From the ground up: Surface and sub-surface effects in fifteenth- and sixteenth-century Netherlandish paintings

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Publication date
2013

APPENDIX 4a

General information about reconstructions made for *From the Ground Up*

The following appendices describe reconstructions that address: the visibility of underdrawing (4b), the appearance and functions of intermediate layers (4c), methods for texturing red glazes (4d) and techniques for painting *changeant* fabrics (4e). Appendices 4b, 4c and 4e contain *illusionistic* reconstructions, in which I copied the appearance of actual paintings as accurately as possible. These are instructive with regard to understanding painting techniques, and can be understood by a non-specialist viewer. Appendices 4c and 4d include *non-illusionistic* reconstructions, where I attempted to replicate the materials and their thicknesses, but did not copy a recognizable image. In both cases, the choice of materials and application methods were (as much as possible) based on documentary sources, the results of analysis, and materials research. I tried to imitate the material composition, (some) historical preparation methods, and achieve similar paint handling and visual characteristics to the actual paintings.

Before the mid-twentieth century, research into early Netherlandish paintings sometimes involved speculating about what types of materials were used, then trying to replicate the process. The "secret" of Van Eyck's binding medium was of particular interest, and some tried to solve this mystery by making reconstructions.[1] Sometimes the materials they chose were based on medieval recipes, or their assumptions about what was available at the time. We now have the added advantage of being able to incorporate the results of scientific analysis, then using this information to make more accurate reconstructions. The concept of "historical accuracy" was introduced in the HART project (Historically Accurate Reconstruction Techniques).[2] One must always acknowledge that the materials available today often differ from the materials that would have been available to the medieval painters. The HART project explored traditional methods of pressing oil and preparing lead white, based on historical

[1] Effman, Elise. 2006. "Theories about the Eyckian Painting Medium from the Late-eighteenth to the Mid-twentieth Centuries." *Reviews in Conservation* 7: 17-26; Roy, Ashok. 2000. "Van Eyck's Technique: The myth and the reality, I." In *Investigating Jan van Eyck*, edited by Susan Foister, Sue Jones and Delphine Cool, 97-100. Turnhout: Brepols; Brinkman, Pim W.F., Leopold Kockaert, Luc Maes, Evert Thielen, Jan Wouters. 1998. "Het Lam Godsretabel van van Eyck. Een heronderzoek naar de materialen en schildermethoden, 2. De hoofdkleuren Blauw, groen, geel en rood." *Bulletin Institut Royal Du Patrimoine Artistique / Koninklijk Instituut Voor Het Kunstpatrimonium* 22: 38-47.

[2] Carlyle, Leslie. 2005. *De Mayerne Programme: HART Report*; Carlyle, Leslie. 2012. "Exploring the grammar of oil paint through the use of historically accurate reconstructions." In *The Conservation of Easel Paintings*, edited by Joyce Hill Stoner and Rebecca Rushfield, 33-38. London and New York: Routledge; Carlyle, Leslie and Maartje Witlox. 2004. "Historically Accurate Oil Painting Reconstructions." In *Art of the Past: Sources and reconstructions*, proceedings of a symposium at Instituut Collectie Nederland, 14-15 October 2004. London: Archetype; and Carlyle, Leslie. 2012. "Practical considerations for creating historically accurate reconstructions." In *Fatto d'Archimia. Los Pigmentos Artificiales en las Técnicas Pictóricas*, edited by Marián del Egido and Stefanos Kroustallis, 105-118. Madrid: Ministerio de Educación, Cultura y Deporte.

recipes.[3] In my reconstructions, I attempted to source materials that were as "historically appropriate" as possible. For instance, I chose stack-process lead white over other types, and (where possible) selected oils made "naturally" in small batches rather than using large-scale industrial processes; however, my reconstructions incorporated a few modern materials, including some oils made by non-traditional processes. The materials I used in my reconstructions are listed in the tables below, followed by my methods for preparing: the panels, leaded oil, and the madder lake and verdigris pigments.[4]

No reconstruction is ever truly "historically accurate." We can only approximate the medieval painting process based on our understanding of historical recipes, and interpretations of scientific analysis. Some concessions must be made based on the materials, time and expertise available. The historical accuracy of the materials is only one of the considerations that must be taken into account when interpreting the results of reconstructions. The influence of the "artist's hand" is also a significant factor. Medieval painters were well-trained craftsmen who had vast experience with the properties of their materials. Hundreds of years later, we can try to emulate their techniques, but we can never truly mimic the knowledge and dexterity they gained through years of training. It is misleading to make assumptions about medieval techniques based only on reconstructions. Researchers from the Hamilton Kerr Institute, Cambridge explained: "Whilst it is easy to demonstrate how an artist did not achieve a certain effect, that does not in itself mean that we know with certainty how an effect was achieved. […] We should be aware that any statements made about a particular case might contribute to future statements about other cases. It follows that error made in interpreting one case may not be restricted to that case, but may contribute to further errors in other cases."[5] Some of my reconstructions were more successful than others. I made several tests that did not work or had unexpected results; it is important to document these here, since they are not mentioned in publications.

Despite these limitations, reconstructions can be a very informative, useful tool. They complement the results of analysis and documentary research by providing a "hands-on" experience of how and why materials were prepared in a certain way, their rheological properties during application, and how a painting may have appeared before it succumbed to the effects of ageing. Reconstructions can also be artificially aged to gain information about how paintings deteriorate over time. I hope that my reconstructions can be a useful source for further research. For this reason, it is important that the steps in the reconstruction process are thoroughly documented in the following appendices.

[3] Carlyle 2005: 13-44.
[4] Materials are also listed within each appendix, and at the end of Articles 2.1 and 2.2.
[5] Massing, Ann (ed.). 2003. *The Thornham Parva Retable: Technique, conservation and context of an English medieval painting*, 228. Turnhout: Brepols.

Purchased materials

Kremer Pigmente GmbH & Co. KG:	www.kremer-pigmente.de/en
Natural Pigments:	www.naturalpigments.com
Sigma Aldrich:	www.sigmaaldrich.com/nederland.html
Van Beek:	www.vanbeekart.nl
Verfmolen de Kat:	www.verfmolendekat.com
Zecchi Colore:	www.zecchi.it

Binding media

Material	Source	Information[6]	Used in reconstructions
Cold-pressed linseed Oil extra (for dry pigments)	Zecchi 3310/125	"It is obtained by raw seed of linen [flax plant]. (Linum usitatissimum). This oil is obtained grinding seed and pressing them. No heating, no solvents in this preparation. It is fully natural. Provenience is Sweden. The producer is not a big one. It is a farmer's cooperative."	4b (as isolation layer and binding medium), 4c, 4e.1, 4e.2
Linseed oil, cold-pressed	Kremer 73054	"Linseed oil, cold-pressed, very light color, may contain a small amount of mucilage."	4d
Linseed stand oil, 50 P	Kremer 73200	"Linseed oil, stand-oil, heat-polymerized, without heavy metals." [Production method is not specified. It has the consistency of honey. Yellow-orange, but somewhat lighter in colour than the cold-pressed linseed oil.]	4c.5
Linseed oil, sun thickened	Kremer 73011	"Oleum Crassum, from Italy." [Production method not specified]	4d
Sun thickened linseed oil	Zecchi	"This is made by us. We make it starting with cold-pressed linseed oil	4c.5

[6] Information about oils from Zecchi Colore is from personal correspondence with the owner, Massimo Zecchi. The information about Kremer oils from their website: www.kremer-pigmente.de/en. [My observations about the materials are included in brackets].

	A 3331	join to some piece of lead metal in big glass jars exposed one full summer season to the sun. We produce it in our country house. The addition of lead is specially requested us by the 2-3 famous realisitic painters schools present in our town. (Aharles Cecil studio, The Florence Academy of Art, Angel studio etc.) because they need a faster drying than normal." [The inclusion of lead in sun-thickened oil is not typical, but leaded oils were used by some medieval artists. It would be more accurate to refer to this oil as a "sun-thickened leaded oil." It has a similar orange-yellow colour to cold-pressed linseed oil, but less transparent. It has the consistency of honey.]	
Gum arabic	Unknown source, obtained from UvA	5g gum arabic in 45 ml water, pre-mixed	4c
Rabbit skin glue	Kremer 63028	"Made from rabbit hides." Throughout these reconstructions, the percentages of rabbit skin glue/demineralized water are weight/volume (w/v).	4c (binding medium for underdrawing, isolation layers and intermediate layers)
Egg	Free-range egg from Albert Heijn		4c (egg white used as binding medium for underdrawing), 4c.10, 4d (egg and yolk ground with madder)

Underdrawing materials

For my reconstructions using wet and dry underdrawing materials, see Appendix 4c.3 and 4.

Material	**Source**	**Information**	**Used in reconstructions**
Charcoal sticks	Zecchi	"Pyrrhus" natural charcoal for drawing - square cut B/HB/H. No longer sold on Zecchi website.	4b, 4c.6, 4c.7, 4c.9, 4e.1
Charcoal powder	Verfmolen de Kat "Houtskoolpoeder"	*Translated from website: "*A natural organic pigment produced by the burning of beech branches. Suitable for making an underpainting. Is transparent."	4c (wet underdrawings)
Black chalk (pieces)	Kremer 12450 Black drawing chalk, pieces	"Deep black, from France. The black chalk is a natural black slate with a high carbon content. Deposits of this type of slate can be found in Thüringen, parts of France, and Andalusia. Cennino Cennini writes about black chalk from Piedmont; stating that it was soft enough to be sharpened with a penknife, very black, and good for drawing. These qualities allow the black chalk to be cut into smaller pieces. Put into a pencil holder and sharpened to a point, the chalk produces extremely fine black lines."	4b, 4c.6, 4c.7, 4c.8, 4c.9, 4c.10, 4e.1, 4e.2
Black chalk (pieces)	Zecchi, 4020	Natural "Pietra Nera" lumps	4c.6, 4c.7
Red chalk	*Zecchi*, 0097	Natural "Sanguine" lumps	4c.7, 4c.8
Vine black	Kremer 47000	"Pure plant black"	4c.6, 4c.9
Bone black	Kremer 47100		4c.6, 4c.7, 4c.9
Lamp black	Kremer 47250	"Furnace black"	4c.6, 4c.9

Pigments

Material	Source	Information	Used in reconstructions
Lead white[7]	Rublev stack process lead white (dry), available from Natural Pigments 475-11S, 475-15S	*From Natural Pigments website:* "Rublev Colours Stack Process White Lead is made in small amounts according to 16th century Dutch method, differing little to the "stack" process of history. It is basic carbonate of lead and usually contains about 70% of lead carbonate and 30% of lead hydroxide. This grade of white lead is composed of the actual flakes that fall off the corroded lead sheets and the white lead that is mechanically removed. It is washed and ground ready for use by the artist." Refractive Index: n_α=1.803 n_β=2.074 n_γ=2.076 Analysed by Luc Meegens (scientific researcher at the RCE): "The Rublev lead white is almost pure hydrocerussite ($Pb_3(CO_3)_2(OH)_2$) and not as the said on their web site "70% of lead carbonate and 30% of lead hydroxide. It contains another minor phase (a few percent) which I could not identify."	4b, 4c.7, 4c.8, 4c.9, 4c.10, 4e.1, 4e.2
Lead white (stack process)	Made by Arie Wallert according to the stack process method	Arie Wallert prepared the lead white himself in 1989 according to the traditional two-step process. The "curl" of lead shows some yellow areas (presumably massicot) and other impurities (minium? lead acetate?). For information on how I washed and prepared this pigment for use, see Appendix 4c.7.	4c.7, 4d
Champagne chalk	Kremer 58000		4c.5, 4c.6, 4c.7, 4c.9, 4c.10
Charcoal powder	Verfmolen de Kat "Houtskoolpoeder"	*Translated from website: "*A natural organic pigment produced by the burning of beech branches. Suitable for making an underpainting. Is transparent."	4c.7, 4c.8, 4c.9, 4c.10
Lead (II) oxide	Sigma Aldrich 11526	"99-100.5% (complexometric), yellow"	4c.5, 4c.6, 4c.7, 4c.9, 4c.10

[7] For information about the difference between traditional and modern methods of lead white manufacture see Carlyle 2005: 13-44.

Lead-tin yellow type II	Kremer 10120		4c.7, 4c.8, 4c.9
Azurite	Kremer 10200		4e.2, 4c.8
Vermilion	Kremer 42000		4c.7, 4c.8, 4c.9
Turkish burnt umber dark	Verfmolen de Kat	"Turks gebr. donker omber" PBr 7	4c.7, 4c.8, 4c.9
Burnt umber	Kremer 40730	Burnt umber, light reddish-brown, from Cyprus	4c.7, 4c.8
Dark ochre	Kremer 40310	[Named "dark ochre", but is actually a light red-brown colour]	4c.8, 4c.9
Gold ochre	Kremer 40195	From Poland	4c.8, 4c.10
English red	Kremer light: 40542 deep: 40545	German, mixed red earth, burnt. ["Deep" is a darker, cool red]	4c.8, 4c.9, 4c.10
Red earth	Verfmolen de Kat	Sardinian red earth	4c.10
Raw sienna	Kremer 40400	Natural yellow earth	4c.8
Burnt sienna	Kremer 40430	"Terra di Siena gebrannt" PBr 7, Italian, dark	4c.9
Madder roots	Kremer Pigmente Pieces: 37199 Pulverized: 37201	Root of the madder plant, or garance (Rubia tinctorum) from Turkey. [I used it to make madder pigment: see instructions below]	4c.7, 4c.8, 4c.9, 4c.10, 4d, 4e.1, 4e.2

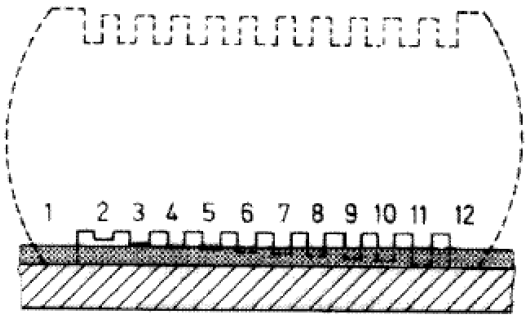
Other purchased materials

All water used in reconstructions was demineralized water.

Materials used to prepare panels:
- Oak support (pieces ± 25 x 50 x 1 cm): quarter-sawn European oak (leftover from veneer), from Amsterdamsche fijnhouthandel: www.fijnhout.nl
- Size for panel: rabbit-skin glue (Kremer 63028)
- Chalk: Champagne chalk (Kremer 58000)
- Chamoix (shammy leather, used to smooth ground, and to emulate rubbing in priming with hand): Praxis: www.praxis.nl
- metal scraper (borrowed from Herman van Otter, UvA)

Materials added to paint:
- colophony, left over from reconstructions by Leslie Carlyle (Reconstruction 4d)
- wood-ash glass: fragment of 18th century glass from broken protective glass of pastel in Rijksmuseum (Reconstruction 4d) / potassium glass (Reconstruction 4c.7.5-C)

Wet film comb thickness gauge



A wet film comb thickness gauge was used to measure the thickness of paint layers immediately after they were applied. The BYK Gardner Wet Film gage (PG-3507) measures thicknesses from 5 to 150µm in 5µm increments (between 1 and 50µm), 10µm increments (between 50 and 100µm) and 20µm increments (between 100 and 150µm).
The thickness is measured by holding the comb perpendicular to – and in contact with – the test surface, then removing it vertically. The thickness of the wet film is determined by looking at the values of first tooth that shows traces of paint and the last uncoated tooth: the thickness lies between the two. In the example in the diagram, the film thickness lies between 3 and 4.[8]

Brushes
- Van Beek: 1½" hogs hair brush (336002) / 1012R Pure sable 00 (330300) / 2002 Pure Kolinsky 2 (339793) / 2003 Pure Kolinsky 2 (339802) / 2053 Filament Plus 10 (339084) / 2001 Pure Kolinsky 10 (339697) / 1012 pure sable #2 (for applying texture in Reconstruction 4d)
- Heger van den Berg: 1520 Red Sable 00 (4017505057398) / 1520 Red Sable 000 (4017505057381)
- Van der Linde: 725 "Cat Tongue" 10 (4040518918608) / 7485 Da Vinci 12 / 31240 Linde 2
- Kremer: sponge (Kremer 99501 "Aquarellschwämme klein" natural sponges, cut into pieces, used in Reconstruction 4c)

[8] The diagram and information are from: "Mechanical Film Thickness Gauges for Coating Plants and Laboratories," www.khushbooscientific.com/erichsen/TBE-233-234-296-333-433.pdf

Other supplies of unknown origin, borrowed from the conservation department at the University of Amsterdam (UvA)

- brushes (mostly hogshair or sable)
- mullers, glass rod and glass plates for grinding pigments
- palette knives
- solvents for cleanup
- nitrile gloves
- pipettes
- masking tape
- melinex
- wooden skewers (saté sticks)
- draw-down bar that produces film thicknesses of 15, 30, 60 and 90 µm (borrowed from Maartje Stols-Witlox)
- scraper for preparing grounds (borrowed from Herman van Otter)
- disposable plastic pots for keeping wet paints: Fisher Emergo: 280103 – pot 50ml WH helder glas DIN 40 + lids 280302 Schroefdop DIN30 PP
- tracing paper
- scraps of cheesecloth and canvas (for blotting tests in 4d)
- black and white tiles: Praxis, www.praxis.nl

Preparation of materials, supports, and pigments

Preparing of supports and grounds

The panels for all of the reconstructions were prepared in similar way. The grounds were prepared based on guidelines by Charlotte Caspers. The supports and grounds were prepared with the assistance of Esther van Duijn and Indra Kneepkens.

Panels = quarter-sawn European oak panels, 12mm thick, 23-25 cm wide, approx 52 cm long (three of the boards are ±61.3 cm long), planed on both sides. Ordered from Amsterdamsche Fijnhouthandel: www.fijnhout.nl

Sizing:

1. Presized recto of wood: 5% rabbit skin glue (RSG w/v) in water (labeled with 'R' in bottom right).
2. Presized verso of wood with 10% RSG in water (labeled with 'V' in bottom right). Glue prepared as above. Applied slightly more thickly than on the verso.
3. Applied another coat to recto: 5% RSG in water.
4. Applied 10% RSG to recto.

Ground:

5. 10% RSG was heated to 40-60^{o}C. Champagne chalk was sieved into the glue solution until the solution was saturated, and slightly heaped on the top (no stirring). It was left on the heat for a while.
5. Each time a layer of ground was applied, the verso of the panel was wiped with a damp cloth to prevent warping.
6. Applied 1st layer of ground to the recto using a hogshair brush in vertical strokes.
   Ground: 10% RSG in demineralised water + chalk..
   The ground material was kept heated *au bain marie* while each layer dried to the touch. Overnight, it was refrigerated than reheated au bain marie (30-40oC), and some water was added if necessary.
6. Once the 1st layer was dry to the touch, applied 2nd layer of ground using horizontal strokes. For the rest of the layers, the direction was alternated (vertical/horizontal).
7. Applied 5 layers of ground in total.
8. Scraped grounds with metal scraper, using vertical and horizontal strokes, turning the board periodically to ensure evenness.
9. After scraping, some additional ground layers were applied. Total: 7 layers.
10. Scraped ground with scraper, using a better method: putting pressure on the sides of the scraper so that it bows out in a convex fashion, then pushing the scraper away from you:) →
11. The ground was sanded with 320 grit sandpaper wrapped around a wooden block. Sand in parallel lines in both horizontal and vertical directions until a smooth surface was achieved.
12. The surface was wiped with a dry *chamoix* (shammy leather) to remove excess dust.

[Steps 11 and 12 (sanding with sandpaper) are not historically accurate. In the fifteenth and sixteenth centuries, painters probably sanded their grounds with the skin of a shark or

skate, the skeleton of a cuttlefish, or coarse reeds. It was important that the ground be smooth and less absorbent, so after some experimentation, we chose to use sandpaper in the final stages.]

Sized panels

Ground being heated au bain marie

Preparing leaded oil

The leaded oil was prepared by two UvA Masters' students (Lidwien Wösten and Nienke Woltman). It was made following a recipe for a drying oil used for reconstructions at the UvA, adapted from a recipe from the DeMayerne manuscript (1620).[9]

Cold-pressed linseed oil (Kremer) and Lead (II) oxide (Sigma Aldrich) in 6:1 proportions. The oil was warmed to 110°C, then the lead oxide was added and stirred (in a fume cupboard with adequate personal protection). The resulting oil was dark brown; apparently it becomes lighter over the course of weeks. After three weeks of sun exposure, the oil became a dark orange colour, and some precipitate (milky whitish-yellow) settled at the bottom. Its consistency is similar to cold-pressed linseed oil.

[9] Recipe from Renate Woudhuysen-Keller and Charlotte Caspers.

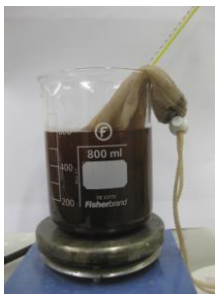
Preparing madder from roots

This pigment was used for reconstructions 4c, 4d and 4e. It is based on the Standard Madder Lake Recipe 1 (Code: ML-Std) from *Back to the Roots: Workshop on the Preparation of Historical Lake Pigments*, organized by the Doerner Institute, Munich.

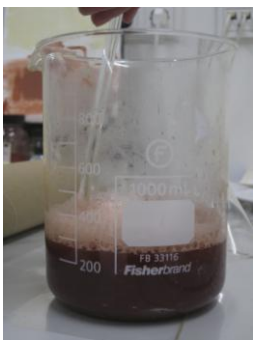
Materials:
- madder root, pulverized (Kremer 37201)
- potassium carbonate (Kremer 64040)
- potash alum (Kremer 64100)

Day 1:

- Put 50g coarsely-ground madder root in netting bag large enough to allow the plant material to move freely and soak overnight in a 2500ml (2.5L) beaker with 1500ml (1.5L) water.



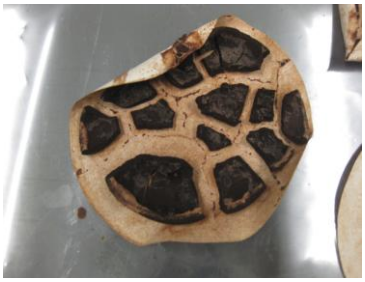
Day 2:
- After soaking, heat the solution up to 70°C and extract the dye for 30 minutes.
- Remove the bag and filter the solution **hot** using a glass funnel and folded (coffee) filters.

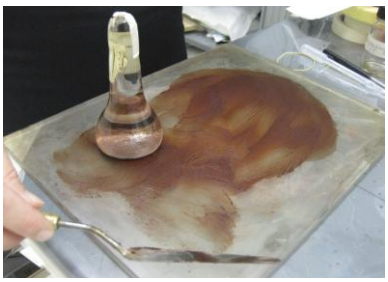


- Add 25g potash alum ($KAl(SO_4)_2$)to the warm solution and reheat to 70-80°C.
- Meanwhile, make up a solution of 9.4g potassium carbonate (K_2CO_3) in 250ml water (in a 2.5L beaker).
- Add the dyestuff solution slowly (but not too slowly) to the alkaline solution with constant stirring using a glass rod. Check the pH (it should be about 6, no less).
- Leave the precipitate to settle overnight.

Day 3:
- The next day, throw away the supernatant liquid. Filter and wash the pigment using a Buchner filter until the filtrate is clear and no further colour comes off.

These quantities yield about 10g of pigment after drying.





Day 4:

- Grind the pigment with water on a glass plate with a muller. Allow it to dry and scrape it off.
- The dry pigment can now be ground with oil.

Preparing verdigris

Materials:

- copper strip, 1mm thick (Salomon's Metalen, www.salomons-metalen.nl)
- glass jar (Xenos, www.xenos.nl)
- organic red wine vinegar (Albert Heijn, grocery store)

The verdigris strips were suspended above the vinegar vapors in a closed jar. The copper was not in direct contact with the vinegar. Green crystals started to form with in a day, and within two weeks, it had formed a thick green crust. The crust was removed by scraping one copper strip against the other. The copper strips were then put back into the jar with new vinegar for another two weeks. The second batch of verdigris was bluer than the first batch.

Copper strips in jar after 2 days

Copper strips in jar after 2 weeks