Note from the Making and Knowing Project:

This essay was written in a graduate course at the University of Amsterdam offered by Tonny Beentjes, Ellen van Bork, and Tamar Davidowitz in 2014 and 2015 to students enrolled in the MA program in Conservation and Restoration. Students worked on various recipes from BnF Ms. Fr. 640 related to mold-making and metalworking.

This is an un-edited student paper that relies on an earlier state of the Making and Knowing Project's transcription and translation of Ms. Fr. 640. For an updated version of the text, see:

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Dossier

The Making and Knowing Project
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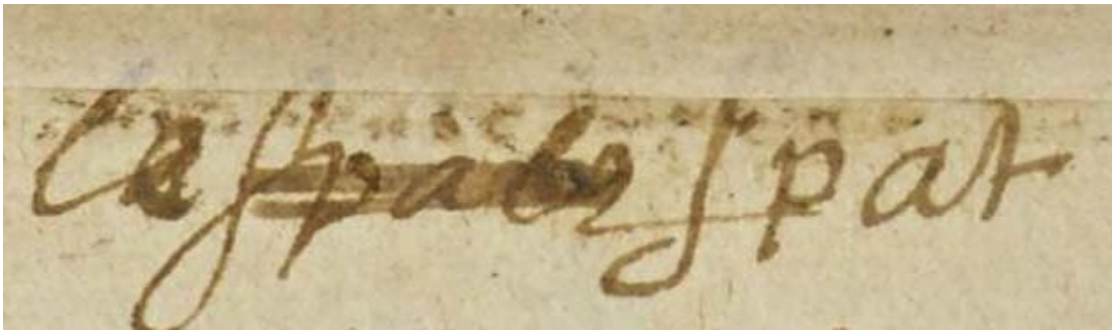
A research of the use of "spat" in the preparation of molds in Manuscript BnF Ms. Fr. 640



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Introduction

This dossier covers the research on manuscript BnF Ms. Fr. 640 done by master students Ingeborg Kroon and Elisabeth Kuiper of the University of Amsterdam, department Conservation and Restoration of Cultural Heritage. This research is done in collaboration with the Colombia University of New York and part of 'The Making and Knowing Project: reconstructing the 16th - century workshop of BnF Ms. Fr. 640'. The French BnF Ms. Fr. 640 manuscript that is extensively investigated in this project, is from the *Bibliothèque nationale de France* in Paris and dates approximately to the 1580s. It most probably originates from the region of Toulouse, France.[1] The manuscript comprises a large collection of recipes and techniques relating to a wide range of subjects. An anonymous and to date unknown author discusses subjects varying from preparations of medical remedies to the making of pigments for painting purposes, creating craftworks or general instructions for painters and metalworkers. The manuscript specifically focuses on the latter category and discusses varying techniques in the process of molding and 'life-casting' of plants and animals in gold, silver or in other metals.[2]

As the author of the manuscript explores a variety of recipes and 'ingredients' in his casting instructions, it is of interest to understand which components these are. The main focus of the research project in this dossier is the study of 'spat': a material that is used in the preparation of molds for casting. The following study aims to find out what this unknown material might have entailed. In this dossier the process of thinking about the material spat and all steps involved in the (experimental) research are documented.

The dossier starts with an annotation in which the whole study of the material spat is described. The first part of the annotation is a literature research supported by art technological and contemporary sources. During the investigation, specialists were consulted to gain more insight in the subject. This study resulted in a selection of candidates for the material and by reconstructing a recipe from the manuscript the most suitable materials were tested. The annotation ends with a conclusion in which the results are described. The photos that were made during the research are added in appendix one. The summary of all folios that were related to the research is added in appendix two and finally the logbook with the activities and thinking processes is added in appendix three.

[1] < http://www.makingandknowing.org/?page_id=23>.
[2] Smith 2010.

A research of the use of “spat” in the preparation of molds in Manuscript BnF Ms. Fr. 640

The material spat as described in the manuscript

Regarding the techniques involved in preparing the molds for casting processes, the author of the BnF Ms. Fr. 640 manuscript suggests an assortment of materials and techniques. The most commonly used recipe seems to consist of four parts plaster of Paris, two parts crushed tiles and one part *alum de plume*. When lacking one of these materials the author often experiments in adding varying materials to the mold. Calcined oyster, burned marrow of ox horn and other elements are among the components, which he suggests as molding materials. One of the constituents suggested for the composition of the mold is a material called spat. By searching through the manuscript it becomes clear the word spat is mentioned in three different folios: 108r, 119v and 137v. The author seems to be inconsistent in his terminology about the material because he mentions it twice on folio 108r, the first time as *le spat*, the second time as *spalt*. Interesting about folio 119v is that the author has corrected himself in his writing. It seems like he starts out, writing *Le Spa(...)* than crosses this out and writes spat instead. Due to the variability in terminology, it is important to research the manuscript for other spellings of the material spat. The result of this search is a matching material on nine different folios, where the author refers to a similar material that most probably is related to, or the same as, spat.[3]

On folio 041r the author describes *aspalte* as an additive to sand, in order to achieve a compact sand mixture, which holds together better. On foilos 058r and 066r the material *lasphalte/laspalte* is mentioned, but in this folios it seems that it is used as filler or ground for paint. On folio 066r *“(...) umber and a bit of lacquer”*[4] are added to the *aspalte*, which renders it usable as paint for shadowed areas. After these references, on folio 085v, the material *laspalte* is again described as an additive to a sand mixture. The first references in the manuscript where the author specifically indicates the molding qualities of spat are on folios 106r and 108r. According to the description on folio 106r the term *laspalte* “(…) *is the most excellent sand you can find for molding in a box frame (...)”*[5] and it comes from Augsburg, Germany. Folio 108r also mentioning its origin,

[3] Folios: 041r (aspalte), 058r (laspalthe), 066r (aspalte), 085v (laspalte), 106r (laspalte), 108r (le spat, le spalt), 119r (laspalt), 119v (As~~pals~~pat, aspalte, le spat), 137v (le spat). See appendix two for the text of the folios.
[4] BnF Ms. Fr. 640: 066r.
[5] BnF Ms. Fr. 640: 106r.

Germany, and for the first time a description is added to the terms below the title *spalt.* On folio 119r the provenance of the material is repeated and on the next folio (119v) the author further suggests a way to rework *aspalt.* This reference provides a detailed recipe about the material. The use of the term *spat* is mentioned on foilo 137v as well. As before, the material is said to originate from Germany, *" (...) and is excellent sand for box molds for all metals."*[6]

From the descriptions on the folios one can conclude that the material called spat (and other terms) is used for three applications:

1. Asphalt as a color preparation, which is used as a primer and for the painting of shades (folios 058r and 066r).
2. Burned asphalt, which is added to the sand mixture as a binding agent for molds used to cast large metal objects. The author suggests specifically that it should be burned with the sand from a mine. (folios 041r and 085v).
3. Spat that is used as excellent sand for molding. It is said to be very soft and is repeatedly described to originate from Germany, Augsburg (folios 106r until 137v).

Asphalt as a color preparation (1)

The first two categories, described above, coincide with the first four pages on which the 'spat terms' are used. The manuscript seems to be a worker's handbook to keep handwritten techniques of an experimenting craftsman. Although written down in a neat and tidy way, the recipes seem not to be structured in any specific order and written down while experimenting. Sections tend to include phrases like 'I think' and 'some people use' and at time there are notes scribbled in the borders of the pages that mean to alter or improve the previous directions. Assuming that the pages are arranged in chronological order and (except for additions in the margin) were more or less written this way, it might indicate that the author is unsure about materials in these first references. On the other hand, the material used for painting purposes could be 'asphalt': a color preparation that consists of a mixture of organic (the binding medium bitumen) and inorganic materials (fillers).[7] Asphalt is a material that is chemically and physically unclear but is described in various historic manuscripts and texts related to painting. The most important conclusion regards the color of this raw asphalt, which is brown to grey.[8] The material that the author describes relates to casting and is repeatedly described as white in color. This incoherence provides a fundamental obstacle for research in this direction and

[6] BnF Ms. Fr. 640: 137v.
[7] Berrie 2007: 111.
[8] Berrie 2007: 121.

reveals that the author might have meant another material with the term *asphalt* related to color preparation as with the term *asphalt* related to casting. It indicates that the experimenting author practitioner might have been confused in his terminology. This is no unusual confusion though. In a time when knowledge was handed down mainly through oral tradition, terminology will have varied and multiple synonyms will have been in use at the same time. Old treatises and manuscript can be found to use enormous arrays of contradictory statements and synonymous terms of materials, like for example asphalt.[9]

Burned asphalt (2)

It is not clear what the author means with his instructions on 'burning asphalt', as seen in the second application category. It is also not evident if the author is referring to life-casting or sandcasting when using this mixture. He particularly states that it is useful for the casting of big objects, which differs from the descriptions of the spat in the third application. The information on the folios that refer to burned asphalt is brief and will be further discussed in the paragraph 'calcite'.

Spat as an excellent sand (3)

In the descriptions on the folios ranging from 106r until 137v much relevant information can be found that characterizes the material spat. These recurring and corresponding characteristics ascribed to the materials make it likely that the author is actually referring to the same material when he alternates inconsistently between terms spat, spalt and laspalte (see table 1).

It is from Germany (106r, 119r 119v, 137v), mainly Augsburg (108r)	Excellent sand for casting metals. (106r, 108r, 119r, 119v, 137v)
It is a white stone (108r), has the color of plaster (108r, 119v)	The more it is used the better it is. (106r, 137v)
It is very soft and breakable with the fingernails into powder (108r), light and soft as flour (119r, 119v), it has long and soft filaments which are easy to handle (119v).	For casting gold, silver (106r) and copper, lead, tin, (108r), usable for every metals (119v, 137v)

Table 1. Characteristics of spat.

[9] For example: bitume de Judee, Judenpech, erdpech, bergpech, bergteer, aardpek, bergharz, judenharz, judenleim. Berrie 2007: 113-115.

The material spat described in historical sources

To start this research into spat, not only is it interesting to examine the manuscript closely, it is also useful to explore other historic and contemporary sources that talk about (life-)casting techniques. Important references are for example Hugh Platt's *The Jewell House of Art and Nature* (1594), letter correspondence of Constantijn Huygens (1629), Johannes Kunckel's *Ars Vitraria* (1689), and Johann Georg Krünitz' *Oekonomische Encyklopädie* (published between 1773 and 1858). These works describe a material that might be associated to the spat in the BnF Ms. Fr. 640 manuscript. The authors of these works also use different kinds of terminology for the same material: Platt talks about *spawde,* Kunckel writes about *spath* and Huygens mentions the word *spaet.*

As a basis, Platt uses finely powdered alabaster and adds plaster of Paris and brick. For sharper castings, he claims, gypsum, *alumen plumosum* or spat can be added to the mixture. Although,*"I have seen sometimes many good patternes of metal, cast off very sharpely in spawde alone (...)".*[10] In order to achieve this it is important to heat the flasks before casting the metal and sprinkle the spat with moisture of sal ammoniac.[11] Finally, Platt mentions that it is important to play with the proportions of the powders, and to measure and weigh them until one finds a good mixture.

In a letter correspondence dated 1629 Huygens describes the use of spat from England of which, like the manuscript, he forms balls adding sal ammoniac.[12] He describes the spat from Germany being less translucent in comparison with spat from England.

Kunckel comments on the use of a well-rinsed spat, a certain kind of earth or mineral, which should be made into a very fine matter.[13] The spat should be purified with water and deposited in a copper kettle, which is suspended over a fire and will make the water dry up. As long as the kettle is over the fire, it should be stirred well until the substance is as hard as it was in the beginning. One part of this spat and another part *federweiss* should be mixed and placed in the fire again. According to Kunckel, the mixture should afterwards be pulverized again.

It becomes clear that similarities can be found between the materials described in these historic sources and the information given in the manuscript. As can be seen from the multiple references in other sources, a certain material must have been well known among metallurgists, from Germany and France to England. If this is so, mineralogical and natural historical references should mention the material as well. A search into a whole range of historic sources indeed reveals that the

[10] Platt 1979, 52.
[11] Idem.
[12] Heer, de 1993, 282.
[13] Kunckel 1992, 405.

term spat is not used anymore today, but was commonly used to describe some sort of mineral in the past. Johann Georg Krünitz, for example, includes in his comprehensive *Oekonomische Encyklopädie* (published between 1773 and 1858) the material *spalt*. Interestingly, he distinguishes a difference between the materials *spat, spalt* and *spath*, but notes at the end of the section that these might actually be the same materials. The material *spalt*, similar to the spat described in the manuscript, is a shiny, scaly stone that is almost like 'kristalgyps'. Another similarity to the manuscript is that it can be found in Augsburg, Germany. Krünitz concludes this type of rock seems not to be anything else than a 'regular' *spath*.[14] About *spath* in turn, Krünitz tells us this is an old mineralogy term that was in the past used to refer to a certain rock deposition that holds one of the principal veins of gold or silver. "*Der Spath ist also nichts anders, als ein sauerstoffhaltiger Kalk, mit einer fremden Beimischung, wie mit Säuren oder Kies, auch Thon, Talk und Metalle."*[15]

Possible candidates

The next step in this research is selecting different materials that are thought of as being candidates for spat. The previous sources hand the research of the material spat some information to investigate further in additional references. In addition to this preliminary literature study, advice was sought from multiple fields of expertise. Specialists from the field of mineralogy, ceramics and conservation science handed this research some background information and insights in order to select possible candidates for spat. All the options are subdivided in categories named by the material: fluorite, barite or heavy spar, feldspar, pozzolana and calcite.

Fluorite

A source that dedicates a whole chapter on spat is *Histoire générale des drogues* by Pierre Pomet (1694). Again, the mineral is said to come from Augsburg, Germany where it can be found in abundance. Like the spat in the manuscript, it is scaly and white and it is so soft that with a fingernail, it can be crumbled to powder. Additionally, Pomet adds that *"Spalt is used by several sorts of workmen, being said to be good to assist the founders in melting of their metals; which I cannot affirm to be fact, having never seen it tried."*[16] Interesting about the text by Pomet is the confirmation of the location of Augsburg and also, the use of the material as a flux for the melting of ores and

[14] Krünitz, 1773-1858. 15 June 2015, search: spath. <http://www.kruenitz1.uni-trier.de/>.
[15] Idem.
[16] Hill 1748: 106.

metals. This could possibly mean spat is the mineral fluorite (CaF2) because this mineral is found in Germany, it is described as scaly, and it is indeed used as flux for smelting the metals.

Krünitz describes the same properties as Pomet, which support this candidate for spat. Besides, the colors of the spat is white, yellow, red, brown and greenish according to Krünitz, which corresponds to the possible colors of fluorite. Also, in *Kabinet der natuurlyke historien, wetenschappen, konsten en handwerken* by W. van Ranouw (1723), fluorite is said to be called 'Spath' by the 'High-Germans'.[17] Additional contemporary literature describes that fluorite occurs in veins, the same property of spat described in the manuscript.[18] Other interesting facts are the synonyms of fluorite which included the word 'spar': fluorspar and Derbyshire spar. Both Kunckel and Agricola in his *De re metallica* (1556), comment on the utilization of fluorite in the glass industry. Kunckel, as mentioned earlier, was both a German alchemist and a practiced glass artist, but uses spat in relation to casting metals as well. Agricola (1494-1555), a German scholar and scientist, was known as 'the father of mineralogy' and could therefore shed some light on the material.

Indeed in *De Re Metallica* the author names a material, which he calls *Spatum* (Latin).[19] It finds similarities to the previously discussed spat minerals in the sense that it is said to be a material, both used in metallurgy and in the glass industry. Agricola states that the spat is the third category of three types of stones.[20] These three categories of minerals are stated to be closely related and similar in appearance. Unfortunately he does not comment on metal casting itself, although he indicates the qualities of this mineral for smelting purposes (which described earlier in Pomet and Krünitz).[21] In *De Re Metallica* the three minerals of which Agricola speaks are not further explained, but in *Interpretatio* (1612) they are clarified in terms of description.[22] Also, in the 1912 translation of *De Re Metallica* the editors Herbert and Lou Henry Hoover provide extensive, explanatory footnotes on the subject. Confessing their inability to understand most of the substances, they try to list all characteristics and information given. From this clarification the material must have embraced

[17] Ranouw 1723, 102.
[18] Jackson 2005: 246.
[19] Agricola 1612: 380.
[20] *"The third genus is the material from which glass is made."* Idem.
[21] *"(...) it is necessary, for this kind of ore, to have a very hot furnace in which slags, or cakes melted from pyrites, or stones which melt easily in the fire, are first melted, so that the ore should not settle in the hearth of the furnace and obstruct and choke up the tap-hole (...)"* Idem.
[22] The three minerals, in Latin and in German, are: 'lapides qui igni liquescunt primi generis' (schöne flüsse), 'secundi' (flüsse zum schmeltzen flock quertze) and-'tertii' (quertze oder kisselstein). Idem.

varieties of quartz, flint, and silicious material generally. It is a white stone, from Germany, which has utilization in both the glass industry, as a flux and for painting purposes.[23]

Contrary to the material spat, wich the author of the BnF Ms. Fr. 640 manuscript describes, fluorit has a hardness of four on the scale of Mohs. The hardness of fluorite does not correspond to the description of our author practitioner in the manuscript, which should be soft enough to allow a fingernail to scratch the surface. The hardness of a fingernail can be determined as being a two or a maximum of two and a half on the Mohs scale.[24]

Barite

Different from what the editors of the revised *De Re Metallica* say about spat in the above text, another translation of spat is given in the 1912 translated volumes. In a table, which means to clarify their text, they provide a translation or interpretation of spat as the mineral barite. It is unclear why exactly they added this and if they are sure about their translation, but it is repeated in other sources. Barite, occurring mainly as a gangue mineral in metalliferous hydrothermal veins, is also found as cavity-filling concretions in limestone, sandstones, shale and clays and can be associated with fluorite, galena and calcite.[25] Barite, further more, is the naturally occurring form of barium sulphate ($BaSO_4$). The mineral barite also has many synonyms including barite, heavy spar and in *"(…) the sixteenth century the German author on mining subjects, Agricola, calls it spat."*[26] This can be an explanation of the confusing terminology that is used by the different authors. Besides, the mineral generally occurs in a white color but can also be found tinted in other colors like pale yellow, brown or red as a result of impurities.[27] Also, like the manuscript, barium sulfate is used as filler for the preparation of paints.

Agricola, in the 1912 translation, therefore points out barite as the mineral *spatum.* A translation which can be verified in more contemporary sources. The mineral occurs white, and as a natural deposit associated to limestone (which can be found in Germany). Barite has a 2.4 up to 3.5 on the hardness scale of Mohs, which corresponds to the description in the manuscript as well.

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[23] As said, in De Re Metallica the third category is called Spatum, which is polished and thick. The editors of the work see there is little doubt to the material being fluor-spar. In De Re Metallica it is said that the miners *"(…) call them fluores, by the heat of fire, like ice in the sun, they liquefy and flow away (…) The third kind, as you see here, is white. (…) It is indeed not made far from here, at Breitenbrunn, which is near Schwarzenberg. Moreover, from fluores they can make colours which artists use."* Idem.

[24] Dr. Braekmans, specialist in archeological ceramics. Interview at the University of Leiden 3 March 2015.

[25] Deer 1967: 609.

[26] Eastaugh 2004: 47.

[27] Deer 1967: 608.

Feldspar

Another mineral that is used in the production of glass throughout history, after comment from Kunckel and Agricola, is Feldspar. Although literature does not present us with a connection of feldspar to a use in metallurgy or molding, multiple specialists in the fields of ceramics and experimental archaeology do offer the possibility of feldspar being the spat the author of the BnF Ms. Fr. 640 manuscript uses for casting. Indeed feldspar is a greyish or yellowish white mineral, which would meet the requirements to some degree. According to Krünitz the feldspar in French would be called *Spath des Champs*. Feldspaths are a group of rock-forming tectosilicate minerals that can be found composed of a variety of major elements. There are three kinds of feldspars, with the main element varying from kalium, sodium to calcium.[28] This diversity does pose a problem for the experiments. As discussed earlier though, spat could be a material that is used in the glass industry. Therefore, the choice of material will be made in agreement with the ceramics department and will be feldspar that is and was used for glass or glazes of ceramics. A problem concerning feldspar is that it is a six on the Mohs scale of mineral hardness and is too hard to be scratched with a nail, as the manuscript describes.[29]

Pozzolana

Consulted specialist Dr. Braekmans, assistant professor from the university of Leiden who is specialized in archaeological ceramics, mineralogical provenances and chemical analyses, presents another option.[30] It is the material pozzolana, a soft, volcanic sediment and one of the primary deposits of volcanic ash. It can be found in Germany and Italy and was used by the Romans already in the production of cement. Pozzolana is a siliceous material, which in a chemical reaction reacts with calcium hydroxide in the presence of water.[31] Vitruvius indeed indicates four kinds of pozzolana: a black, white, grey and red type that can all be found in the neighborhood of the Mount Vesuvius.[32] Today the definition of pozzolana encompasses any volcanic material, pumice or volcanic ash. Because characteristics like hardness, approximate color and provenance seem to correspond to the material spat, it might be interesting to study this material further. A problem concerning pozzolana is that there is no indication of etymological connection in the terminology of the two words.

[28] Idem.
[29] Idem.
[30] Interview with Dr. Braekmans at the University of Leiden 3 March 2015.
[31] Gambhir 1986: 44.
[32] Vitruvius in: Hewlett 1988, 3.

Calcite

Often referred to in literature is also the 'calcareous' spar. It would be interesting to explore this further for multiple reasons. Calcite, although slightly too hard (three on Moh's scale) is a white mineral, a carbonate mineral, and the most stable polymorph of calcium carbonate ($CaCO_3$). Other crystal forms are aragonite and vaterite. Limestone, for example, consists of two of these crystals: calcite and aragonite. Calcium carbonate, in its rough form, finds utilization in the construction industry and for road building. It also finds applications for ceramics and glazing, and as decorating fillers. In *An Essay Towards a Natural History of the County of Dublin* from 1772 a comparison is made with limestone and spat. This makes clear limestone and spat are different meterials, although closely related. The text describes that, like limestone, spat *"(...) calcines in the fire very readily and freely, but does not upon calcination attract the moisture of the air so soon as Limestone, nor heat in water so soon: otherwise in water and with Sal Ammoniac, it exhibits the same appearances as Limestone."*[33] Throughout the manuscript the author is often burning or calcining materials, which are then used as molding material. It even seems that the terms 'burning' and 'calcining' are used alternately, as seems to be the case with the oyster shells. Seeing as the author mentions "*burned asphalt*" (folio 041r) and "*burn it with asphalt*" (folios 041r, 081v) multiple times, it would be interesting to experiment with a mineral that is calcareous as well.

Regarding the chemical reaction when heated, some predictions can be made beforehand. In the thermal decomposition reaction of calcium carbonate (the main constituent of calcite or limestone) the material forms calcium oxide, or quicklime, releasing carbon dioxide in the process. When, like the manuscript describes, this material is submersed in water the calcium oxide reacts to form calcium hydroxide. Calcium hydroxide, or slaked lime, is used in plasters and for cement. Also, this material is used as an addition to sand in the process of producing mortar. The manuscript does mention few times that *"sand from a mine"* should be burned together with asphalt (folios 085v and 041r), which might be an indication of this preparation.

Properties of the materials

In order to make a selection from the possible candidates, the compositions, colors, hardness, melting points, solubility limits and provenances were listed in table 2 on the next pages and compared with the characteristics from the manuscript.

[33] Rutty 1772: 79.

Name	Color	Composition	Hardness (Mohs ' scale)	Melting point	Solubility in water	Provenance	Manuscript
Feldspar, mineral	Ranges in colors, also white - Alkali: normally colourless or white potassium sodium alkali - Plagioclase: normally colourless or white - Barium feldspar/ celsian: Colourless, white or yellow	Mineral - Alkali: (K, Na) $[AlSi_3O_8]$ - Plagioclase: Na $[AlSi_3O_8]$- Ca $[Al_2Si_2O_8]$ - Barium feldspar: Ba $[Al_2Si_2O_8]$	All three kinds: 6-6.5	- Alkali: 1150ºC	Insoluble	- Alkali and plagioclase: Abundant worldwide - Barium feldspar: Japan, Wales, Scotland, New Jersey, Namibia	Advantage: Disadvantages:
Pozzolana Tuffa Pumice stone	Ranges in colors, also white	Vulcanic sediment	-		Soluble	- Nama origin from Italy - Mainly from Eiffel Germany - Found around Augsburg	Advantage: Disadvantages: - The name
Calcite/ chalkspar	Colorless or white	Mineral $CaCO_3$	3	1339 °C	Insoluble	Abundant worldwide	

Fluorite / Flüsspat	Extremely veriable	Mineral CaF_2	4			- England - Germany	<u>Advantage</u> <u>Disadvantages</u> - Used as a flux for metals.
Baryte/ heavy spar	Various (included white)	Mineral $BaSO_4$	2.5-3.5		Insoluble	- Germany - China	<u>Advantage</u>: - Agricola <u>Disadvantages</u>: - Chacterised by its unusually heavy weight. -

Table 2: The properties of the different candidates for the materials spat.

Selection of the materials

After careful consideration and in line with advice from experts and specialists a selection is made of the materials that will be tested in the reconstructions. The materials that will be tested on characteristics and behavior in the reconstructions will be the following:

A: Pumice stone powder
B: Heavy spar/ barite
C: Feldspar potassium
D: Feldspar soda/natron
E: Calcium carbonate

Fluorite is not a part of this list, for the following reasons: after setting up a table of candidates and possibilities for the material spat the conclusion can be made that fluorite is both too hard (a four on the scale of Mohs) and the colors in which it occurs are considered too varied. Also, further research is needed to determine which or what kind of fluorite should be tested. For this reason the decision is made not to continue with this material in these experiments.
Furthermore, the reconstructions are done with powdered minerals instead of rough stones. This is mainly because the materials that will be tested nowadays are already produced as powders. Although it can now not fully be determined what obstacles are met when trying to crush the materials, information from Mohs scale of hardness and mineralogical sources provide statistics to determine these characteristics.

Characterization of the materials

Before starting with the reconstruction it is relevant to make a characterization of the different materials based on the color, weight, structure and softness [Fig. 1 and 2]. In order to do this, the manuscript is kept close and the tested materials are compared to the descriptions that are given. The author of the manuscript makes observations on the four aspects (color, weight, structure and softness) and describes the spat quite accurately, as mentioning earlier. Spat is described as a white stone *"(...) which is light, soft and malleable as flour (...)"*[34] Due to this statement, the materials are first weighed to determine their densities. As a result from weighing the powders it becomes clear there are some interesting dissimilarities. The pumice proves to be the lightest material, closely followed by the calcium carbonate. Between the feldspar potassium and feldspar soda there is a minor difference. Finally the heavy spar is, not surprisingly, the heaviest material of them all. The

[34] BnF Ms. Fr. 640: 119v.

difference is quite remarkable. Concerning color, the author practitioner describes spat to be similar to plaster of Paris: "*spalt is a white like cooked plaster"* (folio 108r). For this reason and to follow this advice, the shades of these materials are compared to each other and subsequently also to some plaster of Paris. Although most materials are white, the shade of the feldspar potassium proves to be the best match with the plaster of Paris, closely followed by calcium carbonate. The pumice, which is more brownish, resembles plaster of Paris the least. The structure of calcium carbonate is the finest and consists of the smallest granules, pumice is composed of the biggest particles. The softness of the materials (spat is malleable as flour) is tested by passing it through the fingers. The softest and driest powder is the feldspar soda and closely behind it is the calcium carbonate, which is a little more viscous. The pumice proves to be the least soft material.

Reconstruction: *a way to rework spat*

On folio 119v, the author of the manuscript describes a detailed recipe how to prepare the material spat. This is the most complete recipe comparing to others and includes instructions concerning the preparation of spat. For this reasons this recipe is the most relevant to examine the possible candidates. The recipe is as follows:

> *"Way to rework Aspalt*
>
> *You find an earth in Germany, the color of plaster, but have long and soft filaments which are easy to handle. Grind them coarsely because they are mixed with earth and filth. Then soak them into sal ammoniac's water, following the above indication, and make balls. Heat these balls in a potter's furnace. Then soak it in the same water again. Filth will remain at the bottom, and the very asphalt, which is light, soft and malleable as flour is, stick to water, remain on the top, and make water cloudy. Pour this cloudy water in another pot. Then empty water, to do that tilt your pot, or sponge the water up. The very asphalt will remain at the bottom of your pot, dry it. Then soak it into sal ammoniac's water, and use it for moulding box. If this matter shrinks in the moulding box, even if reheated and dried, you must reheat it on a good fire again, and redden it as you did for medals and flat things. This asphalt is the best matter to cast gold, silver, copper, lead and tin. Because it holds fire and reddens whenever you want, without changing. The more you use it the better it is, and does not change. First it is white, and becomes grey after being used. Take the reused asphalt for lead,*

tin and brass, but gold would get brittle, and wouldn't easily be stripped of casting. Put away each asphalt separately depending on each metal."[35]

Because of the numerous stages in the recipe, it will be carried out step by step in different experiments. The first step in the reconstruction is making the sal ammoniac water and moisturizing the powders with this water in order to make balls of it. The powders used in the reconstruction are fairly pure and not mixed with earth and filth as the spat the author describes, therefor it is not necessary to grind the powders. It is interesting to examine how the different kind of materials reacts in the sal ammoniac water and if it is possible to make balls out of them. The second step in this experiment is heating the balls in a furnace, followed by grinding and soaking them. In the last step molds are made with the materials.

Preparing the sal ammoniac's water

In the first part of the reconstruction the initial process of the recipe is carried out: soaking the already grinded powders into sal ammoniac's water.[36] In order to follow these instructions, 'the above indication' of preparing 'sal ammoniac's water' is followed. This recipe can be found on folio 118v:

"(...) sal ammoniac water made of sal ammoniac the size of two walnuts, in a bottle of common water the size of a bottle in which one boils ground barley, or in a good pot of water. You should find the water fairly salty. I mixed in half a glass of sal ammoniac two silver spoonfuls of eau de vie."[37]

The recipe of this sal ammoniacs water describes the quantities of the sal ammoniac and eau de vie, but the amount of water added is rather unclear. For this reason it is relevant to compare the recipe of sal ammoniac's water with recipes from Platt (1594) and Huygens (1629). Platt describes mixing a bottle of water with an ounce of sal ammoniac and mingles it with aqua vite.[38] Huygens describes mixing half a bottle water with two ounce of sal ammoniac.[39] It seems that every author uses different proportions of sal ammoniac.

[35] BnF Ms. Fr. 640: 119v.
[36] Idem.
[37] BnF Ms. Fr. 640: 118v.
[38] Platt 1979: 52-53.
[39] Heer, de 1993: 283.

Sal ammoniac is ammonium chloride (NH_4Cl), which is soluble in water. It is not clear why the author of the manuscript, Platt, Huygens and others add this to the mixture.[40] The author of the BnF Ms. Fr. 640 manuscript adds the sal ammoniac to many different kinds of things. It is assumable that it has more to do with a kind of superstition. Nonetheless, the sal ammoniac water is added to the water because in this manner the recipe is reconstructed as precisely as possible. In the reconstruction, one tablespoon of sal ammoniac was mixed with 800 millilitres water. Because sal ammoniac could be harmful when swallowed, the saltiness of the water was not tested, although the manuscript advices to do. In the next step, 'eau de vie' was added to the sal ammoniac water. 'Eau de vie' is French for a clear, colorless fruit brandy. This is another ingredient the author uses a lot in his recipes. Unfortunately, in the manuscript there is not a specific description of which kind of brandy he uses. For this reconstruction it seems acceptable to use a cognac.[41] In the 200 millilitres of the sal ammoniac water two tablespoons of cognac where added.

Mixing the materials with the sal ammoniac water

The recipe does not report the amount of sal ammoniac's water added to the material.
The author describes on folio 119r that *"Good sand when moistened does not stick at all to the hand when pressed."*[42] Platt reports that the *pap* should not be too stiff [43] and Huygens mingles the powders with the sal ammoniac water until it sticks to the fingers when pressed but it should not be too wet.[44] From this information the conclusion can be made that the authors reports the properties of the mixture quite differently. For this reconstruction the sal ammoniac water was added per 10 millilitres in order to control and monitor the experiment.

It is also not evident why the author makes balls of the spat, there is no explanation in the manuscript and it is unclear what size of the balls should be. Huygens also makes balls of the spat: as big as a fist.[45] Since this is the only description, the decision was made to make similar balls of each material, which are a little smaller than a fist because this size would be more practicable for the experiments. In order to compare the balls after the following steps in the reconstruction, three balls were made from each material. Since the powders differ in weight, a plastic cup was filled with each

[40] Professor of chemistry of conservation and restoration dr. N. Tennent could not think of any chemical reason why sal ammoniac is added.
[41] Hennessy Fine de Cognac, Qualite rare, 40% vol.
[42] BnF Ms. Fr. 640: 119r.
[43] Platt 1979: 52.
[44] Heer, de 1993: 283.
[45] Heer, de 1993: 282.

material and with that quantity one ball was made. In this manner the soaked materials were all formed into balls [Fig. 3, 4 and 5], as the recipe describes.

Each different material absorbs another amount of moisture before it is possible to form balls. Pumice requires the most water and becomes dark brown. Both the feldspars require the same amount of fluid and become a compact ball that cracks when squeezed, because of the lack in plasticity [Fig. 6]. The heavy spar and the calcium carbonate absorb the moisture very fast and both become malleable like clay.

Heating

Finally, the balls are put onto a fire resistant plate and heated in a potter's furnace [Fig. 8]. Since the author of the manuscript or other publications mentioned earlier, do not give any instructions about the temperature or time of which the balls should be heated, the decision of the heating process was made in deliberation with Mrs. K.E. van Lookeren Campagne, an expert from the department of ceramics. Mrs. van Lookeren Campagne is lecturer in conservation of ceramics and glass at the University of Amsterdam and has a lot of experience and knowledge of pottery and the use of furnaces through the ages. The temperature (850 degrees Celcius) and time (one hour) chosen, reconstructs the recipe as accurate as possible and is based on knowledge about the maximum heat a potter's furnace reached in the end of the sixteenth century. The heating process and chemical reaction of calcium carbonate, is also taken into account. The heating of these balls is presumed to result in some sort of chemical reaction. Due to the release of carbon dioxide in the case of this last material, the balls are put in the oven separate from the others.

Grinding

The balls have changed a lot by the heating process [Fig. 7 and 9]. The size of the pumice balls is greatly reduced and it has become hard like stone. The color has furthermore changed to a more dark/reddish brown. The heavy spar turns into dark grey and has forms a shell during heating which breaks off on the surface. A soft, powdery substance covers the surfaces of both feldspar's balls. The color of feldspar potassium turns out to be pink and the color of feldspar soda more orange. The calcium carbonate balls, which expectantly have become calcium oxide through the heating process, are not visibly changed much after removing them from the furnace, although they show some cracking of the surface.

The next step of the recipe described on folio 119v is soaking the powders in the sal ammoniac water. Since it seems not reasonable to soak the balls directly from the furnace into the

water, the balls should first be grinded into powders. The author of the BnF Ms. Fr. 640 manuscript does not report this procedure, but Huygens does. Huygens mentions that the balls should be crushed as small as possible.[46] Since this is the only description, the decision was made to grind the balls as finely as possible with a mortar.

It turned out to be impossible to grind the pumice balls, which led to elimination of pumice in the further steps of the reconstruction. Also, the results from the earlier experiments are mostly negative; pumice proves to be an incorrect material for spat. It took an extensive effort to grind the heavy spar balls into fine powder [Fig. 10] but the feldspar balls where quite easily crushed into powder. It is not easy to grind the calcium balls: it even takes quite an effort. During crushing in a mortar though, the same kind of shell, or surface layer, appears to be present around the balls as seen on the heavy spar [Fig. 11]. The powder of the calcium has become more beige [Fig. 12].

Soaking

In the following step the powders are soaked in the sal ammoniac water. The other authors, Platt and Huygens mention the soaking but do not give a description of this process. The main reason of the process is probably to purify the spat from filth and earth, which is not necessary for the pure powders used in this reconstruction. It is very likely that the materials used in this experiment would sink into the bottom. For this reason the decisions was made to leave out the first part of the process because there would probably not be any heavy filth or earth which would remain at the bottom.

In his recipe the author is unclear about whether the spat is soluble or insoluble in water. His description about the behavior of the spat in the water can be interpreted in several ways. In his recipe on folio 119v the author describes that the spat sticks to the water and will make the water cloudy, which would suggest it is soluble in water. But in a sentence later, the author describes the spat remaining on the top and on the bottom, which would suggest it is insoluble in water. Since there is not a clear explanation of this ambiguity the decision was made to monitor and analyze the behavior of the different materials into the sal ammoniac water. The properties of the materials listed in table two points out that heavy spar and both feldspars are insoluble in water. If the calcium carbonate has turned into calcium oxide through the heating process it would be soluble in water.

In this reconstruction the heavy spar and both feldspar were separately soaked into the sal ammoniac water as mentioned before.[47] The heavy spar makes the water very cloudy but finally

[46] Heer, de 1993: 282.
[47] The powders of two balls were soaked into 600ml of sal ammoniac water

everything sinks to the bottom, leaving a layer of almost clear water on the top. The feldspar potassium and soda make the water a bit cloudy in the beginning, but become submerged quite fast after that [Fig. 13 and 14]. This experiment shows the insolubility of all three materials. Another approach (more controlled and safer) is chosen for the experiments with calcium oxide, because the expected chemical reaction of calcium oxide in combination with water is supposed to produce heat. The calcium oxide mixed with a small amount of water reacts to form the slaked lime.[48] The powder in water, produces heat, as expected, and calcium oxide completely dissolves in the water to form a milky, white fluid [Fig. 15 and 16].

Making molds with the materials

The fifth and last step of the reconstruction is meant to examine the utilization of these matters as a molding material. The various materials were examine on shrinking and cracking. Unfortunately it is not evident for which exact casting the author uses spat. On one hand the author mentions spat being excellent sand for box molds on several folios, which could indicate sand casting. But on the other hand the author describes casting an animal or lizard with the spat, which could suggest the technique of life-casting.[49] Since the technique for which spat is used is not evident, the decision is made to prepare different types of molds for each material: one with a sand structure to imitate sand-casting, and one in a more liquid state to reconstruct life-casting in a plaster [Fig. 17 and 18]. In both techniques it is desirable to make a good imprint of an object.

In the sand molds an imprint is made on top of it, but this proves unsuccessful for the feldspar potassium and soda. Besides, the feldspar's sand molds show many large air bubbles and cracks after drying [Fig. 19]. It is possible to make an imprint in the heavy spar but the granules are too coarse which made the print less detailed. After drying, the texture of the sand mold of heavy spar is still too rough and lacks cohesion. It is also difficult to make a print in the sand mold of the slaked lime: the forms keep adhering to the material and eventually break the molding material. After drying the print in the sand mold, it shows some sharp details [Fig. 20].

The reconstruction of the life-casting is done by leaving a simple, round releasable figure on the bottom of the form and pouring the liquid mixture of each material on top of it. Despite the liquid mold of heavy spar turning out less rough than seen in the sand mold, the material shows many gaps inside the print. Although it is impossible to take the figure out of the tray without breaking the mold,

[48] The powders of two balls were soaked into 300ml of sal ammoniac water
[49] BnF Ms. Fr. 640: 119v.

the prints in both feldspars result in quite sharp details around the edges [Fig. 21 and 23]. Also, the density of the feldspars from the mold that was poured as a liquid is quite compact and has a lot less air bubbles than the other ones. Unfortunately it is not possible to take the liquid molds of slaked lime out the forms. For these reason the print that was made in the bottom of the mold cannot be analyzed [Fig. 22].

Conclusion

It can be concluded from the previous literature study and subsequent experiments that a search of the material spat is not as straightforward as one might think. Although the material seems to have been common in the time the manuscript was written, and various sources can be found to account its use and existence, the exact meaning of the term has become quite unclear. All that is left are descriptions of characteristics and utilizations. Therefore, the research done in this study has focused on this information. Based on a survey of relevant literature, combined with the descriptions from the manuscript, a number of minerals and materials were selected and tested on properties and behavior. From these experiments can be concluded that (both varieties potassium and soda) feldspar could be a material that is suitable as molding material, although the temperature with which it was prepared in the experiment was too low to lead to any chemical changes. This raises questions about why the materials were heated at all. The values used in these experiments were based on an estimation of temperature that could be reached in a late 16^{th} century potter's furnace. The chemical change of feldspar for example, as with the preparation of the pigment *smalt*, would presumably lead to a glassy material that would not be suitable for molding. Also, the naturally occurring mineral feldspar does not correspond to the softness described in various sources. The calcite, or calcium carbonate, that was tested leads to more positive expectations, as during the preparation there is both a chemical change and a utilization of the obtained product in plaster and cement. Also, the calcium hydroxide that is produced allows making a sharp impression, but the material is fragile and brittle, which makes it unusable for sand casting. The materials pumice and barite did not prove satisfactory at all in the experiments or in the cast simulations. Both materials are therefore considered unsuited as a candidate for the material spat.

Further research

In order to conclusively find out what the material spat from the BnF Ms. Fr. 640 manuscript is, it is recommended to further investigate the subject. There are still a lot of uncertainties and although

there are results to show for the experiments, there is still a range of experiments, which could be carried out for a better understanding of the behavior of the different candidates for spat. It is hardly possible to say in this stage if the materials tested are the correct ones. Some do correspond to the characteristics more than others do. The next step would be to examine the fire resistance of the remaining materials. As the author of the manuscript describes, spat is excellent sand for casting because *"(...) it holds fire and reddens whenever you want, without changing."*[50] It would subsequently be interesting to analyze the color change of the materials, as the spat should turn from white into grey after being used.[51] If these experiments result in a likely candidate for spat, a final suggestion would be to try the material in a mold for casting metal. Although it is unsure whether spat was used in the mold alone or if it was mixed with earth or the regular plaster mixture, Platt describes spat being used alone as well as in a mixture. (Platt 1594, 52) Both these options could be tested in a later stage.

In addition, it could be interesting to consult a mineralogist specialized in deposits in the region of Augsburg. Although during this research contact was sought with multiple German scientific sources, none answered back.

Acknowledgments

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[50] BnF Ms. Fr. 640: 119v.
[51] Idem.

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Appendix 1 Photos

Experiment 1: Characteristics

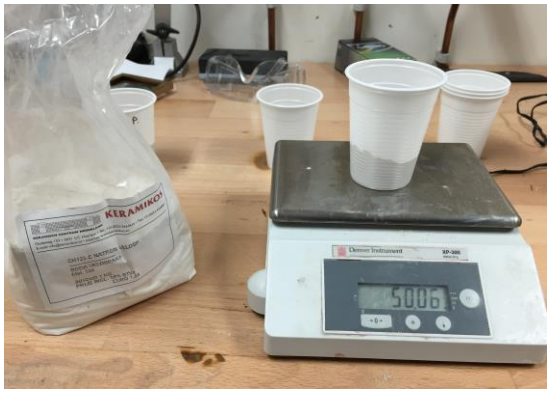


Fig. 2: Determine the colors

Experiment 2: Preparation of spat

Fig. 3: Preparing the balls

Fig. 4: Mixing the powder with the moisture, in this photo heavy spar.

spar soda

Experiment 3: Grinding the balls

In this photo left: calcium carbonate, right: calcium oxide

Experiment 4: Soaking the powders

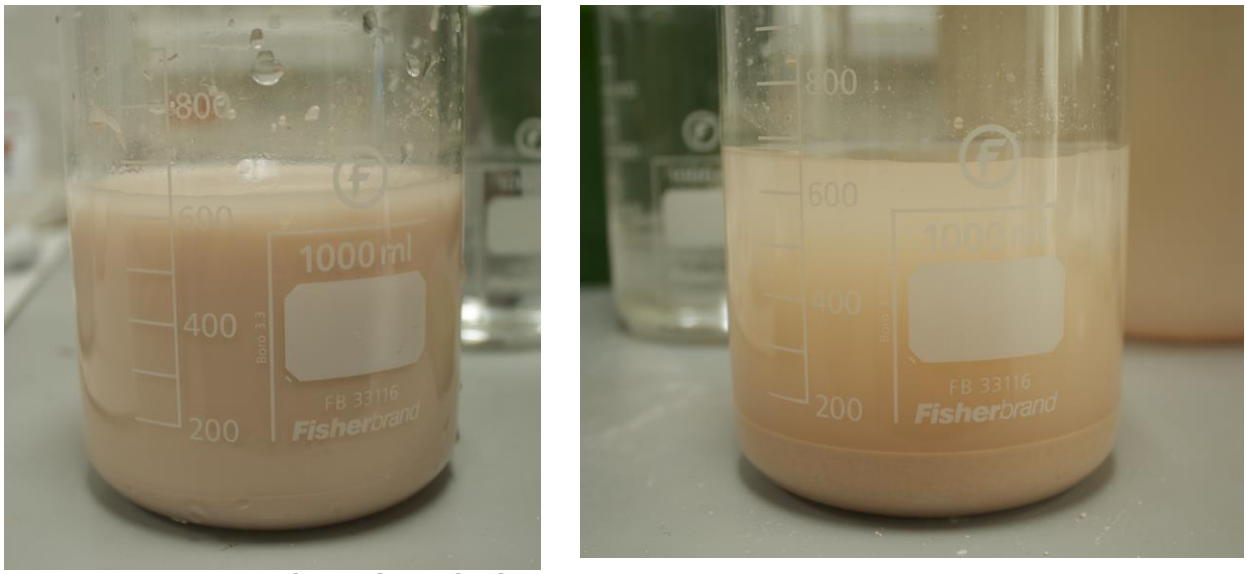


Fig. 14: Mixing the powders with sal ammoniac water. In this photo feldspar soda.

l ammoniac
ım.

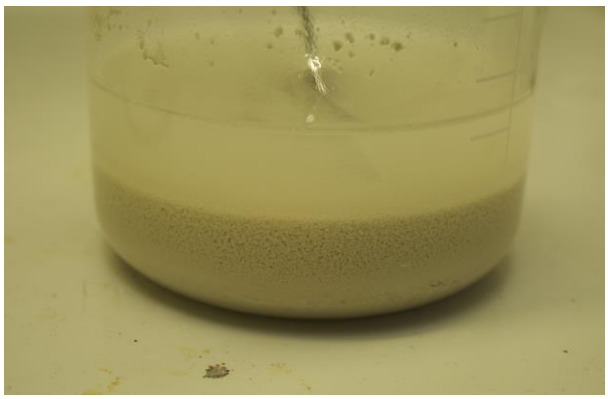


Fig. 15: Mixing the calcium oxide with sal ammoniac water.

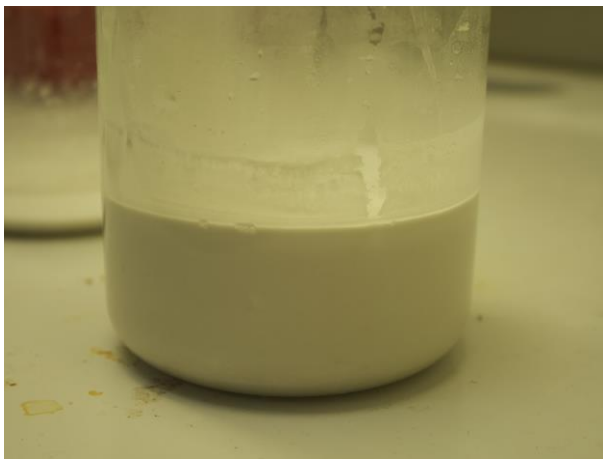


Fig. 16: The reaction of calcium oxide with water formed slaked lime.

Experiment 5: Making sand- and liquid molds

d

Fig. 18: The results of the sand- and liquid molds. From top to bottom: heavy spar, feldspar potassium and feldspar soda.

Fig. 19: The sand molds after drying

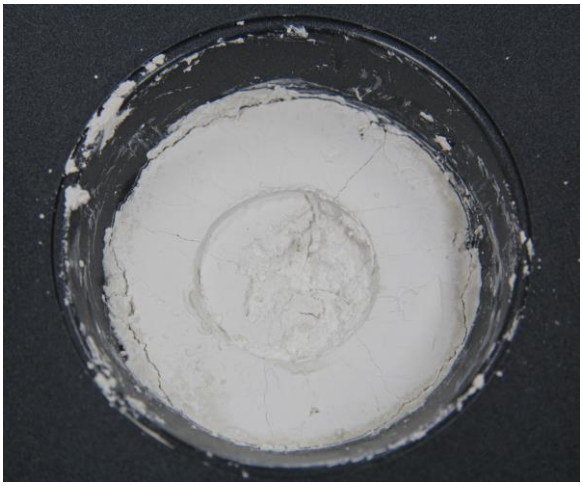
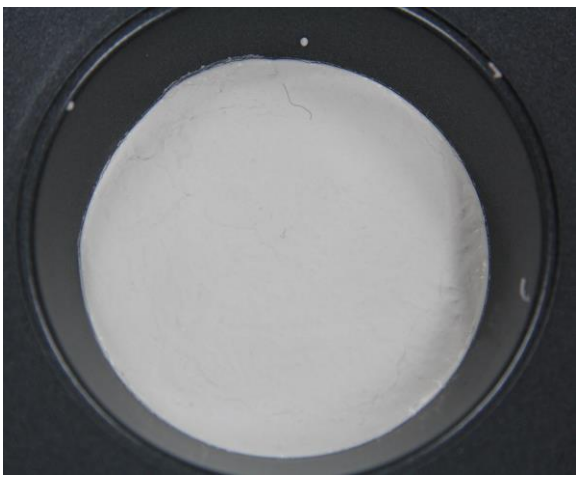


Fig. 20: The sand mold of slaked lime after drying



old of slaked lime after

drying

g. 23: Close-up of the liquid mold of feldspar
da

Appendix 2 Folios

041r (aspalte), 058r (laspalthe), 066r (aspalte), 085v (laspalte), 106r (laspalte), 108r (le spat, le spalt), 119r (laspalt), 119v (As~~pals~~pat, aspalte, le spat), 137v (le spat).

1. Transcription [tc_p041r, 12 March 2015]

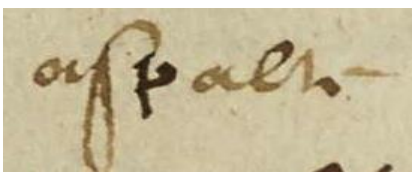
<title id="p041r_a3">**Sable**</title>

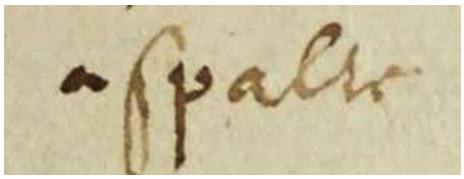
<ab id="p041r_b3">Le **sable** doibt estre ~~jecte~~ pour gecter choisi non pas si aride<lb/>
quil naye poinct de prise Ne trop gras aussy Et combien quil<lb/>
sen trouve de naturel Touteffois ce nest pas par tout Et si<lb/>
tu es en lieu quil ne sen trouve poinct Tu le peulx composer Mays<lb/>
non pas avecq **terre** grasse car le **sable** nen veult aulcunem{ent} car<lb/>
elle faict soufler bien fort Mays tu luy peulx donner liaison<lb/>
avecq de la **brique** fort broyee sur le **mable** ou **plastre** ou **albastre**<lb/>
calcine ou chose semblable ou **moelle de corne de boeuf** bruslee<lb/>
ou **aspalte** brusle parmy Si tu le broyes bien subtillem{ent} sur<lb/>
le **porphire** il ~~s~~ adquiert prinse & puys tu le peulx brusler<lb/>
avecq **aspalte** ou le mesler dune quarte partye de **tripoly** Garde<lb/>
quil ne tumbe de **pain** dans ton **sable** Car cela faict fort<lb/>
soufler</ab>

Translation [tl_p041r, 12 March 2015]

<title id="p041r_a3">Sand</title>

<ab id="p041r_b3">The sand to be used for casting should be chosen such that it is not too dry for it won't hold together, nor should it be too fat. And although you find some in nature, however, it is not everywhere. And if you are in a place where it is not found, you can put it together yourself but not from fat earth, because the sand should contain none at all, since it causes a lot of air bubbles. But you can make a connection by mixing it with brick well ground on marble, or plaster or calcinated alabaster or something similar, or the burned marrow of ox horn or burned **asphalt.** If you grind it quite finely on porphyry, it holds together better & then you can burn it with **asphalt** or mix it with a quarter of tripoli. Make sure no bread falls into your sand because this causes a lot of air bubbles.



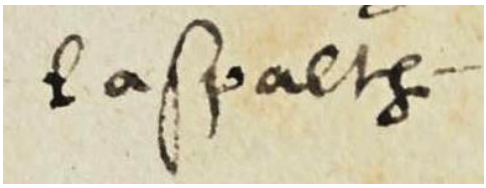


2. Transcription [tc_p058r, 12 March 2015]

<ab id=”p058r_b1c”>
Le cristallin estant broye a eau semble avoyr corps Mays a huile il nen ha point Il se broye aveq la laque et aveque **laspalthe** qui ne seicheroient de fort long temps sans cela </ab>

Translation [tl_p058r, 12 March 2015]

<ab id=”p058r_b1c”>
Crystalline ground with water seems to be thick unlike when it is ground with oil. It can be ground with some lacquer and **aspalth** which wouldn’t dry but after a long time without any of it. </ab>



3. Transcription [tc_p066r, 12 March 2015]

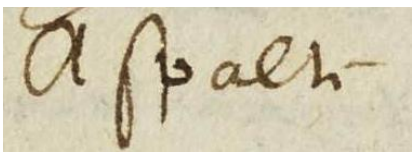
Ombres </title>

<ab id=”p066r_b2”>
Pour femme **aspalte** terre dumbre et un peu de laque

Translation [tl_p066r, 12 March 2015]

Shades </title>

<ab id=”p066r_b2”>
For woman, shadowed areas can be made from **asphalt,** umber and a bit of lacquer </ab>



4. Transcription [tc_p085v, 12 March 2015]

<title id=“p085v_a3”>**Sable** de mine</title>

<ab id=“p085v_b3”>Il veult estre bien recuict pour les grands **metaulx** Aulcuns<lb/>
le bruslent au four jusques a ce quil soict bien noir Et le<lb/>

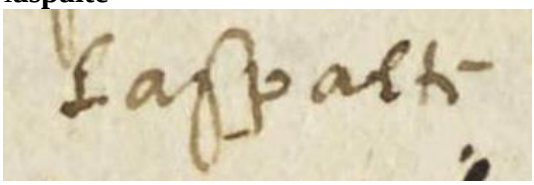
subtilient sur le **porphire** Aultres le bruslent avecq de<lb/>
l**aspalte** Mays quand il est trop brusle il ne moule pas si net<lb/>
pourcequil nha pas de corps et est trop maigre tu luy en pourras donner avecq du **tripoly** ou<lb/>
feultre brusle</ab>

Translation [tl_p085v, 12 March 2015]

<title id="p085v_a3">Sand from a mine</title>

<ab id="p085v_b3">It wants to be well recooked for big metal [objects]. Some people burn it inside a furnace until it becomes quite black and they grind it on the porphyry. Other people burn it with **asphalt**, but when it is too burned, it does not mold so cleanly, because it lacks body, and is too thin. You can give body to the sand with tripoli or burned felt.</ab>

l**aspalte**



5. Transcription [tc_p106r, 12 March 2015]

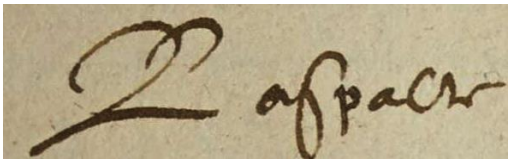
<title id="p106r_a1">Pour gect</title>

<ab id="p106r_b1">L**aspalte** ~~est~~ qui se trouve en Allemaigne est le plus excellent<lb/>
sable pour mouler en chassis qui se puisse trouver Car il est<lb/>
propre pour l**argent** & pour l**o**r & tant plus il sert et est vieulx<lb/>
il est meilleur On y moule fort tanvre & subtil</ab>

Translation [tl_p106r, 12 March 2015]

<title id="p106r_a1">To cast</title>

<ab id="p106r_b1">**Asphalt** from Germany is the most excellent sand you can find for molding in a box frame, because it is fitting for silver & for gold. And the more you use it and the older it is, the better it is. With it, one molds very slender & subtle things. </ab>



6. Transcription [tc_p108r, 12 March 2015]

<ab id="p107r_b2n">Le **spat** est une **pierre** blanchastre qui se trouve en<lb/>
allemaigne & principallem{ent} a Auguste de quoy on se sert pour<lb/>
le plus excellent **sable** qui se puisse trouver pour **plomb**<lb/>
estain cuivre argent & **or**. Et tant plus il sert tant plus<lb/>
il est meilleur Il est propre pour gecter en chassis choses<lb/>
plattes pour choses rondes il nest pas si duisant ne<lb/>
si tenant au feu que le susdict compose de **plastre**</ab>

<title id="p108r_a1">**Spalt**</title>

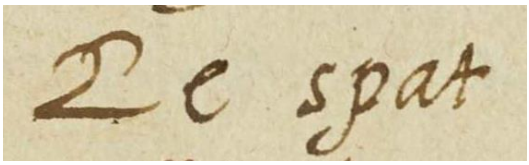
<ab id="p108r_b1a">Le **spalt** est blanc comme **plastre** cuict Et se trouve en monceaulx<lb/>
& pierres faictes a longues escailles & longs filets il est fort tendre<lb/>
de sorte quavecq longle on le peult racler & en faire pouldre c{omm}e<lb/>
de n{ost}re **croye** de champaigne Et pourceque toute chose qui provient<lb/>
des la **terre** est mellee de quelque aultre substance pour le<lb/>
purifier on le broye venant de la **piererie** asses grossierem[{ent}] puys<lb/>
on le destrempe avecq de l**eau de sel armoniac** En mecta{n}t la<lb/>
grosseur dune noix diceluy dans une grande bouteille d**eau** Et</ab>

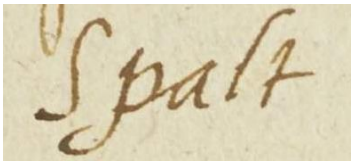
Translation [tl_p108r, 12 March 2015]

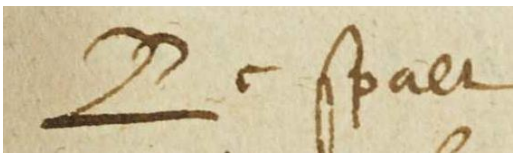
<ab id="p107r_b2n">**Spalt** is a whitish stone which can be found in Germany, mainly in Augsburg from which can be made the most excellent **sand** that can be found for [casting] **lead**, **tin**, **copper**, **silver** and **gold**. And the more it is used, the better it is. It is clean for casting flat things in a frame. For rounded things, it is not as attractive [because it] does not hold in the fire as the aforementioned [things] composed of **plaster**.</ab>

<title id="p108r_a1">**Spalt**</title>

<ab id="p108r_b1a">**Spalt** is white like cooked **plaster** and one can find it in mounds and stones made in long stairs and long veins. It is very soft such that with a fingernail and it makes a powder like that of our **chalk** from Champagne. And because everything which is provided from the **earth** is mixed with some other substance, to purify it [the spalt], one boils it with somewhat large **gemstones** then tempers it with **essence of sal ammoniac**. One puts [a lump of it] the size of a walnut in a large bottle of **water** and</ab>







7. Transcription [tc_p119r, 12 March 2015]

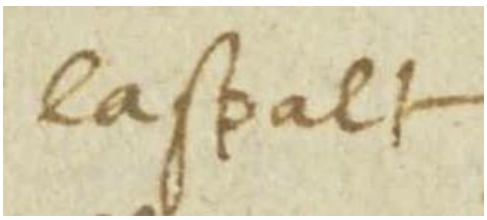
<ab id="p119r_b1e">
Le bon **sable** ne prend poinct a la main en le pressant esta{n}t humecte </ab>

<ab id="p119r_b1f">
Le parfaict ~~sable~~ pour le chassis est l**aspalt** qui se trouve en </lb>
Allemaigne qui est doux co{mm}e **farine** ~~& presque~~ estant mouille & presque </lb>
tous les auttres sont grumeleux </ab>

Translation [tl_p119r, 12 March 2015]

<ab id=”p119r_b1e”>Good **sand** when moistened does not stick at all to the hand when pressed.</ab>

<ab id=”p119r_b1f”>The perfect sand for the box frame is the **asphalt** found in Germany, which is soft as wet flour, & almost all the rest are lumpy.



8. Transcription [tc_p119v, 12 March 2015]

<title id=”p119v_a1”>
Facon dacoustrer **As~~pals~~pat**</title>

<ab id=”p119v_b1”>
Il se trouve en terre en allemaigne de couleur de plastre cuit fait a longs filets fort doux a manier Et pourcequil est mesle de terre et ordure On le pile grossierement et on en faict des pelotes layant pour ces effect destremper en eau de sel armoniac de telle composition quil ta este dit cy dessus on met recuire ces pelotes a feu de la fornaise des potiers Puys on le destrempe encore en mesme eau la terre et le grossier et ordure bout a fonds et le pur **aspalte**

qui est leger et doux et maniable comme farine destrempe adhaere avec leau et a la superficie en brouillant leau laquelle trouble se vuide en un vase a part Ayant rester on vuide leau par inclination ou bien on la retire avec un esponge Et le pur **aspalte** demeure au fonds desseiche le et lemploye en chassis estant humecte deau de sel armoniac et lessaye au chassis dans lequel sil se retire estant recuit ou desseiche cest adire quil le fault encore recuire a bon feu et le rougir ainsy pour medaille et choses plattes sers toi de cestuy cy car cest le plus parfait de tous pour or argent cuivre plomb letton et estain Car il soustient le feu et se rougis quand il est besoin sans se corrompre Et tant plus il sert tant plus il est meilleur et ne se gaste point Au commancement il est blanc et servant il vient gris touteffois prens gare de metre a part celuy qui a servi pour gecter plomb et estain et letton car lor si aigriroit et ne viendroit pas bien et pour mieux faire tu pourras metre a part diceluy pour servir a chaque metal </ab>

<note id="p119v_c1a">
Il endure dix ou douze gects sans se corrompre il soustient le feu et se rougist il est propre pour tous metaux Il est si tenace que pour peu quen […] chassis soict canelle il tient. </note>

<note id="p119v_c1b">
Le spat ne faict presque poinct de prise bien quil soit espece de plastre ou il se rompt aysement avecq les doigts </note>

<title id="119v_a2">
Excellent secret pour mouler creux et fort subtil en or fin </title>

<ab id="p119v_b2">
Jecte avec ton sable susdict ton animal et lezard ou autre chose avec argent de billon et viendra fort net Mays advise de le mouler creux ou ly laisser a tout le moins un trou dans laquelle ou autre endroit apres dore le dor fin le plus uniment quil te sera possible trois ou quattre ou cinq fois et jusque a ce que ton or puisse avoir lespesseur dun papier ou autre suffisante et toutes les escailes se nousteront tousjours esgalle Apres met le dans leau fort bonne qui par ce trou corrodra le billon et lor demeurera creux et leger et admirable. </ab>

Translation [tl_p119v, 12 March 2015]

<title id="p119v_a1">
Way to rework **Aspalt**</title>

<ab id="p119v_b1">
You find an earth in Germany, the color of plaster, but have long and soft filaments which are easy to handle. Grind them coarsely because they are mixed with earth and filth. Then soak them into sal ammoniac's water, following the above indication, and make balls. Heat these balls in a potter's furnace. Then soak it in the same water again. Filth will remain at the bottom, and the very **asphalt**, which is light, soft and malleable as flour is, stick to water, remain on the top, and make water cloudy. Pour this cloudy water in another pot. Then empty

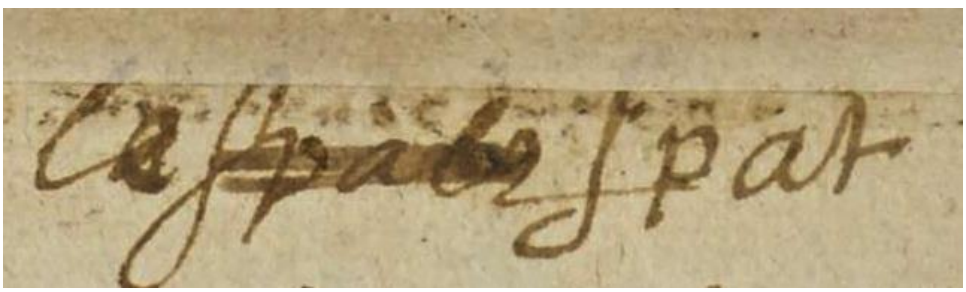
water, to do that tilt your pot, or sponge the water up. The very **asphalt** will remain at the bottom of your pot, dry it. Then soak it into sal ammoniac's water, and use it for moulding box. If this matter shrinks in the moulding box, even if reheated and dried, you must reheat it on a good fire again, and redden it as you did for medals and flat things. This **asphalt** is the best matter to cast gold, silver, copper, lead and tin. Because it holds fire and reddens whenever you want, without changing. The more you use it the better it is, and does not change. First it is white, and becomes grey after being used. Take the reused **asphalt** for lead, tin and brass, but gold would get brittle, and wouldn't easily be stripped of casting. Put away each asphalt separately depending on each metal. </ab>

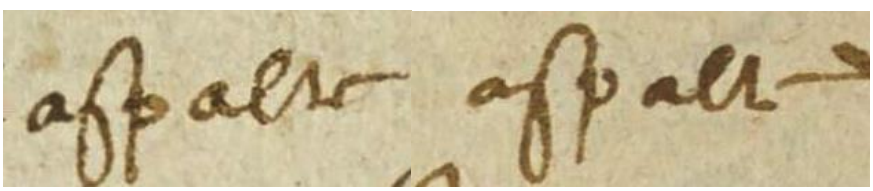
<note id="p119v_c1a">
Asphalt enables 10 or 12 casts without changing, it holds fire and reddens. It is usable for every metals. […] </note>

<note id="p119v_c1b">
Asphalt hasn't so much body, even if it is a kind of plaster, and you can easily break it with your fingers. </note>

<title id="p119v_a2">
Excellent secret to mould hollow and very finely fine gold </title>

<ab id="p119v_b2">
Cast your animal or lizard or other thing with the above mentioned sand, with alloyed silver you'll get a very neat cast. But be sure to mould hollow, or at least make a hole. Then gild your animal with fine gold, it must be the most homogeneous possible, gild 4 or 5 times, until your gold becomes as thick as a piece of paper, scales must remain as they were. Then dip your cast into aqua fortis or into good water, it will corrode the alloyed silver through the hole, but gold will be hollow, light and wonderful. </ab>



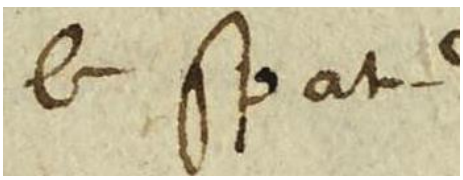


9. Transcription [tc_p137v, 12 March 2015]

<ab id="p137v_b1e>Les rascleures des moules peuvent encores servir lemploya{n}t<lb/>
au lieu de **brique** apres les avoir recuits & les lopins aussy<lb/>
des moules qui ont servy On en lute aussy les choses<lb/>
dimportance co{mm}e ouvrages d**or** ou d**argent** On le recuit<lb/>
aussy & on lacoustre avecq ~~se~~ **eau de sel armoniac** comme<lb/>
le **spat** dallemaigne & est excelelnt **sable** pour chassis pour<lb/>
tous metaulx</ab>

Translation [tl_p137v, 12 March 2015]

<ab id="p137v_b1e>The scrapings of the mold can also be used instead of bricks after being reheated, and also the leftover bits of the mold that have already been used. You can also pat it over important things, like works in gold or silver. You can also reheat it and blend it with water diluted with sal ammoniac, like **spar** from Germany, and is excellent sand for box molds for all metals.</ab>



Appendix 3 Logbook

Literature study

Week 1 **4-9 February**

The first week of this project is started with an assignment on reading and interpretation of historic texts. These texts are chosen from well-known works and discuss primarily the use of furnaces in order to smelt ores or metals for further production.

El Arte de los Metales, Alvaro Alonso Barba (first published in 1640)
Alvaro Alonso Barba was Master of Arts and curate of the Parish of San Bernardo, Potosí, Bolivia. *El Arte de los Metales* was approved in 1637 and recommended to the crown for publication. First published in Spain in 1640 and reprinted in 1675 and 1729. Translated from the Madrid Edition of 1729 into English in 1923 by Ross E. Douglas and E. P. Mathewson, it was the earliest published work on American Metallurgy.
El Arte de los Metales consists of five books. The first book summarizes geological knowledge of Barba's time. Many Latin mineralogical terms, amongst others are taken from Pliny, Dioscorides, Strabo, Galen. The Latin mineralogy of Encellius in *De Re Metallica* has been found to be of help in translating the first book. Books two to five are based on his knowledge, acquired by years of active work in mining and ore treatment in a region of rich silver mines.
Chapter six. Furnaces for smelting with charcoal (p. 197).
Barba discusses three kinds of furnaces. *Hornos Castellanos/*Spanish furnaces for smelting all sorts of ores, *Guayras* or wind ovens and *Tocochimbos,* which are ovens like the *muffle furnaces* used by silversmiths and for cupelation. He describes the construction of these ovens, how they were built and used. The text also provides some illustrations, but it is not sure if these were part of the original work.

Willen van Laer: *Weg-wyzer voor aankoomende Goud en Zilversmeeden*, 1721.
Van Laer was one of the first who has written down all about the gold- and silversmiths practices in the Netherlands. The book contains the original text written in Old Dutch in the 18th century and was widely sold and released in 1721, 1730 and 1786. His recipes are written from his own knowledge and experiences.

On pages 200 until 203 he describes how a wind-furnace should be built for melting metal. To understand the descriptions of van Laer about his wind-furnace the text should be read several times. In general, the explanation of building up the furnace is clear and expanded. The drawings, which are included in the beginning of the book, are relevant to the interpretation of his text, although they had to be studied various times in order to understand it.

One problem with interpreting his instructions of building the furnace is the measurements in 'feet', a length that is time-limited and not conclusive. The greatest

difficulty in the interpretation is the order of the text: it is not chronological and logical. It is clearly a description that is written from his own thoughts without having applied a logical structure of how to build the furnace.
Conclusion:

The reading and comparing of these previous texts, makes clear that interpretation can be difficult. Also, interpretation can vary from one reader to another. When working with historic texts, you must be careful not to interpret without thought. It is important to understand who exactly wrote the piece and what his or her motives might have been. Texts can be translated in multiple ways and interpretation also is dependent on background. Are illustrations original or added later, does the author write from experience or theory?

Week 2 **10-16 February**

At the start of this week we have discussed the texts that were read during the week. Afterwards, the assignments regarding the Making and Knowing project are divided amongst the students. The central focus of this study at this point is the use of spath in the production of molds used to life-cast animals and plants.

We started this study with a visit to the Rijksmuseum, Amsterdam, to see the table piece (1549) by Wenzel Jamnitzer. His work is an outstanding example of the technique of life-casting plants and small animals. The work of Jamnitzer is related to the instructions in the Manuscript, not only for the life-casting technique that was used for great parts of the piece, his work was also contemporaneous to the manuscript. Furthermore, like the author of the manuscript, Jamnitzer also worked from central Europe and might have made use of a similar selection of materials.

Manuscript, *BnF Ms. Fr. 640*
Having access to the manuscript through Google Drive, we set out finding all pages where the manuscripts mentions molding of sand mixtures and talks about the material ‘spalt’ (folio 108r) and ‘alum de plume’.

Making sand mixture:
The author of the manuscript describes which sand mixture should be used for life-casting and casting medals. An important thing for this mixture is grinding the different ingredients as fine as possible. After grinding it should be sieved for the best result. (106v)
The sand mixture consists of:

4 parts ground **plaster** (preheated)
2 parts red **tiles** from roofing
1 part **stone alum**

The best plaster is the hard one, from raw stones, which does not crumble into powder when rubbing it with the fingernails. The plaster should be cleaned very accurately to remove dirt. To prepare the plaster it is best to boil the stones in the fire while stirring. The plaster will turn from heavy to light and becomes manageable, as if it were water.

Boil and stir the plaster until its heavy and thick again. Cool the plaster off before you mix it with the rest. (106v)
The plaster from Paris is a good material to use and also is the one from Spain, which is a very hard stone and looks like white salt. (159v)

The tiles which should be used in the mixture are the ones that cover houses. They are hard and should be cleaned of stones and large gravel. Before grinding and sieving them, it is necessary to reheat them until they have been quite red for a couple of hours. (106v)

Stone (or: rock/feather) alum is a very important ingredient in the mixture because it binds the sand and allows the sand to withstand the fire without cracking or breaking the mould. At this point it is not clear which material the author is referring to, it might be interesting to investigate this further. It is difficult to grind and sieve this material (because it is woolly and fat), it must be grinded on a marble slab or in a mortar. Another benefit of stone alum is that it will soften the mold (107r). Before using stone alum it must be reheated in fire, so that the impurities will be burned out. After this it can be crushed in a mortar and ground more finely on marble (108v).

All these powders should then be mixed. Do not forget to moisten the sand with a little sal ammoniac (117v).

Contemporary sources

To start our research into *spat*, not only do we find it interesting to examine the manuscript closely, we also think it useful to explore other historic and contemporary sources that talk about (life-)casting techniques. Important works of reference are for example Hugh Platt's *The jewell House of Art and Nature* (1594), letter correspondence of Constantijn Huygens (1629), Johannes Kunckel's *Ars Vitraria* (1689) and Johann Georg Krünitz' *Oekonomische Encyklopädie* (published between 1773 and 1858).

Hugh Platt, *The Jewell House of Art and Nature* (1594)

In his book *The Jewell House of Art and Nature* from 1594 Platt describes stepwise how to prepare a mixture, composed of different kind of materials, which could be used for life-casting. Before you can mix the plaster with other powders, it should be roasted and broken into small pieces. The composition of 'the pap' consists of burnt and finely powdered alabaster, plaster of Paris and brick. For more sharp casting gypsum, alumen plumosum or spawde could be added to the mixture. *"I have seen sometimes many good patternes of metal, cast off very sharpely in spawde alone, but you must heat the flaskes well, before you poor in the metals, and you must sprincle the spawde with some moisture, wherin there is some Sal Armoniack, before you door imprint your patterns, some commend a light and downy substance, finely gathered from the upper most part of the ashes of old coales."* (Platt, 1594, 52). Finally, Platt mentions that it is important to play with the proportions of the powders, and to measure and weigh until one finds a good mixture.

Johannes Kunckel, *Ars Vitraria* (1689)

On p. 405 Kunckel mentions the use of "(a well-rinsed) Spath (a certain kind of earth or mineral which can be obtained)", which should be made into a very fine matter. It should then be deposited in a copper kettle which is suspended over a fire and which

will make the water dry up. As long as the kettle is over the fire, one needs to stir well until the substance is as hard as it was in the beginning.
One part of this burned *Spath* and another part *Federweiss* should be mixed. (...) placed in the fire and afterwards pulverized again.

Brief summary on contemporary sources
Materials that are used for molding range in terminology from *spalt, spath, spawde, plaster, alumen plumosum, alum de plum* to *federweiss*. An observation in our research is the confusion of terms that are associated to the translation of these words. What are these materials and to what extent are they similar or related? For this reason we have decided to proceed with an etymological study of the names and a research into their mineralogical background. The following information is divided into two separate files, one concerning the material *spat* and one on *alum de plume*. We decide to concentrate on the latter material as well, because it raises questions about the materials used by Kunckel and Platt. Additionally, it is the only one of the three basic materials that the Manuscript uses repeatedly and is still unclear to us at this point.

Brief summary of definition of spalt (see document spalt)
- Spalt/spat is possible fluorspar or fluorite, a flux of metals.
- Spath is possible the same as calcite/ chalkspar, or feldspar and is used as a kind of plaster for moulds.

Candidates for alum de plume (see document alum de plume)
- Asbestos
- aluin
- soapstone

Notes:
- Need to find more about spath
- The difference between calcite/chalkspar, feldspar
- More research about difference between spalt and spat. Does the author make a distinction or is it incorrect spelling?
- Which mineral is specific from Augsburg?

- Three options for alum de plume, but this is not our main subject, should we do more research or not?
- More research on asbestos.
- Could federweiss (kunkel) be the same as feather alum = alum de plume?
- We should research the word ‘aspalth’, which the author used at least one time (index: folio 106r). What does he means with aspalth? Could it be the same as spalt/spath?

Week 3 **17-23 February**

Week 3 started with a meeting with Joosje van Bennekom (Rijksmuseum), Tonny Beentjes, Tamar Davidowitz and Ellen van Bork about the research this far.

-Our results up to this week were discussed:

-Manuscript is clear on a basic recipe, which it uses to make molds for casting plants and small animals and primarily consists of alum de plume, plaster and tiles (from a roof).

-Platt also adds alabaster, "*aleblaster",* to his mixture.

-Alum de Plume: According to our research; *Alum de plume* could be meaning the Dutch *aluin*, English *alum* or *asbestos*. It is very resistant to fire.

-Spath: According to the sources found in contemporary and historic literature we conclude that there is a distinction between *spath* and *spalt/spat*. Spat is often described in relation to the fusion and flux of metals, which is something that the manuscript does not mention, for as far as we know. Spath on the other hand, is predominantly used to describe a stone, like chalk. Regarding this distinction we decided to examine the original text of the manuscript more closely, and since there is just one mention of the material, we are not perse convinced that he specifically means to add the spat to his mold. To contradict this theory though, the author does mention that "the more, the better" should be used, which is odd if it did in fact concern a flux.

-Two pages before the title of 'Le Spalt' there is mention of *Aspalt*, which is described having the same features as spat, in the sense that both "are better the more it is used" and "mold very slender and subtle things". Are these materials possibly the same or similar?

-On folio 108r the manuscript first uses "spat" and than in the title and following description "spalt". This could mean either that the author was confused or mistaken and means the same thing, or he is actually describing two different materials.

Important questions at this point:

-What kind of molding material is already tested?

Plaster, pulverized tiles, salmiak. Plaster as a binding agent, the tiles as an inert filler, salmiak to try to guarantee a cleaner casting skin of the metal.

-Wat does the author mean when he describes aspalt?

-What is the significance of 'spalt'/'spath'. Joosje van Bennekom, who has done research on the table piece by Jamnitzer, tells us to have found an article by Kunckel that describes a different recipe from the time and region of Jamnitzer. In samples from clay-like materials in between the plants on the Jamnitzer piece were found a substance that did not yield much conclusive results, except that it was yliet(?). Remarkable about the Jamnitzer piece is particularly the lack of air bubbles on the cast plants and figures. In comparison to the try-outs (of columbines) by Tony Beentjes, the Jamnitzer only has few bubbles, where the modern version had more. Does this mean there is an ingredient missing in the sand mixture?

Still to be done/found out:

-making of an outline

-Regarding spaat/spat:

-Examining aspalt more closely in all sources

-Making the distinction between spat/spath even more clear. How resistant is spat to the heat of fire according to the manuscript? Making

a distinction between the degree in which spat and spaat are resistant to heat.

-Finding a mineralogist that might help us further regarding the distinction of these minerals.

-Mail from Pamela Smith suggests that there are more recipes regarding 'aspalt'. Up until this point we only know of the one on page 106r, which is only a short piece.

Continuation study

Because in an earlier stage we already found out that the Index (provided by the BnF Ms. Fr. 640) was not complete with regard to all pages on which certain materials were used, we decided this week to leaf through the whole manuscript manually in order to find out for sure if there are no more uses of the words 'spat', 'spalt' or 'aspalt'. Additionally and unfortunately we found the translation of these words not translated consistently. Alternately translations were used like 'spar', 'spath' or 'spat'. For this reason we looked up all original pages, to try to find out exactly where and how the manuscript mentions these terms.

We found the manuscript to mention 'asphalt'/'aspalt' (inconsistency in translation) on the following pages:

041r (aspalte), 058r (laspalthe), 066r (aspalte), 085v (laspalte), 106r (laspalte), 119r (laspalt), 119v (As~~pals~~pat, aspalte, le spat), 138r (le spat).

All these pages and specifically the place where the author mentions the terms are assembled in one separate document. Because translation is dependent on the way the author has written the word, we decided to add photos of every word. With this data a comparison can be made, which might shed light on the question if the author means to make a distinction between the terms 'spalt', 'spat' and 'aspalt'. The study of his handwriting resulted in one specific case where the author has written the start of a word, crossed it through and writes 'Aspalt' instead. It is our interpretation that the author starts out, writing *Le Spa(...)* than crosses this through and writes *spat* instead. Although this is just a tiny lead to go on, it might be an indication that the author might be confused about the terminology that he uses. Our research of mineralogy has not given the idea that naturally occurring asphalt is the same material that the author is referring to.

As becomes clear from the previous, the author of the manuscript constantly uses a different spelling for the material aspalt. Also, at one point he seems to be confused in writing and corrects what he means to say.

We are now in the process of finding out what the author says about asphalt on these pages, the characteristics and use. In this order we can find out what he possibly could have meant by "the use of asphalt".

We sought contact with the Naturalis Biodiversity Center, Leiden, but unfortunately they could not help us further. Therefore we have had mail contact with a geology lecturer of the University of Leiden, faculty of archeology, Dr. Joanna Mol. Dr. Mol has given us some information about *veldspaat*, *aluin* and *asbest*, but has forwarded

our email to a colleague called dr. Dennis Braekmans. At this point we are awaiting his reply.

Week 4 **24-2 March**

Asphalt document processed:
This week, we improved the asphalt document (the document including small pictures of all places where the author writes [le] spat/[a]spalt[e]) , printed the pages and cut them in fragments. We did this because the author is not consistent in his terms and we are under the impression that he might be confused about terminology himself. We think the author might actually be meaning the same thing when he says spat, spalt or even aspalte. To prove this, we highlighted all words or phrases that keep returning throughout the document in cases where the author is referring to either one of the 'spalt terms' with a yellow marker. Examples are that he keeps commenting on "the more is used, the better it is", also "it is an excellent sand" and the material is white in color and plaster-like. We arranged the fragments first in chronological order and then tried to make clusters of similar descriptions. This lead to development of three categories:

1. Folio 058r and 066r.
   Asphalt as a color preparation, used as a primer and, adding umber and lacquer, for the painting of shades.
   <ab id="p066r_b2">
   For woman, shadowed areas can be made from **asphalt,** umber and a bit of lacquer </ab>
2. Folio 041r and 085v.
   Burned asphalt, possibly the same material as 1., but added to the sand mixture, used for molding for casting big metal objects. Used as a binding agent for the molding sand. It should not be burned too much, because this renders it too thin. It is quite unclear what the author means with this (there is no description of characteristics or colors, only that it should be 'burned' and that it is used as a bonding agent for sand mixtures). It seems that the author is here not referring to life-casting, but rather the casting of big objects. Although we are not sure, for now we will leave it at, because there are no specifics on color or appearance and there are no more clues.
3. Folio 106r until 137v
   The spalt/spat/aspalt from Germany. Very soft, excellent sand, kind of plaster, white, malleable as flour.

Our classification of number 1 and 2 are incidentally the first 4 pages on which the 'spalt term' is used. Assuming that the pages are arranged in chronological order and, except for additions in the margin, were more or less written this way, this might indicate that the author is referring to another material in this first description.

Regarding categorie 1:
On pages 058r and 066r the author mentions the material twice. Both times he

describes the material in connection to primers and shading of paintings. A meeting with the conservation department of paintings lead then to the discovery that 'asphalt' is used in manuscripts and texts more often as a pigment.
Important notes from ***Artist's Pigments: A Handbook of Their History and Characteristics, volume 4.*** **Barbara H. Berrie. 2007** Chapter: Asphalt: Catarina I. Bothe, translated by Linda Parshall, p. 111-149.

- Material asphalt is a puzzle in a historical, chemical and physical way.
- Asphalt is transparent brown *"(…) current research into the properties of asphalt in both conservation and science is still in its infancy."* (p. 111)
- Asphalt is a color preparation which consist of a mixture of organic and inorganic materials. Organic (binding medium) = bitumen = viscous dark brown residue produced by the evaporation of petroleum. Inorganic materials = various and serves as filler. Due to their extreme complexity: no chemical formula can be established. (p.111)
- *"Scientific literature is not alone in having difficulty finding the correct terminology; the confusion of terms is also present in the literature of conservation and technical investigation of art."* (p. 113)
- Result of old treaties, and manuscripts is: enormous array of contradictory statements, and synonymous terms: *bitume de Judee, Judenpech, erdpech, bergpech, bergteer, aardpek, bergharz, judenharz, judenleim.* (p.113-115)
- First references to use of asphalt as a pigment: 1584 roma. Paint called: spalto, aspalto. (p.113)
- Valuable for underpainting, and recommends asphalt for shading skin.
- *"Asphalts with a high mineral matter content and little bitumen are, in contrast, brown to gray, the intensity and the tone of the color being influenced by the quantity, type, and size of the mineral particles. The colors of pulverized asphalt correspond to those of the lump: whereas pure bitumen and bitumen-rich asphalts are deep black in their pulverized state, asphalt containing much mineral matter is dark gray to brown."* (p. 121)

Conclusions from asphalt as a color preparation:
It is chemically and physically unclear what the material asphalt is in the context of art and paint. The most important conclusion regards the color of the raw asphalt, which is brown to grey. It is used as under paintings and shadows in paintings. This could mean that the author of the manuscript distinguishes different kinds of asphalt; when he describes asphalt as an excellent sand, the color is white. This supports the idea that we had: with the word asphalt related to casting he probably means the same as with the word spalt and spat.

The 1849 publication *Original treatises dating from the XIIth to XVIIth centuries, on the arts of painting, in oil, (…)* by Mary Philadelphia Merrifield, also redirects us in the index from *spalto* to *asphaltum,* which is an indication that at least in the craft of art and paintings, these terms were used alternately.

Asphalt category 3:

Different kinds of spellings but the descriptions and characteristics correspond. (see below)

Spelling chronological in manuscript:
106r Laspalte
107r Le Spat
108r Spalt
Le spalt
119r laspalt
119v L ~~espa(..)~~ Spat
aspalt
aspalt
Le Spat
137v Le Spat

Laspalte/ laspalt	**Le spat / spalt**
From Germany, excellent sand to cast subtile and slender things. (106r, 119r)	From Germany, mainly Augsburg, and one of the best sands for casting metals. (107r) (137v)
The older and more used, the better it is. (106r)	The more it is used the better it is. (107r, 137v)
The color of plaster, with long soft filaments. (119v)	It is white like cooked plaster (108r, 119v) and found in stones with long stairs and veins. (108r)
Mixed with filth so to purify it, it should be ground and soaked in Sal Amoniack. (119v)	To purify it: boil it with gemstones and temper with essence of Sal Ammoniack. (108r, 137v)
It is soft, light and malleable as flour. (119v)	It is very soft and breakable with the fingernails into powder. (108r, 119v)
Fire resistant (119v)	<u>It does not hold in the fire as the aforementioned things(?) composed of plaster. (107r)</u>
Turns after use from white to grey. (119v)	Whitish stone. (107r, 108r)

For casting gold, silver, copper, lead, tin. (106r, 119v)	For casting gold, silver, copper, lead, tin. (107r)

Concluding from the previous chart it becomes clear that the author might be confused about the spelling of the word. *Laspalt* for example, could also be read as: *le spalt*. The description of the material is quite similar, we could assume that he does mean the same material when he writes *laspalt*/*laspalte*/*le spat*/*le spalt*. In order to be consistently ourselves, from now on we will use the word **spat** when we refer to the material the author writes about.

Contact with dr. Dennis Braekmans,
mineralogy specialist on the University of Leiden
We received an answer from dr. Dennis Braekmans, a geochemical specialist in minerals at the University of Leiden. In his e-mail he describes feldspar as being a very hard mineral which doesn't correspond with the description of the author of the manuscript. A material being soft could possibly be talc, gypsym, pumice, travertin or other volcanic ash stones. If we include the geology around Augsburg we see mainly shale and some volcanic deposits, according to Braekmans. Without much background or experimental knowledge, Braekmans presents the option of pozzolana (a Si-Al compound which reacts with Ca-hydroxides in plaster). It could improve the properties and detail quality of the mold.
Although the e-mail contact with Braekmans answers some of our questions regarding mineralogy and properties, it also raises further questions. For this reason we decided to make an appointment to speak in person to discuss the possible candidates of *spat* and the geochemical details of the materials.

Overview of possible experiments
The next thing point of action was to set up an overview of possible experiments that we could do when we find the right candidates:

1. Testing 'spath'
Candidates for Spath
- Feldspar
- Calcite
- Fluoriet
- Pozzolana

Testing on:
Characteristics:
-Should be white, like plaster, be very soft and should easily pulverize into a powder with the fingernail (not much body).
- Origin: should have a specific origin in Germany, Augsburg. Is found in mounds/stones made in long stairs and veins.

In combination with mold material:
- Fire resistance: should hold fire and redden.
- After using: it should be better when its older/more used. It should turn from white to grey after use.
- Result casting: should cast more subtle, slender things.
- Suitability metals: should be suitable for every metals.

2. Testing *alum de plume* (probably the same as *federweiss*: Kunckel)

Candidates for *alum de plume*
- Asbestos (not safe to try: replacement?)
- Aluin
- Talc (soapstone)

Testing on:
Characteristics:
- Should be soft, white, shiny, made of long pieces, fragile, woolly, fluffy, fat. Would not pass through a sieve.
- Grinding: the raw stone should be difficult to grind, but the powder from a pharmacy can be easily crushed in a mortar.

In combination with mold material:
- Binding with the other powders: should be a binding medium.
- Softness of the mold: should make the mold softer.
- Cracking and breaking: should be very resistant against fire without cracking or breaking

For testing the two in combination with mold material this are the options:

1. Experiments with sand mixtures made by ourselves with recipes from the manuscript. Test: adding *alum de plume*, and 'spath'.

Making/ testing sand mixture recipes
The author of the manuscript describes which sand mixture should be used for life-casting and casting medals. An important thing for this mixture is grinding the different ingredients as fine as possible. After grinding it should be sieved for the best result. (106v)
The sand mixture consists of:

4 parts ground **plaster** (preheated plaster from Paris)
2 parts red **tiles** from roofing
1 part ***alum de plume***

2. Experiments with old/used mold material from Tonny Beentjes. Molds are without alum de plume. Test: Adding *alum de plume* and 'spath'.

B: Testing *Alum de plume*
C: Testing 'spath'

3. Experiments with old/used mold material. Test: adding ‘spath’.

C: Testing ‘spath’

Spath
Feldspar
Calcite
Fluoriet
Pozzolana

Alum de plume
Asbestos replacement?
Aluin
Talc (soapstone)

Required materials

A **B** **C**

Sand mixture
Plaster from Paris
Red roof tiles

Historische Mineralogie, Volkelt 1775
We have also consulted the following 18th century German publication on minerals and stones: *Historische Mineralogie: oder beschreibung der Mineralien* (Volkelt, 1775). The author of this book describes all different minerals and stones to his knowledge, which were used in the past.

p. 87
“2. Plaster-like rock
Plaster-like or selenitic rock (...) gives no fire (...) consists of a chalk-earth which is mixed with vitriolic acid.
Also can be found:

1. The plaster/gypsumstone
2. --- alabaster
3. --- gypsum spath
4. *Das fraueneis*
5. *Der Bononische Stein*”

Research candidates spat:

This week we did more research on possible candidates for spat. All our new information was added to our documents. The following is the most important information in summary:
Spat is a collective term referring to interconnected crystals that will cleave or break easily.

- **Gypsum spat**
  Tough, difficult to break into powder.
- **Feldspat**
  Hardness on Moh's scale: 6.
  Orthoclase feldspar ($KAlSi_3O_8$), plagioclase feldspars (with respective compositions $NaAlSi_3O_8$ to $CaAl_2Si_2O_8$).
  Melting point: 600 to 750 °C.
  Soft, easy to grind, falls into dust when it's in contact with water.
  Suggested by Loe Jacobs in e-mail contact with Joosje van Bennekom about the 'spath' which Kunkel describes.
  Also called in French 'spath des champs'.
- **Chalkspar/calcite**
  Hardness on Moh's scale: 3.
  $CaCO_3$
  Colorless, white and variously tinted.
  Calcite is calcium carbonate. Not possible to scratch with fingernail, but can be scratched with a cent.
  Melting point: (decomposes at 899°C) 1339 °C
  Insoluble in water
- **Vloeispat/ fluorite**
  Hardness on Moh's scale: 4.
  CaF_2
  Colorless, green, yellow, pink.
  Occurs in veins.
  Used as a flux for metals.
- **Baryte spat/ heavy spar**
  $BaSO_4$
  Hardness Moh's scale: 3-3,5.
  Colorless, white, blue, yellow, red.
  Characterized by its unusually heavy weight.
  Heavy spar: mineral consisting of barium sulfate.
  Insoluble in water.
  Mentioned in H.C and L.H. Hoover's translation of Agricola's *De Re Metallica*, where they translate "Marmor in metallis repertum" as spat, Barite: heavy spar, (p.115).
  Not possible to scratch with fingernail, but it could scratch with a cent.
- **Seleniet/ satin spar**
  $CaSO_4 \cdot 2H_2O$
  Hardness Moh's scale: 2.
  Calcium sulfate dihydrate
  Four crystalline varieties: selenite, satin spar, gypsum rose, desert flower.
  Related to gypsum.

- **Pozzolana**
  Option brought forward by geologist Dennis Braekmans.

Spat can be find in Augsburg and England. This is mentioned by:
- Krünitz (1773-1858).
- Huygens, 1629: Huygens describes the use of spat from England of which he makes balls and adds Sal Ammoniac (Huygens 1629 in de Heer 1993). He describes the spat from Germany being less translucent in comparison with spat from England.

Preparing our interview with dr. D. Braekmans
Fortunately Dr. D. Braekmans is available for an interview within a short-time period. In order to prepare this interview we assembled the most important information this far in an overview:

Characteristics described in the manuscript:
- White stone, after use it becomes grey.
- Found in: mounds and stones made in long stairs and long veins. Long soft filaments which are malleable.
- Very light and soft, easily crumbled into powder with the fingernails.
- From Germany, mainly Augsburg.
- Excellent sand for casting in a box frame.
- White like cooked plaster, color of plaster, kind of plaster.
- Holds fire and reddens.
- The more it is used, the better it becomes.
- For casting slender and subtle things.
- For casting: lead, tin, copper, silver, gold.
- Has to be purified before use with sal ammoniac.

Way to rework spat:
1. Grind them coarsely because they are mixed with earth and filth.
2. Then soak them into sal ammoniac's water, following the above indication,
3. and make balls.
4. Heat these balls in a potter's furnace.
5. Then soak it in the same water again. Filth will remain at the bottom, and the very asphalt, which is light, soft and malleable as flour is, stick to water, remain on the top, and make water cloudy.
6. Pour this cloudy water in another pot.
7. Then empty water, to do that tilt your pot, or sponge the water up.
8. The very asphalt will remain at the bottom of your pot, dry it.
9. Then soak it into sal ammoniac's water, and use it for moulding box.
10. If this matter shrinks in the molding box, even if reheated and dried, you must reheat it on a good fire again, and redden it as you did for medals and flat things.

Candidates:

Gypsum spat
Feldspat
Chalkspat
Fluorite
Barytspat
Seleniet/ satin spat
Pozzolana

Augsburg:
Spat can be found in Augsburg and England.

Week 5 **3-9 March**

Online we found a *An Alchemists Glossary of Terms, Definitions, Formulas & Concoctions,* created by The Third Millenium Online. This glossary offers an entire overview of terms.

Spar
A class of compounds characterized by a crystalline form that features shiny reflective plate surfaces.
Spath (Spat) Stone
A naturally occurring mineral solid, containing mostly Calcium Sulfate ($CaSO_4$).

It describes Selenitic spar or selenite as:
Selenitic Spar
Any mineral assigned to the family of "spars" that could be calcined like gypsum ($CaSO_4 \cdot 2H_2O$).

Calcium Sulfate (CaSO4): The hemihydrate (CaSO4·~0.5H2O) is better known as **plaster of Paris**, while the dihydrate (CaSO4·2H2O) occurs naturally as gypsum. It is prepared by heating the mineral gypsum to about 150°C.
CaSO4·2H2O + heat → CaSO4·0.5H2O + 1.5H2O (steam)
This burned plaster, calcined gypsum, can be hydrated with water, by which procedure the mold hardens.

Plaster of Paris is named in the Manuscript as a basic ingredient to the sand mixture for molding.

If the author of the document really means the same thing when he calls the material aspalt, spalt, le spat or aspalte, we have a recipe on how to prepare the 'excellent sand' for the 'moulding box':

1. Grind them coarsely because they are mixed with earth and filth.
2. Then soak them into sal ammoniac's water, following the above indication,
3. and make balls.
4. Heat these balls in a potter's furnace.
5. Then soak it in the same water again. Filth will remain at the bottom, and the very asphalt, which is light, soft and malleable as flour is, stick to water, remain on the top, and make water cloudy.
6. Pour this cloudy water in another pot.
7. Then empty water, to do that tilt your pot, or sponge the water up.
8. The very asphalt will remain at the bottom of your pot, dry it.
9. Then soak it into sal ammoniac's water, and use it for moulding box.
10. If this matter shrinks in the moulding box, even if reheated and dried, you must reheat it on a good fire again, and redden it as you did for medals and flat things.

So, could it be that the above recipe is a method of extracting a sulfate, same as is done with gypsum? Could the mineral with which the recipe starts be a selenitic spar, of which calcium sulfate can be made? Barite, which is Agricola's translation of the

material ‘spat’, is also called heavy spar, $BaCO_4$, and consists primarily as a barium sulfate. Would this sulfate react in the same way as would the calcium sulfate?
-Barium sulfate is a white crystalline solid that is odorless and insoluble in water.
-In metal casting, the molds used are often coated with barium sulfate in order to prevent the molten metal from bonding with the mold.

Interview dr. D. Braekmans 3 march 2015 University Leiden

On folio 108r the author describes where the stone is found: in Germany and mainly in Augsburg. Can you tell us something about the minerals or stones which are found around Augsburg?
Before this interview I looked at the geological map of Augsburg. Mainly shale, sedimentary deposits and clay sources are found in this area. My advice would be to send an e-mail to the geological department of the University of Augsburg, I’m definitely sure they know which material refers to spat on the basis of the descriptions from the manuscript.
We already sent them an email, in English, but we didn’t got an answer. But maybe it is a good idea to send the email again but this time in German.

The author of the manuscript describes on folio 119v a ‘way to rework spat’. What does this process tells us about the material he uses?
The fact that the author rolls small balls of the spat, indicates that the material must have a degree of plasticity. There must be a fraction of clay in it, otherwise you would not be able to roll balls. Sand or loam would fall apart.
The manuscript also mentions these sand balls to be heated, there is no indication of temperature. This can not have been higher than approximately 500 degrees Celsius, a higher temperature will cause the clay in the mixture to harden. After the heat treatment the material is rinsed again with water. The mixing with water leads to an emulsion, which is placed in another pot. This process removes the dirt and a residue remains. This residue eventually is to be used for molding. To me, this process is not obvious and I can not understand why the author would be doing this.

One of the possible candidates for spat is feldspar, what is your opinion about feldspar according to the descriptions of the manuscript?
The author of the manuscript describes the stone being very soft, from this fact it cannot be feldspar. This mineral is very hard: number six on the hardness scale of Moh. Feldspar is unable the scratch with your fingernail, therefor it should have number 1 to a maximum of 2,5 on Moh’s scale of mineral hardness.

One other possible candidate is barite, different historical sources describes this as being spar/spat. Is this a plausible possibility?
I don’t think the mineral barite is found around Augsburg, but only in northern Africa.

In the email contact you suggested pozzolana as a candidate for spat, can you tell us more about this material and the reasons why this could be the spat?
Pozzolana is a white siliceous and aluminous compound, which could improve the properties and detail quality of the mold. It reacts with water and is found around

Augsburg. The only problem is the name: it is etymologically or otherwise unrelated to traditional spars. It is a mixture of claystone, but also other minerals. Nowadays is being used primarily in the cement industry.

Can any of the other characteristics that are described in the manuscript lead to any clues?
- Long stairs and veins is not helpful, still many possibilities.
- Long soft fibers: not a lot of minerals are soft.
- It reddens: suggesting it is red-hot or iron oxide present?
- White is the most common color in which minerals occur.

- *To the water is added 'sal ammoniac', Ammonium Chloride (NH_4Cl). Why is this used? What is the function exactly?*
This addition could be purely out of habit, or it could have a purpose. You could try to figure this out.

- An alternative method, proposed by Braekmans, is to analyze samples of other life-cast objects using XRF or SEM to see what elements can be found in potential residue on the object.

Still to research:
- Minerals that form thread-like fibers.
webmineral.com
Chemical composition of all minerals in the world.

-The author does not indicate a regular clay, otherwise he would have probably just said this. Clay also, is not found in the long filaments that are described.

-Lou Jacobs of the University of Leiden indicates not to use a mineral that is calcareous or has calcium in its composition, because calcium gets decomposed when heated to a certain temperature and when this happens it produces gasses which cause the mold to crack or break.
This will happen around 670 degrees Celsius. So, if you want a mold that can withstand heat, you should not use a calcareous clay. Regarding calcite in cement, this is another reaction and could therefore be an option.

-Sources indicate a connection between English and German spath, it occurs in both countries, but is slightly different in appearance.
A mineral that can be found in England, as well as Germany is fluorite. Fluorite though, is both quite hard, number 4 or 5 on Moh's scale of hardness and it occurs in many colors.
We can also think of a type of metamorphic rocks. In the south of England, and in Germany in the region of Eiffel and Augsburg we find all kinds of sedimentary deposits and minerals, which have formed under pressure. Therefore per definition they are not crystallized nicely, but appear as slate or shale, schist.

Advice:

-Try contacting the university of Augsburg, department of geology, and asking for geological information about the region. They should know plenty about the subject.
-Try finding out what could be the purpose of the sal ammoniac in the recipe.
-Try finding information regarding technical analyses done on deposits that are found on other historical life-cast objects.
-The material *spalt* might be pumice. It is very soft. Although it is not a mineral, the author regarding the time in which he lived, might be confused himself about sediments and minerals. The author does say *"you find an earth"*, which would not indicate it being a mineral. On the other hand, he also mentioned *"a white stone"* multiple times. Although it is also does not occur in long soft filaments, it is found like thin veins in the earth's crust. It is relatively rare.
He also indicates it being *"like our chalk from Champagne".*
Chalk = soapstone? Does occur in Germany.
<u>Continuing our research of *spalt*</u>

Moh's scale of mineral hardness
This qualitative scale indicates the scratch resistance of various minerals. It consists of 10 minerals arranged on hardness. A fingernail would be 2,5. The Moh's scale is a purely ordinal scale. Corundum, for example, is twice as hard as topaz, but diamond is four times as hard as corundum.

1=Talc
2=Gypsum
3=Calcite
4=fluorite
5=Apatite
6=Orthoclase, porcelain
7=Quartz
8=Topaz, tourmaline
9=Corundum (naturally occurring aluminum oxide), ruby, sapphire
10=Diamond

Kunckel's Spath
Edgar Lein can be found to have shed light on the process of casting from life. In his *Ars Aeraria: Die Kunst des Bronzegießens und die Bedeutung von Bronze in der florentinischen Renaissance* (Lein 2004) he examines the late seventeenth-century *Ars Vitraria* of Johann Kunckel (1630–1703) and of an anonymous author (probably Kunckel) who reprints Kunckel's recipes. In this research it becomes clear, that although Lein investigated the publications by Kunckel extensively, he does not discuss bother with technical terms and materials. The work is more about the art historical background and does not learn us anything new about the material spat.

Still to do this week:
-Explore the book '*An introduction to the rock-forming minerals' by* W. A. Deer *et all.* (1967). There is an extensive chapter written about feldspars in this book. Good for figuring out characteristics about the material that we would be testing.

-Finding out more about pozzolana. There are 5000 sorts of tufa. What kind could we use and how do we figure out which one to test. Maybe we can ask the department of ceramics, historical interiors or paintings.
-Make a step by step plan of how we will test our materials.

Addition to literature study

In *De Re Metallica* Agricola (1556) describes the following:
"(…) it is necessary, for this kind of ore, to have a very hot furnace in which slags, or cakes melted from pyrites, **or stones which melt easily in the fire**, are first melted, so that the ore should not settle in the hearth of the furnace and obstruct and choke up the tap-hole (…)"
In *De Re Metallica* these stones are not further explained, but in *Interpretatio* three types of these stones, with their German equivalent, are named further:
-'lapides qui igni liquescunt primi generis' or schöne flüsse.
-'secundi' , -flüsse zum schmeltzen flock quertze.
-'tertii', -quertze oder kisselstein.
The translators of this work, confessing their inability to understand most of the substances, try to list al characteristics and information given. In *De Re Metallica* the third category is called *Spatum*. "Tertium Spatum appellat, quod politius & densius est"; "Spatum is called the third order, which is polished and thick." (Agricola 1556, 129).

About the materials furthermore is said that the third variety must have embraced varieties of quartz, flint, and siliceous material generally. In *De Natura Fossilium* he states that there are three orders (*genera*).
"The first resembles the transparent gems; the second is not similar and is generally not translucent; it is translucent in some part, and in rare instances altogether translucent. The first is sparingly found in silver and other mines; the second abounds in veins of its own. The third genus is the material from which glass is made, although it can also be made out of the other two. The stones of the first order are not only transparent, but are also resplendent, and have the colors of gems, for some resemble crystal, others emerald, heliotrope, lapis lazuli, amethyst, sapphire, ruby, chryslithus, morion, and other gems, but they differ from them in hardness (...) To the first genus belongs the lapis alabandicus, if indeed it was different from the alabandic carbuncle. It can be melted according to Pliny, in the fire, and fused for the preparation of glass. It is black, but verging upon purple. It comes from Caria, near Alabanda, and from Miletus in the same province. The second order of stones does not show a great variety of colours, for it is generallt white, greyish, or yellowish. Because these (stones) very readily melt in the fire, they are added to the ores from which the metals are smelted. The small stones found in veins, veinlets, and the spaces between the veins, of the highest peaks of the Sudetic range (Suditorum montium), belong partly to this genus and partly to the first. They differ in size, being large and small; and in shape, some being round and angular or pointed; in colour they are black or ash-grey, or yellow, or purple, or violet, or iron colour. All of these are lacking in metals. Neither do the little stones contain any metals which are usually found in the streams where gold dust is collected by washing (...) In the rivers where are collected the small stones to be found, all somewhat rounded and very light weight, and devoid of

all metals. The largest are black, both on the outside and inside, smooth and brilliant like a mirror; the medium-sized are either bluish black or ash-grey; the smallest are of a yellowish colour, somewhat like a silkworm. But because both the former and the latter stones are devoid of metals, and fly to pieces under the blows of the hammer, we classify them as sand or gravel. ***Glass is made from the stones of the third order and particularly from sand. For when this is thrown into the heated furnace it is smelted by the fire (…) This kind of stone is either found in its own veins, which are occasionally very wide, or else scattered through the mines. It is less hard than flint, on account of which no fire can be struck from it. It is not transparent, but it it of many colours - that is to say, white, yellowish, ash-grey, brown, black, green, blue, reddish or red. This genus of stones occurs here and there in mountainous regions, on banks of rivers, and in the fields. Those which are black right through to the interior, and not merely on the surface, are more rare; and very frequently one coloured vein is intersected by another of a different colour – for instance, a white one by a red one; the green is often spotted with white, the ash-grey with black, the white with crimson. Fragments of these stones are frequently found on the surface of the earth, and in the running water they become polished by running against stones of their own or another genus. In this way, likewise, fragments of rocks are not infrequently shaped into spherical forms. (…) This stone is out to many uses; the streets are paved with it, whatever its colour; the blue variety is added to the ash of pines for making those other ashes which are used by wood-dyers. The white variety is burned, ground, and sifted, and from this they make the sand our of which glass is made. The whiter it is, the more useful it is"***

The editors of the work see there is little doubt as to the first or second order being in part fluor-spar. In De Re Metallica it is said "the miners call them fluores, by the heat of fire, like ice in the sun, they liquefy and flow away". "The third kind, as you see here, is white. A fourth is a yellow colour, a fifth ash colour, a sixth blackish. (...) It is indeed not made far from here, at Breitenbrunn, which is near Schwarzenberg. Moreover, from fluores they can make colours which artists use."

Interestingly, Kunckel (1689) also connects the material *spath* to the glass industry.

Conclusions literature study

We started this week making an overview of the pending experiments. We put together a chart with columns including characteristics like composition, color, hardness on Moh's scale, melting point, solubility in water and provenance, in comparison with information from manuscript. From this table we would like to argue which materials we will be testing.

Feldspar soda
Pro: Has the right characteristics.
Con: is very hard.

Feldspar kali
Pro: Has the right characteristics, but a higher melting point than the soda feldspar. Testing to see the difference.
Con: Same hardness as soda feldspar.

Pumice
Pro: Good candidate on many fronts, except for the nomenclature.
Con: The one we are using (from the department of ceramics) is somewhat too brown in color.

Baryte/heavy spar
Pro: Right in color, used as a filler for paints.
Con: Too hard on Moh's scale.

Calcite
Pro: From our chart and the findings we conclude that calcareous spar is named in literature more than a few times. Also, none of the above has calcium as a component in its chemical structure and since the manuscript is often calcimining materials, it would be interesting to have a material that is made up of calcium as well.
Con: Calcium can cause these balls to burst or even explode in the oven due to the gasses that are produced. Therefore, after a meeting with the ceramics department, we have decided to do this experiment separate from the other materials.

Materials that will not participate in the experiments:
-Fluorite, due to its colors, its hardness and the advice of Dennis Braekmans.
-Selenite, because this mineral is closely related to gypsum and is a calcium sulfate. This would therefore be the same as the Plaster of Paris that the author already uses and calls by that name.

Regarding the characteristics of and experimentation on the mineral Calcite:
Calcite, in German *kalkspat*, is the most stable form of calcium carbonate, $CaCO_3$. Calcite is a common constituent of sedimentary rocks, limestone in particular, and is found in England, and Germany as well. Limestone is composed of the two different minerals aragonite and calcite, both crystal forms of calcium carbonate.
Chemically, when calcium carbonate is heated it decomposes. The thermal decomposition of calcite occurs above approximately 825 degrees Celsius. The material then breaks up in calcium oxide and carbon dioxide. Calcium oxide with

water converts into calcium hydroxide. Calcium hydroxide, or slaked lyme, in turn is used in plasters and cement and has a long history of this utilization (Hamer and Hamer 2004). The process of this preparation, might correspond to the recipe from the manuscript in which *spat* is prepared.

Experiments Week 6 and 7 10-23 March

As can be seen in the table (see table p. 42-44) we made a selection of possible candidates for *spat* which we want to subject to a number of experiments:

A: Pumice stone powder
B: Heavy spar / barite
C: Feldspar potassium
D: Feldspar soda
E: Calcium carbonate

Experiment 1: Characteristics

Before we want to carry out a variety of experiments on the different materials, it is important to look at the characteristics. What is the color, weight, structure and softness of the powders and how does this relate to the properties of plaster of Paris?

1.1 Weight

We filled plastic cups with the different kind of candidates with 50 grams each. By comparing the level until where the material filled the cups, we got an estimate about the density. The materials in order of increasing weight:

Pumice
Calcium carbonate
Feldspar potassium
Feldspar soda
Heavy spar

These results correspond to what we expected of this experiment. The difference in density between potassium feldspar and soda feldspar is hard to find with this experiment. We decided to compare the weight of the materials to plaster of Paris, because the manuscript specifically names a resemblance between the two. By weighing 50 gram of plaster of Paris for comparison, it turns out that this material corresponds the most in density to pumice powder and calcium carbonate.

1.2 Color

The color of spat, according to the manuscript, should be ‘white like cooked plaster’. In numbers, of which 1 resembles plaster the most in appearance, consistency and feel, and 5 the least:

Feldspar potassium	1: looks like plaster the most in shade of white.
Calcium carbonate	2: similar white color as plaster but somewhat more grey.
Feldspar soda	3: whiter than plaster.
Heavy spar	4: somewhat grey/pink in the color white.
Pumice	5: is more brownish in color, least resembles plaster of Paris.

1.3 Structure

Structure increasing from coarse to fine:

Pumice	Biggest granules. Dry, not entirely, but form loose grains.
Heavy spar	Fairly big granules, not much correlation between the grains.
Feldspar potassium	Small granules.
Feldspar soda	Small and fine granules.
Calcium carbonate	Finest structure and smallest granules, very atomizing.

1.4 Softness

Softness increasing from hard to soft, also including the stickiness:

Pumice	The least soft, not very sticky, more like sand.
Heavy spar	Soft but oilier, more dense.
Feldspar potassium	Soft and more oilier, sticks to the finger.
Calcium carbonate	Very soft and very sticky to the finger.
Feldspar soda	The most soft and dry, more like sand.

Experiment 2: Preparation of spat

The main experiment we want to carry out is the 'way to rework aspalt', which the author describes in folio 119v. The powders we use in these experiments are fairly pure and not mixed with earth and filth as the spat the author describes, but it is interesting to examine how the different kind of powders react in the sal ammoniac water and if it is possible to make balls out of them. The first step in this recipe is making sal ammoniac water, the second process is moisturizing the powders with this water in order to make balls of it. The second step in this experiment is heating the balls in a furnace.

2.1 Making the sal ammoniac water

Recipe from the manuscript:

"But I did refine upon marble what seemed to me too coarse, and having thus prepared it (reused sand from core molds), I moistened it with the ***sal ammoniac water*** *made of sal ammoniac the size of two walnuts, in a bottle of common water the size of a bottle in which one boils ground barley, or in a good pot of water. You should find the water fairly salty. I mixed in half a glass of sal ammoniac two silver spoonfuls of spirits. Having thus moistened the sand in order to give it a nice hold, though it still came apart easily."* (folio 118v)

Interpretation of the recipe from the manuscript:

In addition to this recipe it is relevant to compare it with the Platt's recipe from 1594 and of Huygens from 1629. Platt describes mixing every bottle of water with an ounce of sal ammoniac and some also mingle it with aqua vite (Platt 1594, 52-53). Huygens describes mixing half a bottle water with two ounce of sal ammoniac (Huygens 1629 in de Heer 1993, 283). Sal ammoniac is ammonium chloride (NH_4Cl), which is soluble in water. It is not clear why the author of the manuscript, Platt, Huygens and others add this to the mixture. Professor of chemistry of conservation and restoration dr. N. Tennent could not think of any chemical reason why sal ammoniac is added. The author adds the sal ammoniac to many different kinds of things. We can assume that it has more to do with a kind of superstition. Nonetheless we decided to add sal

ammoniac because we want to reconstruct the recipe of the manuscript as precisely as possible.

Because sal ammoniac could be harmful when swallowed, we decided not to taste the saltiness of the water after adding sal ammoniac, although the manuscript advices to do. By *spirits* the author means *eau de vie* which is French for a clear, colorless fruit brandy. We decided a cognac would meet this description.

Sal ammoniac water we made:

- 800ml water
- one tablespoon sal ammoniac
- 200ml of this mixture
- mix it with 2 tablespoon of cognac (Hennessy Fine de Cognac, Qualite rare, 40% vol)

2.2 Mixing the powders with sal ammoniac water

On the next folio the author describes the follow proceedings:
"You find an earth in Germany, the color of plaster, but have long and soft filaments which are easy to handle. Grind them coarsely because they are mixed with earth and filth. Then soak them into sal ammoniac's water, following the above indication, and make balls." (folio 119v_b1).
The materials we use for this experiment are very pure. For this reason we do not have to grind them before mixing with the sal ammoniac water. Before soaking the powders in the sal ammoniac water we need more information because the recipe does not describe the proportions which are used. The author describes that *"Good **sand** when moistened does not stick at all to the hand when pressed."* (folio 119r) Platt report that the *pap* should not be too stiff (Platt 1594, 52) and Huygens mingles the powders with the sal ammoniac water until it sticks to the fingers when pressed. It should not be too wet though (Huygens 1629 in de Heer 1993, 283). From this information we can conclude that the authors reports this mixture differently.

For our experiment we decided to add the sal ammoniac water per 10 milliliters and making notes after each turn. In this manner we can control and monitor the experiment. We decided to moisten the powders until we could make a ball out of them. It is also not evident why the author makes balls of the spat, there is no explanation in the manuscript and it is also unclear what size the balls should be. Huygens also makes balls of the spat: as big as a fist (Huygens 1629 in de Heer 1993, 282). Since this is the only description, we decided to make similar balls of each powder, which are a little smaller than a fist because this size would be more practicable for the experiments. We want to make three balls of each material in order to compare the balls after the following experiments. Since the powders differ in weight, we decided to fill a plastic cup with each powder and make one ball with that quantity. For the best monitoring of this experiment we made the balls one by one.

A Pumice stone powder

Filled plastic cup: 100 gram
Adding the sal ammoniac water:

- 10 ml good absorption
- 20 ml granules getting bigger
- 30 ml
- 40 ml Still sand-like
- 50 ml
- 60 ml Almost perfect for making ball, a little fragmentation
- 65 ml Enough moisture for making ball

Ball A1 weight: 149 gram
Ball A2 weight: 146 gram
Ball A3 weight: 155 gram

Notes: it turns very dark brown when moistened. It is not like sand or clay, more similar to loam. When breaking the ball, it is a hard brittle fracture. Cracking when squeezing it.

B Heavy spar / barite

Filled plastic cup: 196 gram

- 10 ml very fast absorption
- 20 ml bigger granules and more wet consistency
- 30 ml like clay, very sticky, enough for making ball

Ball B1 weight: 210 gram
Ball B2 weight: 218 gram
Ball B3 weight: 225 gram

Notes: it turns more grey when moistened. Plastically, clay-like and sticky. It is heavy and high in density. When breaking the ball it is very similar to how clay would react: a ductile fracture. It reacts fast with the moisture to become solid in state.

C Feldspar potassium

Filled plastic cup: 150 gram

- 10 ml absorption but not very fast
- 20 ml not much happen
- 30 ml
- 40 ml
- 50 ml wet enough for making ball

Ball C1 weight: 189 gram
Ball C2 weight: 187 gram
Ball C3 weight: 180 gram

Notes: It turns a little beige when moistened. It is a little plastically, but not clay-like. When breaking the ball it has a more brittle fracture. Also cracking when squeezed. This can be explained by the quartz, which is present in the feldspar.

D Feldspar soda

Filled plastic cup: 160 gram

- 10 ml absorption but not very fast
- 20 ml
- 30 ml
- 40 ml turns wet
- 50 ml wet enough for making ball

Ball D1 weight: 199 gram
Ball D2 weight: 200 gram
Ball D3 weight: 208 gram
Notes: the characteristics of the feldspar soda are similar to the behavior of feldspar potassium. It turns more beige comparing to feldspar potassium.

E Calcium carbonate
Filled plastic cup: 100 gram
- 10 ml very fast absorption
- 20 ml almost wet enough for making ball
- 25 ml good for making ball

Ball E1 weight:114 gram
Ball E2 weight:120 gram
Ball E3 weight:118 gram
Notes: when moistened it becomes grey. It is very plastically, looks and feels like clay. When breaking the ball it is very similar to how clay would react: a more ductile break.

2.3 Heating the balls in a furnace
"Heat these balls in a potter's furnace." (folio 119v_b1).
Because the author of the manuscript or other publications mentioned earlier, do not give any information about the temperature or time of which the balls should be heated, we decided to ask Mrs. K. E. van Lookeren Campagne, coordinator of the department of ceramics. Mrs. van Lookeren Campagne is lecturer in conservation of ceramics and glass at the University of Amsterdam and has a lot of experience and knowledge of pottery and the use of furnaces through the ages. Van Lookeren Campagne advised us to choose a temperature between 800 and 950 degrees Celsius and heat it for one hour, because this was the highest temperature, which could be reached around the 16th century. She also advised us to heat the calcium carbonate balls in the oven separate from the other materials, because the calcium carbonate might explode and cause materials to get mixed and contaminate the experiment. Also, she advised us to choose a long procedure of warming the oven, for that the gasses, which will develop, will be able to pass gradually from the balls.

For the pumice, heavy spar, feldspar potassium and feldspar soda we think the heating of the balls has everything to do with purifying them from filth and earth. For this reason we decided to put the balls of these four different kinds of powders in the furnace and heating them for one hour at 850 degrees Celsius. For safety reasons we choose a warm-up procedure of five hours up to 500 degrees Celsius. We used a ceramic plate on which we put the balls.

According to the process of slaked lime, the heating process of the calcium carbonate has another reason. The calcium carbonates decomposes in calcium oxide and carbon dioxide around 820-840 degrees Celsius, according to van Lookeren. The advice of van Lookeren was to choose a warm-up procedure of five hours up to 750 degrees and one hour 850 degrees Celsius.

Experiment 3: Grinding the balls

The next step in the recipe, which is described on folio 119v, is soaking the powders. Before this is possible we need to grind the balls into powder. The author does not report this procedure, but Huygens does. Huygens mentions that the balls should be crushed as small as possible (Huygens 1629 in de Heer 1993, 282). The first step in this experiment is to report the characteristics of the balls after the heating and the next step is grinding the balls as finely as possible.

3.1 Characteristics of the balls after heating

We took the pumice, heavy spar, feldspar potassium and feldspar soda balls out the furnace and determined the changes:

A Pumice

- Size is greatly reduced.
- It has become very hard: like stone
- It has a white film only on the top of the balls
- On the downside very dark brown
- The color changed to a more reddish/dark brown

B Heavy spar

- A sort of thick shell (0,5 cm) has formed on the surface of the balls, which at some points has crumbled off into pieces.
- Size is a little bit reduced
- The color of the surface changed into dark grey and the core has turned into pink

C Feldspar potassium

- Size did not visibly change much
- The surface is covered with a powdery substance, which is very soft
- The color of the surface changed from beige to white; the downside has become white/pinkish.

D Feldspar soda

- Size did not visibly change much
- The surface is also covered with a powdery substance, but less in comparison to feldspar potassium
- The color of the surface changed from dark beige to white with/orange. The downside has become orange.

E Calcium carbonate

- Size did not visibly change much
- The color did not visibly change much
- The structure did also not visibly change

3.2 Grinding the balls

We decided to keep one ball of each candidate without grinding. This way we could always compare the heated balls to the powder at a later stage. The other two balls of each different kind of powder we grinded:

A Pumice

We were not able to grind the pumice stones: it was too hard to break into parts. It has become hard like pottery. Because the color changed into dark brown and it was impossible to grind the pumice stones we concluded it would be unlikely if pumice stone is the spat which the author refers to in the manuscript. We decided to cancel pumice stone in our further experiments.

B Heavy spar

Difficult to grind finely. The shell was easy to grind into powder, but the core was very hard. We had to crush it with a hammer several times. When we had broken the ball up into smaller pieces we could grind it more finely in a mortar. It took up to 20 minutes to achieve a powder.

C Feldspar potassium

As we expected from the appearance: the feldspar potassium could easily be grinded with a mortar into powder without any effort. The color of the feldspar potassium turned out to be white with a little pink in it.

D Feldspar soda

Grinding the feldspar soda turned out to be as easy comparing to the feldspar potassium. The powder of the feldspar soda has an orange color.

E Calcium carbonate

The calcium carbonate, which hopefully turned into calcium oxide by the heating process, was not very easy to grind. It turned out to have an thick shell around the ball, which fell off very easily. But the core, which had a beige color, was more difficult to crush into pieces. After some effort with the hammer and mortar it was possible to grind the balls into powder. The color of the powder is more beige and darker in comparison to the calcium carbonate we started with.

Experiment 4: Soaking the powders

The author describes the next steps in folio 'how to rework spat':
"Then soak it in the same water again. Filth will remain at the bottom, and the very ***asphalt****, which is light, soft and malleable as flour is, stick to water, remain on the top, and make water cloudy. Pour this cloudy water in another pot. Then empty water, to do that tilt your pot, or sponge the water up. The very* ***asphalt*** *will remain at the bottom of your pot, dry it. Then soak it into sal ammoniac's water, and use it for moulding box."* (folio 119v_b1)

The other authors, Platt and Huygens mention the soaking but do not give an description of this process. We tried to reconstruct the steps of the author as precise as possible with each spat candidate. The main reason of the process is probably to purify the spat from filth and earth, which is not necessary for our pure powders. It is very likely that our pure powders would sink into the bottom. We decided to skip the

first part of the process because there would not be any heavy filth or earth, which would remain at the bottom.

It is not clear what the author exactly describes about the solubility of spat in water. The spat sticks to the water and will make the water cloudy, which would suggest it is soluble in water. But then the author describes both the spat remaining on the top and later on remaining at the bottom, which would suggest it is insoluble in water. Because the solubility in water is interpretable in various ways, we decided to monitor the behavior of the different kinds of candidates when mixed with water. We do know that heavy spar, feldspar potassium and feldspar soda should be insoluble in water.

If the calcium carbonate has turned into calcium oxide through the heating process it would be soluble in water. Calcium oxide turns into calcium hydroxide (slaked lime) when mixed with water. During this reaction the water could reach its boiling point and will release a lot of heat: $CaO\ (s) + H_20\ (l) \rightarrow Ca(OH)_2\ (s) + heat$. Because this experiment is not without risks and because we are uncertain if the calcium carbonate has indeed turned into calcium oxide by the heating process, we decided to choose another approach.

4.1 Soaking heavy spar, feldspar potassium and feldspar soda

We choose for this experiment the candidates **B**, **C** and **D**:

- 800ml water with one tablespoon sal ammoniac (as mentioned before)
- Powder of each candidate from 2 balls
- 600ml of this sal ammoniac water
- Powder mixed with this 600 ml
- Examining the behavior of the powders in the water (soluble or insoluble)

B Heavy spar

- It made the water very cloudy
- The biggest granules sunk very fast, it took more time for the fine granules to sink to the bottom
- After waiting a couple of minutes all the heavy spar did sunk to the bottom which would mean it is insoluble in water

C Feldspar potassium

- It made the water cloudy
- It sunk to the bottom quickly which indicates its insolubility in water
- The color turned pink

D Feldspar soda

- It made the water a little cloudy
- It sunk to the bottom very quickly which indicates it is insoluble in water
- The color turned darker orange in the water than before

4.2 Soaking **calcium oxide**: making slaked lime

For safety reasons we decided to carry out this experiment in a fume hood since the gasses and heat could escape more easily. We wore gloves, a lab coat and safety glasses during the experiment. We decided to start with a small amount of calcium

oxide and test it with a small amount of water, to see if there was a lot of heat produced. We did use the water mixed with sal ammoniac because this had already reacted with each other in an earlier stage. The only thing that happened was the forming of the gaseous ammonia, which went away in the fume hood. Since the first test is successful, we continued adding powder and water like in the experiment with the candidates B, C and D.

Experiment:

- First we tried a small piece of the shell (1cm by 1cm) with a couple of drops of water. The water did not react with the piece.
- Then we pulverized one ball and tested a little amount of the powder with a little amount of water (70 ml), but nothing happened either.
- We mixed all the powder of one ball with 300 ml water. The water did become cloudy but it sank very quickly at the bottom: it did not dissolve in the water. There was no heat produced which would indicate the reaction to calcium hydroxide. Because of this result we decided to continue with the experiment as we did with the candidates B, C and D.
- We added the second pulverized ball to the same mixture, without adding more water. During stirring it suddenly became very hot, which indicated the reaction finally taking place. It stayed very hot for approximately 12 minutes. The calcium oxide totally dissolved into the water, which became milky and thick.

Experiment 5: Making sand- and liquid molds

In this experiment we want to examine the various materials on shrinking and cracking. Unfortunately it is not evident for which exact casting the author uses the spat. On one hand he mentions ‘excellent sand for box molds’ which could indicate sand casting. But on the other hand he describes casting an animal or lizard with the spat (folio 119v_b2), which could suggest life-casting with plaster. In both techniques it is desirable to make a good imprint of an object. With this experiment we want to examine if it is possible to make an imprint and analyze the quality of it. For these reasons we decided to examine a more sandy structure and a liquid version of each material. For the sandy structure we try to make an imprint on top of it, and for the liquid we decided to put a simple form on the bottom of the mold. In this manner we could possibly analyze how the various materials act in two different casting techniques.

5.1 Preparation of the molds

After the soaking experiment we waited until all the powder remained at the bottom (except from the slaked lime), then we drained the water out of the glasses. We took a metal muffin form with 12 molds. We measured 1,5 centimeters from the bottom of each mold and indicated this line with tape. In this manner we are able to pour the same amount into each mold. We choose a simple, round, releasable form (a plastic cap) of which we had 6 similar ones. Because of the limitations of 12 molds we started with the materials B, C and D, and after that experiment was finished, we did the same with material E.

Making sand molds

We waited until the water was evaporated and the powder turned more like sand. We filled two molds of heavy spar, two molds of feldspar potassium and also two molds of feldspar soda with this sand mixture. In this sand we tried to make an imprint.

Making liquid molds

We put down the 6 forms in the bottom of the other 6 molds. We moistened each material again with a little sal ammoniac water, until the mixture was liquid again, the consistency of yoghurt. We poured the liquid over the form in the mold, again two molds with heavy spar, two with feldspar potassium and two with feldspar soda.

We decided to dry the molds overnight at room temperature. Because the molds were not dry enough, the next day we chose to put the molds in an oven for two hours in 50 degrees Celsius.

5.2 Results of the molds

B: Heavy spar

The color of both molds is dark grey.

Sand mold:

It is possible to make an imprint, but the granules of the heavy spar are too coarse which makes the imprint less detailed. The whole mold is very granular and there is not a lot of cohesion, but many interstices. The mold of heavy spar does not seems to be a suitable material for sand casting.

Liquid mold:

The liquid mold is less rough compared to the sand mold. Also, it is less dark in color. There is a little bit more coherence between the granules but still a lot of big gaps inside the mold. When taking out the cap, one mold breaks in the center and the other also breaks into pieces. The liquid mold of heavy spar does not seem to be a suitable material for life-casting.

C: Feldspar potassium

The color of both molds is pink.

Sand mold:

In comparison with the other two materials the feldspar potassium did not evaporate very easily. It took a lot of time until it had the consistency of sand. The imprint was difficult to make, because the cap kept sticking to the sand. After removing the cap a part of the sand was also removed. Besides that, the imprint did not stay in the sand because of the insolubility of the feldspar potassium in water. The water remained at the top and made the imprint disappear. After drying there was nothing left of the imprint. The structure of the feldspar potassium is very dense, but there are a lot of big air bubbles in the bottom of the sand molds. There are also some cracks along the edges of the mold, and a little shrinkage of the whole mold. The mold of feldspar potassium does not seem to be a suitable material for sand casting.

Liquid mold:

The imprint of the cap in the liquid mold had sharp rounds along the edges with a lot of good detail. It is impossible to take the cap out of the mold without damaging it, the mold breaks easily into parts. The bottom of the liquid mold does not consist of

big air bubbles, only a couple of small ones. Beside the shrinking and cracking, the liquid mold could possibly be a suitable material for life-casting.

D: Feldspar soda
The color of both molds is orange.
Sand mold:
The feldspar soda sand mold reacts exactly the same as the feldspar potassium, which means it is impossible to make an imprint. On the bottom of the sand mold there are also lot of air bubbles, the same as compared to feldspar potassium. The only difference between the sand mold of the two feldspars is that there has occurred less cracking in the feldspar soda.
Liquid mold:
The imprint of the liquid mold is, just like feldspar potassium, very detailed with sharp edges. But is also impossible to take the cap out of the mold without damaging it. The bottom of the mold consists of more and bigger air bubbles in comparison to the liquid mold of feldspar potassium. The liquid mold of feldspar soda could possibly be a suitable material for life-casting.

E: Calcium carbonate -> Slaked lime
The color of both molds is white with a little grey in it.
Sand mold:
It is difficult to make an imprint in the sand mold of slaked lime: the cap sticks to the sand. After drying it is unfortunately impossible to take the molds out of the muffin forms. Both the sand mold and the liquid mold stick in the forms. The little imprint, which is left on the mold, has sharp edges. The edges of the molds are cracked and there are some bursts in the center of the molds. We try to take one mold out of the form, but by doing that we broke the mold into pieces, which fell apart in powder. Beside the cracking and breaking, the small pieces with an imprint in it are detailed and sharp, which could indicate that slaked lime is possibly a suitable material for sand casting.
Liquid mold:
Unfortunately it is not possible to take the molds out of the form. For this reason we can not analyze if slaked lime would a possibility for a suitable material for life-casting.