Note from the Making and Knowing Project:

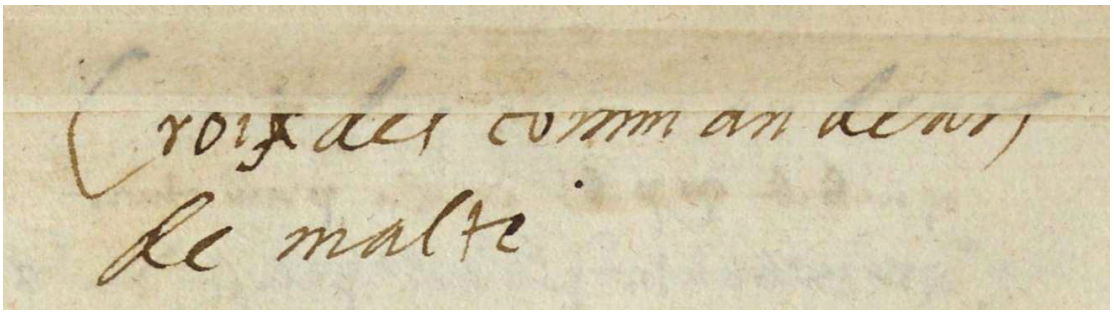
This essay was written for "The Art Technological Source," an 8-week graduate course at the University of Amsterdam offered by Dr. Marjolijn Bol in 2015 and 2016 to students enrolled in an MA program in either Technical Art History or Conservation and Restoration. Students worked on various recipes from BnF Ms. Fr. 640 on the following five topics: 1) tracing and painting on glass, 2) yellow dyes and their applications, 3) dragon's blood, 4) painters' varnishes, and 5) sieves.

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:

> Making and Knowing Project, Pamela H. Smith, Naomi Rosenkranz, Tianna Helena Uchacz, Tillmann Taape, Clément Godbarge, Sophie Pitman, Jenny Boulboullé, Joel Klein, Donna Bilak, Marc Smith, and Terry Catapano, eds., *Secrets of Craft and Nature in Renaissance France. A Digital Critical Edition and English Translation of BnF Ms. Fr. 640* (New York: Making and Knowing Project, 2020), https://edition640.makingandknowing.org. DOI: https://doi.org/10.7916/78yt-2v41.

Annotation

The Making and Knowing Project
BnF Ms. Fr. 640 French Manuscript
Program leader: Prof. Pamela Smith
(Colombia University, New York)



A research of the use of "dragon's blood" in Manuscript BnF Ms. Fr. 640 On Folio 040v

Elisabeth Kuiper

University of Amsterdam
Master conservation and restoration of cultural heritage
Specialization metal conservation

Course: Kunsttechnologisch Bronnenonderzoek
Lecturer: Dr. Marjolijn Bol
Friday May 29th 2015

Content

Foreword

This paper covers research done on the BnF Ms. Fr. 640 manuscript from the *Bibliothèque nationale de France* in Paris. This research is part of the second master years course 'research into art technological sources' on the University of Amsterdam, by lecturer Dr. Marjolijn Bol. The course is a collaboration with the 'Making and knowing project' from the Colombia University in New York, lead by professor in arts Pamela Smith. In this large-scale project, historians, paleographers, technical experts and conservation and materials scientists teach and learn together as they collaborate on researching the 16th century manuscript.
For this course the class was handed multiple subjects of research, all recipes from the BnF Ms. Fr. 640 manuscript, which were divided among the students. In groups of four of five students, historic texts and recipes were analyzed and reconstructed. Within these groups of students varying research questions were devised that strove to be complementary and get to the bottom of the recipes in the manuscript. This group of which this paper is part, focused on a (sub)tropical resin named dragon's blood and was made up of four students: Ingeborg Kroon, Michaëla Groeneveld, Marianne Nuij and myself.

This paper focuses on one recipe in particular (on folio 040v), but is part of the greater focus on the dragon's blood resin. The following research question was analyzed:

To what extent can the recipe "Cross of the commanders of Malta" on folio 040v give an insight in the role of the dragon's blood resin in translucent, 'rouge clair' imitations?

The paper is set up in a way that it corresponds to the requirements set by the Making and knowing project from Colombia University. It starts with an overview of all relevant folios in which the resin dragon's blood is mentioned. Following this list, is the annotation written to answer the research question proposed earlier. Photos of the experimentation process are added in an appendix. The lab work and experimentation is also kept in day-to-day reports in an extensive lab report, which is handed in separately and is done by all four students together.

Transcriptions and translations

Annotation for BnF Ms. Fr. 640, fols. 007r; 029v; 040v; "Cross of the Commanders;" "Rouge Clair;"

BnF Ms. Fr. 640, fol. 007r

Transcription [tc_p007r, 29 May 2015]

<title id="p007r_a3">Doublets</title>

<ab id="p007r_b3">Le bon sang de dragon destrempé en eau de vye porte son<lb/>
mastic ou colle soy mesme, comme aussi faict le verd de vessie & le<lb/>
safran.</ab>

Translation [tl_p007r, 29 May 2015]

<title id="p007r_a3">Doublets [?]</title>

<ab id="p007r_b3">Good **dragon's blood** soaked in **spirits** produces its own **mastic** or **glue**. So do **verd de vessie** and **saffron.**</ab>

BnF Ms. Fr. 640, fol. 029v

Transcription [tc_p029v, 29 May 2015]

<title id="p029v_a6">
Sang de dragon </title>

<ab id="p029v_b6">
Ayes de la larme diceluy bien choisie qui demonstre son rouge transparent Et mets dans une bouteille de verre dans suffisante quantite de la meilleure eau de vye quie tu pourras Et lestouppe bien et si diligemment qui ne sesevente poinct Aultrement il ne vauldroict rien Et le laisse ainsy longuement Car tant plus il demeurera il sera plus beau et meilleur et se dissoudra sil est bon Sinon il viendra comme lie de vin Quand tu en vouldras user fais un petit pertuis au tapon de la bouteille et en verse un peu et le rebouche a chasque fois puys laplique sur lor Le bon sang de dragon se trouve a grands lopins comme pieces de torteau cestuy la ne vault rien si est sophistique et estant rompu il monstre par les costes des escailles transparentes comme esmail rouge cler il est aussy grumelle en quelques endroits comme petits rubis Il fault que leau de vye soict fort ardente et plusieurs passes </ab>

<note id="p029v_c6a">
Le plus obscur sang de dragon est le meilleur et ha plus de taincture cest la larme qui se trouve a lopins comme poix et grosses noisettes qui semble ++ </note>

<note id="p029v_c6b">
Je lay mise dans eau de vye commune y meslant un peu deau fort pour luy donner force Au commancement leau tira un peu de taincture Mays en fin il ne se trouva quune apparence de gomme dragant avelq laquelle je croy quils sophistiquent le sang de dragon </note>

<note id="p029v_c6c">
Le posant sur lor bruny il est subgect a sesclater Et pour ceste occasion aulcuns couchent dessus du vernis de tourmentine Le froid retarde que leau nopere et face extraction de la couleur Et pour ceste occasion on la peult tenir au pres du foeu </note>

Translation [tl_p029v, 29 May 2015]

<title id="p029v_a6">
DRAGON'S BLOOD </title>

<ab id="p029v_b1">
Have a well chosen drop of it which shows its transparent red and put it in a glass bottle with enough quantity of the best eau-de-vie possible and close it very quickly so it doesn't blow out or it will be worth nothing otherwise and leave it so for a long time, because the longer it stays, the more beautiful and better it will be and it will dissolve if it is good otherwise it will turn like some lie-de-vin. When you want to use some, make a small hole in the bottle stopper and pour some and close it again each time and apply it on gold. Good dragon's blood can be found […] this one is no worth if it is sophisticated, and broken it shows on its edges some transparent scale as light red enamel, it is also lumpy in some points like small rubies. The eau-de-vie must be very […] </ab>
<note id="p029v_c6a">
The darker dragon's blood is the best and the larme is the most dying one, which you can find in bits as big as pitch and big nuts which seems [symbol] </note>
<note id="p029v_c6b">
I put it in some ordinary eau-de-vie, adding some aqua fortis to give it strength. At the beginning the water turns slightly coloured, but it just looked like some tragacanth gum with which they sophisticate I think the dragon's blood. </note>

<note id="p029v_c6c">
When it is applied on gold, it is prone to break, this is why some apply on it some turpentine oil. Cold stops the water from pouring into and taking the colour off. And for that, you can hold it by the fire. </note>

<u>BnF Ms. Fr. 640, fol. 040v</u>

Transcription [tc_p040v, 29 May 2015]

<title id="p040v_a1">Croix des commandeurs</lb>
de <u>Malte</u></title>

<ab id="p040v_b1">Ce beau rouge clair qui faict le champ de la croix</lb>
blanche d'**esmail** est larme fine de **sang de dragon**</lb>
destrempé en **eau de vye** ou bien **laque platte d'Inde**,</lb>
qui a mon advis se faict en Flandres, destrempée avecq</lb>
tormentine claire & **larme de mastic** & posée sur une **foeille**</lb>
d'argent, non pas de celle dont usent les *painctres* mays</lb>
de celle plus espesse qui est brunie par *ceulx qui font les*</lb>
foeilles de pierrerie ou par les *orfevres*, & cella luy</lb>
donne ce bel esclat.</ab>

Translation [tl_p040v, 29 May 2015]

<title id="p040v_a1">Cross of the commanders of Malta</title>

<ab id="p040v_b1">The fine rouge clair which is the background of the white **enamel** cross is of fine **dragon's blood** drops soaked with **eau-de-vie** or **Indian laque plate**, which I believe is made in Flanders, distempered with clear **turpentine** and **mastic** drops and applied on a **silver leaf**, not the one used by *painters* but a thicker one, which is burnished by the *makers of foil backings for gemstones* or by *goldsmiths*, and that gives it its fine brilliance.</ab>

Annotation

Introduction

The French BnF Ms. Fr. 640 manuscript from the *Bibliothèque nationale de France* in Paris, dated approximately to the 1580s and most probably originating from the region of Toulouse, comprises a large collection of handwritten recipes and techniques relating to a wide range of topics.[1] 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.

The manuscript mainly seems to be a workers 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.
On specifically six pages (007r, 029v, 040v, 098r, 102v and 165r) the author mentions the preparation and use of a material called *sang de dragon*, dragon's blood. The following paper will cover research done on this subject and specifically on its application as a painting medium. It will focus on one recipe in particular (040v), which will be discussed in a later stage.

Dragon's blood

The first comment on dragon's blood on page 007r is a short, almost inconspicuous one-sentence remark stating that "good dragon's blood soaked in spirits (like *verd de vessie* and *saffron*) produces its own mastic or glue". On this page, no mention is made on the use or application of this material. It is not until page 029v that the author elaborates by adding a recipe for the preparation of

[1] Smith and Beentjes 2010.

dragon's blood. In this recipe a drop of the dragon's blood resin **[fig. 1]** is added to a certain quantity of "the best eau-de-vie" and left for a long time in order for the resin to dissolve in the liquid and to produce a coloring agent.[2] Also, in this description a short comment is made on the application of dragon's blood. It is said that when wanting to use some of the mixture, a small portion can be taken from the bottle and be applied on gold.

In order to understand the comments made on the preparation of the colorant, we need to understand the components used. The material that is curiously called dragon's blood is a resin, which is obtained from various plant species in mainly Africa and Asia. The material is mysterious in the sense that various sources, even from the first century AD (Pliny, 77 AD), can be found to mention its application as a varnish or paint, but almost no identifiable proof on actual artwork remains to verify its use.[3] Due to the variation in import sources, question then remains about the provenance of the dragon's blood resin that was used in 16th century. [4] According to various studies it is *Dracaena draco* or *D. cinnabari* from the island of Socotra, that is described in Cennini's treatise and in those of multiple medieval alchemists and is thought be the principal source historically. [5]

As said, in the recipe on folio 029v in BnF Ms. Fr. 640 the dragon's blood resin is combined with eau-de-vie, which is a fruit distillate. It is the alcohol in this fluid that works as a solvent to dissolve the resin and create a colored solution. Although in the main text no supplementary components are mentioned and both elements seem to suffice to produce a color for gold, notes in the margin do suggest additional action. The dissolved resin can be combined with a lacquer or binding medium, instructions on which are added in other pages as well. In the particular recipe on folio 029v, additives are mentioned in notes in the left-side margin on the bottom of the page. "Some aqua fortis", it says for instance, was

---

[2] The resin is and was purchased in dry pieces and should first be dissolved, Harley 1982, 146.

[3] Both the problems concerning analytical characterization and lack of use can make identification of the resin problematic, Eastaugh 2004, 149.

[4] Study shows that problems are encountered when trying to distinguish the various resins, which can originate from major botanical sources from Asia to South-America like *Dracaena draco* L. (Dracaenaceae), *Daemonorops draco* Blume (Arecaceae) or *Croton draco* Schltdl. (Euphorbiaceae). For a more extensive study on geographical origin and chemical study of dragon's blood resins, see: Bommel, M. and Wallert, A. 2008.

[5] Bommel and Wallert 2008; Eastaugh 2004.

added “to give it strength”. In other sections on later folios these additional materials alter. Also, on these other folios the dragon’s blood is seen to be applied to other substrates, like wood ‘for varnishing lutes’ (folio 098r) or painting on crystal or glass (folio 102v).[6]

Folio 040v

The subject of this paper focuses particularly on the next mention of dragon’s blood, on folio 040v. On this page we find a short section on the material, which incorporates a purpose in the sense of an exemplification, a preparation method and an application on a metallic ground.

Cross of the commanders of Malta (folio 040v)

The fine rouge clair which is the background of the white enamel cross is of fine dragon’s blood larme soaked with eau-de-vie or Indian laque plate, which I believe is made in Flanders, distempered with clear turpentine and mastic larme and applied on a silver leaf, not the one used by painters but a thicker one, which is burnished by the makers of foil backings for gemstones or by goldsmiths, and that gives it its fine brilliance.

Curious about this specific section is particularly the first sentence in which the author illustrates by example what the dragon’s blood mixture is used for. “The fine rouge clair”, he states, is what the background of the white enamel cross of Malta is made of **[fig. 2]**. Earlier, in the recipe on folio 029v, the dragon’s blood varnish is also compared to rouge clair: “it shows on its edges transparent as enamel rouge clair”. Rouge clair is no unfamiliar term. Indeed it is an enameling technique, which is known for its translucent red color.[7] Unlike the preparation and application of dragon’s blood though, in the art of enameling powdered glass is fired onto metal and can bee seen to originate from the desire to imitate inlays of precious stones.[8] The glass powder is built up in layers on a metallic surface,

[6] This last subject is explored more extensively in the annotation by Ingeborg Kroon, Mey 29th 2015.

[7] Bimson and Freestone 1985.

[8] For a more extensive discussion on this subject, see: Bol, M. (2013). Seeing Through the Paint. The Dissemination of Technical Terminology between Three Métiers: Pictura translucida,

which are heated separately to the point at which they melt. At high temperatures the glassy substance bonds to the metal with which it is in contact and a beautiful, colored glaze becomes part of the object.[9] Enamel is most often used for decorative purposes in enameling techniques like *repoussé*, *à-jour*, *cloisonné*, *basse-taille* or *ronde-bosse* enameling. In this last technique, also called dipped or encrusted enameling, a gold object is enameled 'in-the-round', usually in white, either by dipping it in molten glass, or by painting it with a paste of glass and subsequently heating it.[10] This process can be remembered when reading the comments on the white enamel cross in the manuscript. We can also think of the technique of painted enamel, which developed from the 15th century onwards and reached a high in the 16th century in the region of Limoges, 300 kilometers north of Toulouse. Painted enamel is an enameling technique, usually on copper, where a layer of white enamel covers the object. After that it is gradually decorated with colored enamels **[fig. 3]**.[11][12]

Rouge clair, also known as ruby glass, in the most traditional sense of the word, is a an enamel containing nano-scale copper, silver or gold colloids that render the glass neither golden nor transparent, but ruby, depending on the size and concentration of the gold particles **[fig. 4]**.[13] The red color of gold-ruby glass is presumably caused by small particles of metallic gold that form when the gold-containing colorless glass is carefully annealed. Although study shows that the change in color has to do with the forming of chemical bonds between oxygen and gold atoms, the process is not yet fully understood.[14] As pointed out, the technique of achieving red-colored enamel is a complex undertaking requiring skill and experience. The size and distribution of the small metallic particles can change when heated, which in turn has an undesirable effect on the color of the glass. Cennino Cennini writes about the process: "Leave it alone, and do not have

---

Enameling and Glass Painting. In: Andreas Speer (ed.), *Zwischen Kunsthandwerk Und Kunst: Die ‚Schedula Diversarum Artium*' Berlin: De Gruyter, pp. 145-162.

[9] Buckton 1982, pp. 101-109.

[10] *Ibid.*, p. 102.

[11] Ward 2008, 189.

[12] For an extensive read on historical enameling, see: Neri 1662.

[13] Leonhardt 2006.

[14] Wagner 2000.

too much respect for it; for it is not of a constitution to do you much credit".[15] The 16th century goldsmith Benvenuto Cellini finds it is impossible to enamel the beautiful, red '*smalto roggio*' or '*rogio chlero*' onto silver or copper, though it can be done on gold.[16] Still, if the red enamel is not immediately cooled by means of bellows, he warns, the red color may go "so yellow that you can scarce distinguish it from gold". [17] Remarkable is the fact that the author practitioner makes a similar observation in the BnF Ms. Fr. 640 manuscript. After the title "Enamel rouge clair" (folio 124v) the author writes, "pure gold (contrary to alloyed gold) does not work well with enamel because the enamel remains yellowish", furthermore advising to anneal the material to create a more reddish color. The section may be seen to indicate that achieving a red color is no easy task in itself; therefore a different medium would have been sought out. Also, it indicates that the author did indeed know very well the difference between enamel and a varnish or painting medium such as produced from the dragon's blood resin.[18]

Translucent paints

Referring to the Maltese cross, of which the background is colored a bright red or 'rouge clair', would imply that the painting medium indeed was meant to create a red color that resembled enamel. It was therefore not just applied as a thin varnish layer to give the metal a different shade, as might be thought. Quite a few historical sources, indicate that dragon's blood in addition to varying binding media and coloring agents were often used to varnish a metallic surface in the imitation of gold on tin foil or to enhance a golden surface in order to obtain a more desirable and fashionable shade.[19] The 12th century Theophilus for example provides us with a recipe of the sort and the 16th century work of Cellini

---

[15] Thompson, D.V. (ed.) (1954) The Craftsman's Handbook: The Italian 'Il libro dell'arte'. Cennino Cennini. New York: Dover Publications, p. 26.

[16] Indeed gold is an ideal base for translucent enamel, since no discoloring oxide layer forms at the interface between the glass and the metal. For that same reason enameling on base metals, like copper and brass, can lead to a dull appearance, see: Buckton 1982, p. 102.

[17] Ashbee, C.R. (ed.) (1967) The treatises of Benvenuto Cellini on goldsmithing and sculpture. New York.

[18] Folio 124v and 039v do have a few instructions on 'real' enamel, including remarks on the metallic substrate and annealing treatments.

[19] More on this subject is in the annotation of Michaëla Groeneveld, 29th May 2015.

provides us with instructions on 'making colors and coloring the gilded parts'.[20] [21] [22] Seldom is the dragon's blood resin in historical texts used as a coloring agent in order to really produce a translucent paint on metal.[23]

Still, other examples can be found of pigments, like verdigris or orpiment, mixed with resins that mean to produce a translucent paint to apply on metallic substrates.[24] [25] This practice, also known as cold enameling, can be seen as an alternative to the traditional enameling technique. "There is also made on wood (covered by plain and carefully polished tin foil) a type of painting called translucent (*translucida*)", Theophilus tells us.[26] In this act of 'translucent painting' or *pictura translucida*, paint (in Theophilus' case, pigments mixed with linseed oil) is put onto a burnished metal base. The metal reflects through the paint layer to create a translucent effect. An important difference from the previously mentioned application of varnish lies in the fact that translucent paint is applied to a metal substrate in order to enhance the appearance of the substrate, instead of the other way around in which the metal foil is employed to enhance the paint itself.[27]

Indeed there is one panel painting (depicting the *Pentecost*) that contains a red translucent paint that is set over the depiction of the tongues of fire, which is presumably identified as dragon's blood.[28] Still, as said earlier, identification of the pigment-medium mixture is complicated, but this suggestion might be a base for more analytical research into the subject.

---

[20] Hawthorne 1979, 115: 'Coloring the gold'.

[21] Ashbee 1967, 98: 'A recipe for making colours and colouring the gilded parts'.

[22] For more treatises on the subject, see: Merrifield 1967; Also, Jacobus Willeke 1742, 50: *'Een vernis, 't geen op 't zilver gelegt, 't zelve als goud doet voorkomen';* en 218: *'XI Gekoleurt en doorschijnent vernis'*.

[23] The following source does offer a preparation of dragon's blood to prepare a specifically red colored varnish: Parker, G. (1688) *A Treatise of Japaning and Varnishing,* pp. 24-25.

[24] Bol, M. (2012). *Oil and the Translucent: Varnishing and glazing in practice, recipes and histiography, 1100-1600* (dissertation), unpublished work, University of Utrecht.

[25] Eastaugh, 2004.

[26] Hawthorne, J. G. and Smith, C. S. (1979) *On divers arts : the foremost medieval treatise on painting, glassmaking and metalwork (by) Theophilus, ca. 1122; translated from the Latin with introduction and notes by John G. Hawthorne and Cyril Stanley Smith*. New York: Dover Publications.

[27] Bol, M. 2013, 153.

[28] For more information on this, see: Bomford D., Dunkerton, J., Gordon, D. And Roy, A., exhibition catalogue *Italian Painting Before 1400*, Art in the Making, london, 1990, p. 71.

Experimentation

In order to test the possibility that dragon's blood could indeed have served as a *pictura translucida* or imitation of the rouge clair enamel on gold or silver, the recipe in the manuscript was followed as accurately as possible. First, some drops of the dragon's blood resin **[fig. 1]** were placed in a vial with spirits resembling eau-de-vie, a cognac with an alcoholic content of 40% ABV **[fig. 6]**. The resin only slowly dissolved. To speed up the process of dissolving the resin and to prevent a granular appearance, in this experimentation the resin was finely ground **[fig. 7]**. In addition, the resin was dissolved in ethanol. The result of these alterations was a uniform, colored substance.

To test the qualities of this mixture as a varnish and as a colorant, without any additional components, the composition was put onto a metallic surface. A thicker and a thinner layer of the dissolved resin were set on a polished brass plate **[fig. 8]**. The result was a substance that accumulated on the edges of the test piece and showed clear brushstrokes when dried. Also, it is clear that the dragon's blood resin produces a translucent paint. The shiny metallic surface underneath the paint layer is still clearly visible **[fig. 9]**. The dragon's blood varnish dried very rapidly.

In order to follow the preparations on folio 040v, the material was mixed with mastic. Mastic was chosen that was prepared with turpentine, for use as a varnish in painting restorations. The process of preparing a mastic varnish is quite a time-consuming task and for reasons of the limited time, it was chosen to use a pre-mixed composition of 1 part mastic resin to 2 parts of turpentine **[fig. 10]**. Adding the mastic, as instructed, to the dissolved dragon's blood produced a viscous, beautiful red paint that spread well over the surface of a burnished silver plate **[fig. 11]**. Indeed, the translucency and the consistency when applied made it really resemble enamel **[fig. 12, 13]**. An important note is that, the addition of the mastic varnish to the composition, made the applied tests dry much more slowly. Curious enough there is no mention of this in the manuscript.

Conclusion

Golden or precious artworks in medieval times were often decorated with gemstones, enamels or translucent paints in order to enhance their appearance. Some of these techniques can be seen to have developed in order to imitate or resemble the other. This might have been done for various reasons, the previous method may have been too problematic or the method was changed for financial reasons. From a restorer's point of view it is interesting to work with historical sources and especially the original recipes. When understanding the materials used by ancient practitioners through working with contemporary recipes, insight can be obtained in artworks that have survived to this day. Paint layers, for instance, and reasons why they are or are not intact still, can be better understood. It can even aid restoration work, where repair or reconstruction is needed. An interesting study is the research done by Crabbé *et al.* (2013) where recipes by Theophilus and Cellini on surface treatments for gold were reproduced to analyze resulting traces and chemical processes.[29] In the same way can the reconstruction of ancient recipes give insight in the utilization of translucent paints or enamels on historical objects.

Further research

Although the previous study has given more insight in de dragon's blood resin and its utilization as a translucent paint, there are still more questions that need answering. Mainly for reasons of shortage of time, choices were made during this process of experimentation that could be explored further. The recipe for instance, offers the possibility to use 'Indian Laque plate' instead of eau-de-vie. This concept was not explored further in this study. Also, a mastic and turpentine were chosen, that were convenient during the experimentation. Exact proportions if this composition could be explored further in later research. The drying process could also be tested, because this drastically changes when mastic is added. Still, hopefully the previous research has provided future research with a basis.

---

[29] Crabbé, A., Languille, M.A., Vandendael, I., Hammons, J., Silly, M. G., Dewanckel G., Terryn, H. and Wouters, H. J. M. (2013) Colorando Auro : contribution to the understanding of a medieval recipe to colour gilded silver plates. *Applied physics. Part A, Materials science and processing / German Physical Society,* pp. 39-46.

Literature

Ashbee, C.R. (ed.) (1967) The treatises of Benvenuto Cellini on goldsmithing and sculpture. New York.

Bol, M. (2012). *Oil and the Translucent: Varnishing and glazing in practice, recipes and histiography, 1100-1600* (dissertation), unpublished work, University of Utrecht.

Bol, M. (2013). Seeing Through the Paint. The Dissemination of Technical Terminology between Three Métiers: Pictura translucida, Enameling and Glass Painting. In: Andreas Speer (ed.), *Zwischen Kunsthandwerk Und Kunst: Die ‚Schedula Diversarum Artium*' Berlin: De Gruyter, pp. 145-162.

Buckton, D. (1982). Enamelling on gold: a historical perspective. London: The British Museum. In: *The gold Bulletin 15.3,* pp. 101-109.

Bimson, M., & Freestone, I. C. (1985). Rouge clair and other late 14th century enamels on the royal gold cup of the kings of france and england. In: *Annales du 9e congres international d'etude historique du verre. Nancy (france), 22-28 mai 1983.* Centre de publications de l'a. IHV, pp. 209-222.

Crabbé, A., Languille, M.A., Vandendael, I., Hammons, J., Silly, M. G., Dewanckel G., Terryn, H. and Wouters, H. J. M. (2013) Colorando Auro : contribution to the understanding of a medieval recipe to colour gilded silver plates. *Applied physics. Part A, Materials science and processing / German Physical Society,* pp. 39-46.

Drayman-Weisser, Terry. (2003). "The Early Painted Enamels of Limoges in the Walters Art Museum: Historical Context and Observations on Past Treatments." *Journal of the American Institute of Conservation* 42, pp. 2279-312.

Eastaugh, N. (2004). *The pigment compendium : a dictionary of historical pigments*. Oxford [etc.]: Elsevier.

Leonhardt, U. and Philbin, T. G. (2006). General relativity in electrical engineering. In: *New Journal of Physics*, Vol. 8 (10), p. 247.

Neri, Antonio, and Christopher Merret. (1662) *The Art of Glass Wherein Are Shown the Wayes to Make and Colour Glass, Pastes, Enamels, Lakes, and Other Curiosities*. London.

Hawthorne, J. G. and Smith, C. S. (1979) *On divers arts : the foremost medieval treatise on painting, glassmaking and metalwork (by) Theophilus, ca. 1122; translated from the Latin with introduction and notes by John G. Hawthorne and Cyril Stanley Smith*. New York: Dover Publications.

Merrifield, M.P. (1967). Medieval and Renaissance Treatises on the Arts of Painting: Original Texts with English Translations. New York: Dover Publications.

Parker, G. (1688) *A treatise of japaning and varnishing: being a compleat discovery of those arts : with the best way of making all sorts of varnish ... : together with those above an hundred distinct patterns for japan, wood, prints or pictures... engraven on 24 large copper-plates,* Oxford: Print for and fold by the author at Mr. Wood's House over against the Theater in Oxford, pp. 24-25.

Smith, P.H. and Beentjes, T. (2010). Nature and Art, Making and Knowing: Reconstructing Sixteenth-Century Life-Casting Techniques. In: *Renaissance Quarterly*, Vol. 63 (1), pp. 128-179.

Thompson, D.V. (ed.) (1954) The Craftsman's Handbook: The Italian 'Il libro dell'arte'. Cennino Cennini. New York: Dover Publications, p. 26.

Wagner, F. E., Haslbeck, S., Stievano, L., Calogero, S., Pankhurst, Q. A., and Martinek, K. P. (2000). Before striking gold in gold-ruby glass. In: *Nature*, Vol. 407, pp. 691-692.

Ward, G.W.R. (2008). *The Grove Encyclopedia of Materials and Techniques in Art.* New York: Oxford University Press.

Appendix 1. Photos

Fig. 1: Dragon's blood resin
Dragon's blood resin 'tears' (about 0,5 cm). **Copyright:** Picture by author.

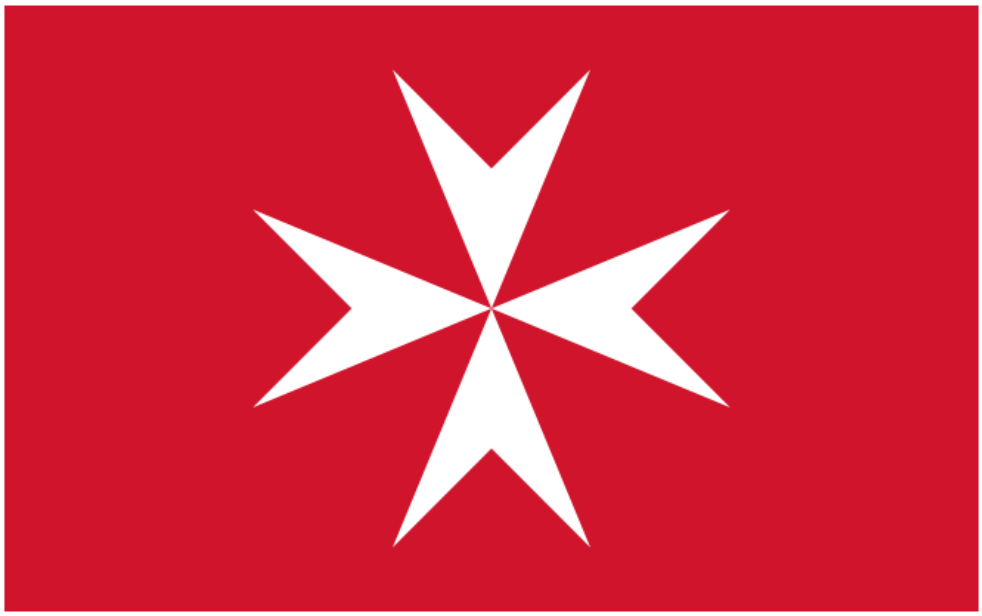


Fig. 2: Dragon's blood resin
Maltese cross. **Copyright:** Picture from Wikipedia, public domain.

Fig. 3: ***The Twelve Sibyls*** **enamel plaques**
By Léonard Limousin, from Limoges, France (around A.D. 1535-40). **Copyright:** The British Museum, London.

Fig. 4: Royal Gold Cup.
Basse-taille rouge clair enamel on gold (around A.D. 1380). **Copyright:** The British Museum, London.

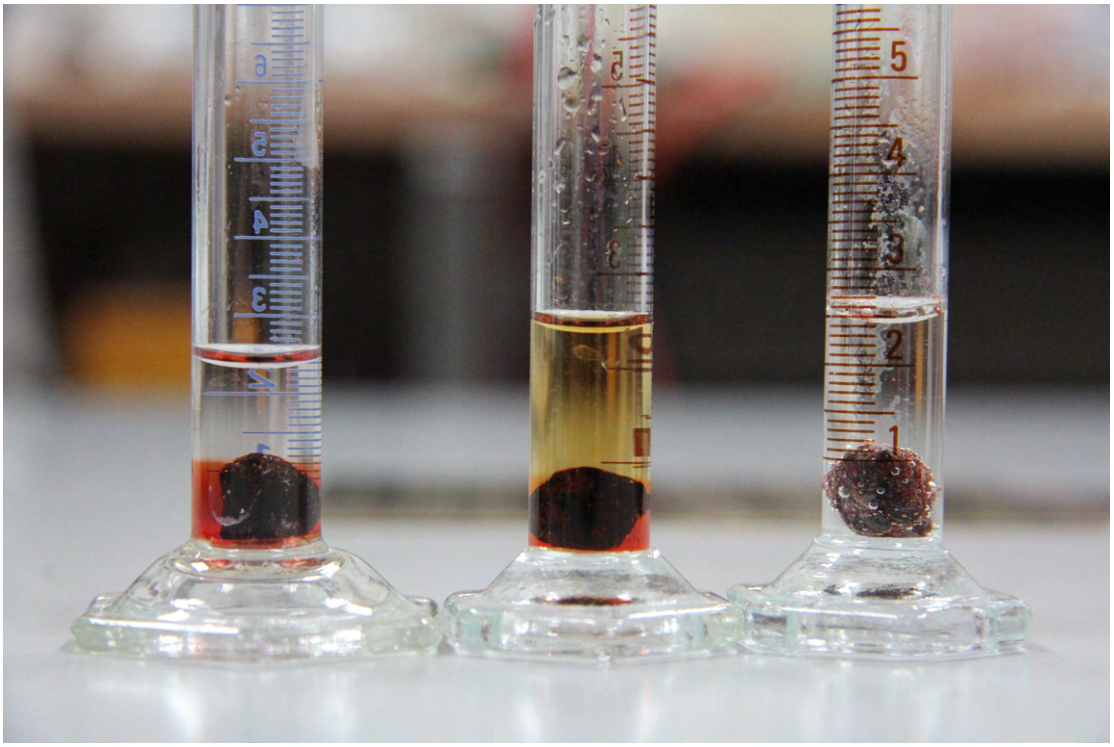


Fig. 6: Resin in multiple 'eau-de-vie' candidates.
From left to right: *Kirschwasser*, Hennessy fine cognac (both 40% ABV) and white wine (11.5% ABV). **Copyright:** Picture by author.

Fig. 7: Ground dragons' blood resin.
Finely ground resin. **Copyright:** Picture by author.

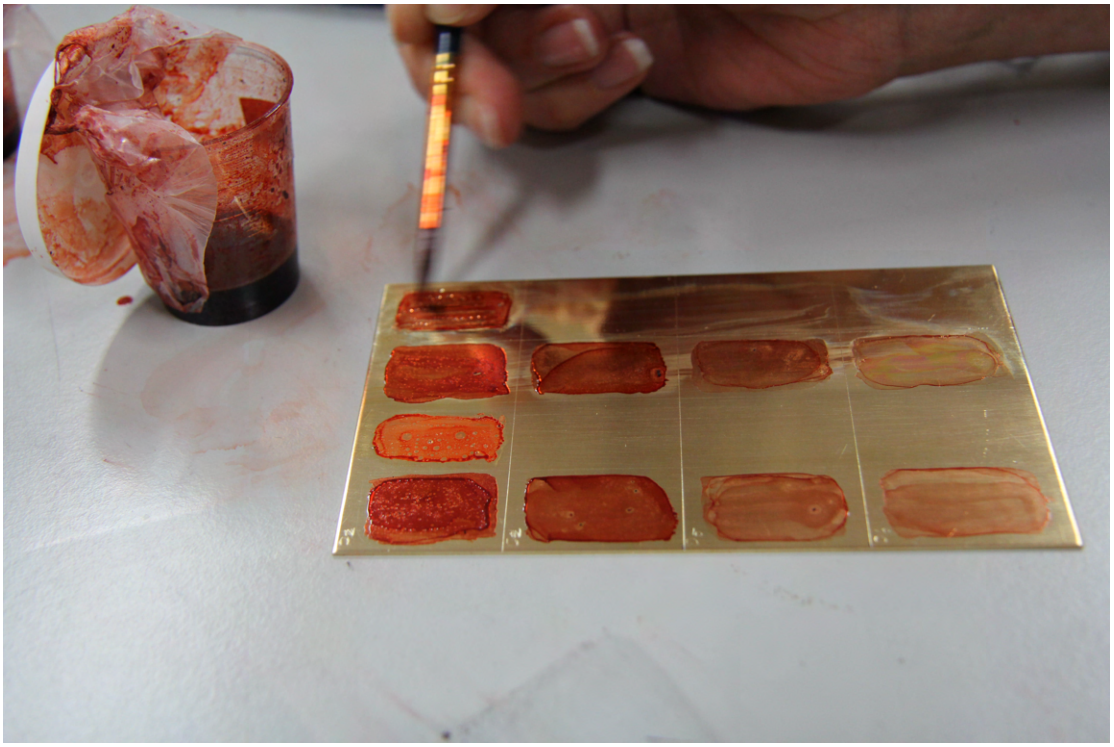


Fig. 8: Applying dissolved dragon's blood on brass.
Application of dragon's blood: brushstrokes accumulation at the edges. **Copyright:** Picture by author.

Fig. 9: Applying dissolved dragon's blood on brass.
Application of dragon's blood: think versus thicker layer. **Copyright:** Picture by author.

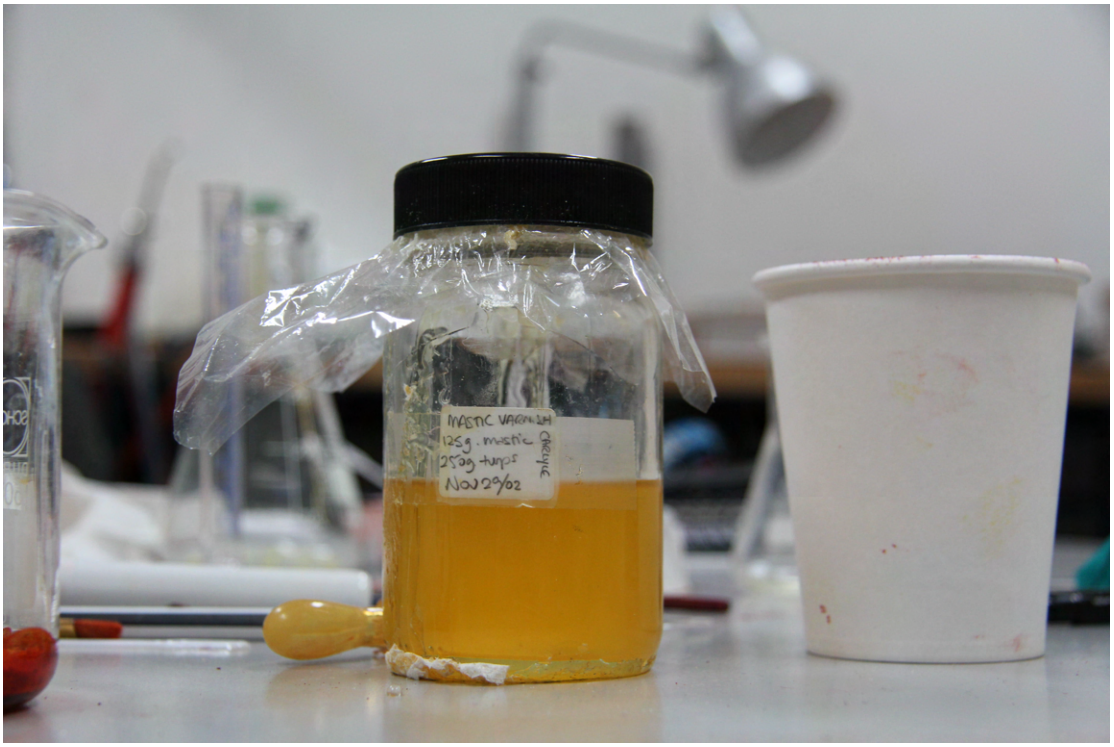


Fig. 10: Adding mastic varnish.
Pre-mixed composition of 1 part mastic resin to 2 parts of turpentine. **Copyright:** Picture by author.

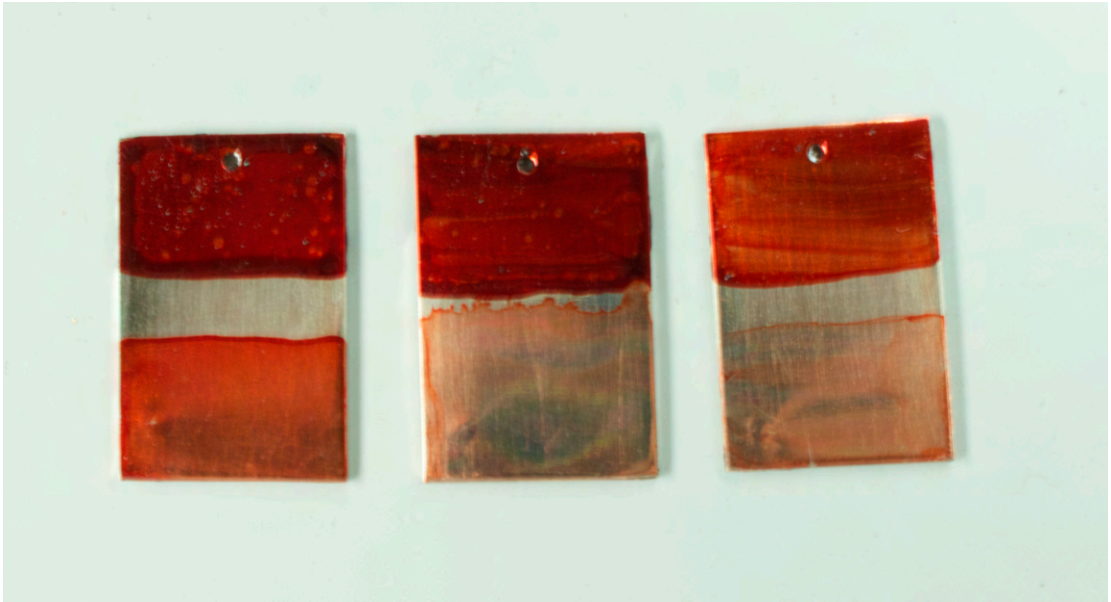


Fig. 11: Applying dissolved dragon's blood + mastic on silver.
Application of dragon's blood with mastic: think versus thicker layer. **Copyright:** Picture by author.

Fig. 12: Applying dissolved dragon's blood + mastic on silver.
Beautiful translucent and uniform composition. **Copyright:** Picture by author.

Fig. 13: Applying dissolved dragon's blood + mastic on gold.
Beautiful translucent and uniform composition. **Copyright:** Picture by author.