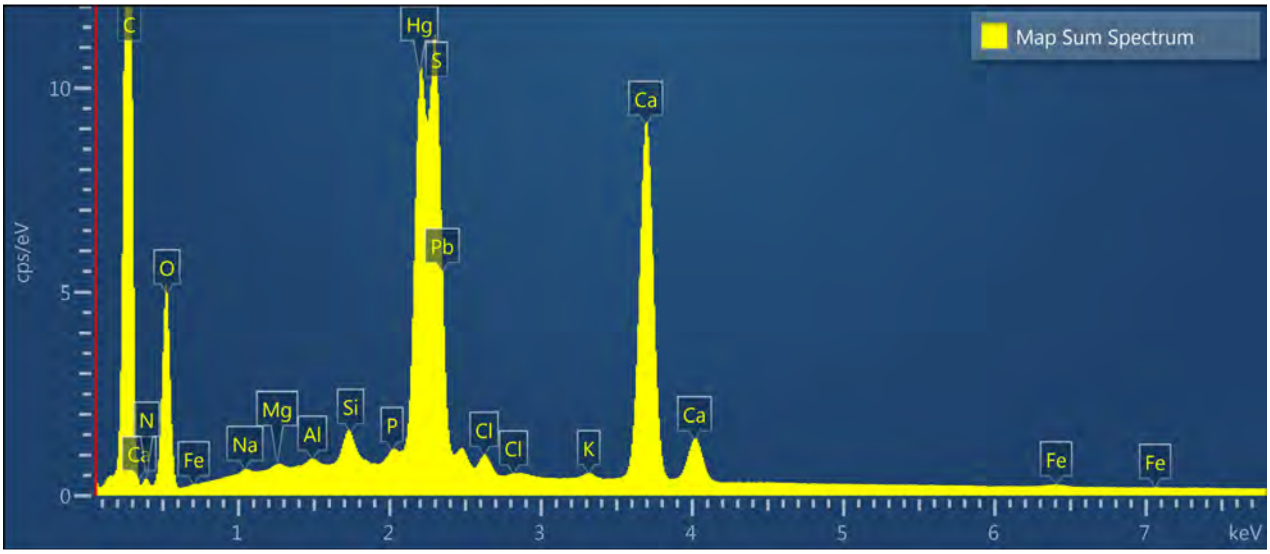
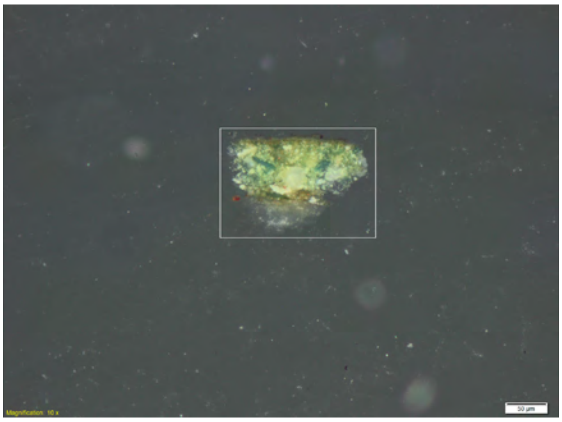
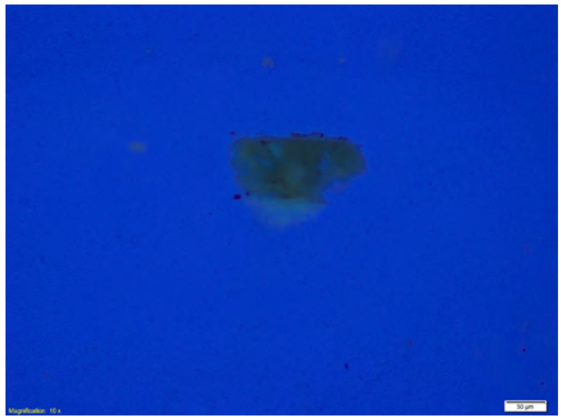


Figure 38: L177.1 EDS spectrum

Layer	Major component	Minor component	Interpretation
3	Cl	Ca, K, Na	Organic surface coating or consolidant
2	Hg, S	Al, Ca, Cl, K, Fe, Mg, Na, Sn, Pb	Vermilion, with some particles of lead tin yellow and iron oxide, some chalk present within paint layer
1	Ca	Cl, K	Chalk ground

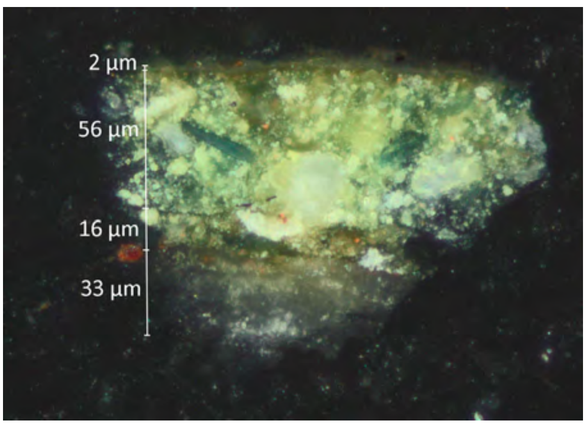
Sample details	
Object: Berg Bishop	**Researcher:** Bettina Ebert
Inv. no./Collection: C2913 MCH	**Lab no.:** L177.2
Sampling date: 2016	**Embedding date:** 2016
Research question: Pigments used, layer structure, particle size and distribution are to be examined and compared to C2912 St Anne to test hypothesis whether sculptures are from same workshop	
Embedding material: EasySection/Technovit ® 2000 LC resin and varnish	
Layer thickness measurements taken in a representative area are marked on images. Layers are numbered consecutively from the ground up. EDS spectra and detailed elemental maps are archived at the MCH and available upon request.	
Sample location: Green base of sculpture	

Cross-section

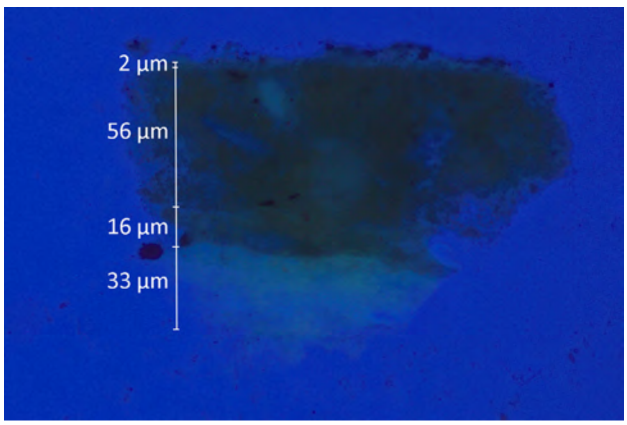
VIS × 10 obj magnification	UV × 10 obj magnification
	

Layer	Description
3	Surface dirt
2	Blue-green paint layer, somewhat more brown at the top and bottom
1	White ground

VIS × 20 obj magnification

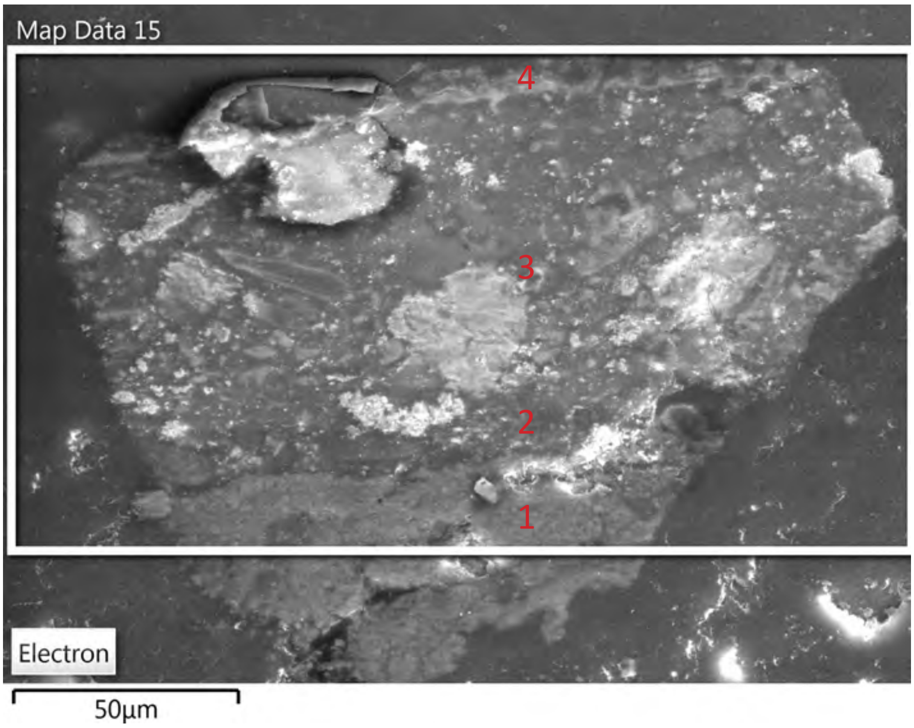


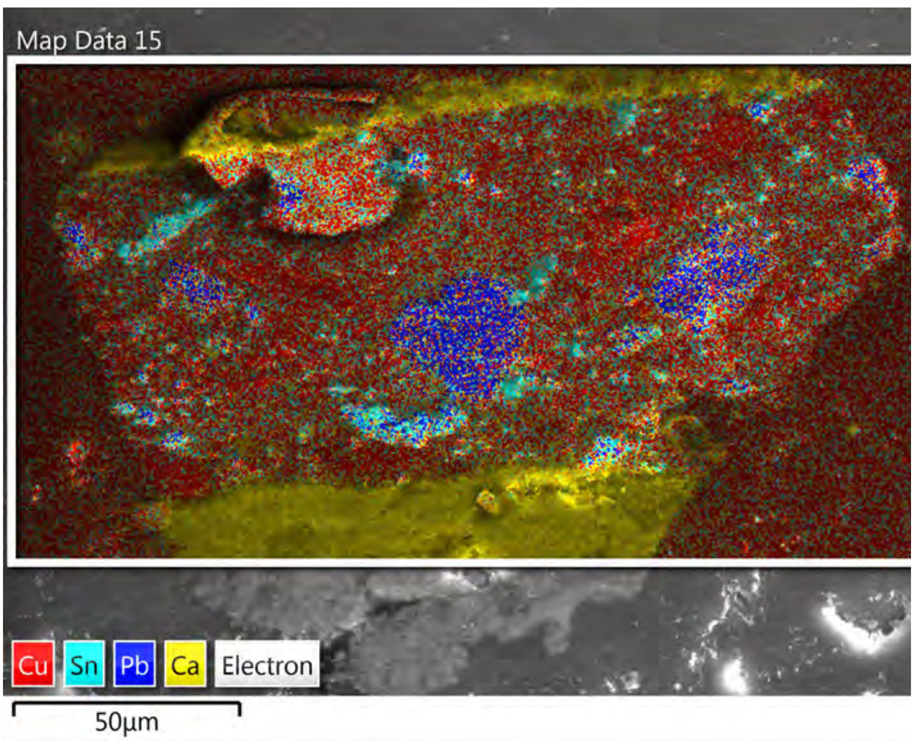
UV × 20 obj magnification



Layer	Thickness (µm)	Description
4	2	Likely surface dirt on top of a fluorescent surface coating
3	56	Thick green paint layer with some large blue-green and large pale yellow particles, some small orange particles, discoloured brown-green towards the top of the layer
2	16	Separate thin green layer, more dark and brown compared to the upper layer, numerous small orange red pigment particles
1	33	White ground

SEM-EDS

Backscattered electron image


False colour layered EDS image


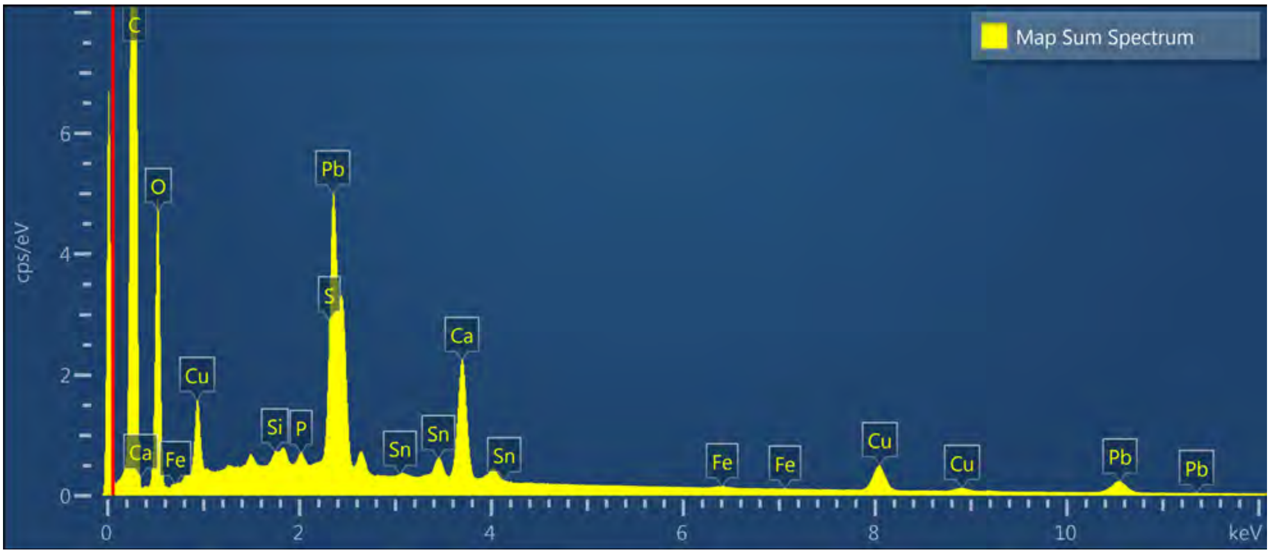
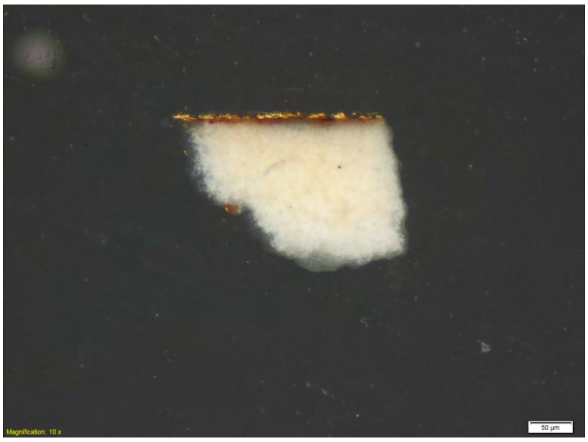
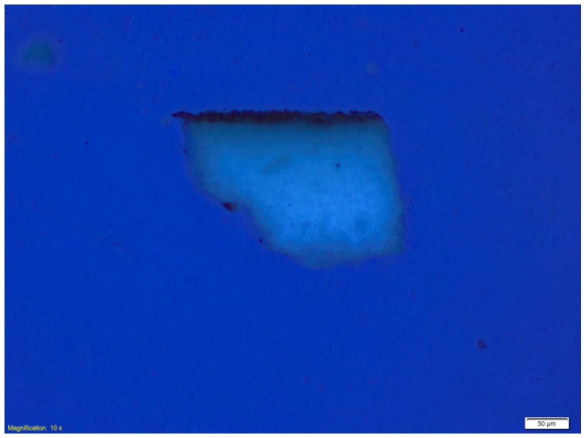


Figure 39: L177.2 EDS spectrum

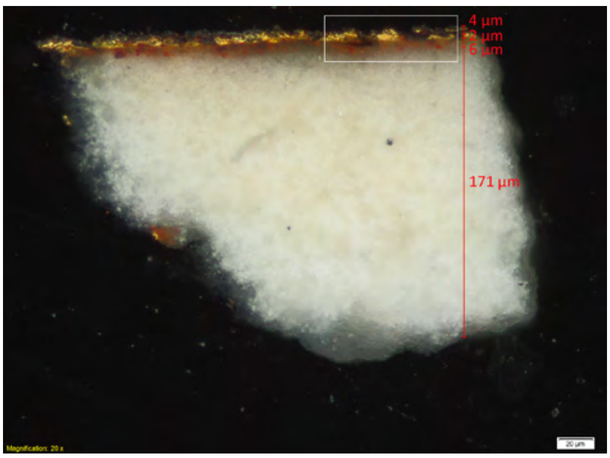
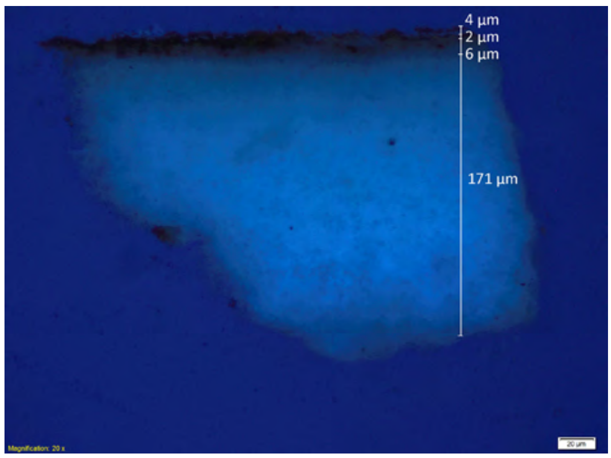
Layer	Major component	Minor component	Interpretation
4	P, Ca		Organic surface coating with embedded dirt
3	Pb, Sn, Cu	Al, Fe, P, Si	Lead white, lead tin yellow and copper green, some iron oxide particles
2	Pb, Sn, Cu	Al, Fe, P, Si	Lead white, lead tin yellow and copper green, some iron oxide particles
1	Ca	P	Chalk ground

Sample details	
Object: Berg Bishop	**Researcher:** Bettina Ebert
Inv. no./Collection: C2913 MCH	**Lab no.:** L177.3
Sampling date: 2016	**Embedding date:** 2016
Research question: Gilding to be examined and compared to C2912 St Anne to test hypothesis whether sculptures are from same workshop	
Embedding material: EasySection/Technovit ® 2000 LC resin and varnish	
Layer thickness measurements taken in a representative area are marked on images. Layers are numbered consecutively from the ground up. EDS spectra and detailed elemental maps are archived at the MCH and available upon request.	
Sample location: Gilded robe, proper right side adjacent to discoloured area	

Cross-section

VIS × 10 obj magnification	UV × 10 obj magnification
	

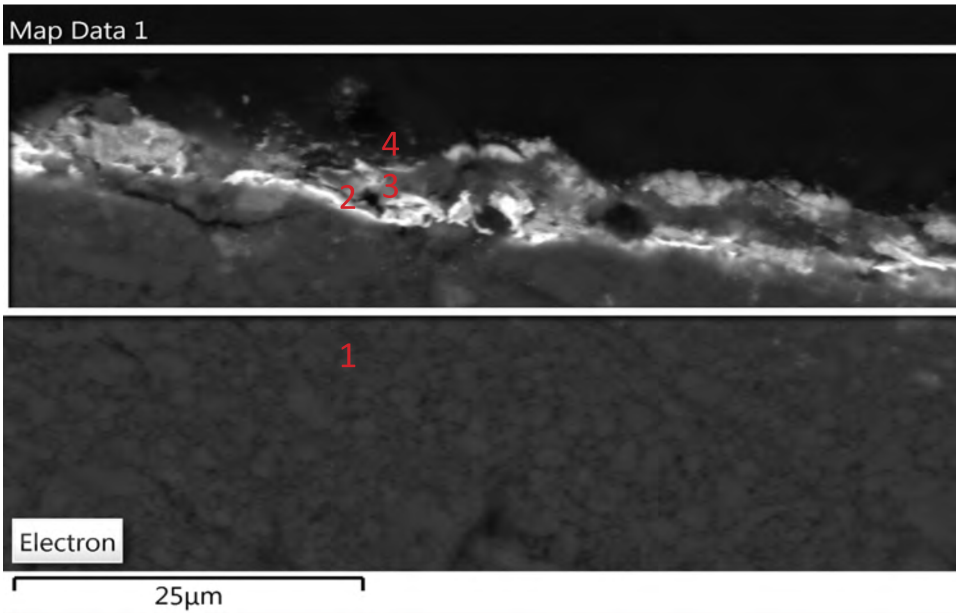
Layer	Description
3	Gold leaf
2	Red gilding ground
1	Thick white ground

VIS × 20 obj magnification	UV × 20 obj magnification
	

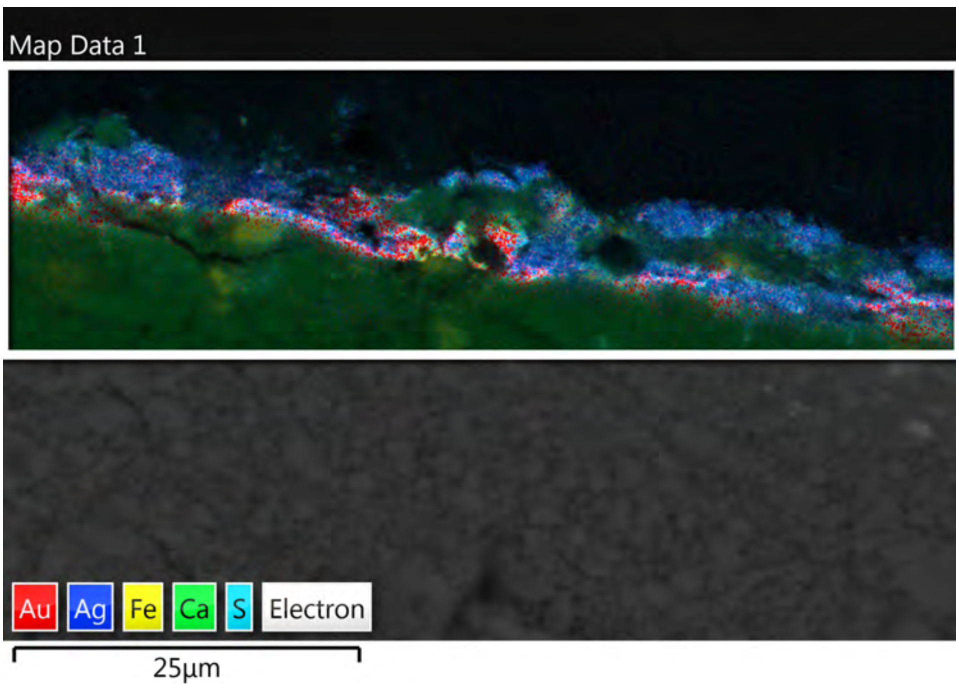
Layer	Thickness (µm)	Description
4	4	Dirt
3	2	Gold leaf
2	6	Red gilding ground
1	171	Thick white ground

SEM-EDS

Backscattered electron image



False colour layered EDS image



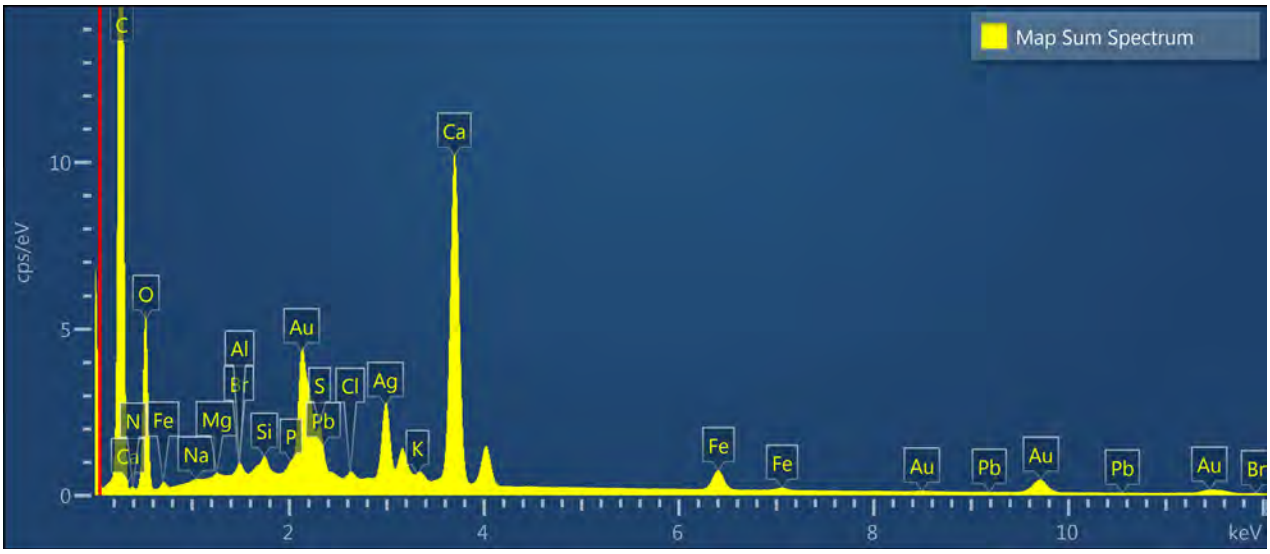
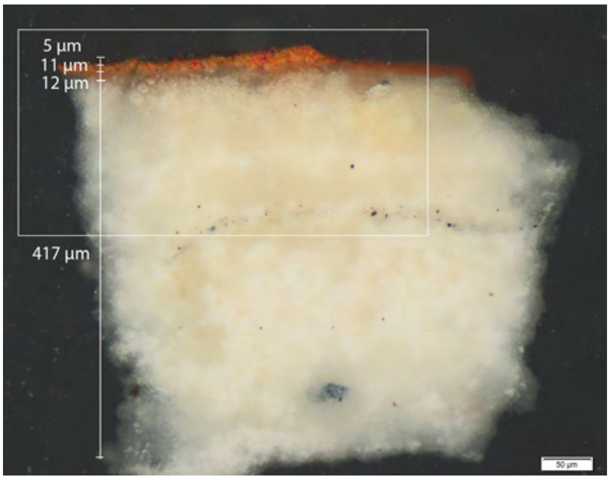
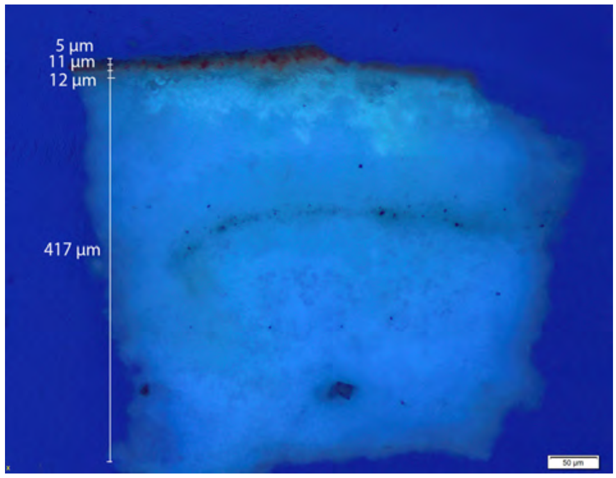


Figure 40: L177.3 EDS spectrum

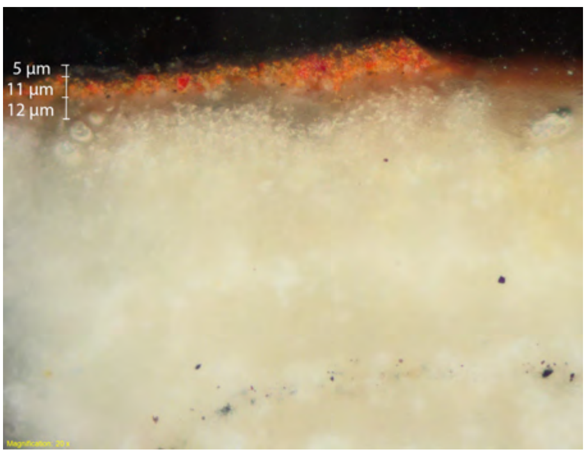
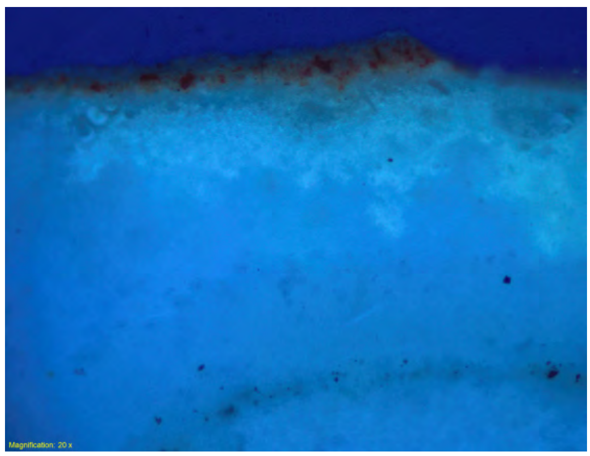
Layer	Major component	Minor component	Interpretation
4	Ca	Cl, P, S	Embedded dirt layer, silver sulfide and chloride degradation products that have migrated to the surface
3	Au, Ag, S	Fe, Cl, P	Gold alloy with silver component (Au 16.42% compared to Ag 3.83% by weight), silver sulfide and chloride degradation products Note: silver is more diffuse than gold, spreading upwards to the surface
2	Fe	Si, Al, Cl, P, S	Iron oxide and ferrous alumino-silicates (bole)
1	Ca	Cl	Chalk ground

Sample details	
Object: Torsken Virgin	**Researcher:** Bettina Ebert
Inv. no./Collection: C2686 MCH	**Lab no.:** L178.1
Sampling date: 2016	**Embedding date:** 2016
Research question: What type of pigments and layer structure were used in the red paint layers?	
Embedding material: EasySection/Technovit ® 2000 LC resin and varnish	
Layer thickness measurements taken in a representative area are marked on images. Layers are numbered consecutively from the ground up. EDS spectra and detailed elemental maps are archived at the MCH and available upon request.	
Sample location: Joseph's red stockings, proper right leg halfway down the shin	

Cross-section

VIS × 10 obj magnification	UV × 10 obj magnification
	

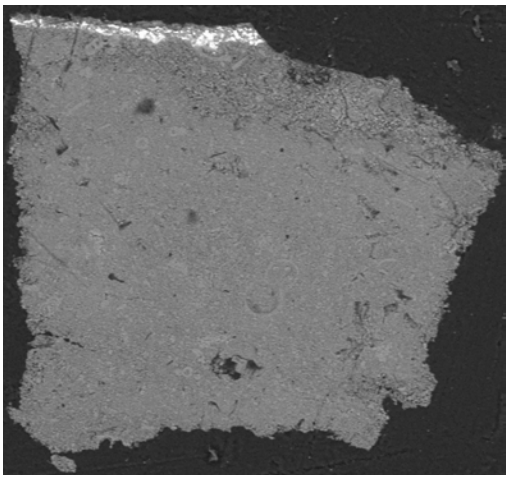
Layer	Thickness (µm)	Description
4	5	Surface dirt
3	11	Thin orange-red paint layer
2	12	Transparent layer
1	417	Thick white ground with some black particles, fluoresces in UV

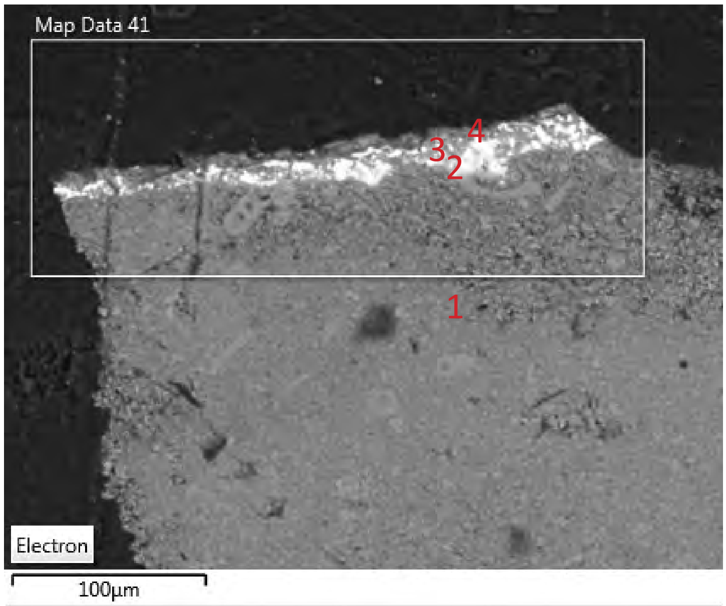
VIS × 20 obj magnification	UV × 20 obj magnification
	

Layer	Thickness (µm)	Description
4	5	Surface dirt
3	11	Orange-red paint layer, large red particles and smaller orange particles
2	12	Transparent unpigmented layer
1		Thick white ground with black particles, possibly from a dirty brush, UV fluorescent, particularly in upper portion, possibly from penetration by unpigmented layer or a later consolidant. Large chalk fossil visible at upper left of ground layer

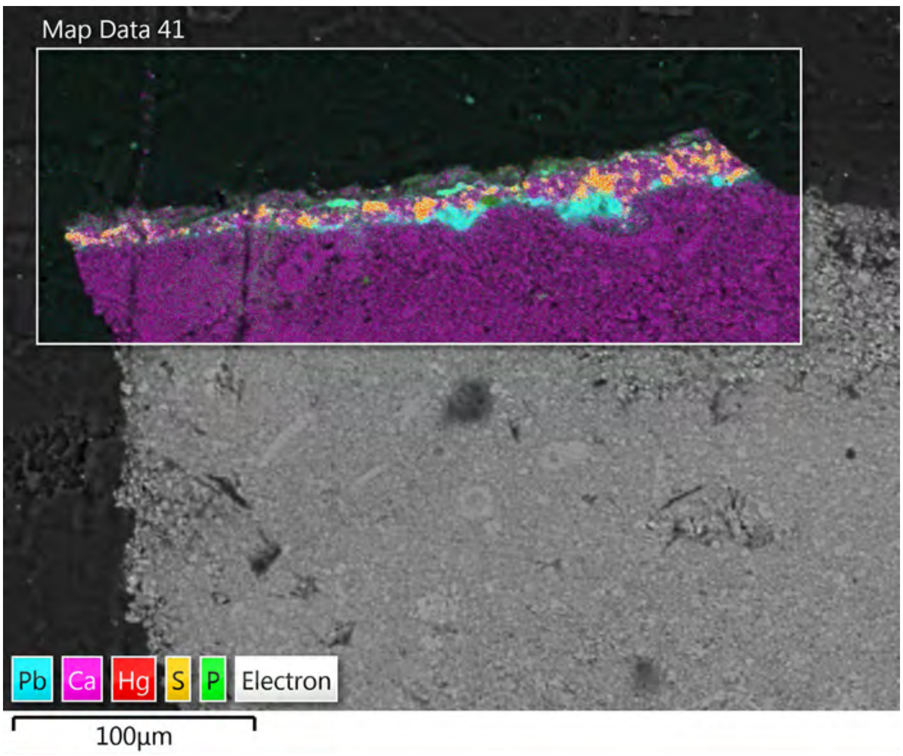
SEM-EDS

Backscatter electron images





False colour layered EDS image



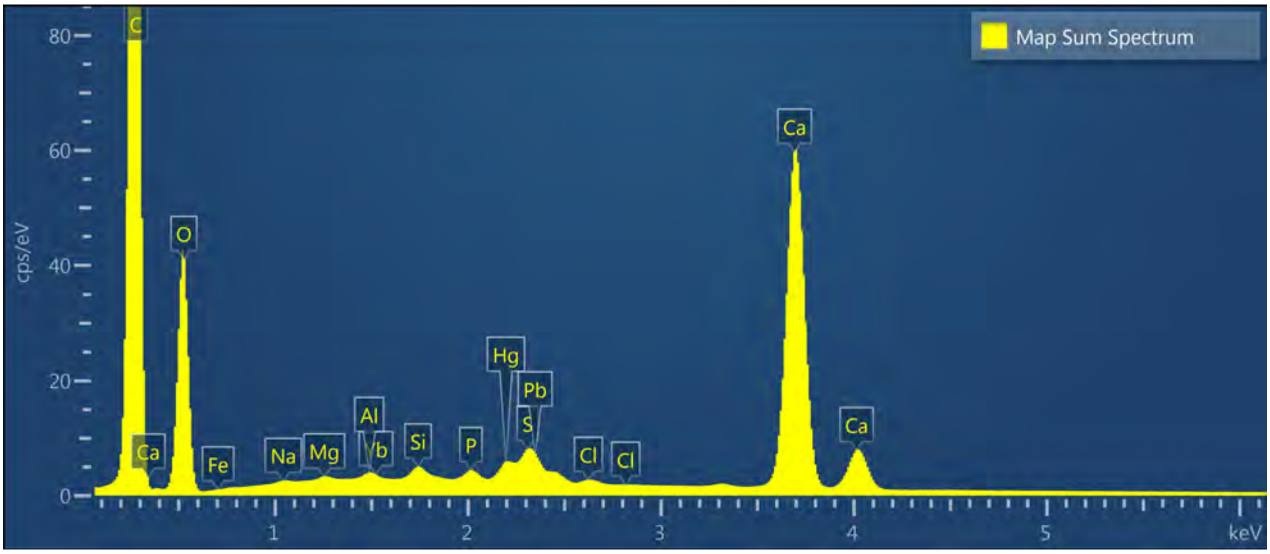


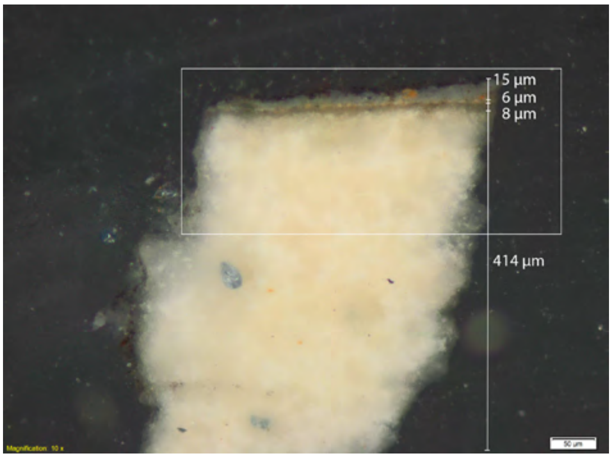
Figure 41: L178.1 EDS spectrum

Layer	Major component	Minor component	Interpretation
4	P, K	Ca, Cl	Surface dirt
3	Hg, S	Ca, Pb, Si, Cl, K, P, Mg	Vermilion with some chalk and red lead, red lead more concentrated towards the bottom of the layer
2	Pb, Cl, S	K, Mg	Saponified lead that has migrated from the paint layer into a transparent unpigmented isolation layer applied onto the ground
1	Ca	Si, Al, Cl, K, Mg	Chalk ground with numerous fossils visible, upper fluorescent portion of ground appears more porous and less dense in SEM image, possibly result of impregnation by isolation layer or consolidant

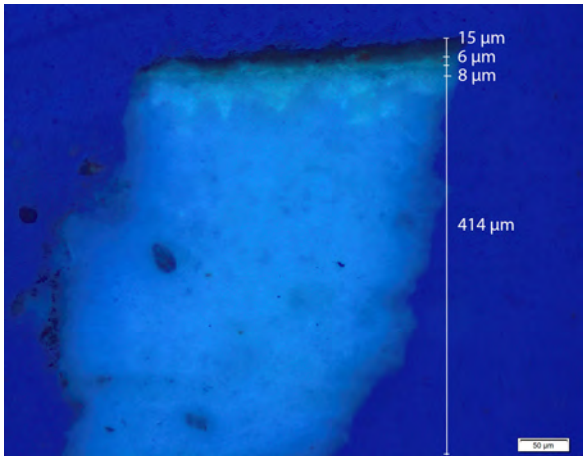
Sample details	
Object: Torsken Virgin	**Researcher:** Bettina Ebert
Inv. no./Collection: C2686 MCH	**Lab no.:** L178.2
Sampling date: 2016	**Embedding date:** 2016
Research question: What type of pigments and layer structure were used in the grey cloak? XRF analysis was inconclusive	
Embedding material: EasySection/Technovit ® 2000 LC resin and varnish	
Layer thickness measurements taken in a representative area are marked on images. Layers are numbered consecutively from the ground up. EDS spectra and detailed elemental maps are archived at the MCH and available upon request.	
Sample location: Joseph's grey cloak, proper right arm	

Cross-section

VIS × 10 obj magnification

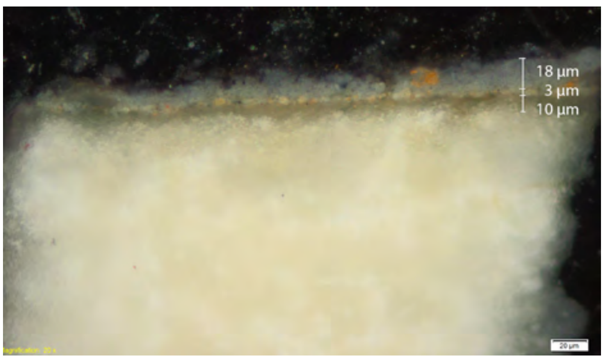


UV × 10 obj magnification

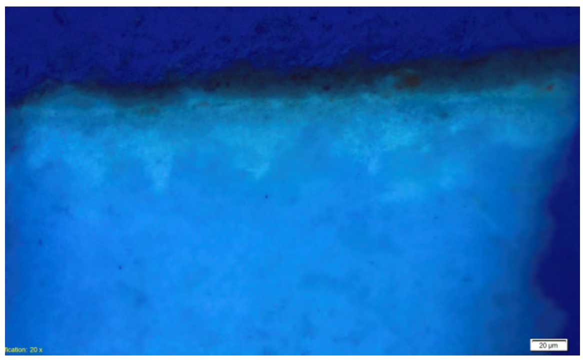


Layer	Thickness (µm)	Description
4	15	Blue-grey paint layer with some orange particles
3	6	Thin pale brown paint layer
2	8	Transparent thin unpigmented layer
1	414	Thick white ground

VIS × 20 obj magnification



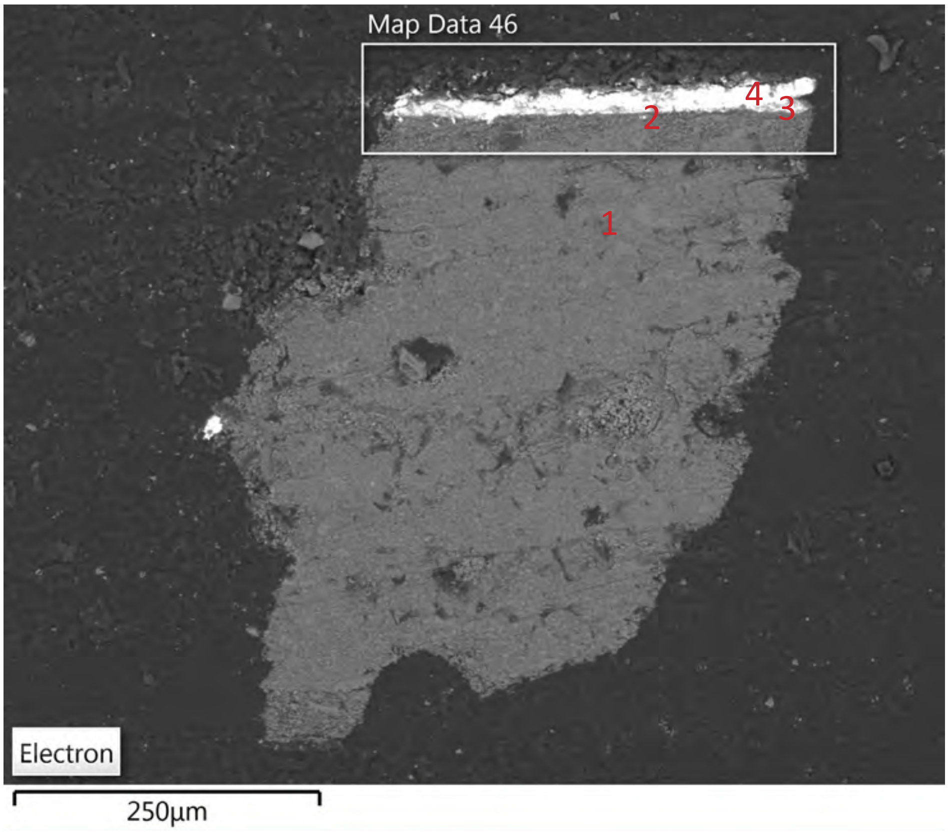
UV × 20 obj magnification



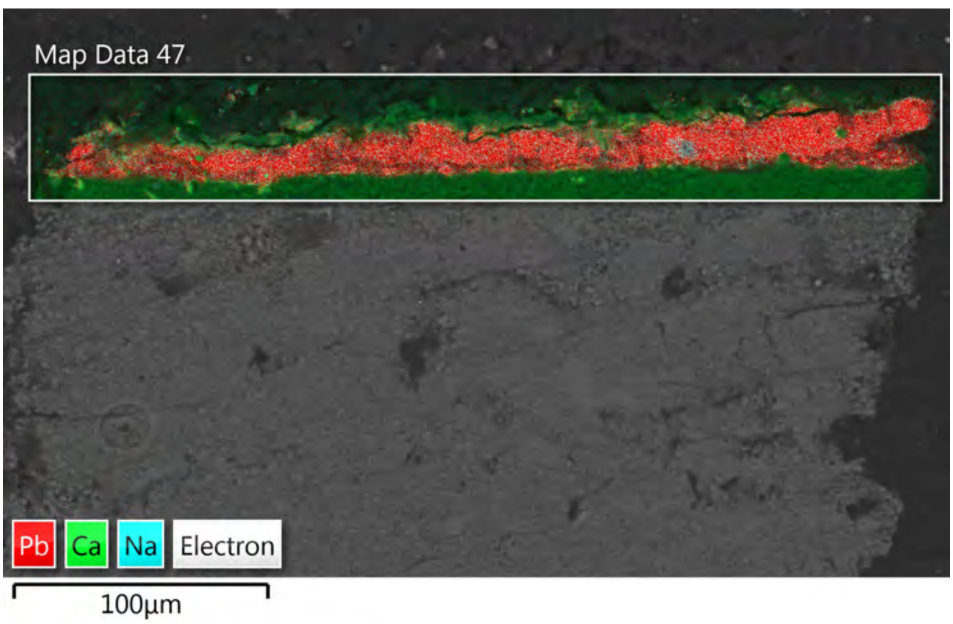
Layer	Thickness (µm)	Description
4	18	Blue-grey paint layer, some large orange pigment particles
3	3	Thin pale brown layer
2	10	Transparent thin unpigmented layer
1		Thick white ground

SEM-EDS

Backscatter electron image



False colour layered EDS image



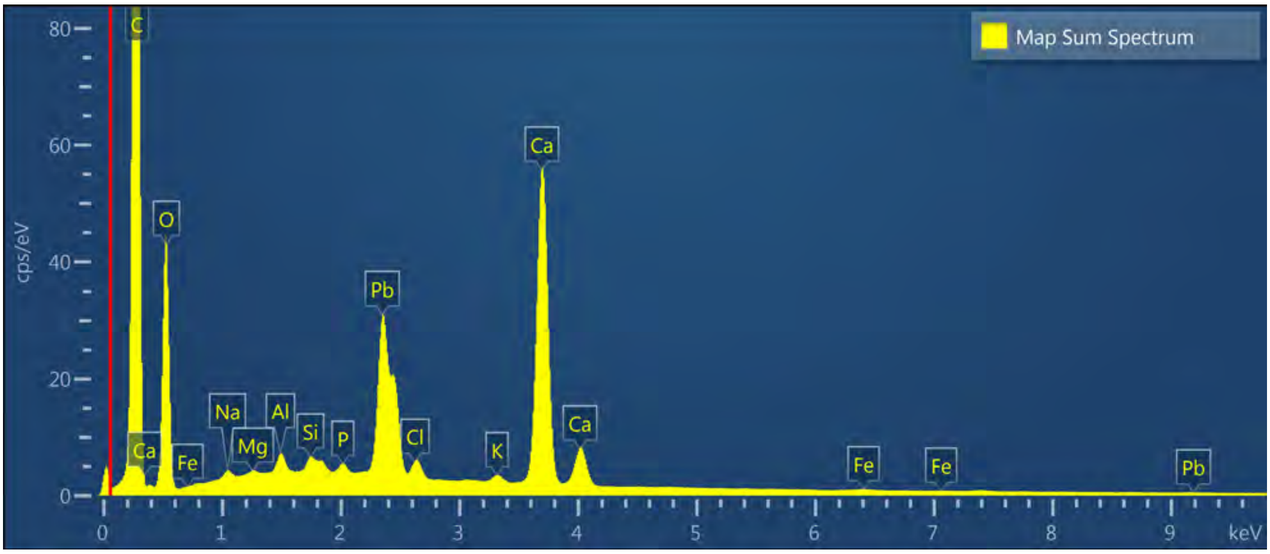


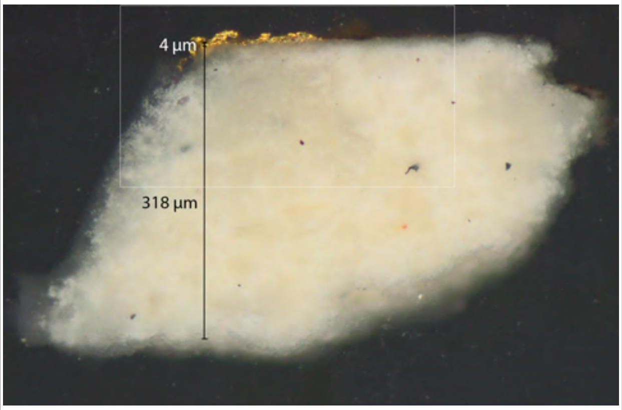
Figure 42: L178.2 EDS spectrum

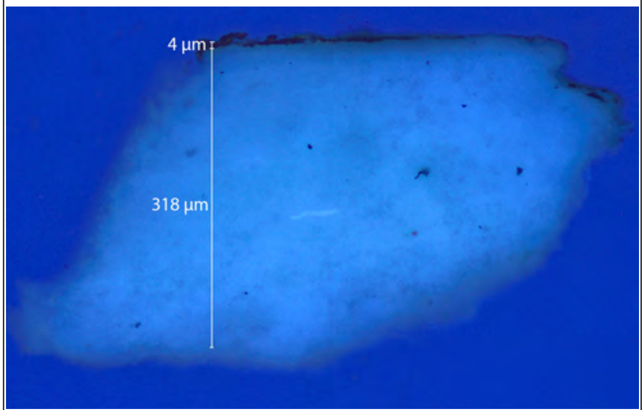
Layer	Major component	Minor component	Interpretation
4	Pb	Fe, P, Mg, Ca, Na, Si, Al, Cl, K	Lead white with a combination of organic pigments (indigo, bone black?), traces of earth pigments
3	Pb	Fe, Mg, Na, Si, Cl, K	Lead white and earth pigments to give pale brown appearance
2	O, C	Mg, K	Unpigmented isolation layer
1	Ca	Mg, Na	Chalk ground

Sample details	
Object: Torsken Virgin	**Researcher:** Bettina Ebert
Inv. no./Collection: C2686 MCH	**Lab no.:** L178.3
Sampling date: 2016	**Embedding date:** 2016
Research question: What is the layer structure and composition of the gilding? Is a bole layer present or is it ground-gilded? How does the gilding differ from the gilding elsewhere on the sculpture?	
Embedding material: EasySection/Technovit ® 2000 LC resin and varnish	
Layer thickness measurements taken in a representative area are marked on images. Layers are numbered consecutively from the ground up. EDS spectra and detailed elemental maps are archived at the MCH and available upon request.	
Sample location: Virgin's gilded robe, proper left side near elbow	

Cross-section

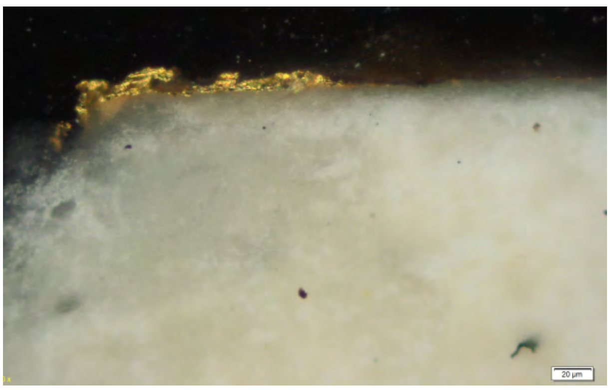
VIS × 10 obj magnification	UV × 10 obj magnification

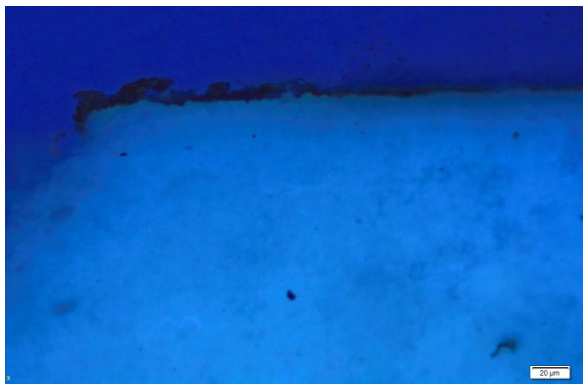




Layer	Thickness (µm)	Description
2	4	Gold leaf
1	318	Thick white ground, some dark pigment particles

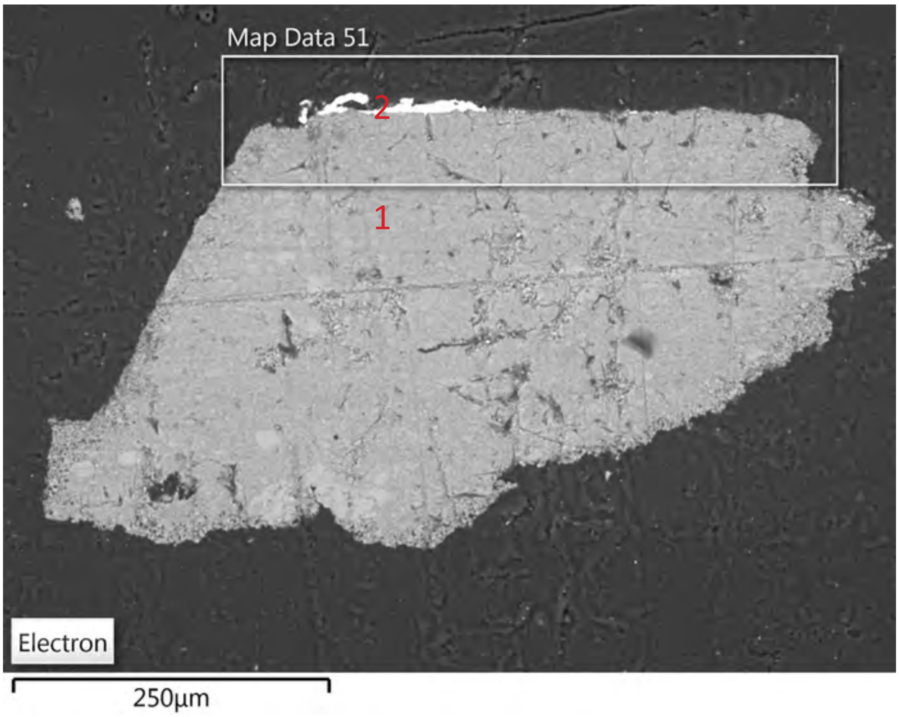
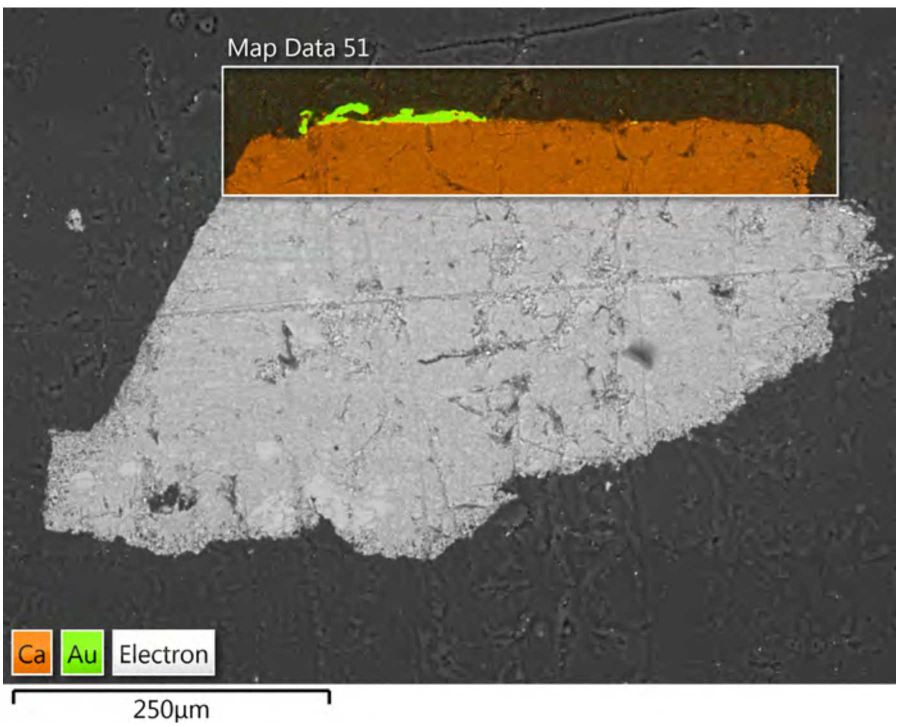
VIS × 20 obj magnification	UV × 20 obj magnification





Layer	Description
2	Gold leaf
1	White ground

SEM-EDS

Backscattered electron image

False colour layered EDS image


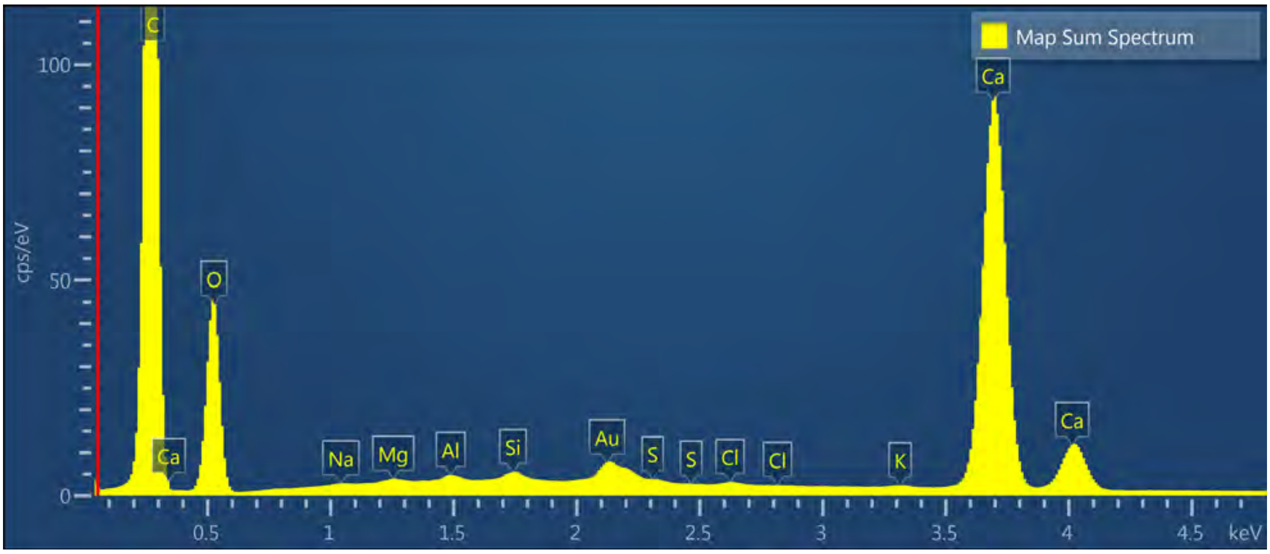
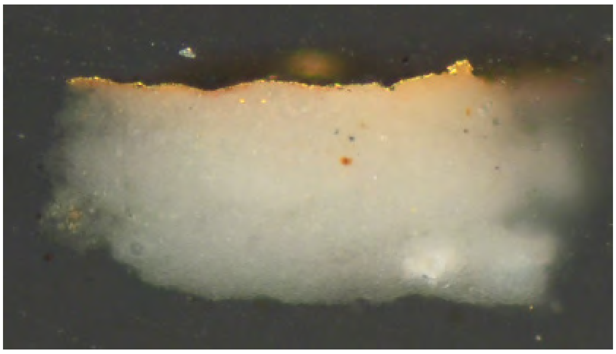
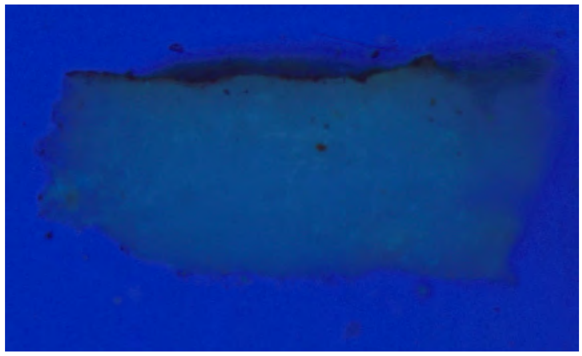


Figure 43: L178.3 EDS spectrum

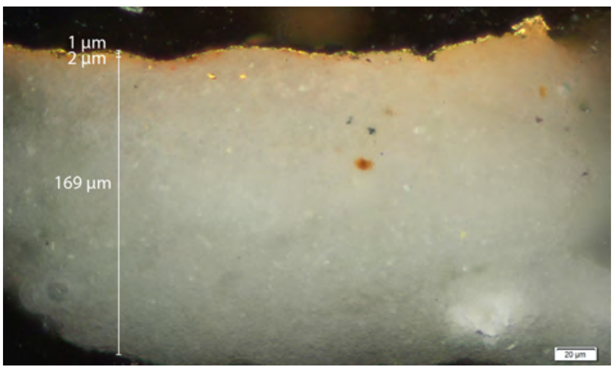
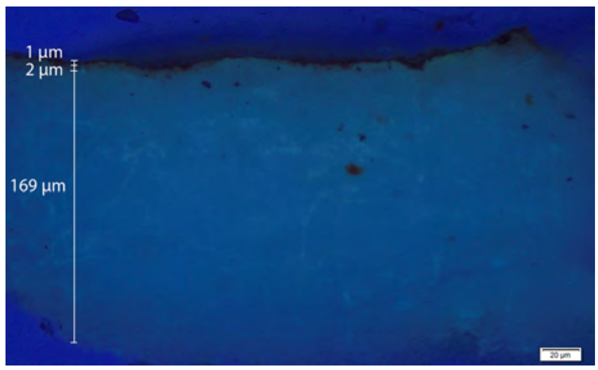
Layer	Major component	Minor component	Interpretation
2	Au	S, Al, Si, Mg, Cl	Gold leaf
1	Ca	Cl, Mg, Si	Chalk ground

Sample details	
Object: Torsken Virgin	**Researcher:** Bettina Ebert
Inv. no./Collection: C2686 MCH	**Lab no.:** L178.4
Sampling date: 2016	**Embedding date:** 2016
Research question: What is the layer structure and composition of the gilding? Is a bole layer present or is it ground-gilded? How does the gilding differ from gilding elsewhere on the sculpture?	
Embedding material: EasySection/Technovit ® 2000 LC resin and varnish	
Layer thickness measurements taken in a representative area are marked on images. Layers are numbered consecutively from the ground up. EDS spectra and detailed elemental maps are archived at the MCH and available upon request.	
Sample location: Jesus' gilded robe, proper right side	

Cross-section

VIS × 10 obj magnification	UV × 10 obj magnification
	

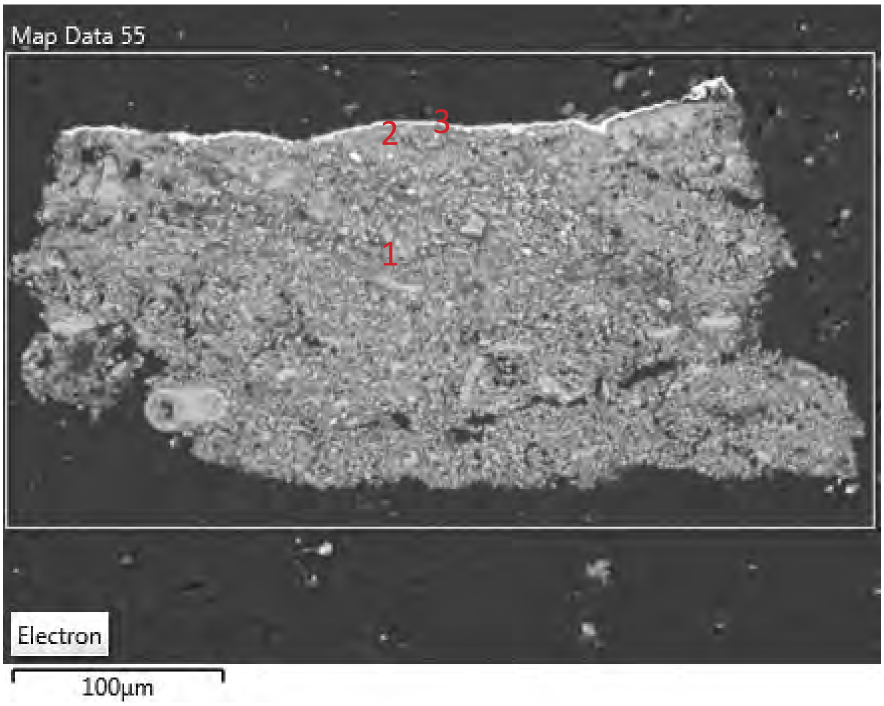
Layer	Description
2	Gold leaf
1	White ground with some dark pigment particles

VIS × 20 obj magnification	UV × 20 obj magnification
	

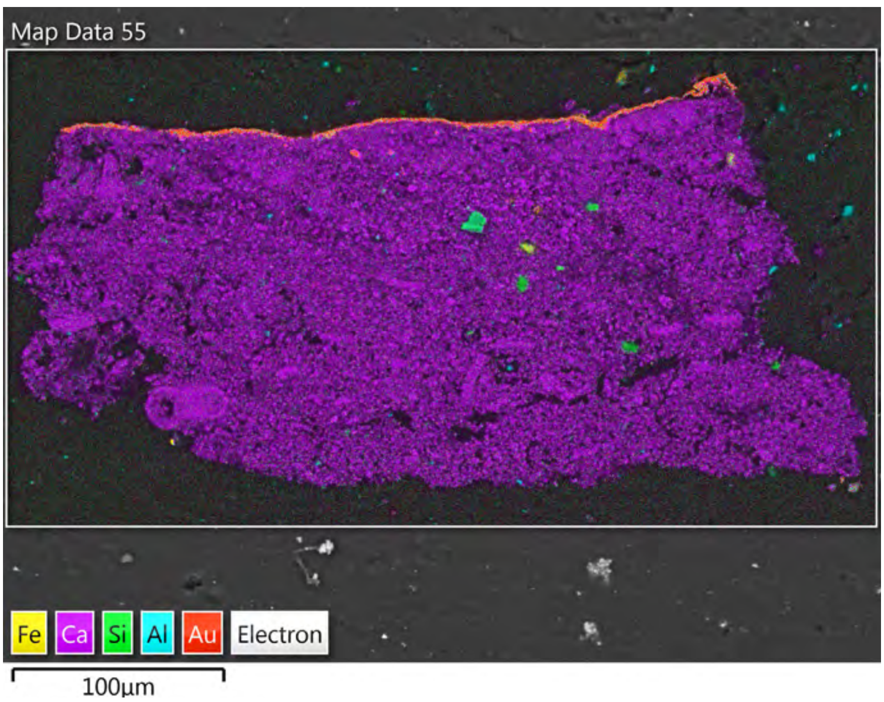
Layer	Thickness (µm)	Description
3	1	Gold leaf
2	2	Partial presence of very faint bole layer
1	169	White ground

SEM-EDS

Backscattered electron image



False colour layered EDS image



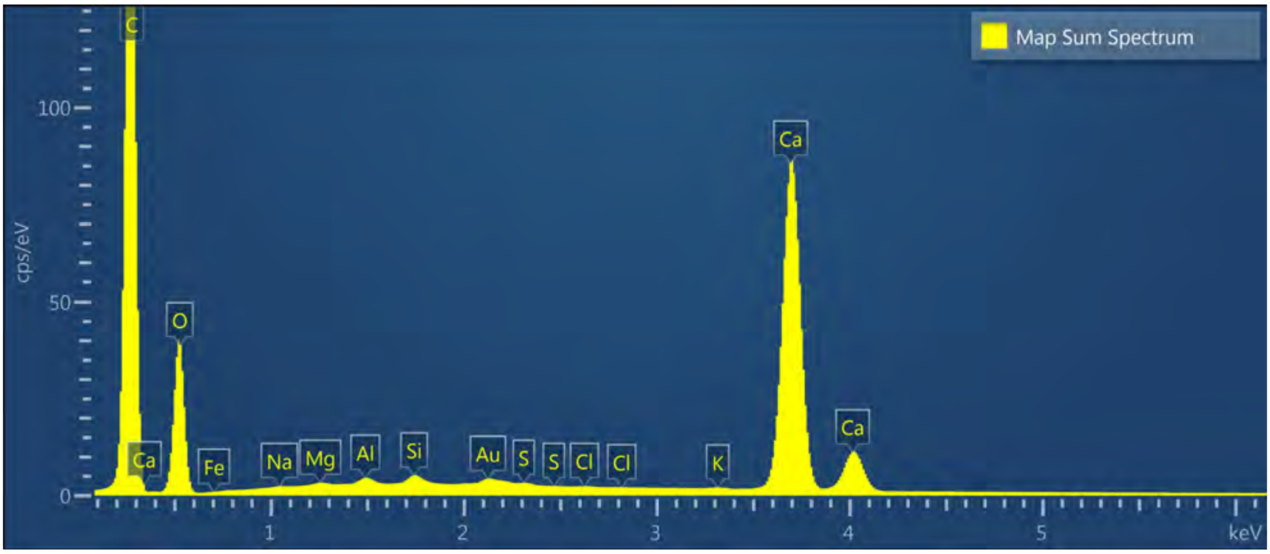
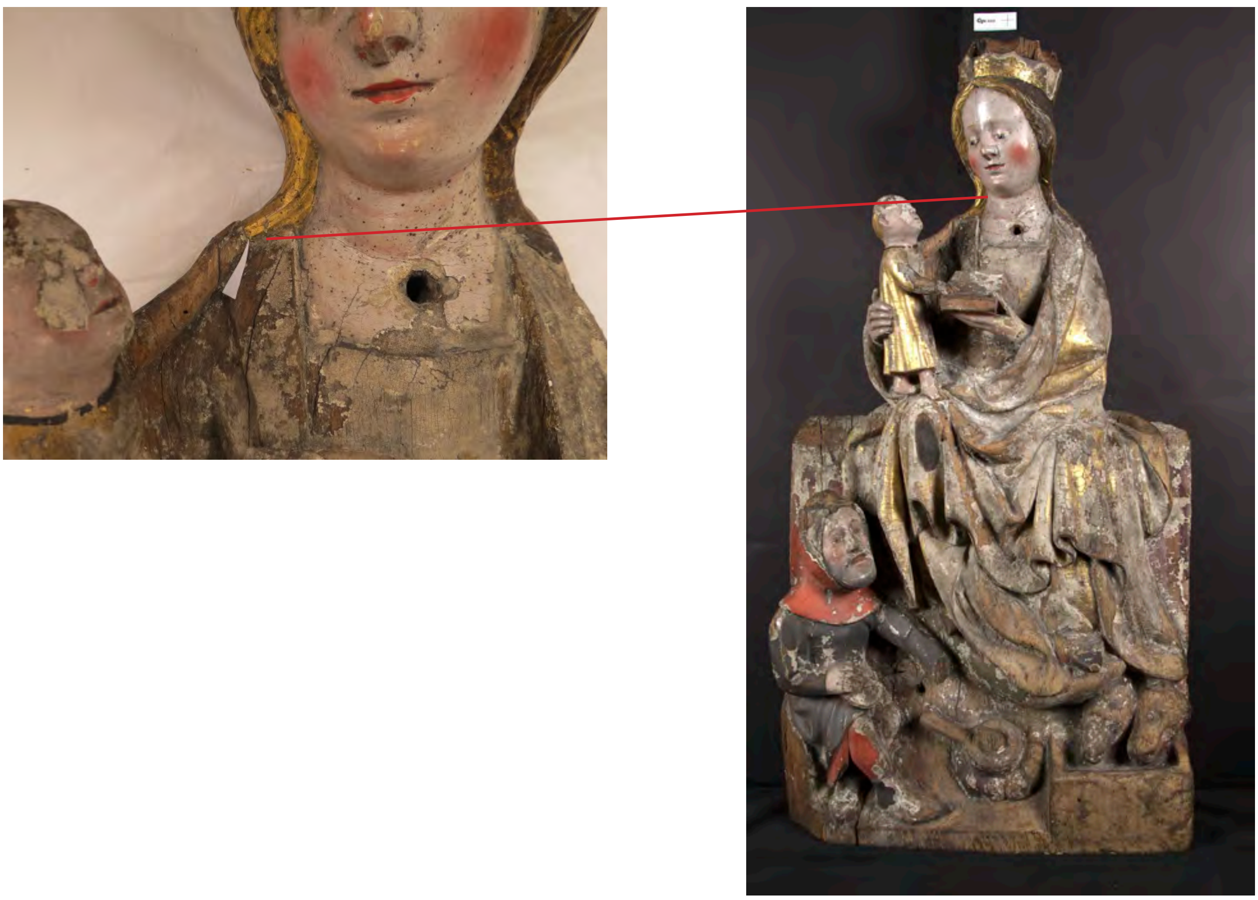


Figure 44: L178.4 EDS spectrum

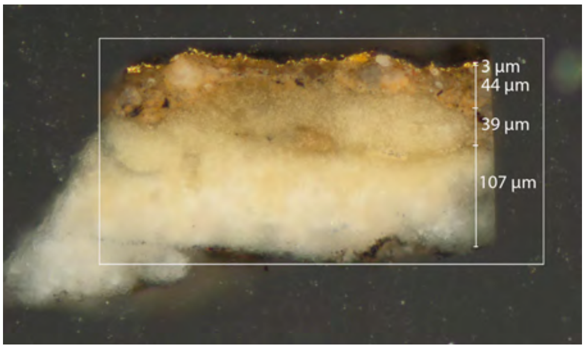
Layer	Major component	Minor component	Interpretation
3	Au	S, P	Gold leaf
2	P, Mg, Si, Fe	Al	Possibly ochre? Inconclusive regarding presence of bole, since all respective elements are only present in trace amounts and not as a continuous layer
1	Ca	Al, Si, Fe, Mg	Chalk ground with traces of some pigments present

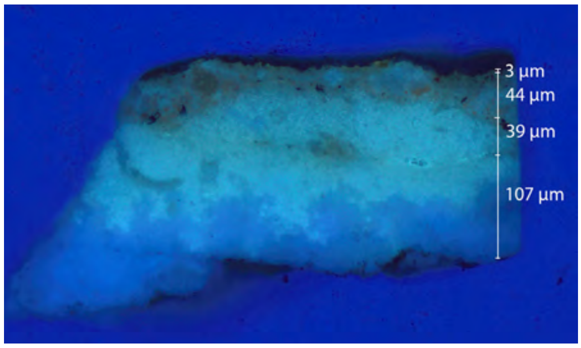
Sample details	
Object: Torsken Virgin	**Researcher:** Bettina Ebert
Inv. no./Collection: C2686 MCH	**Lab no.:** L178.5
Sampling date: 2016	**Embedding date:** 2016
Research question: What is the layer structure and composition of the gilding? How does the gilding differ from gilding elsewhere on the sculpture?	
Embedding material: EasySection/Technovit ® 2000 LC resin and varnish	
Layer thickness measurements taken in a representative area are marked on images. Layers are numbered consecutively from the ground up. EDS spectra and detailed elemental maps are archived at the MCH and available upon request.	
Sample location: Virgin's gilded hair, proper right side near Jesus' hand	



Cross-section

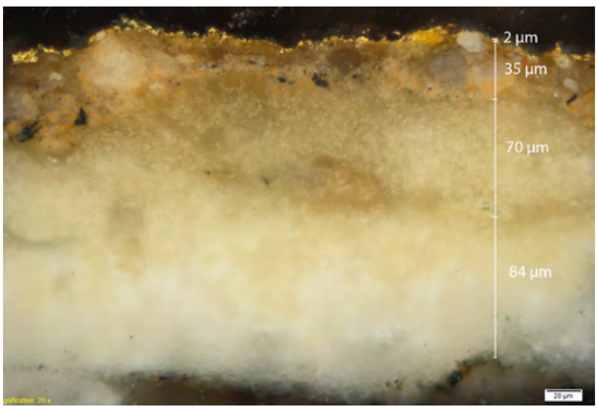
VIS × 10 obj magnification	UV × 10 obj magnification

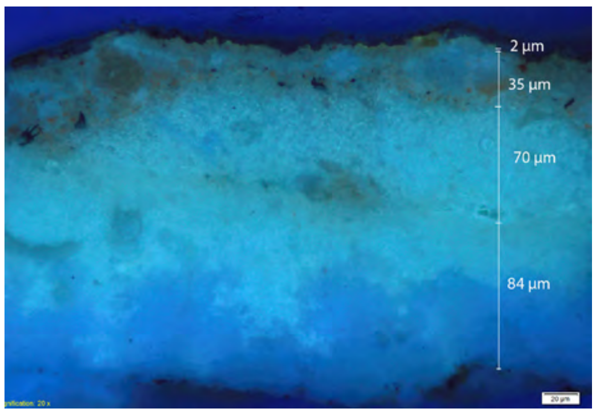




Layer	Thickness (µm)	Description
4	3	Gold leaf
3	44	Pale yellow-brown layer, fluorescent in UV
2	39	Upper ground layer, saturated with UV-fluorescent material
1	107	Lower white ground layer, upper section saturated with UV-fluorescent material

VIS × 20 obj magnification	UV × 20 obj magnification

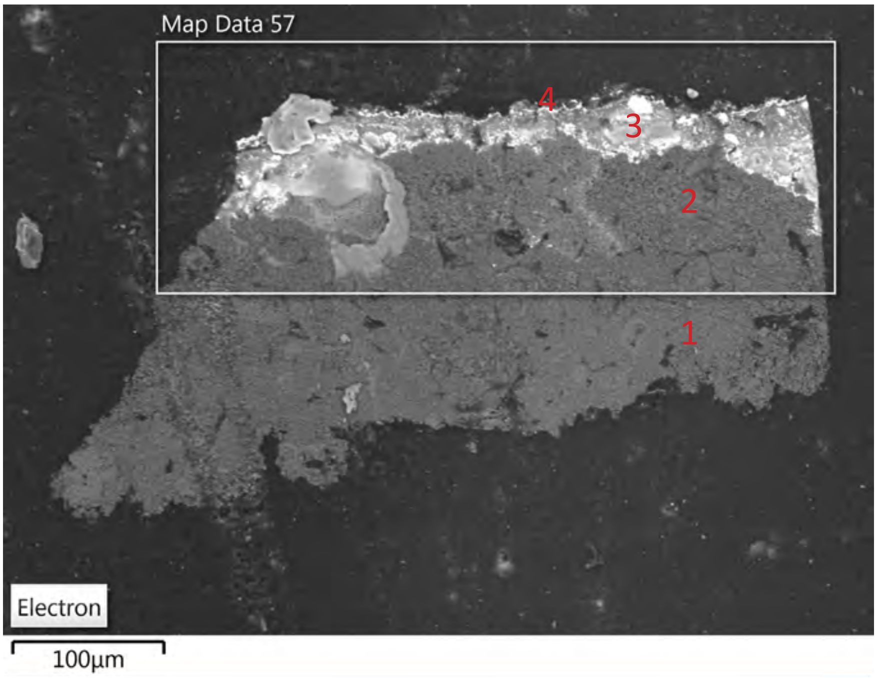




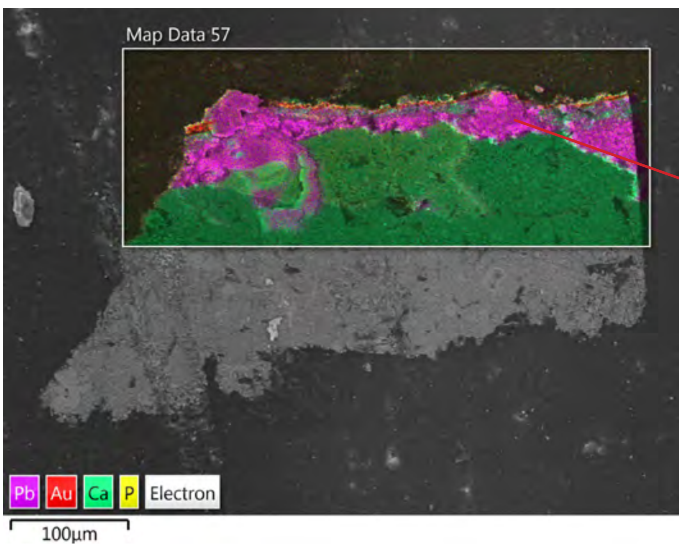
Layer	Thickness (µm)	Description
4	2	Gold leaf
3	35	Pale yellow-brown layer with variety of pigment particles and sizes, layer of variable thickness
2	70	Upper ground layer, stained yellow and fluorescent in UV
1	84	Lower white ground layer, upper section stained and saturated with UV-fluorescent material

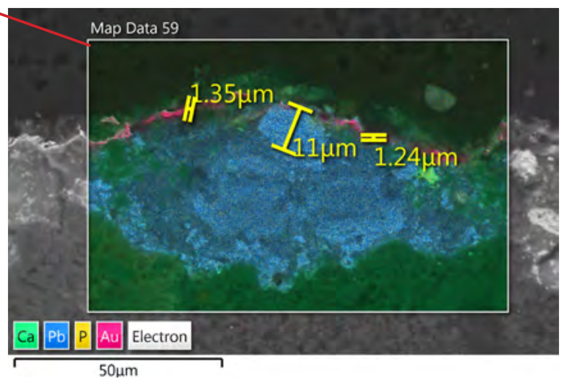
SEM-EDS

Backscattered electron image



False colour layered EDS images





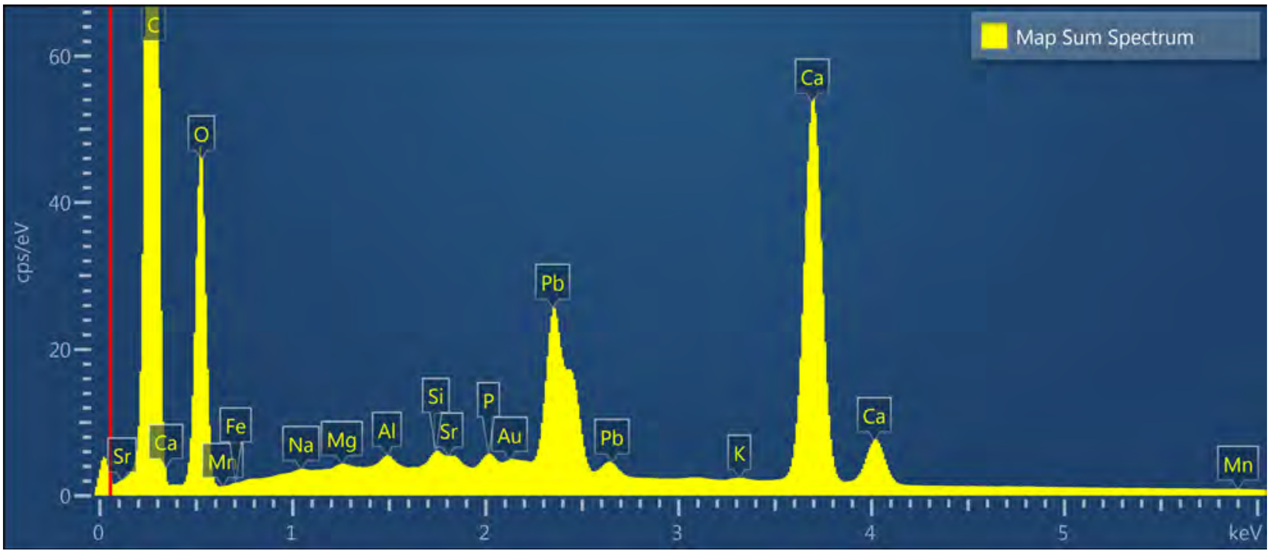
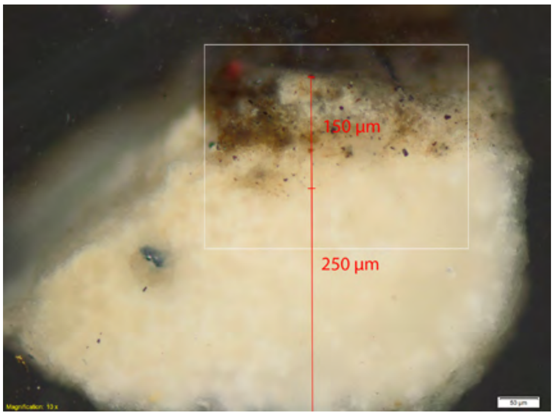
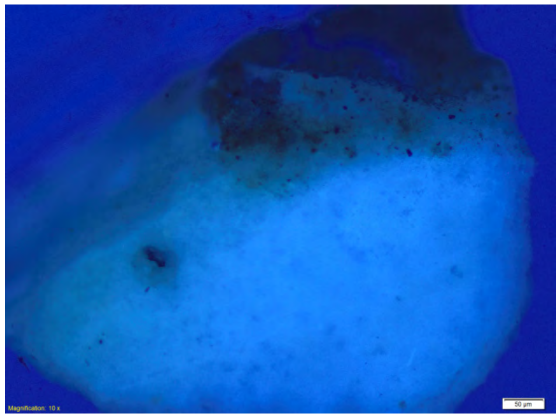


Figure 45: L178.5 EDS spectrum

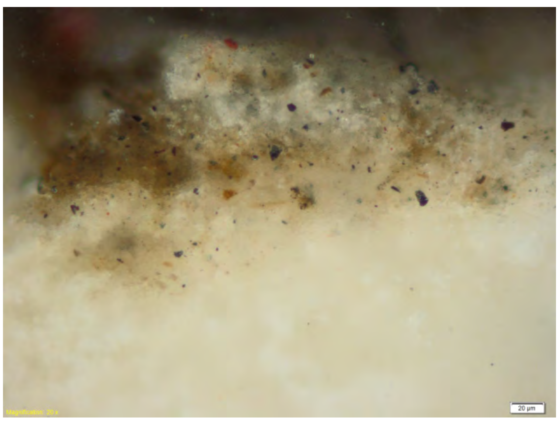
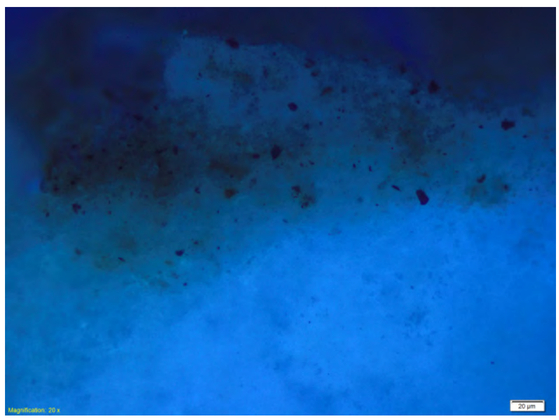
Layer	Major component	Minor component	Interpretation
4	Au	P, Si, Fe, Al	Gold leaf with some surface dirt
3	Pb, P	Fe, Ca, Si, Al	Mixture of lead white, bone black, earth pigments
2	Ca	Si, Al	Chalk ground
1	Ca	Si, Al	Chalk ground

Sample details	
Object: Torsken Virgin	**Researcher:** Bettina Ebert
Inv. no./Collection: C2686 MCH	**Lab no.:** L178.6
Sampling date: 2016	**Embedding date:** 2016
Research question: What is the layer structure and composition of the gilding? Is a bole layer present or is it ground-gilded? How does the gilding differ from gilding elsewhere on the sculpture?	
Embedding material: EasySection/Technovit ® 2000 LC resin and varnish	
Layer thickness measurements taken in a representative area are marked on images. Layers are numbered consecutively from the ground up. EDS spectra and detailed elemental maps are archived at the MCH and available upon request.	
Sample location: Virgin's gilded crown	

CROSS-SECTION

VIS × 10 obj magnification	UV × 10 obj magnification
	

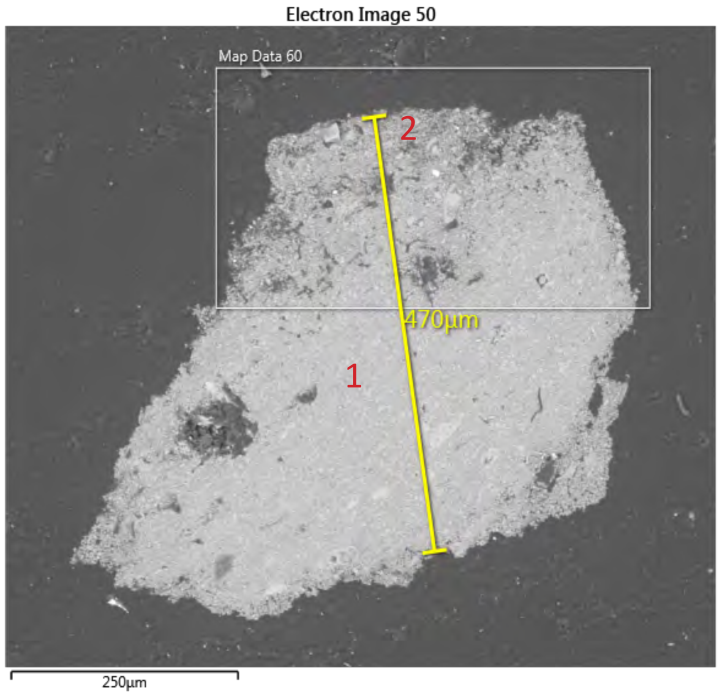
Layer	Thickness (µm)	Description
2	150	Brown layer
1	>250	White ground

VIS × 20 obj magnification	UV × 20 obj magnification
	

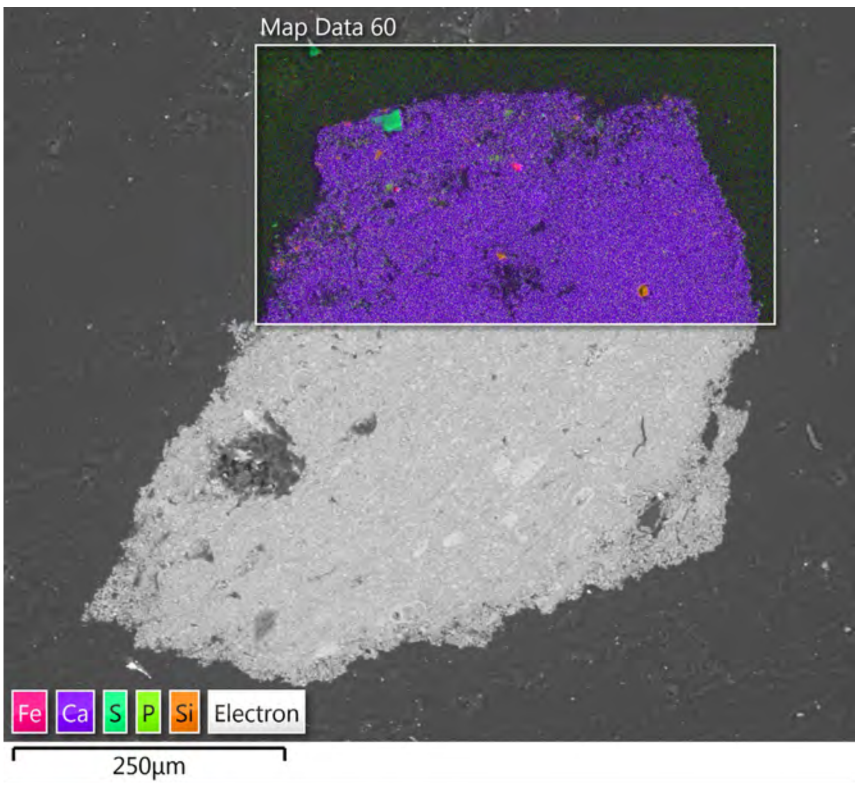
Layer	Description
2	Brown layer, possibly mixture of pigments and surface dirt
1	White ground

SEM-EDS

Backscattered electron image



False colour layered EDS image



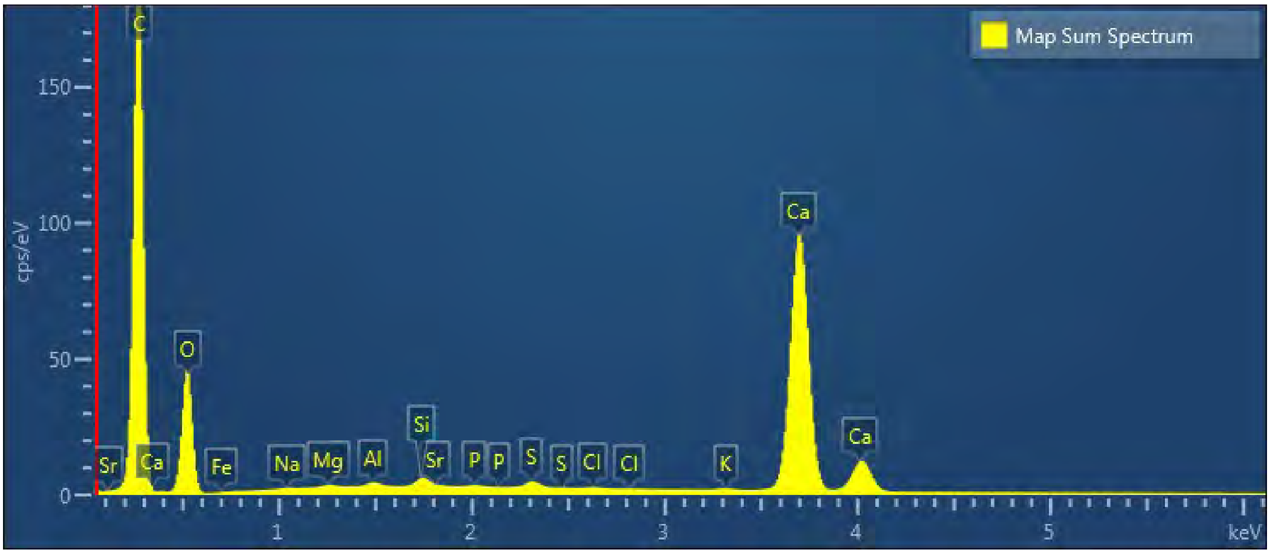


Figure 46: L178.6 EDS spectrum

Layer	Major component	Minor component	Interpretation
2	Ca	Si, Al, S, P, Mg, K, Fe	Chalk ground, traces of organic pigments and earth pigments, surface dirt, no gilding present in sample
1	Ca	Mg, Si, P, Al, S	Chalk ground with some other pigment particles

Appendix 9: Gas chromatography-mass spectrometry

Sample details	
Object: Berg St Anne C2912	**Analysis date:** April 2017
Sample: L59.1	**Weight:** 64µg
Initial volume: 20µl	**Injected volume:** 1µl
Research question: What binding media (proteinaceous / oil-based) were used in paint and ground?	
Sample location: Blue dress of the Virgin, as marked on archival photograph	

% fatty acids: 0	**% protein:** 2
P/S ratio: -	**A/P ratio:** -

Free Fatty Acid	Concentration, ppm	Amino Acid	Concentration, ppm
Pimelic	0	Alanine	11.53
Suberic	0	Glycine	16.64
Lauric	0	Valine	3.19
Azelaic	0	Leucine	5.05
Sebacic	0	Isoleucine	1.81
Myristic	0	Proline	13.29
Palmitic	0	Serine	1.10
Stearic	0	Threonine	1.35
Oleic	0	Phenylalanine	1.69
		Hydroxyproline	9.91

Analysis	Results	Interpretation
Fatty acids	Not detected	Pattern of peaks on chromatogram indicative of high molecular weight wax from conservation treatment
Proteins	0.97 correlation coefficient to collagen and gelatine	Indicative of animal glue

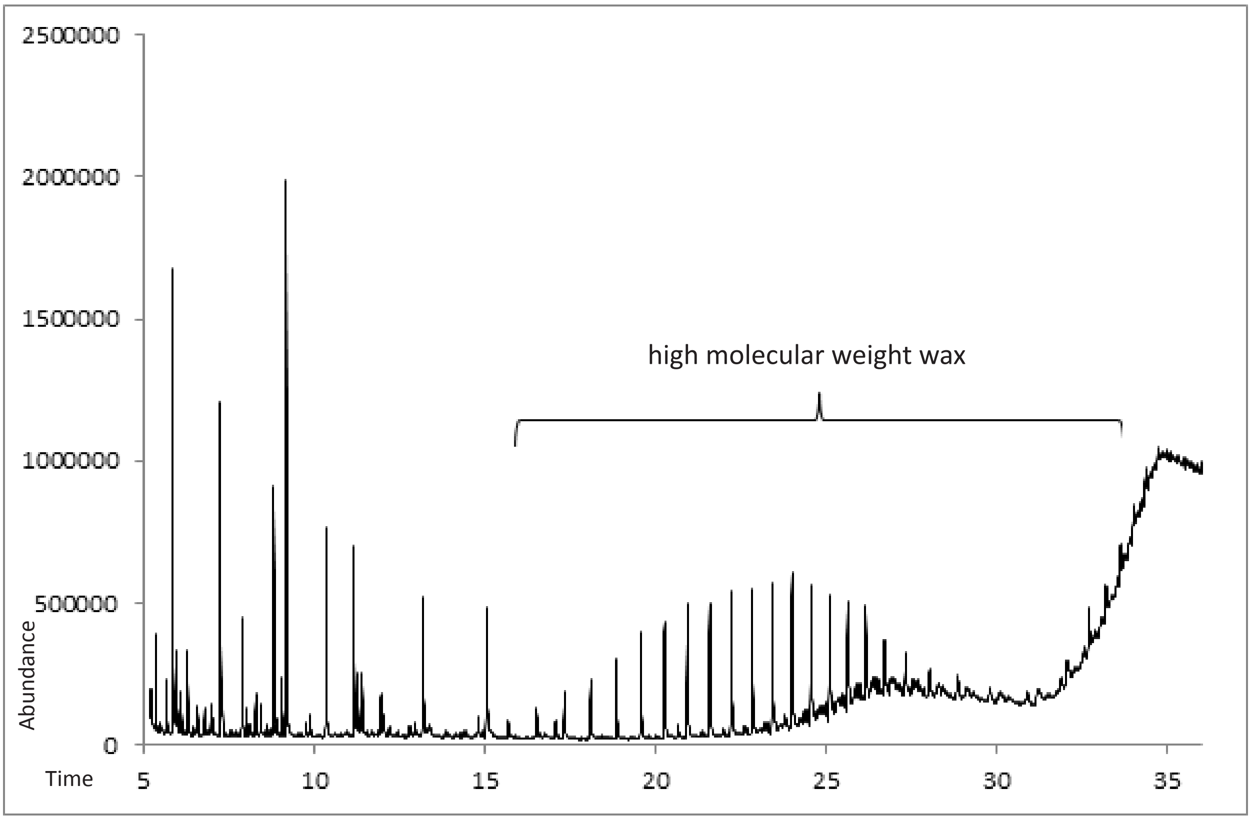


Figure 47: L59.1 Fatty acid total ion chromatogram (TIC)

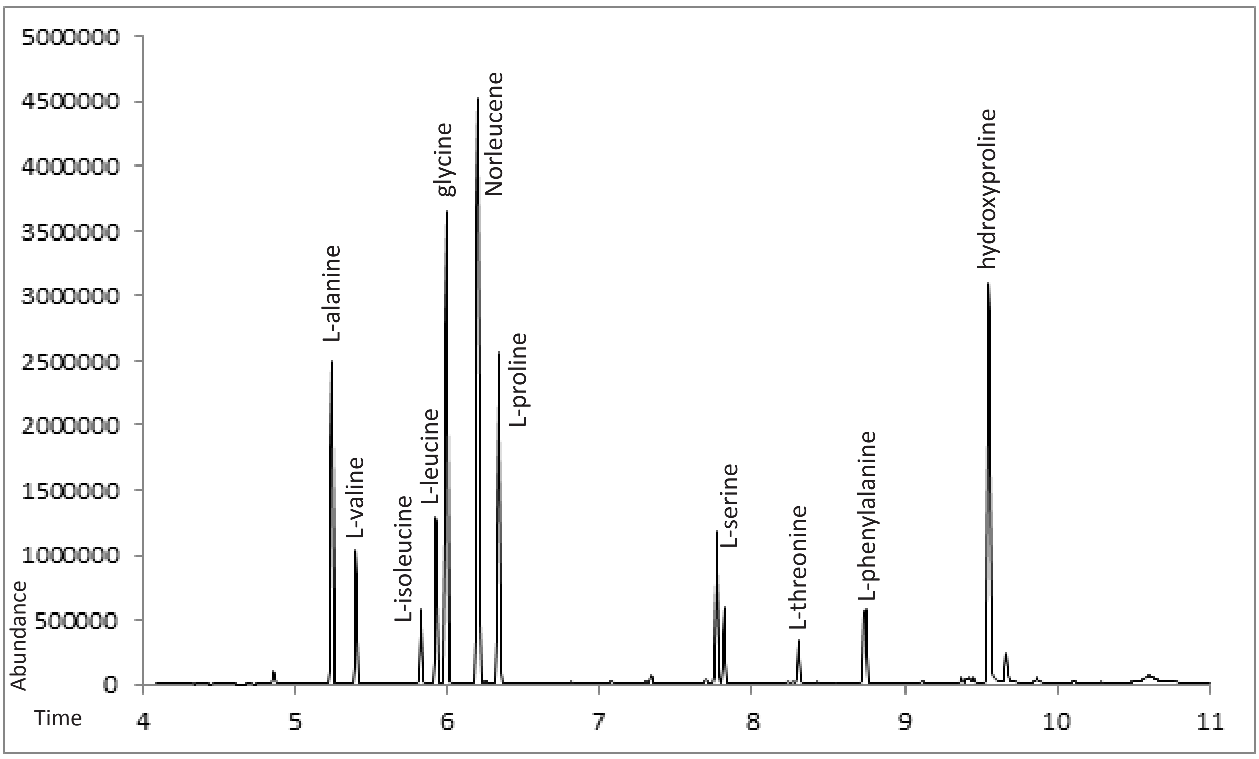
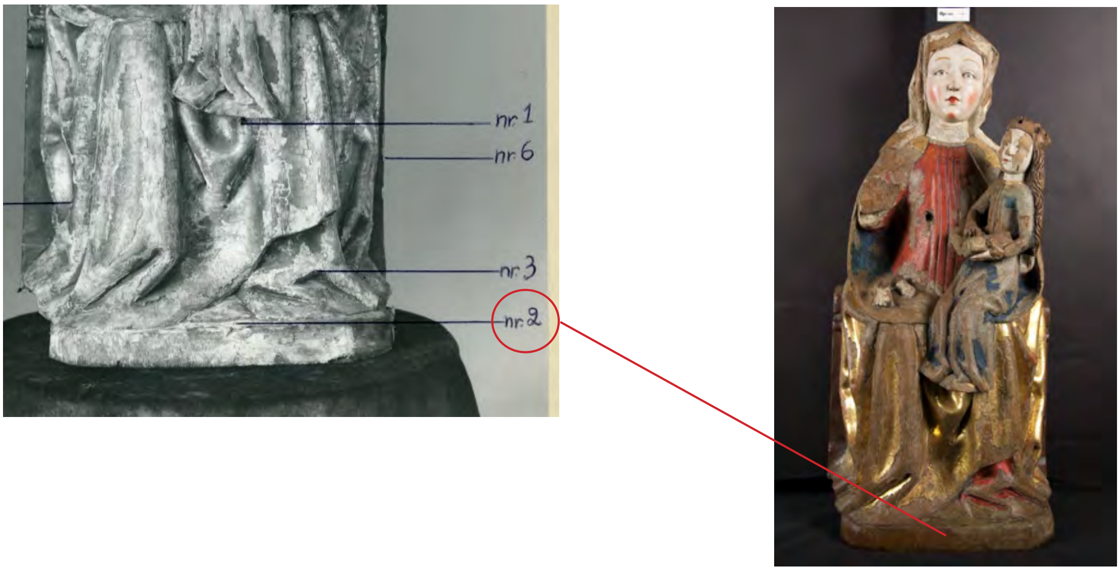


Figure 48: L59.1 Amino acid selected ion chromatogram (SIM)

Sample details	
Object: Berg St Anne C2912	**Analysis date:** April 2017
Sample: L59.2	**Weight:** 59µg
Initial volume: 20µl	**Injected volume:** 1µl
Research question: What binding media (proteinaceous / oil-based) were used in paint and ground?	
Sample location: Green base of sculpture, as marked on archival photograph	



% fatty acids: 0.35	**% protein:** 0
P/S ratio: 1.33	**A/P ratio:** 1.66

Free Fatty Acid	Concentration, ppm	Amino Acid	Concentration, ppm
Pimelic	0	Alanine	0.82
Suberic	3.62	Glycine	1.93
Lauric	0	Valine	0.38
Azelaic	17.3	Leucine	0.70
Sebacic	0	Isoleucine	0.29
Myristic	0	Proline	1.27
Palmitic	10.4	Serine	0.58
Stearic	7.84	Threonine	0.23
Oleic	3.57	Phenylalanine	0.32
		Hydroxyproline	1.63

Analysis	Results	Interpretation
Fatty acids	Present	Indicative of oil-based medium, P/S ratio suggestive of linseed oil. Presence of oleic acid likely deriving from formation of soaps, which have kept the oleic acid bound within the paint. Otherwise, oleic acid would no longer be present in such old paint samples.
Proteins	Trace amounts only, 0.98 correlation coefficient to collagen & gelatine	Likely deriving from ground remnants on sample or consolidation treatment, indicative of animal glue

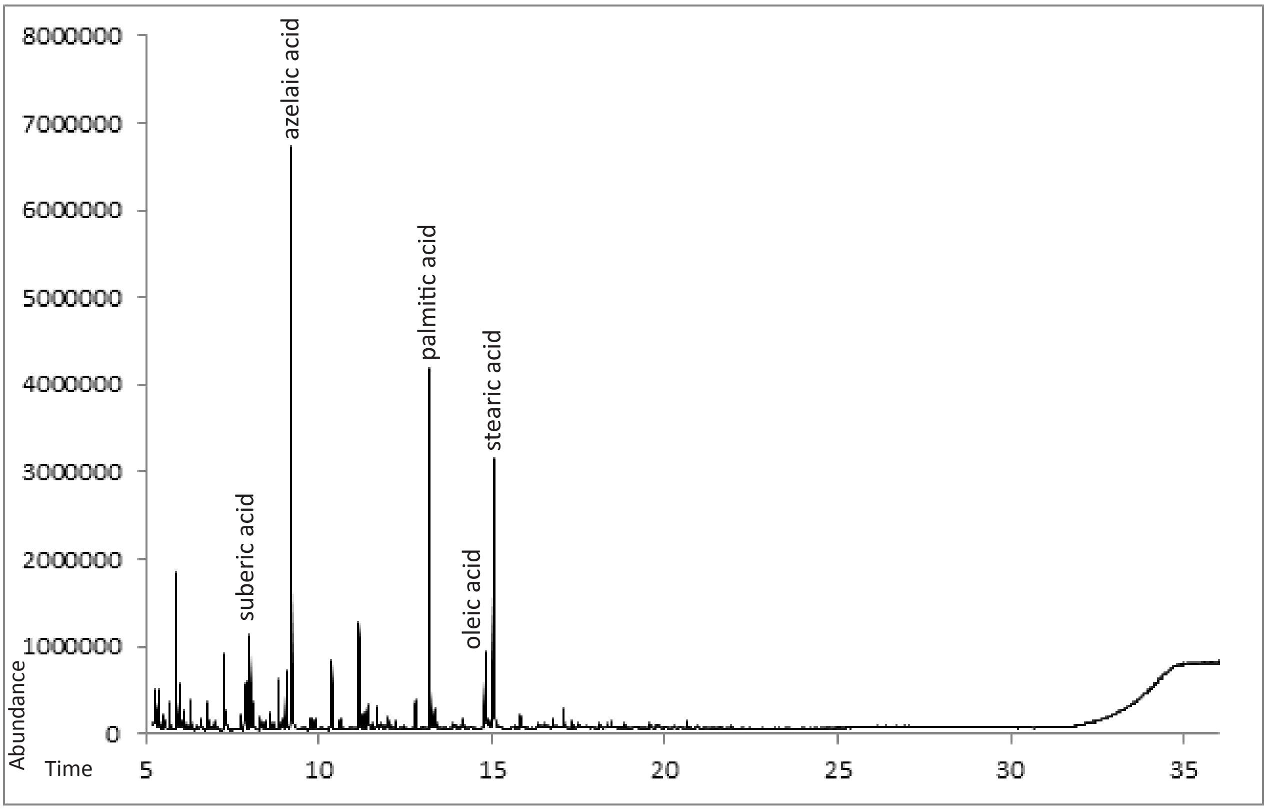


Figure 49: L59.2 Fatty acid total ion chromatogram (TIC)

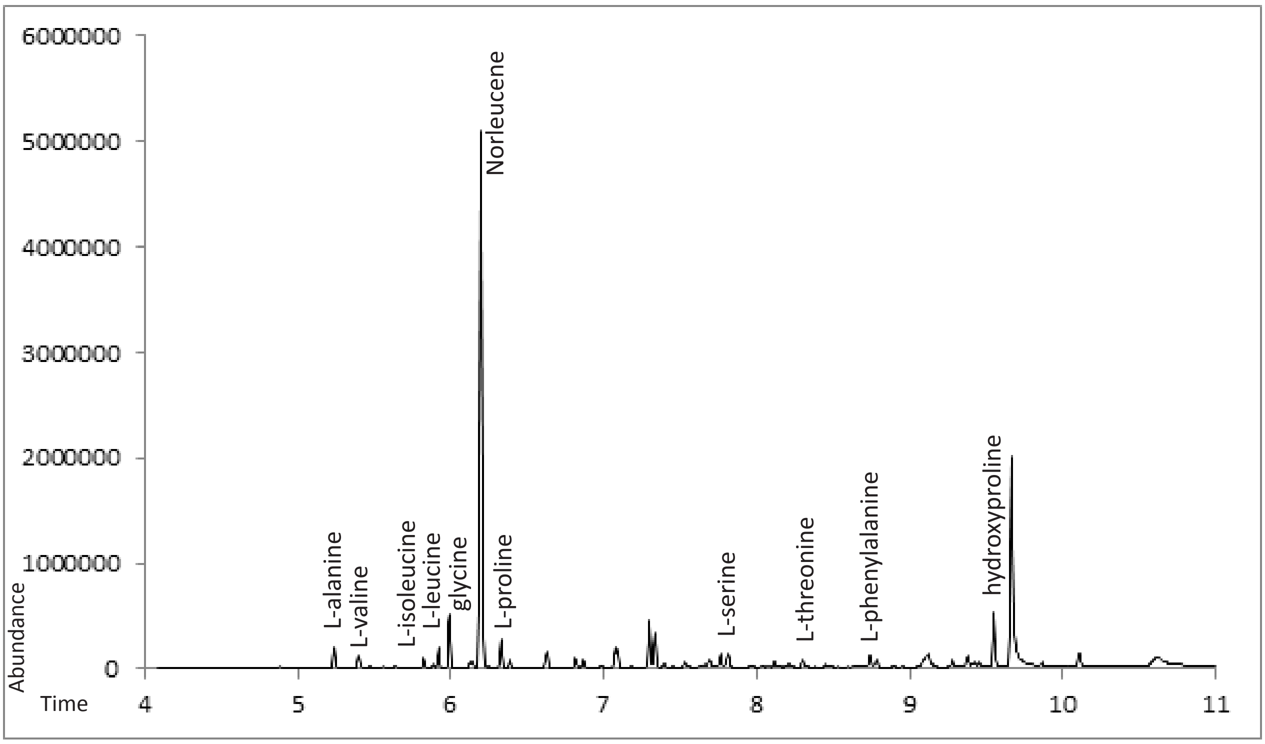
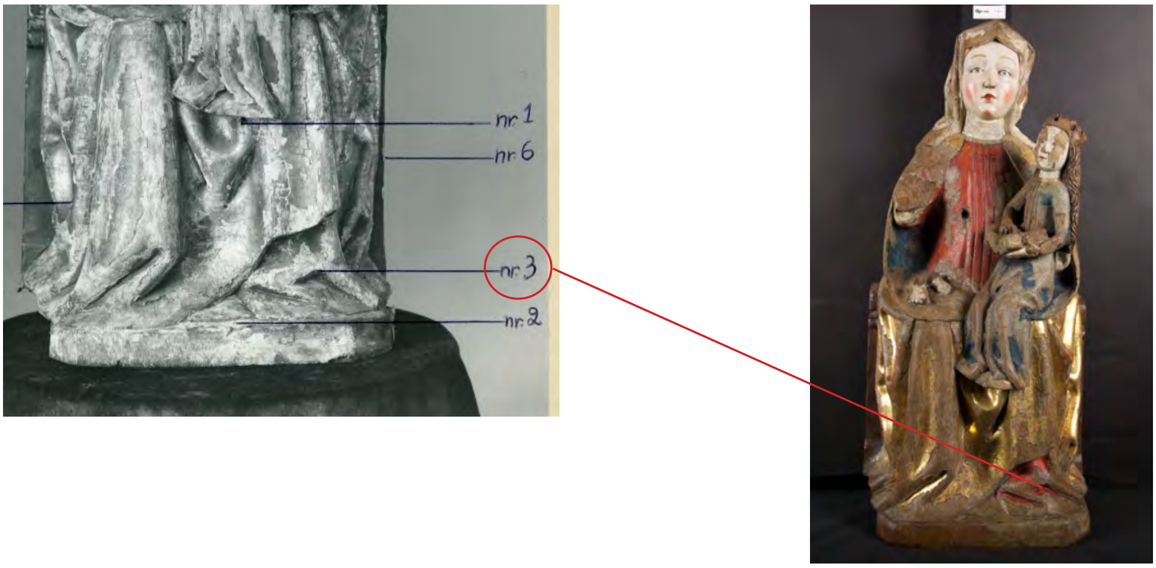


Figure 50: L59.2 Amino acid selected ion chromatogram (SIM)

Sample details	
Object: Berg St Anne C2912	**Analysis date:** April 2017
Sample: L59.3	**Weight:** 318µg
Initial volume: 50µl	**Injected volume:** 1µl
Research question: What binding media (proteinaceous / oil-based) were used in paint and ground?	
Sample location: St Anne's red dress, as marked on archival photograph	
% fatty acids: 0.05	**% protein:** 5
P/S ratio: 1.28	**A/P ratio:** 0.00



Free Fatty Acid	Concentration, ppm	Amino Acid	Concentration, ppm
Pimelic	0	Alanine	40.34
Suberic	0	Glycine	53.67
Lauric	0	Valine	23.70
Azelaic	0	Leucine	39.83
Sebacic	0	Isoleucine	19.00
Myristic	0	Proline	40.60
Palmitic	3.11	Serine	22.37
Stearic	2.44	Threonine	25.07
Oleic	0	Phenylalanine	19.74
		Hydroxyproline	43.30

Analysis	Results	Interpretation
Fatty acids	Not detected (trace amounts only)	Pattern of peaks on chromatogram indicative of high molecular weight wax from conservation treatment
Proteins	0.96 correlation coefficient with collagen and gelatine	Indicative of animal glue (likely within ground layer)

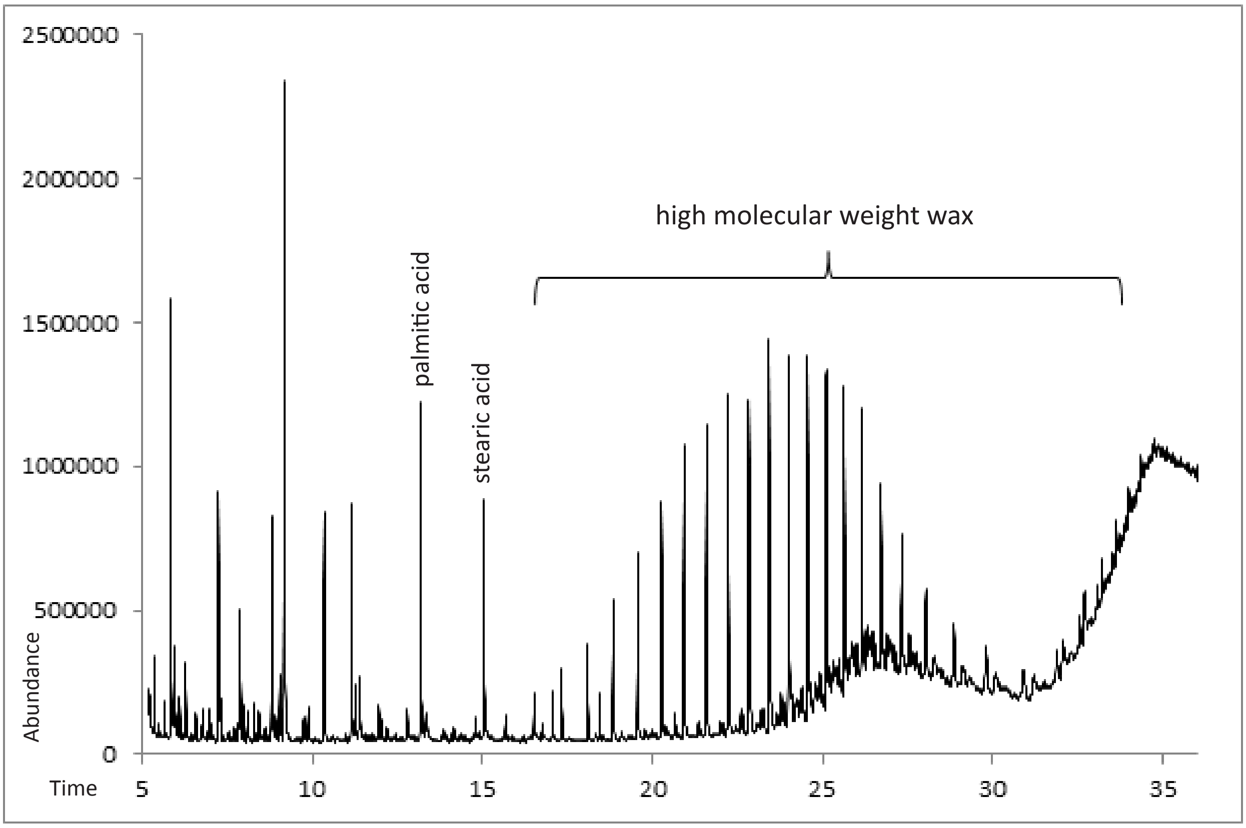


Figure 51: L59.3 Fatty acid total ion chromatogram (TIC)

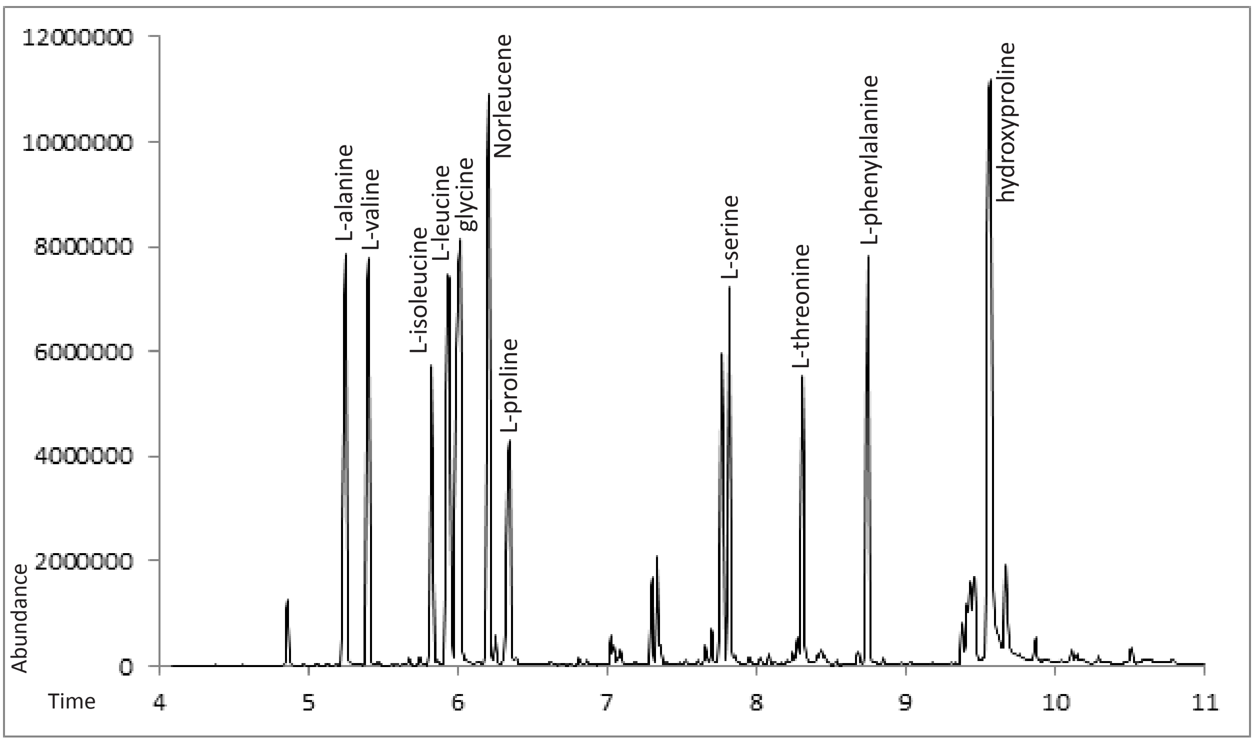
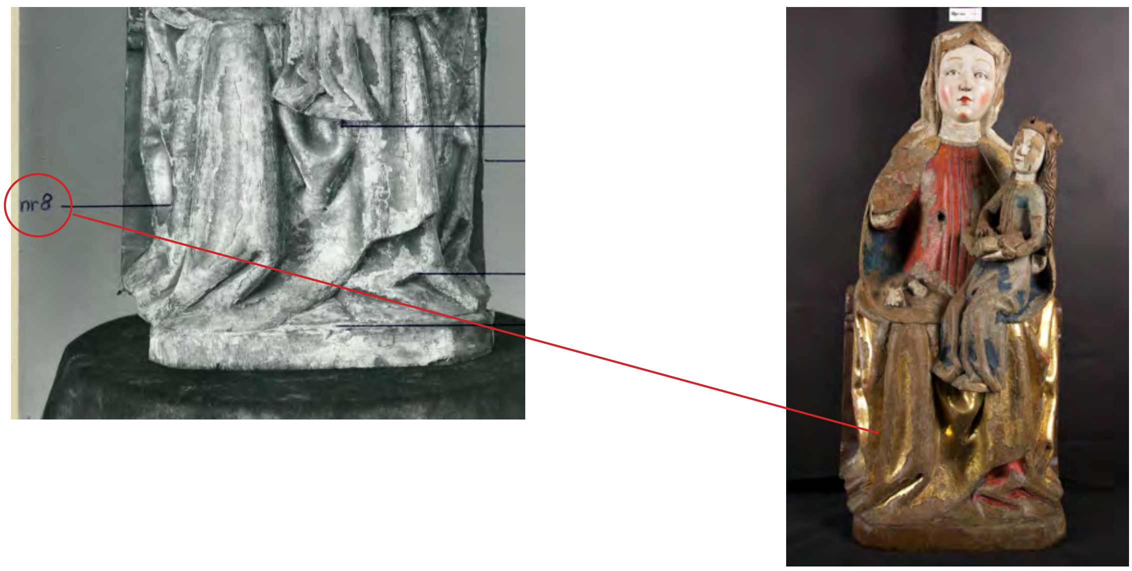


Figure 52: L59.3 Amino acid selected ion chromatogram (SIM)

Sample details	
Object: Berg St Anne C2912	**Analysis date:** April 2017
Sample: L59.8	**Weight:** 94µg
Initial volume: 100µl	**Injected volume:** 1µl
Research question: What binding media (proteinaceous / oil-based) were used in gilding and ground?	
Sample location: St Anne's gilded robe, as marked on archival photograph	
% fatty acids: 0	**% protein:** 24
P/S ratio: -	**A/P ratio:** -



Free Fatty Acid	Concentration, ppm	Amino Acid	Concentration, ppm
Pimelic	0	Alanine	30.42
Suberic	0	Glycine	49.56
Lauric	0	Valine	15.55
Azelaic	0	Leucine	19.43
Sebacic	0	Isoleucine	9.51
Myristic	0	Proline	35.26
Palmitic	0	Serine	12.35
Stearic	0	Threonine	13.13
Oleic	0	Phenylalanine	9.04
		Hydroxyproline	35.70

Analysis	Results	Interpretation
Fatty acids	Not detected	Pattern of peaks on chromatogram indicative of high molecular weight wax from conservation treatment
Proteins	0.99 correlation coefficient with collagen and gelatine	Indicative of animal glue binder

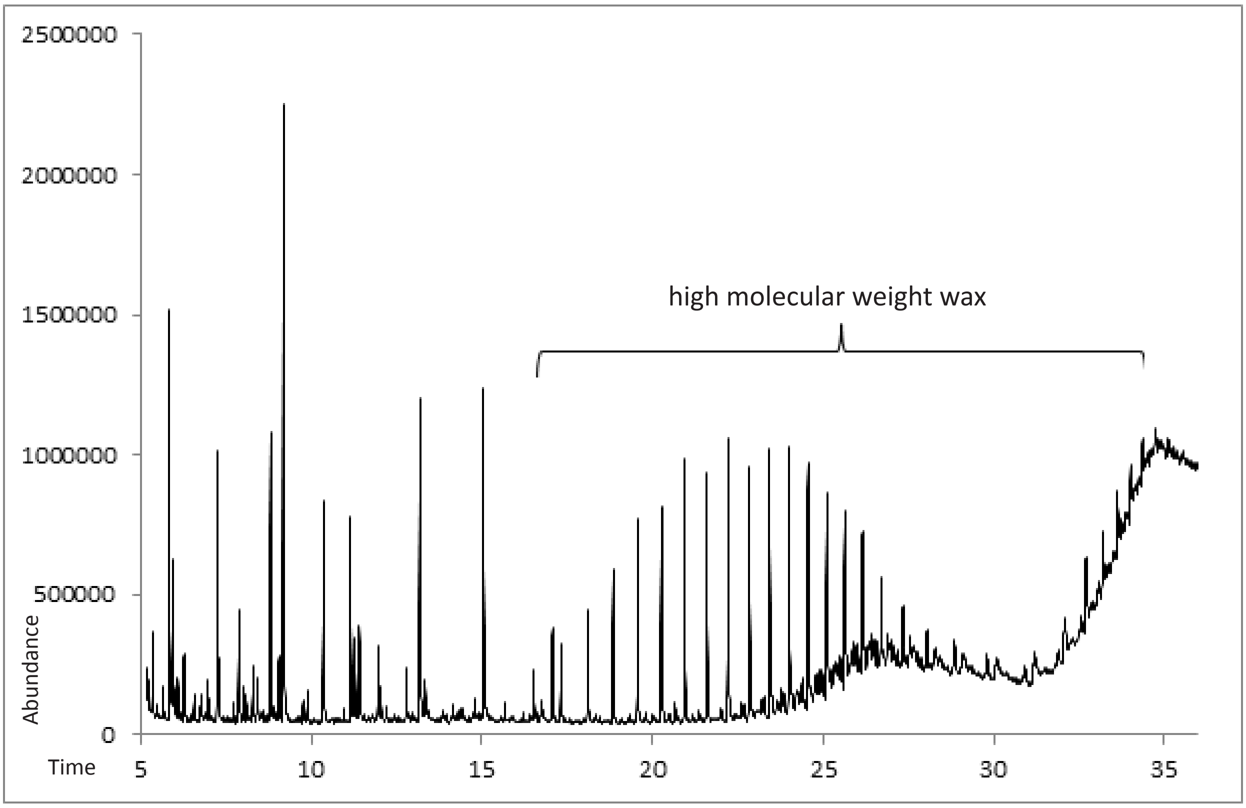


Figure 53: L59.8 Fatty acid total ion chromatogram (TIC)

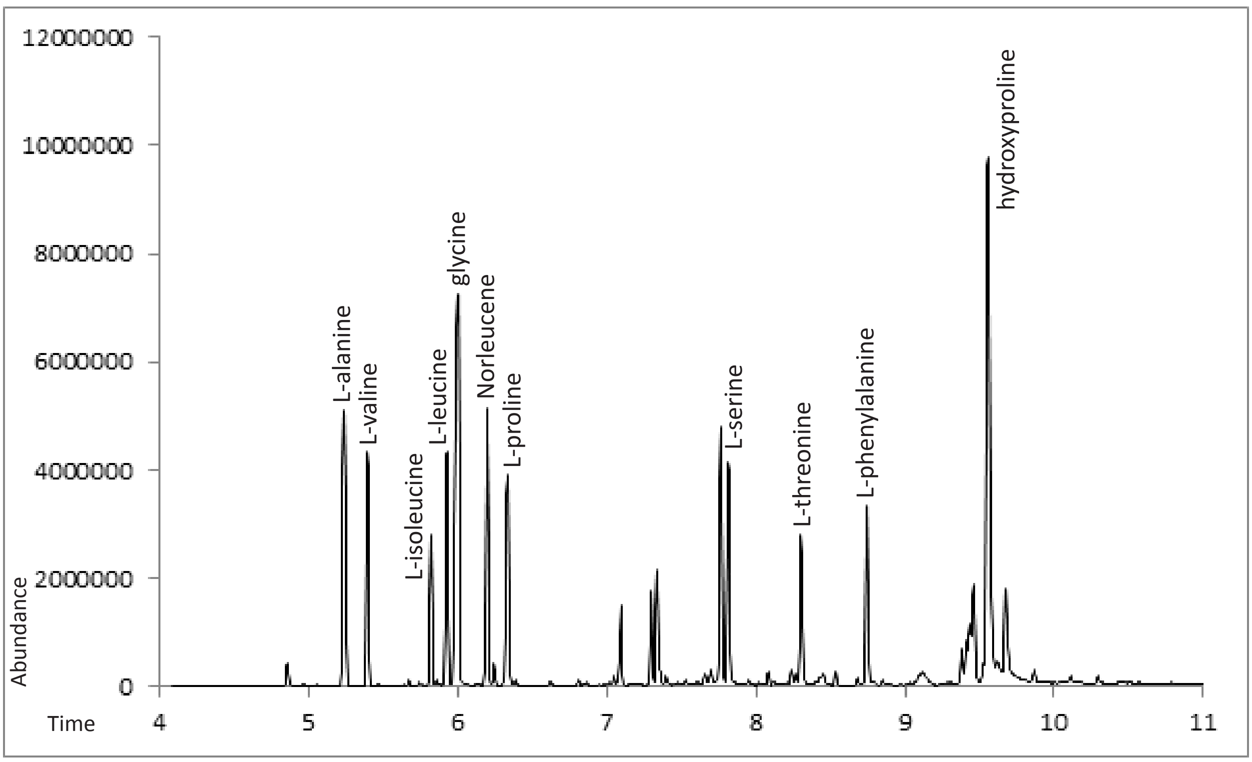


Figure 54: L59.8 Amino acid selected ion chromatogram (SIM)

Sample details	
Object: Berg St Anne C2912	**Analysis date:** April 2017
Sample: L59.10	**Weight:** 94µg
Initial volume: 20µl	**Injected volume:** 1µl
Research question: What binding media (proteinaceous / oil-based) were used in the ground?	
Sample location: Ground from Virgin's crown	

% fatty acids: 0.13	**% protein:** 2
P/S ratio: 1.50	**A/P ratio:** 0.26

Free Fatty Acid	Concentration, ppm	Amino Acid	Concentration, ppm
Pimelic	0	Alanine	13.05
Suberic	0	Glycine	20.12
Lauric	0	Valine	4.58
Azelaic	1.6	Leucine	8.56
Sebacic	0	Isoleucine	3.08
Myristic	0	Proline	16.94
Palmitic	6.07	Serine	1.97
Stearic	4.05	Threonine	2.21
Oleic	0	Phenylalanine	3.53
		Hydroxyproline	14.58

Analysis	Results	Interpretation
Fatty acids	Not detected (trace amounts)	Pattern of peaks on chromatogram indicative of high molecular weight wax from conservation treatment
Proteins	0.97 correlation coefficient with collagen and gelatine	Indicative of animal glue binder

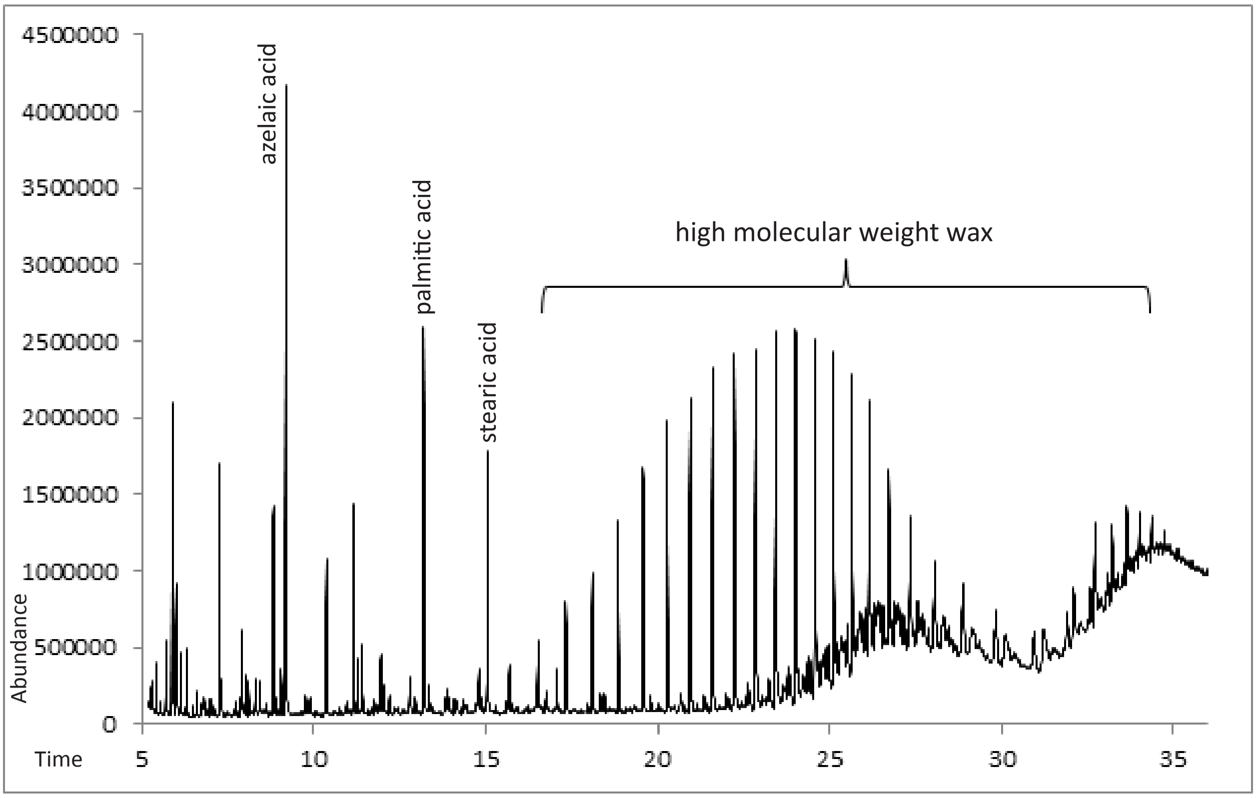


Figure 55: L59.10 Fatty acid total ion chromatogram (TIC)

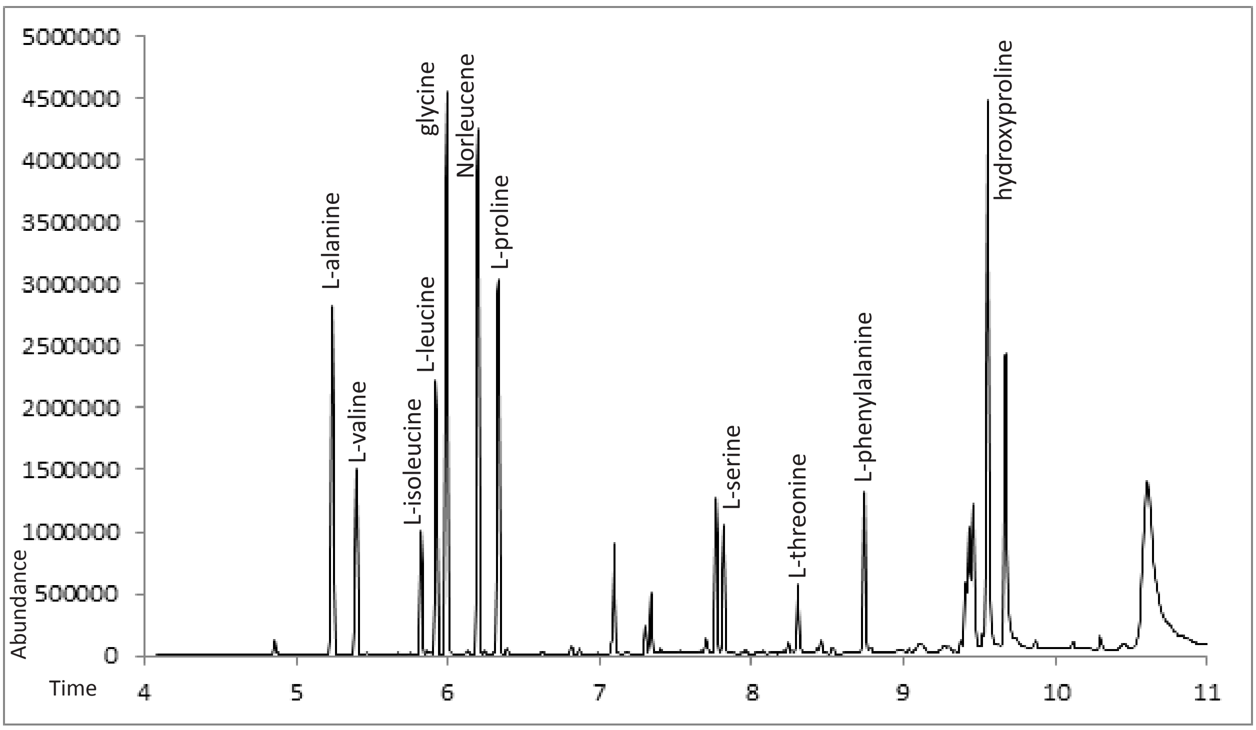


Figure 56: L59.10 Amino acid selected ion chromatogram (SIM)

Sample details	
Object: Berg St Anne C2912	**Analysis date:** November 2016 (Joy Mazurek)
Sample: L59.11	**Weight:** 39µg
Initial volume: 90µl	**Injected volume:** 1µl
Research question: What type of glue was used to adhere the wooden boards together?	
Sample location: Between back and middle boards on base of sculpture	

% fatty acids: 0	**% protein:** 43
P/S ratio: -	**A/P ratio:** -

Free Fatty Acid	Concentration, ppm	Amino Acid	Concentration, ppm
Pimelic	0	Alanine	24.57
Suberic	0	Glycine	64.04
Lauric	0	Valine	4.75
Azelaic	0	Leucine	8.06
Sebacic	0	Isoleucine	2.92
Myristic	0	Proline	32.58
Palmitic	0	Serine	6.30
Stearic	0	Threonine	8.50
Oleic	0	Phenylalanine	3.59
		Hydroxyproline	31.93

Analysis	Results	Interpretation
Fatty acids	Not detected	N/a
Proteins	0.99 correlation coefficient with collagen and gelatine	Indicative of animal glue

Sample details	
Object: Berg Bishop C2913	**Analysis date:** April 2017
Sample: L177.1	**Weight:** 196µg
Initial volume: 100µl	**Injected volume:** 1µl
Research question: What binding media (proteinaceous / oil-based) were used in paint and ground?	
Sample location: Red base of bishop's mitre	
% fatty acids: 0.07	**% protein:** 7
P/S ratio: 1.22	**A/P ratio:** 0.00

Free Fatty Acid	Concentration, ppm	Amino Acid	Concentration, ppm
Pimelic	0	Alanine	21.79
Suberic	0	Glycine	27.19
Lauric	0	Valine	8.48
Azelaic	0	Leucine	14.06
Sebacic	0	Isoleucine	5.57
Myristic	0	Proline	24.10
Palmitic	1.4	Serine	4.82
Stearic	1.15	Threonine	5.66
Oleic	0	Phenylalanine	6.05
		Hydroxyproline	21.32

Analysis	Results	Interpretation
Fatty acids	Not detected (trace amounts)	Silane compound deriving from GC column
Proteins	0.95 correlation coefficient with collagen and gelatine	Indicative of animal glue

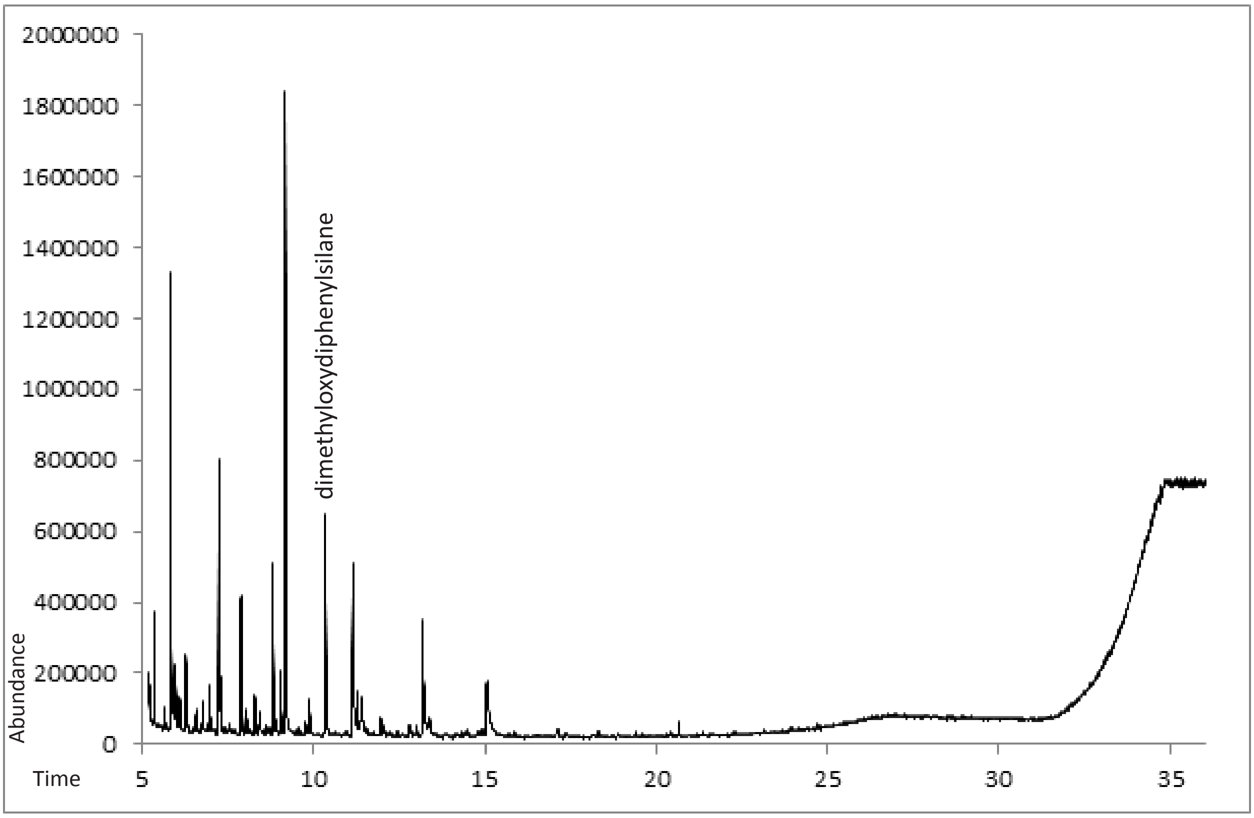


Figure 57: L177.1 Fatty acid total ion chromatogram (TIC)

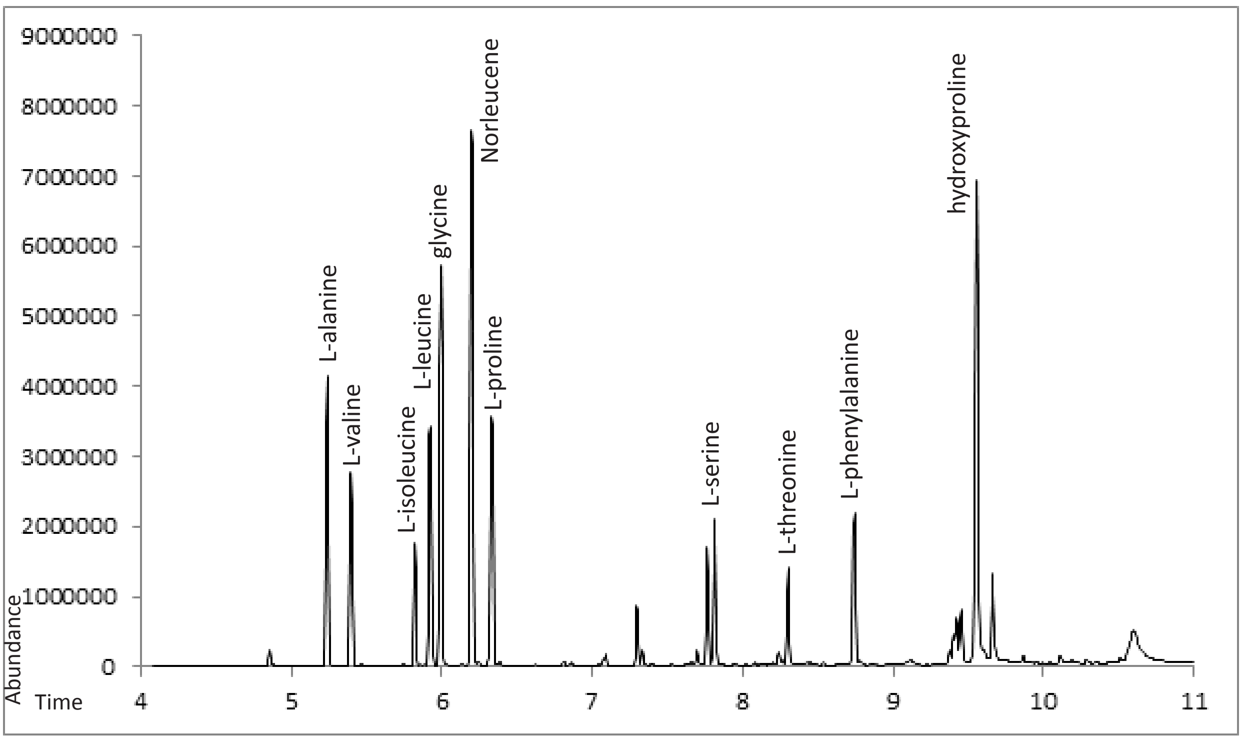


Figure 58: L177.1 Amino acid selected ion chromatogram (SIM)

Sample details	
Object: Berg Bishop C2913	**Analysis date:** April 2017
Sample: L177.2	**Weight:** 227µg
Initial volume: 50µl	**Injected volume:** 1µl
Research question: What binding media (proteinaceous / oil-based) were used in paint and ground?	
Sample location: Green base of sculpture	
% fatty acids: 1.06	**% protein:** 4
P/S ratio: 1.45	**A/P ratio:** 1.62

Free Fatty Acid	Concentration, ppm	Amino Acid	Concentration, ppm
Pimelic	5.26	Alanine	26.13
Suberic	16.33	Glycine	33.83
Lauric	0	Valine	16.63
Azelaic	78.33	Leucine	24.32
Sebacic	4.79	Isoleucine	12.57
Myristic	0	Proline	28.28
Palmitic	48.32	Serine	8.91
Stearic	33.44	Threonine	9.65
Oleic	24.03	Phenylalanine	10.82
		Hydroxyproline	23.78

Analysis	Results	Interpretation
Fatty acids	Present	Oil-based paint layers, P/S ratio indicative of linseed oil Presence of oleic acid likely deriving from formation of soaps, which have kept the oleic acid bound within the paint. Otherwise, oleic acid would no longer be present in such old paint samples.
Proteins	0.96 correlation coefficient with collagen and gelatine	Indicative of animal glue in ground layer

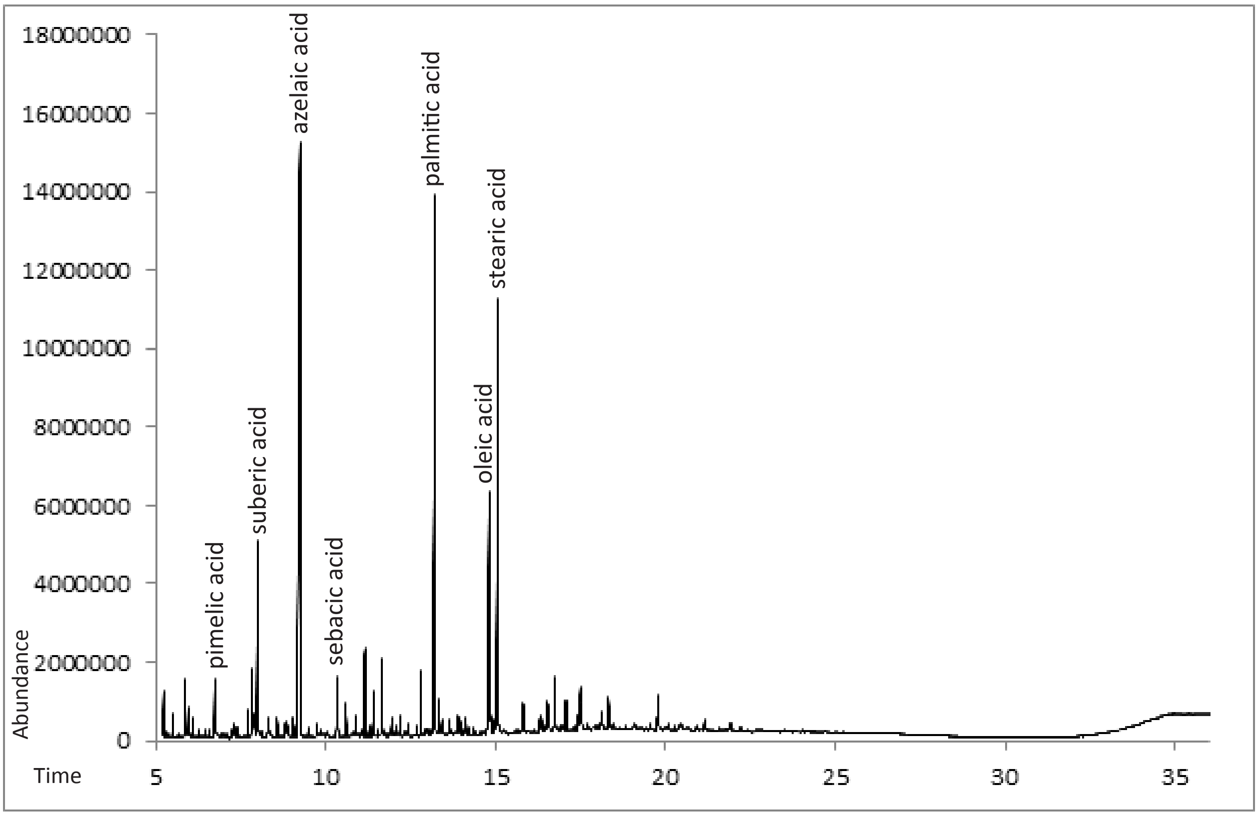


Figure 59: L177.2 Fatty acid total ion chromatogram (TIC)

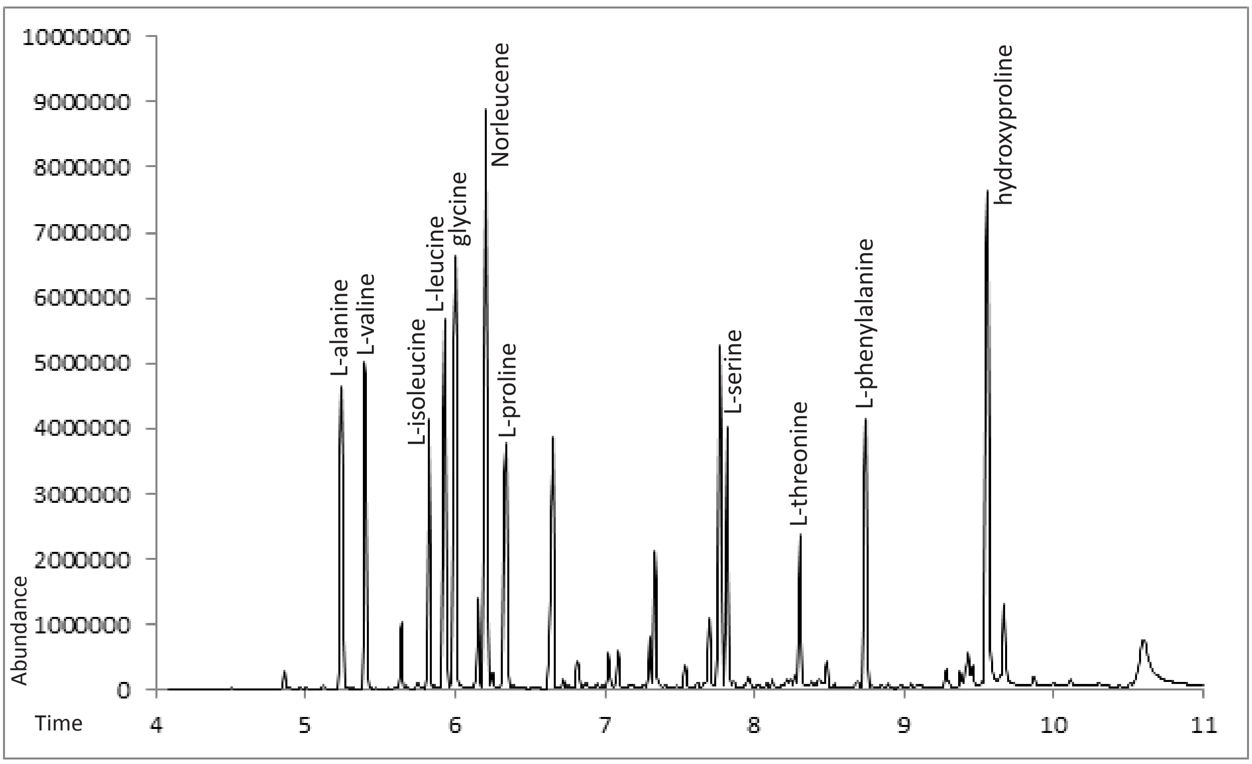
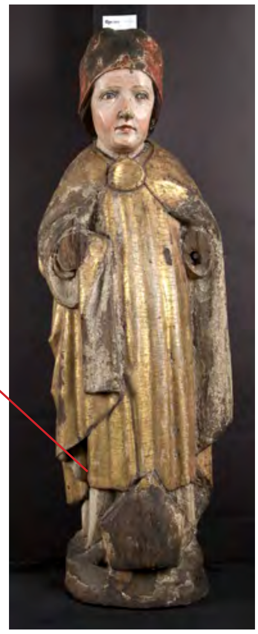


Figure 60: L177.2 Amino acid selected ion chromatogram (SIM)

Sample details	
Object: Berg Bishop C2913	**Analysis date:** April 2017
Sample: L177.3	**Weight:** 199µg
Initial volume: 50µl	**Injected volume:** 1µl
Research question: What binding media (proteinaceous / oil-based) were used in gilding and ground?	
Sample location: Gilded robe	
% fatty acids: 1.03	**% protein:** 2
P/S ratio: 1.21	**A/P ratio:** 0.26



Free Fatty Acid	Concentration, ppm	Amino Acid	Concentration, ppm
Pimelic	0	Alanine	14.35
Suberic	1.81	Glycine	19.67
Lauric	0	Valine	4.47
Azelaic	10.81	Leucine	7.08
Sebacic	0	Isoleucine	2.89
Myristic	0	Proline	16.46
Palmitic	40.81	Serine	1.65
Stearic	33.84	Threonine	1.77
Oleic	0	Phenylalanine	2.73
		Hydroxyproline	13.80

Analysis	Results	Interpretation
Fatty acids	Lipid profile, lack of fatty acid profile	Possibly egg (A/P ratio indicative of lipids)
Proteins	0.96 correlation coefficient with collagen and gelatine	Indicative of animal glue in ground layer

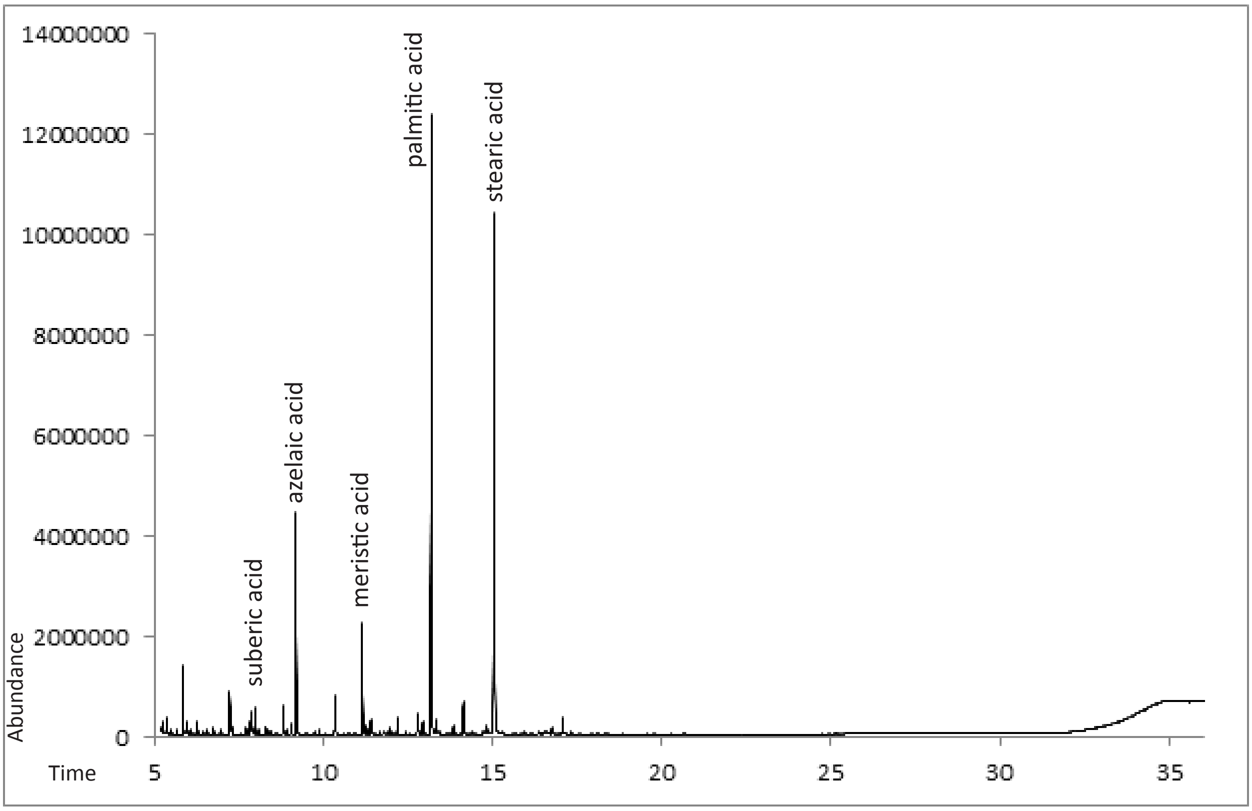


Figure 61: L177.3 Fatty acid total ion chromatogram (TIC)

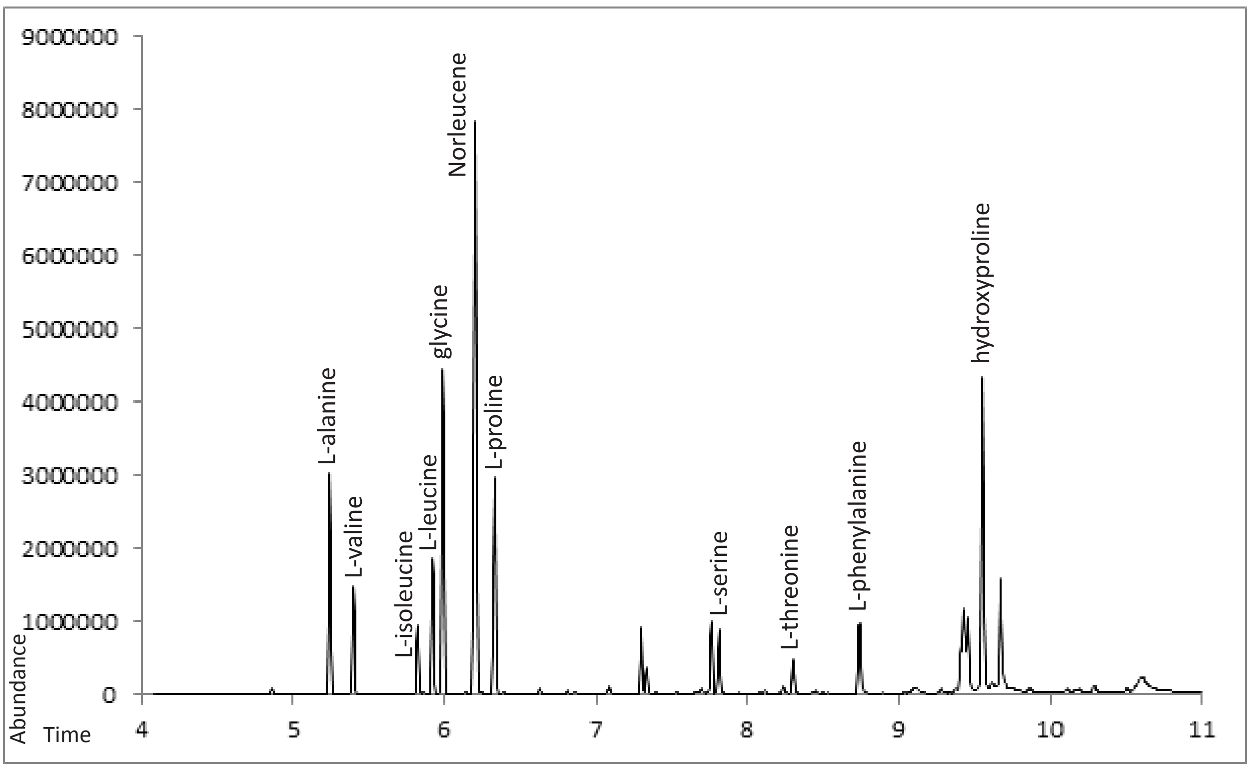


Figure 62: L177.3 Amino acid selected ion chromatogram (SIM)

Sample details	
Object: Berg Bishop C2913	**Analysis date:** April 2017
Sample: L177.4	**Weight:** 356µg
Initial volume: 50µl	**Injected volume:** 1µl
Research question: What in addition to wood pulp and fibres do the accretions consist of?	
Sample location: Accretion from verso	
% fatty acids: 0.19	**% protein:** 6
P/S ratio: 0.57	**A/P ratio:** 0.56

Free Fatty Acid	Concentration, ppm	Amino Acid	Concentration, ppm
Pimelic	0	Alanine	43.66
Suberic	2.95	Glycine	43.47
Lauric	0	Valine	35.27
Azelaic	7.39	Leucine	55.84
Sebacic	0	Isoleucine	32.02
Myristic	0	Proline	40.15
Palmitic	13.28	Serine	54.22
Stearic	23.45	Threonine	41.51
Oleic	0	Phenylalanine	32.19
		Hydroxyproline	23.39

Analysis	Results	Interpretation
Fatty acids	Some fatty acids detected	Likely deriving from wood fibres
Proteins	0.98 correlation coefficient with guano	Possibly bird droppings

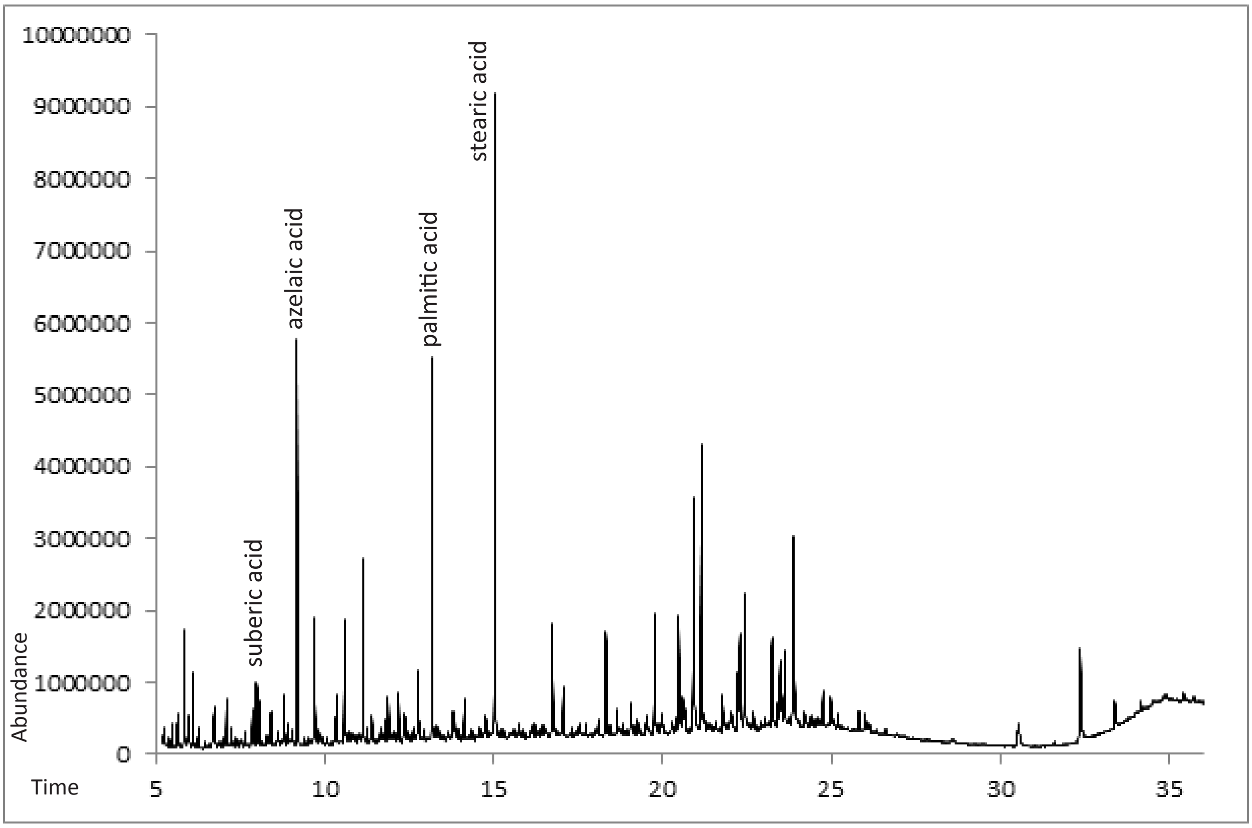


Figure 63: L177.4 Fatty acid total ion chromatogram (TIC)

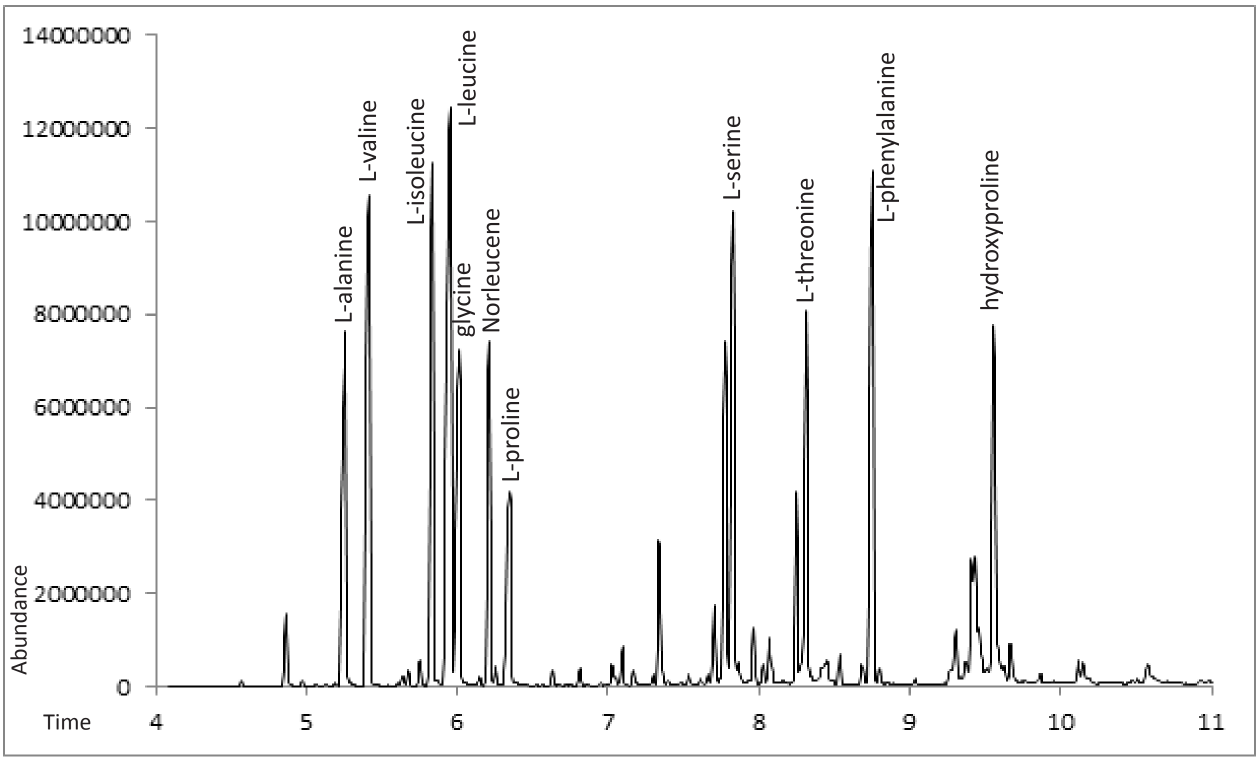


Figure 64: L177.4 Amino acid selected ion chromatogram (SIM)

Sample details	
Object: Torsken Virgin C2686	**Analysis date:** April 2017
Sample: L178.1	**Weight:** 73µg
Initial volume: 50µl	**Injected volume:** 1µl
Research question: What binding media (proteinaceous / oil-based) were used in paint and ground?	
Sample location: Joseph's red stockings, proper right leg, halfway down the shin	

% fatty acids: 0.59	**% protein:** 1
P/S ratio: 1.20	**A/P ratio:** 1.43

Free Fatty Acid	Concentration, ppm	Amino Acid	Concentration, ppm
Pimelic	0	Alanine	2.45
Suberic	2.80	Glycine	6.49
Lauric	0	Valine	0.46
Azelaic	12.28	Leucine	0.83
Sebacic	0	Isoleucine	0.28
Myristic	0	Proline	2.99
Palmitic	8.59	Serine	0.40
Stearic	7.16	Threonine	0.36
Oleic	0	Phenylalanine	0.44
		Hydroxyproline	3.07

Analysis	Results	Interpretation
Fatty acids	Present	Oil-based paint, P/S ratio indicative of linseed oil, A/P ratio suggestive of drying oil Pattern of peaks indicative of presence of high molecular weight wax from conservation treatment
Proteins	0.99 correlation coefficient with collagen and gelatine	Indicative of animal glue in ground layer and/or as consolidant

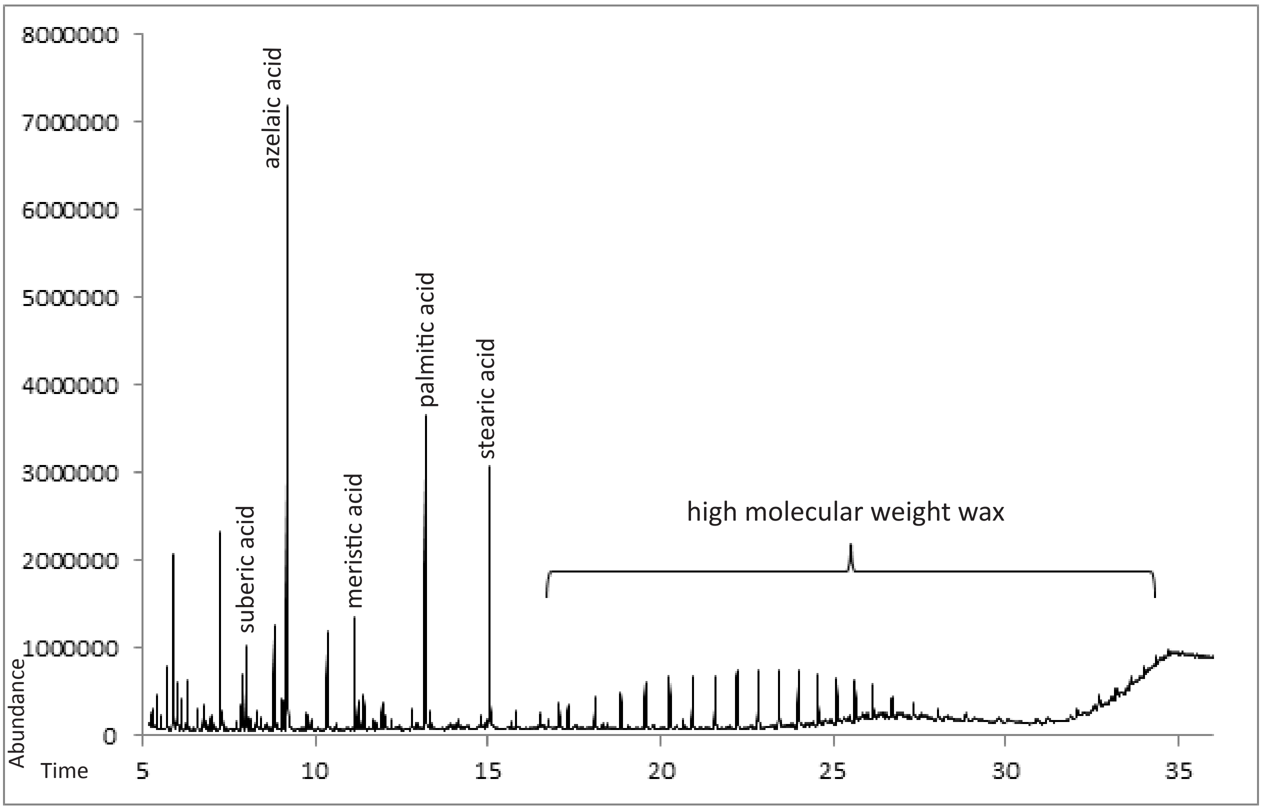


Figure 65: L178.1 Fatty acid total ion chromatogram (TIC)

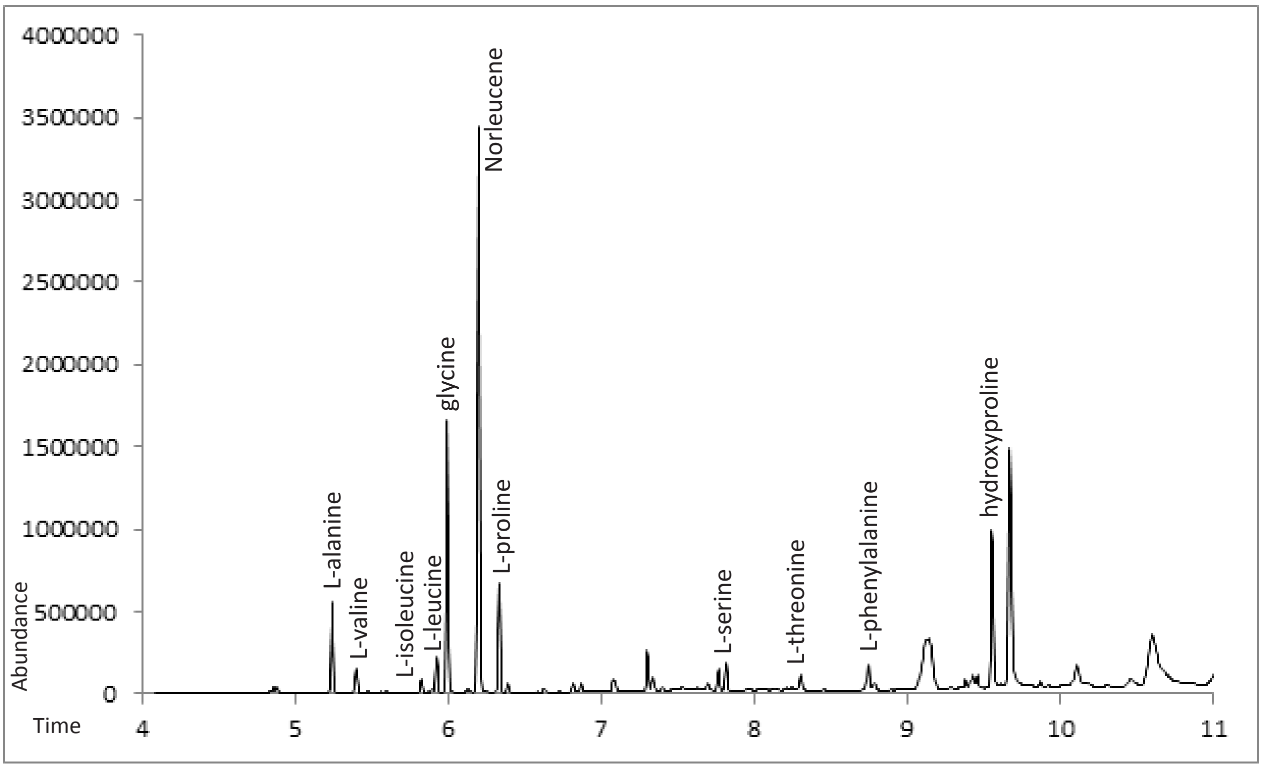


Figure 66: L178.1 Amino acid selected ion chromatogram (SIM)

Sample details	
Object: Torsken Virgin C2686	**Analysis date:** April 2017
Sample: L178.2	**Weight:** 315µg
Initial volume: 50µl	**Injected volume:** 1µl
Research question: What binding media (proteinaceous / oil-based) were used in paint and ground?	
Sample location: Joseph's grey robe, proper right arm	
% fatty acids: 0.59	**% protein:** 1
P/S ratio: 1.38	**A/P ratio:** 1.39

Free Fatty Acid	Concentration, ppm	Amino Acid	Concentration, ppm
Pimelic	4.31	Alanine	10.42
Suberic	12.54	Glycine	15.97
Lauric	0	Valine	3.02
Azelaic	51.51	Leucine	5.63
Sebacic	5.55	Isoleucine	1.94
Myristic	0	Proline	11.47
Palmitic	36.94	Serine	1.07
Stearic	26.87	Threonine	1.24
Oleic	0	Phenylalanine	2.07
		Hydroxyproline	8.79

Analysis	Results	Interpretation
Fatty acids	Present	Oil-based paint, P/S ratio indicative of linseed oil, A/P ratio suggestive of drying oil
Proteins	0.98 correlation coefficient with collagen and gelatine	Indicative of animal glue in ground layer and/or as consolidant

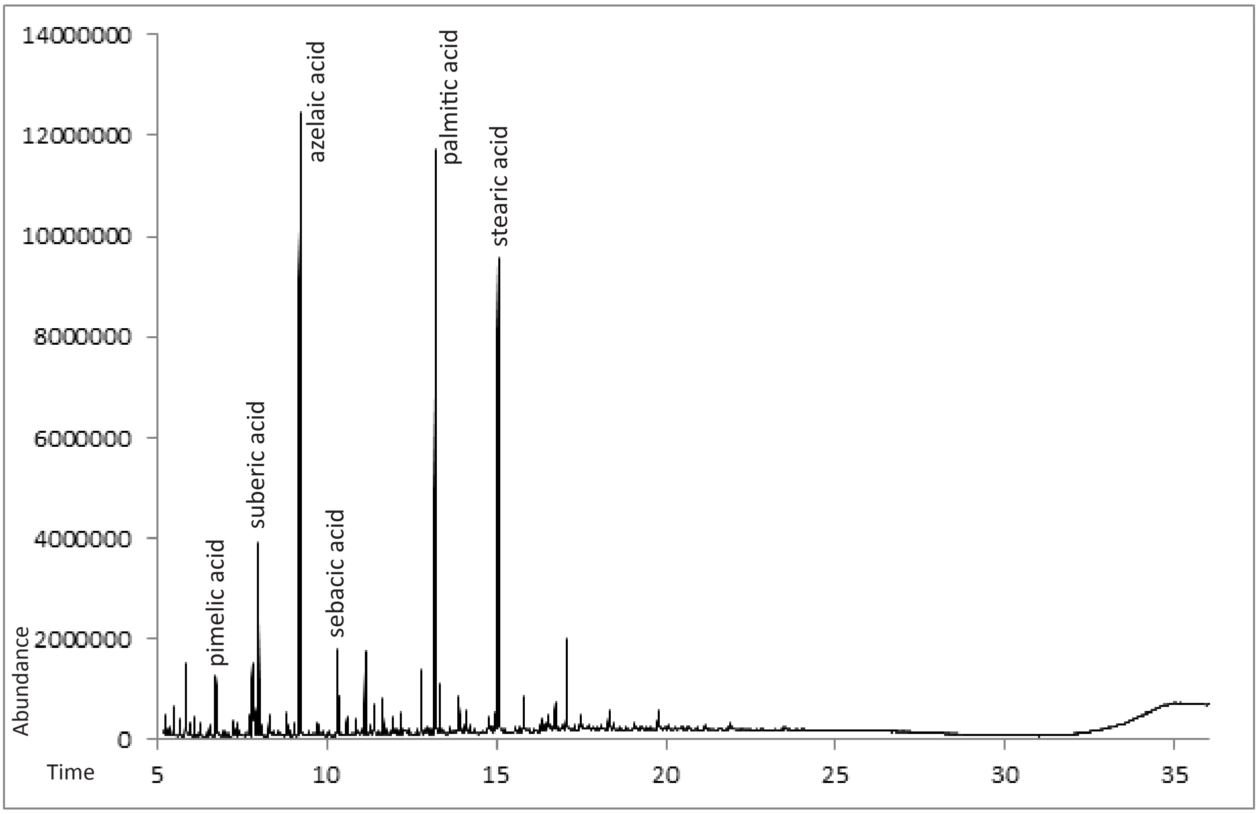


Figure 67: L178.2 Fatty acid total ion chromatogram (TIC)

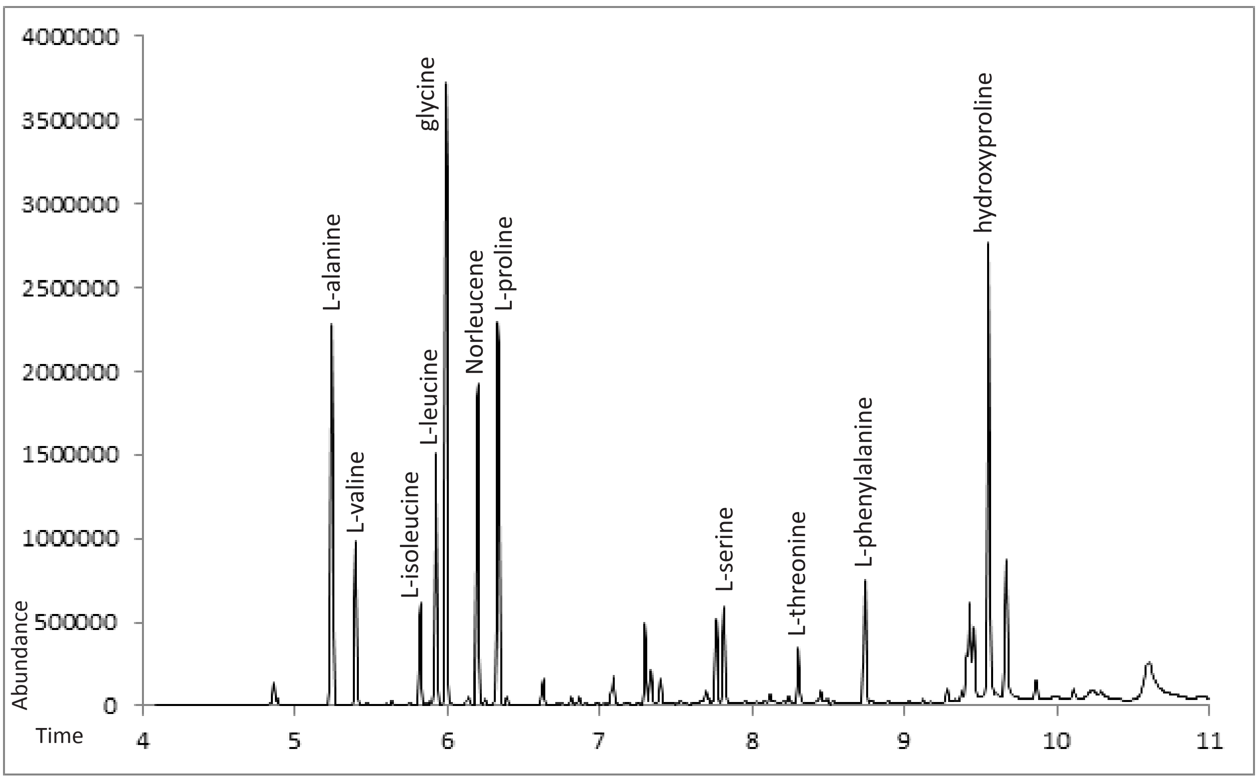


Figure 68: L178.2 Amino acid selected ion chromatogram (SIM)

Sample details	
Object: Torsken Virgin C2686	**Analysis date:** April 2017
Sample: L178.3	**Weight:** 164µg
Initial volume: 50µl	**Injected volume:** 1µl
Research question: What binding media (proteinaceous / oil-based) were used in gilding and ground?	
Sample location: Virgin's gilded robe, proper left side near elbow	
% fatty acids: 0.22	**% protein:** 7
P/S ratio: 0.75	**A/P ratio:** 0

Free Fatty Acid	Concentration, ppm	Amino Acid	Concentration, ppm
Pimelic	0	Alanine	30.39
Suberic	0	Glycine	40.44
Lauric	0	Valine	15.39
Azelaic	0	Leucine	26.47
Sebacic	0	Isoleucine	11.32
Myristic	0	Proline	32.92
Palmitic	7.06	Serine	8.64
Stearic	9.36	Threonine	10.18
Oleic	0	Phenylalanine	11.03
		Hydroxyproline	28.64

Analysis	Results	Interpretation
Fatty acids	Not detected (trace amounts)	
Proteins	0.96 correlation coefficient with collagen and gelatine	Indicative of animal glue

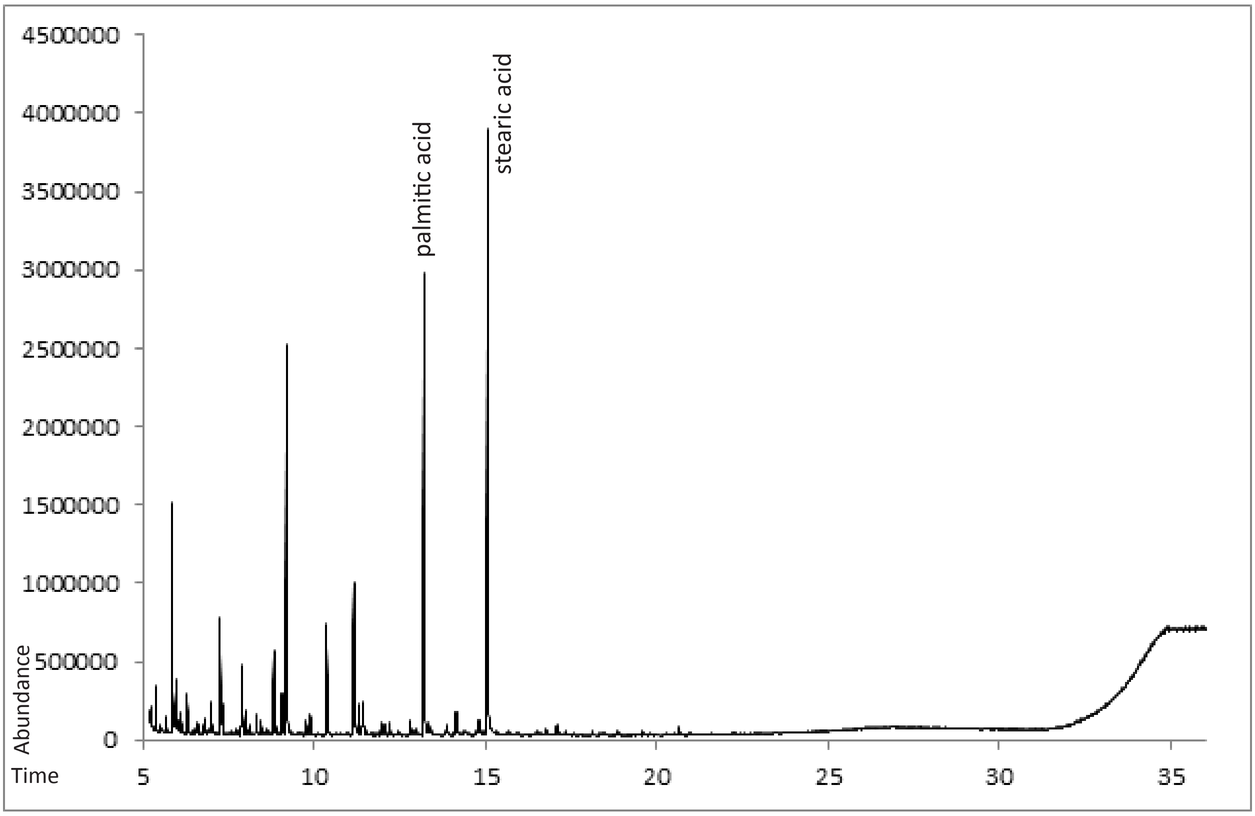


Figure 69: L178.3 Fatty acid total ion chromatogram (TIC)

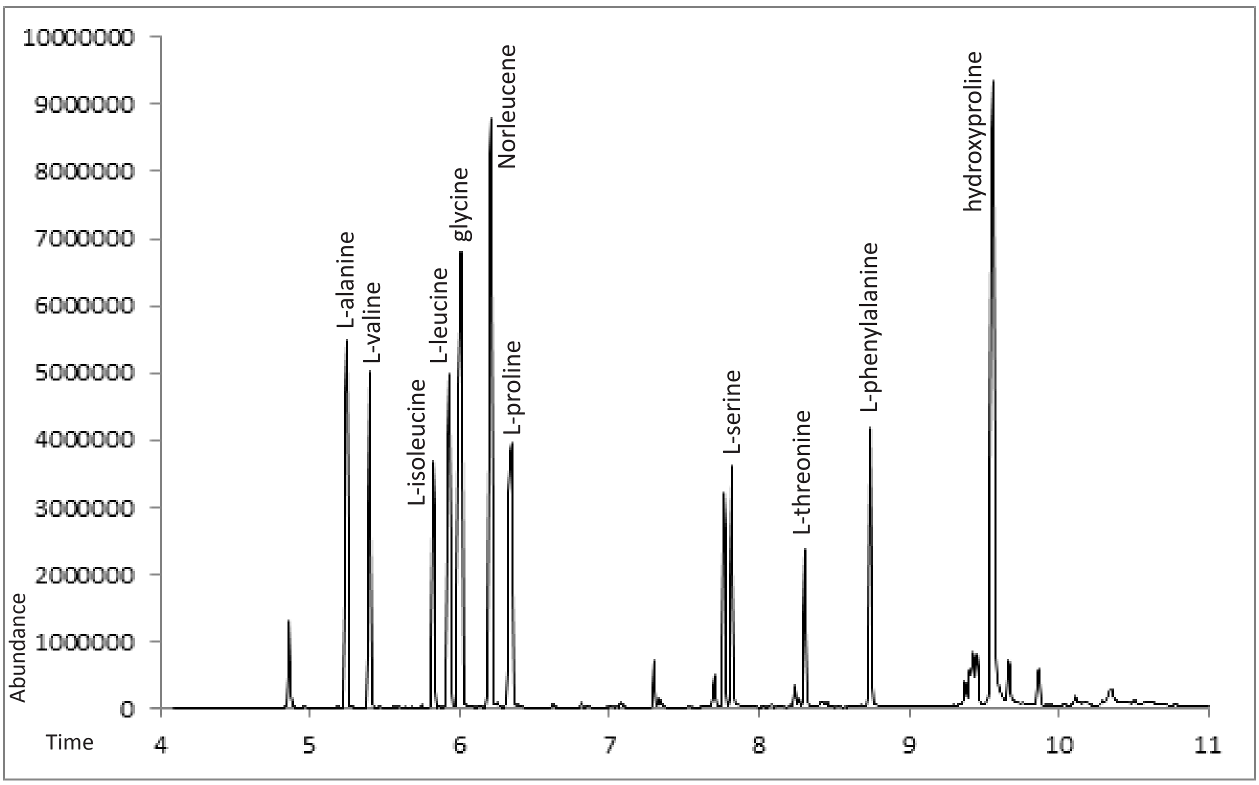


Figure 70: L178.3 Amino acid selected ion chromatogram (SIM)

Sample details	
Object: Torsken Virgin C2686	**Analysis date:** April 2017
Sample: L178.4	**Weight:** 157µg
Initial volume: 50µl	**Injected volume:** 1µl
Research question: What binding medium (proteinaceous / oil-based) was used in the ground?	
Sample location: Ground only from Jesus' gilded robe	
% fatty acids: 0.06	**% protein:** 2
P/S ratio: 1.12	**A/P ratio:** 0

Free Fatty Acid	Concentration, ppm	Amino Acid	Concentration, ppm
Pimelic	0	Alanine	12.62
Suberic	0	Glycine	19.58
Lauric	0	Valine	3.96
Azelaic	0	Leucine	6.39
Sebacic	0	Isoleucine	2.38
Myristic	0	Proline	15.75
Palmitic	1.73	Serine	1.25
Stearic	1.54	Threonine	1.49
Oleic	0	Phenylalanine	2.28
		Hydroxyproline	10.64

Analysis	Results	Interpretation
Fatty acids	Not detected (trace amounts)	
Proteins	0.98 correlation coefficient with collagen and gelatine	Indicative of animal glue

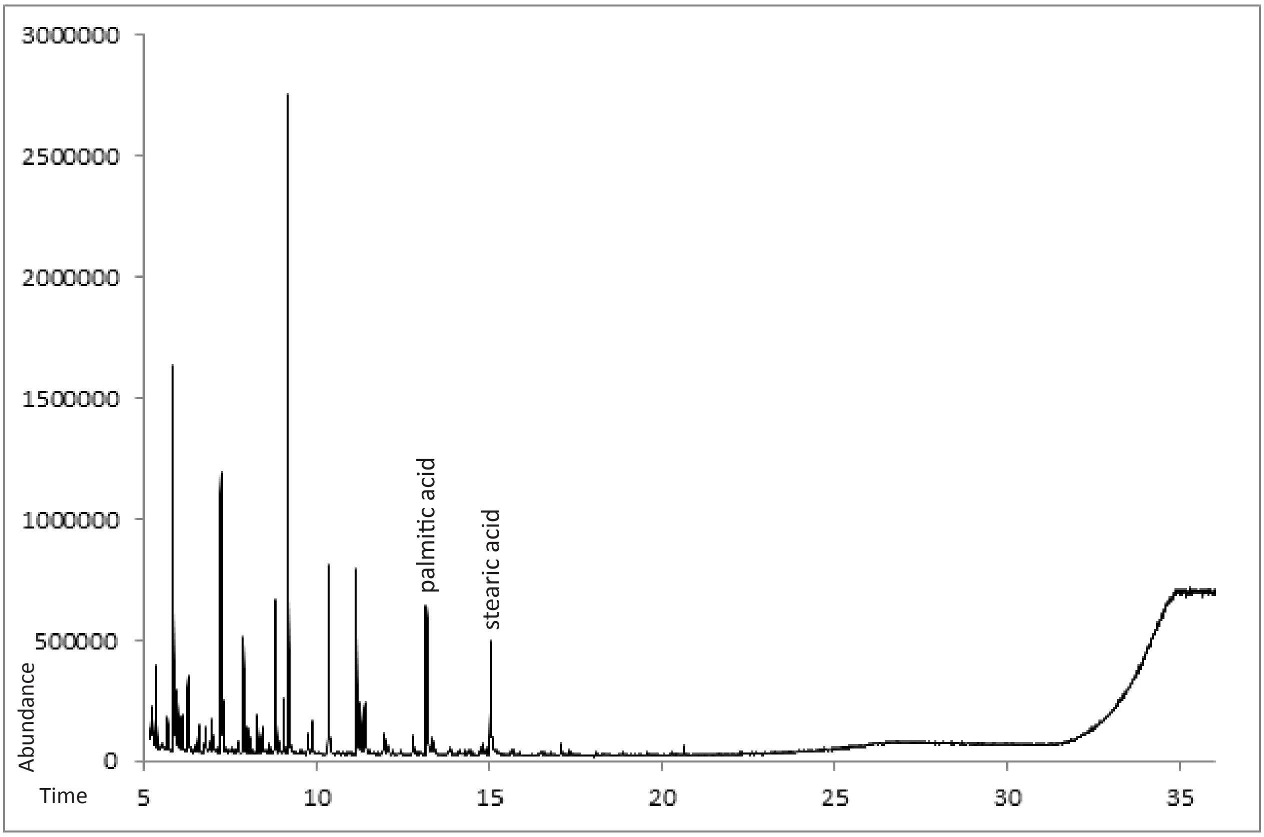


Figure 71: L178.4 Fatty acid total ion chromatogram (TIC)

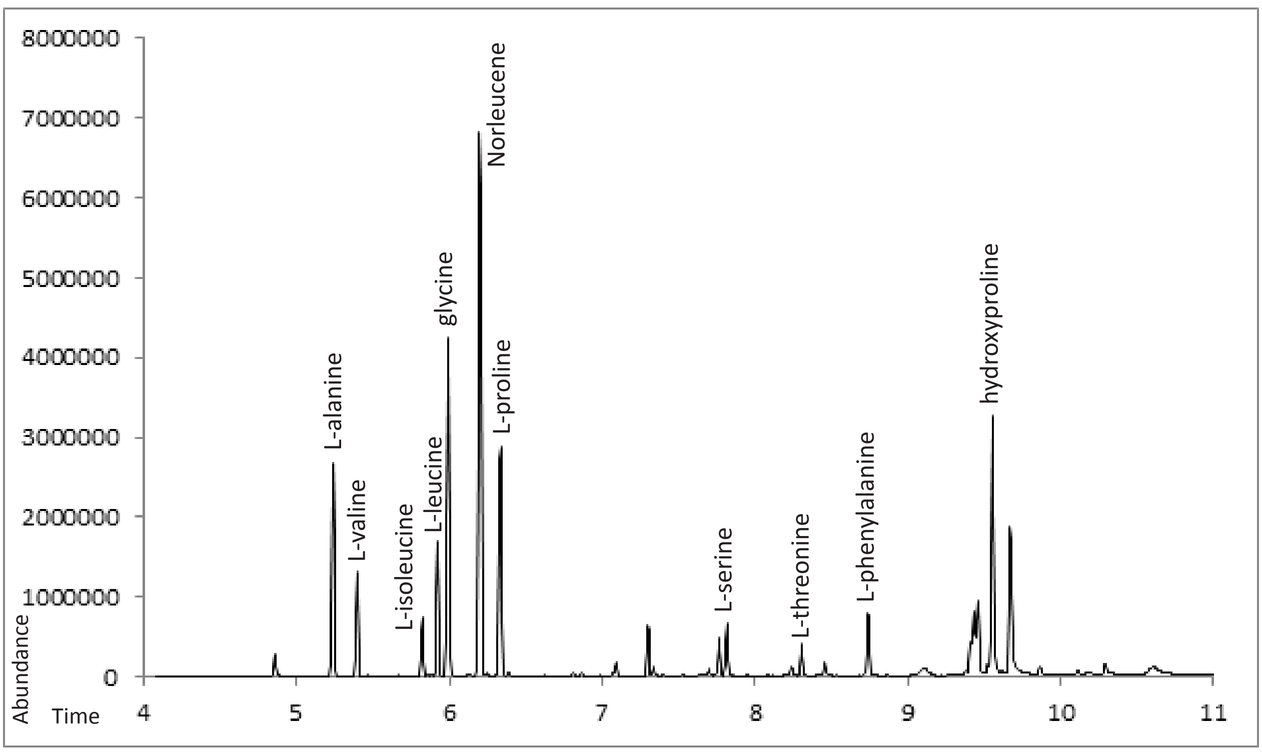
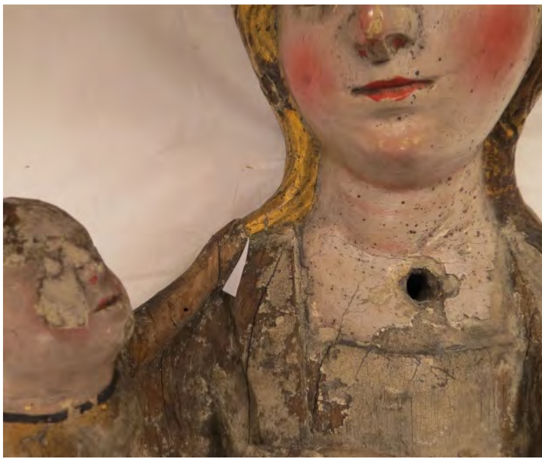


Figure 72: L178.4 Amino acid selected ion chromatogram (SIM)

Sample details	
Object: Torsken Virgin C2686	**Analysis date:** April 2017
Sample: L178.5	**Weight:** 611µg
Initial volume: 100µl	**Injected volume:** 1µl
Research question: What binding media (proteinaceous / oil-based) were used in gilding and ground?	
Sample location: Virgin's gilded hair	
% fatty acids: 0.35	**% protein:** 4
P/S ratio: 1.41	**A/P ratio:** 1.51



Free Fatty Acid	Concentration, ppm	Amino Acid	Concentration, ppm
Pimelic	2.13	Alanine	33.65
Suberic	6.99	Glycine	52.51
Lauric	0	Valine	20.03
Azelaic	32.32	Leucine	34.67
Sebacic	2.66	Isoleucine	15.80
Myristic	0	Proline	40.99
Palmitic	21.38	Serine	11.19
Stearic	15.16	Threonine	13.40
Oleic	0	Phenylalanine	15.38
		Hydroxyproline	29.71

Analysis	Results	Interpretation
Fatty acids	Present	Oil gilding, P/S ratio indicative of linseed oil
Proteins	0.97 correlation coefficient with collagen and gelatine	Indicative of animal glue, likely in ground

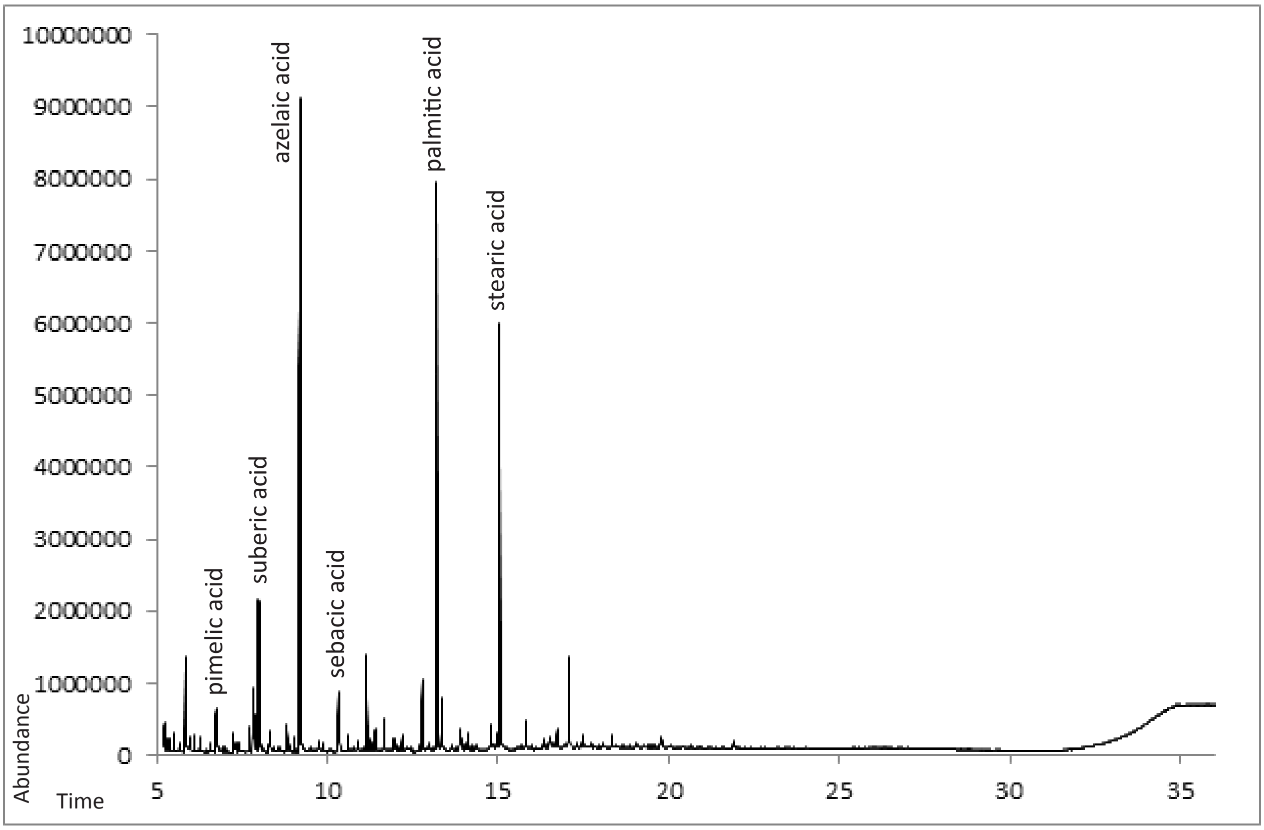


Figure 73: L178.5 Fatty acid total ion chromatogram (TIC)

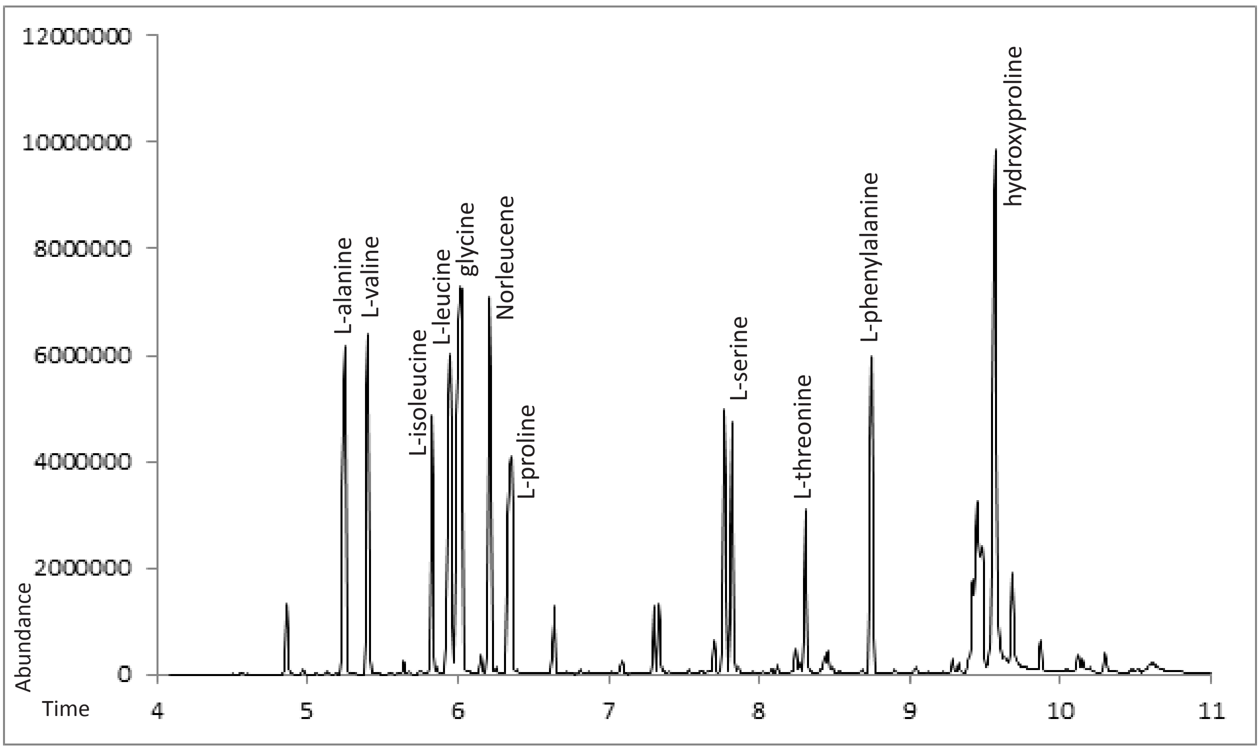


Figure 74: L178.5 Amino acid selected ion chromatogram (SIM)

Sample details	
Object: Torsken Virgin C2686	**Analysis date:** April 2017
Sample: L178.6	**Weight:** 623µg
Initial volume: 100µl	**Injected volume:** 1µl
Research question: What binding media (proteinaceous / oil-based) were used in gilding and ground?	
Sample location: Virgin's gilded crown  	
% fatty acids: 0.04	**% protein:** 2
P/S ratio: 1.50	**A/P ratio:** 0

Free Fatty Acid	Concentration, ppm	Amino Acid	Concentration, ppm
Pimelic	0	Alanine	20.39
Suberic	0	Glycine	25.63
Lauric	0	Valine	9.65
Azelaic	0	Leucine	14.59
Sebacic	0	Isoleucine	6.82
Myristic	0	Proline	22.60
Palmitic	2.37	Serine	3.33
Stearic	1.58	Threonine	3.65
Oleic	0	Phenylalanine	6.36
		Hydroxyproline	17.86

Analysis	Results	Interpretation
Fatty acids	Not detected (trace amounts only)	
Proteins	0.96 correlation coefficient with collagen and gelatine	Indicative of animal glue

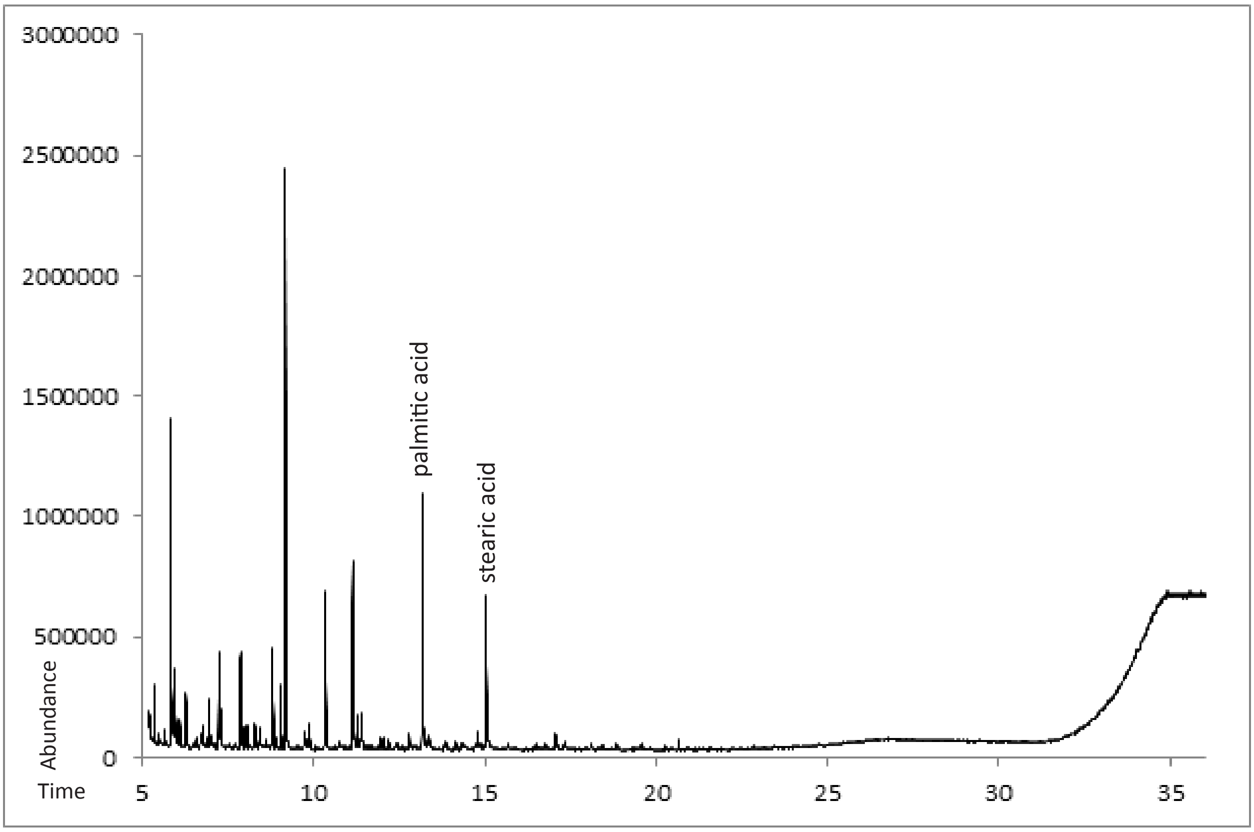


Figure 75: L178.6 Fatty acid total ion chromatogram (TIC)

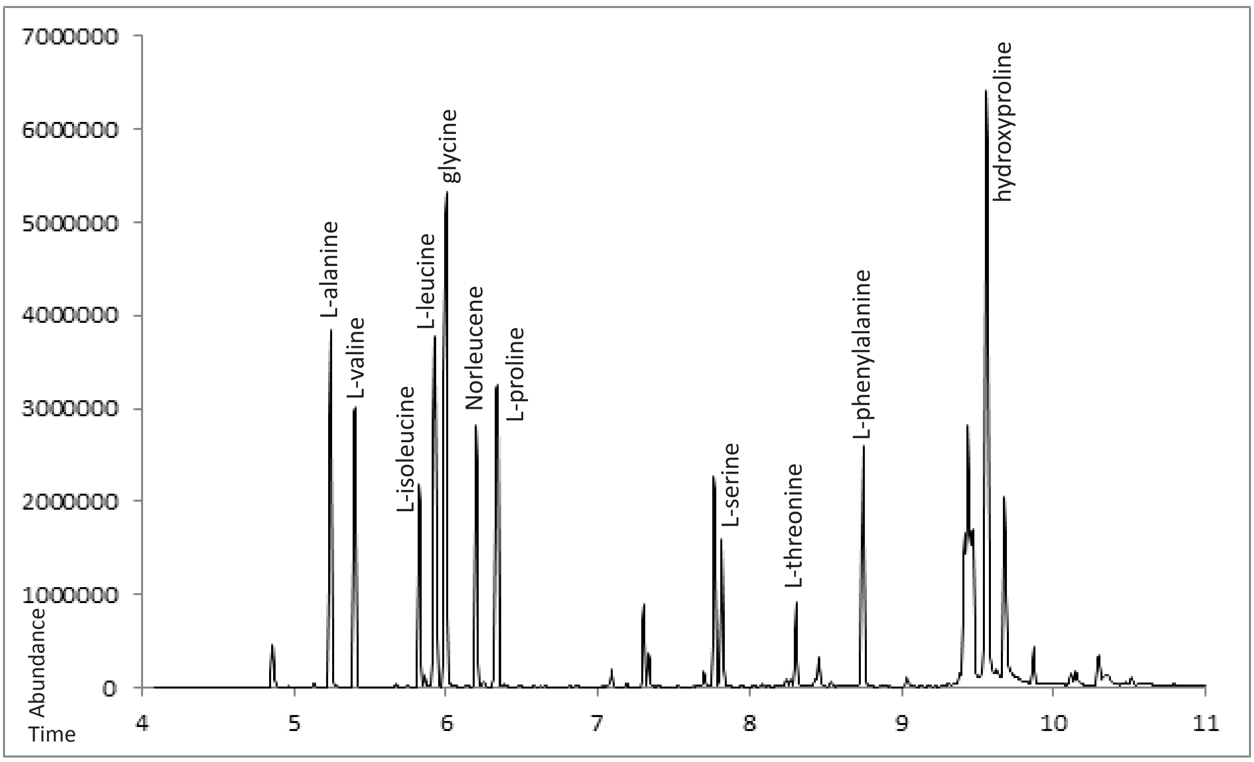


Figure 76: L178.6 Amino acid selected ion chromatogram (SIM)

Appendix 10: Summary of analytical results

C2912 Berg St Anne						
Sample	**Description**	**Stratigraphy**	**pXRF**	**SEM-EDS**	**GC-MS**	**PLM**
L59.1	Blue from Virgin's robe	3. Dark blue paint layer 2. Pale blue paint layer 1. White ground	Azurite paint layers, chalk ground	3. Azurite, with isolated chalk particles, some silicates, iron oxide and orpiment or realgar 2. Azurite and chalk, some iron oxide and silicates, and orpiment or realgar 1. Chalk ground	Animal glue paint binding medium	-
L59.2	Green base	4. Brown-green paint layer 3. Blue-green paint layer 2. Blue-green paint layer 1. White ground	Copper green and lead tin yellow paint layers, possibly some iron oxide, chalk ground	4. Copper resinate glaze (?) with some lead tin yellow 3. Lead tin yellow and copper green (verdigris?) 2. Lead tin yellow and copper green (verdigris?) 1. Chalk ground	Linseed oil paint binding medium	-
L59.3	Red from St Anne's dress	4. Dark red semi-transparent paint layer 3. Thin orange-red paint layer 2. Very thin red layer 1. White ground	Vermilion paint layer, chalk ground	4. Organic red glaze precipitated onto calcium 3. Vermilion 2. Bole from adjacent gilded areas 1. Chalk ground	Animal glue binding medium	-
L59.4	Red border of headscarf	3. Bright orange-red paint layer 2. Transparent layer 1. Thin white paint layer	-	3. Vermilion, with some lead white 2. Organic red lake precipitated on calcium, some alumino-silicates or alum 1. Lead white base layer	-	-
L59.5	Virgin's gilded hair	4. Thin grey layer 3. Beige paint layer 2. Resinous layer with pigment particles 1. White ground	-	4. Silver and silver degradation products 3. Ochre, lead white and other pigments 2. Resinous mordant with chalk and lead white 1. Chalk ground	-	-

C2912 Berg St Anne						
Sample	**Description**	**Stratigraphy**	**pXRF**	**SEM-EDS**	**GC-MS**	**PLM**
L59.6	Brown throne	3. – 6. Brown paint layers 2. Thin beige paint layer 1. White ground	Lead white or red lead, earth pigments, copper green, bone black, chalk ground	4. – 6. Mixture of organic black pigment, lead white and earth pigments 3. Chalk, earth pigments, traces of other pigments 2. Mixture of organic black pigment, lead white and earth pigments 1. Chalk ground	-	-
L59.7	St. Anne's neck	3. White paint layer 2. Pinkish white paint layer 1. White ground	Forehead/cheek: Lead white, vermilion, chalk ground	3. Lead white and vermilion 2. Lead white, vermilion and chalk 1. Chalk ground	-	-
L59.8	Gilding, St. Anne's robe	3. Gold leaf 2. Red bole 1. White ground	Gold leaf, bole and chalk ground	3. Gold leaf 2. Ferrous alumino-silicate (bole) 1. Chalk ground	Animal glue binding medium	-
L59.9	Canvas fibre, verso	-	-	-	-	Flax or other related bast fibre
L59.10	Ground from Virgin's crown	3. Brown layer 2. Grey ground (white layer with dark pigment particles) 1. Brown layer	-	3. Organic layer (glue) 2. Chalk, alumino-silicates, organic black pigment, ochre 1. Organic layer (glue)	Animal glue binding medium	-
L59.11	Glue between boards (base)	-	-	-	Animal glue	-

C2913 Berg Bishop						
Sample	**Description**	**Stratigraphy**	**pXRF**	**SEM-EDS**	**GC-MS**	**PLM**
L177.1	Red base of bishop's mitre	3. Fluorescent coating or consolidant 2. Red paint layer 1. White ground	Biretta: Vermilion, chalk ground	3. Organic surface coating or consolidant 2. Vermilion 1. Chalk ground	Animal glue binding medium	-
L177.2	Green base	4. Fluorescent coating or consolidant, embedded dirt 3. Blue-green paint layer 2. Brown-green paint layer 1. White ground	Lead white, lead tin yellow, copper green, iron oxide, chalk ground	4. Organic surface coating with embedded dirt 2. – 3. Lead white, lead tin yellow and copper green, some iron oxide particles 1. Chalk ground	Linseed oil paint binding medium, animal glue ground binding medium	-
L177.3	Gilded robe	4. Dirt layer 3. Gold leaf 2. Red bole 1. White ground	Gold leaf, bole, chalk ground Discoloured area: Silver degradation products, gold alloy leaf with silver, bole, chalk ground	4. Dirt and silver degradation products 3. Gold alloy with silver component 2. Ferrous alumino-silicate (bole) 1. Chalk ground	Egg binding medium for gilding, animal glue ground binding medium	-
L177.4	Accretion, verso	-	-	-	Some fatty acids from wood, protein content correlation to guano, possibly bird droppings	Wood cells and fibrous material
L177.5	Canvas fibre, verso	-	-	-	-	Flax or other related bast fibre

C2686 Torsken Nativity					
Sample	**Description**	**Stratigraphy**	**pXRF**	**SEM-EDS**	**GC-MS**
L178.1	Joseph's red stockings	4. Dirt layer 3. Orange-red paint layer 2. Transparent layer 1. White ground	Vermilion, lead white or red lead, chalk ground	4. Surface dirt 3. Vermilion, chalk and red lead 2. Isolation layer with saponified lead from paint 1. Chalk ground	Linseed oil based paint (drying oil) and animal glue ground and/or consolidant
L178.2	Joseph's grey robe	4. Blue-grey paint layer 3. Pale brown paint layer 2. Transparent layer 1. White ground	Lead white, earth pigments, chalk ground	4. Lead white, some earth and organic pigments 3. Lead white and earth pigments 2. Unpigmented isolation layer 1. Chalk ground	Linseed oil based paint (drying oil) and animal glue ground and/or consolidant
L178.3	Virgin's gilded robe	2. Gold leaf 1. White ground	Gold leaf, trace elements including Si and Fe, chalk ground	2. Gold leaf 1. Chalk ground	Animal glue binding medium
L178.4	Jesus' gilded robe	3. Gold leaf 2. Partially present very faint bole layer 1. White ground	-	3. Gold leaf 2. Possibly ochre, inconclusive bole presence (not continuous layer, trace amounts of elements only) 1. Chalk ground with traces of other pigments	Animal glue binding medium
L178.5	Virgin's gilded hair	4. Gold leaf 3. Pale yellow-brown layer 2. Upper ground layer, stained yellow 1. White ground	Gold leaf, lead white and iron oxide pigmented mordant layer, chalk ground	4. Gold leaf and surface dirt 3. Lead white, bone black and earth pigments 2. Chalk ground 1. Chalk ground	Linseed oil mordant for gilding, animal glue binding medium for ground layers
L178.6	Virgin's gilded crown	2. Organic and earth pigments, surface dirt 1. Chalk ground	Gold leaf, trace elements including Si and Fe, chalk ground	Unsuccessful, as no gilding layer was present in sample, only chalk ground, organic pigments, earth pigments and surface dirt	Animal glue binding medium