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8 The Muller

Insights into Practical Artistic Knowledge through Re-Making Experiments

Maartje Stols-Witlox

Abstract

This essay argues that investigations into objects from the past benefit from a move beyond reading and looking, discussing how multi-sensory experiences help unpack the black box of historical artistic practice. The essay focuses on the muller, an object that played a central role in historical painting, as it was used to grind pigment in oil. As evident from historical written sources (c.1580–1900), handling the muller required skill and an intimate knowledge of the various pigment properties. This essay not only unravels written advice on how to use a muller but also reconstructs that advice. Such a reconstruction allows us to examine the influence of mulling on pigment particle size and paint flow properties.

Keywords: muller; grinding stone; oil paint preparation; historical recipe; reconstruction

Neither Vasari (1568), van Hoogstraten (1578) nor de Lairese (1712) mention the muller in their treatises. Yet, all three painter-authors would have had one or several mullers in their studios. This must have been so, as early modern artists purchased their paints as loose pigments and binders. The muller was the tool they used to grind these materials into paint. A muller is a simple object. It is nothing more than a flattened stone or a similarly hard object that one uses to crush or grind a particular material. As explained in the Oxford English Dictionary, it is typically employed in conjunction with a flat slab or plate, and the material to be mulled is crushed between

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the surface of the muller and that of the slab.¹ In the case of paint-making, the muller serves both to decrease the size of pigment particles or to break up clumps of particles, and to mix and disperse these pigments in a liquid to make paint – in the Western tradition, typically oil for oil paint, egg for tempera paint, or water and gum for watercolour.

Paint-grinding receives passing attention in Karel van Mander's (1604) *Schilderboeck*, in anecdotes involving pupils or studio assistants – traditionally tasked, in a more successful studio, with paint preparation.² According to Van Mander, following Pliny, the Greek painter Erigonus learned to paint by observing Nealces at work, while Erigonus was employed to grind the paints for this artist.³ In his life of Taddeo Zuccherò (1529–1566), whose career as painter had a rocky start, Van Mander mentioned paint-grinding in a description of the hardships endured by the aspiring artist, having to go 'from shop to shop grinding paints for a small wage'. Yet, as we learn from Van Mander, Taddeo persisted: he 'did not lose his courage or eagerness to learn: but sustained it with effort and discomfort as best as he could'.⁴

We learn more about the muller by looking at painted interiors of artist's studios and by reading historical recipe books. Such texts provide insights into the actual handling of the muller and into the sensory cues that guided the artist during paint-grinding, and they reveal why certain materials, shapes or techniques were considered appropriate for the task. The body of historical recipes studied for this essay dates from the late sixteenth century to the end of the nineteenth century.⁵ Examining recipes from

1 The Oxford English Dictionary defines the muller as 'A stone (or similar object) with a flat base or grinding surface, which is held in the hand and used, in conjunction with a grindstone or slab, in grinding painters' colours, medicinal powders, etc.', while indicating that from 1823 onwards, sources use the word also for 'other mechanical devices for grinding or crushing', based on sources that use the same term for grinding equipment material can be passed through or placed inside of. Entry 'muller, n.¹'. URL Oxford English Dictionary, Oxford University Press, <https://doi.org/10.1093/OED/1044678732> (last accessed 31 July 2023).

2 Van Mander 1604, 5r, 78v, 79r.

3 'Den goeden en snellen gheest van Erigonus. en behoef niet vergheten te worden, welcken eerstmael niet en diende, dan slechs om Nealces zijn verwen te wrijven, alwaer hy soo veel is ghevordert, met desen Schilder alleen maer te sien wercken, dat hy namaels de const van schilderen heeft gheleert den doorluchtighen Pasijs, broeder van Aegineta, beeldenae'. Van Mander 1604, 87r.

4 'Doch en verloor noch Taddeo den moedt noch leer-lust niet: maer onderhield hem met grooter moeyte en ongemack so hy best mocht, van winckel te winckel achter Room verwe wrijvende voor cleenen loon', Van Mander 1604, 161r.

5 The methodology applied to establish the recipe collection was as follows: historical recipe sources gathered in previous research by the author and known to describe paint-making were searched so as to find descriptions of paint-grinding. Terminology used to refer to the muller

such a lengthy period allows reflection on the development of the use of the muller, while the inclusion of nineteenth-century recipe books, written increasingly for audiences of amateurs or aspiring artists who had no master to study with, opens up a large body of information with an unprecedented level of detail. It is important to realize that from the 1840s onwards, artists would be able to purchase readymade paints in tubes.⁶ Paint-making was at that time largely the terrain of artist's materials manufacturers, operating from the larger cities and trading their paints internationally.⁷ In such larger establishments, paint-grinding was executed increasingly on large, machine-driven mills. Yet, hand-grinding with the muller did not completely disappear from artistic practice. Callen (2000) discusses the commercial availability of hand-ground paint in late-nineteenth-century Paris. Possibly, artists' mistrust of the quality of machine-ground paint played a role in the continued availability of hand-ground paint and the survival of the practice of hand-grinding in artist's studios.⁸

In what follows, we first take a close look at the object of the muller, studying the how and why of its characteristics (size, material and shape). The second section focuses on the effects of mulling and on texts describing the way the muller was used in paint-making. Reconstructions inform the analysis of such historical texts, as the multi-sensory experience of reconstructing affords an enhanced understanding of the practical

mulling and paint-grinding in Dutch, English, German, French, Spanish and Italian was used for a list of terms that could be subsequently used for full-text search in online repositories of historical books (archive.org, Google books, data.bnf.fr), which led to the discovery of additional sources. The time period studied was 1500–1900, while transcribed and earlier published sources were included for reference. All recipe texts were entered into a database created with Filemaker Pro. To date, this database contains 132 recipe texts, 8 from the sixteenth century, 18 from the seventeenth century, 43 dating from the eighteenth century and 63 from the nineteenth century. Images of artists' studios that illustrate this article were identified using the database of the RKD, the Dutch Institute for Art History, by searching their image collections for images of artist's studios dating from the early modern period.

6 In 1841, the American artist George Rand patented the collapsible zinc paint tube (Harley 1971).

7 Mayer et al. 2011, 144 discuss the availability of French and English brands of paints (Goupil & Co, Winsor & Newton, Rowney & co, Roberson's) in 1850s New York.

8 See on colour-grinding in the nineteenth century also: Callen 2000, 98–100. As artists wanted to buy dependable paint of constant quality, paint formulation became more standardized. Yet archival research demonstrates that some manufacturers would take orders for small batches of paint, catering to the individual demands of painters. The personal accounts of artist Frederick Leighton at colourman Charles Roberson & Co. in London contains orders by Leighton for paints ground extra stiff. Woodcock 1995, 33. Additional examples of artists ordering tailor-made paints are discussed in Bomford 1990, 41.

implications of grinding, thus raising our understanding of written accounts and depictions of this activity. Reconstructions, moreover, allow us to explore operational variables that influence the character of the paint and thus the visual language of the artist. This chapter, arguing that investigations into objects from the past benefit from a move beyond reading and looking, discusses how multi-sensory experiences with objects such as mullers can help unpack the black box of historical artistic practice. Methodologically, the chapter falls within the field of multi-sensory research into historical practices of making, a field attracting growing interest through the work of, among others, Pamela Smith and Leslie Carlyle.⁹ Investigating by re-doing enlightens the art historian's understanding of artists and their art.

The Muller

The use of the muller has extended far beyond paint-making. Differently shaped grinding stones for food or medicine preparation, among other uses, are encountered throughout time and across a wide range of cultures; the action of reducing materials to a powder with a muller and a slab, or alternatively with a mortar and pestle, is a common processing method. Mortar and pestles hardly feature in the recipes describing pigment grinding and paint-making, likely because they do not lead to a sufficiently fine division of particles. This is alluded to by Robert Dossie (1758, 164), who mentions mortar and pestle as a tool to prepare glass or 'hard bodies' for grinding on a stone or a mill. An important difference between grinding with a muller and with mortar and pestle is the fact that a worker can fully lean on the muller and thus exert much more pressure than would be possible with a mortar. While material can be pounded with a pestle, this movement is far less coordinated than the grinding movement afforded by the muller.

Paint mills are mentioned for paint-making from the eighteenth century onwards. In the eighteenth century, paint mills consisted of two flat stones, one of which could be turned around. The pigment slurry would be introduced into the hole in the middle of the top stone, and turning would cause it to be mixed and spread towards the outside of the stone, where it was collected. However, as Dossie writes, paint mills were suited only for the preparation of courser paints.¹⁰ By the third decade of the nineteenth

9 See Dupré et al. 2020.

10 'Levigation of colours, where great quantities are in question, is performed in hand and horse-mills: but this fails to produce so perfect an effect, as the muller and stone, which is used

century, there is evidence that steel paint mills were employed to prepare the courser paints used by house or decoration painters.¹¹ Such mills consisted of a tapered funnel with a ribbed lower edge, which was placed on a horizontal iron slab with a ribbed edge. Turning the handle, the paint-maker could turn this iron slab around, the paint being ground between the lower edge of the funnel and the slab.

Mullers are typically used in combination with a grinding stone – a flat or concave plate on top of which the muller is moved back and forth. The materials and shapes of mullers and grinding stones are dictated by particular usage and depend on local availability. Mullers for paint-making feature in artist's inventories, among others that of the widow of Johannes Vermeer.¹² They also travelled the globe: they were taken on board ships sailing the early modern seas, most likely for maintenance and repairs during the voyage.¹³

Abraham Bosse's etching shows a *Painter in His Studio* handling the muller to grind pigments in a binder (fig. 8.1). The artist stands in a slightly bent position, wearing a headband to keep his hair from falling into his eyes – or into the wet paint. He leans on the muller with both hands, using his weight to exert force, even though the position of his feet suggests a relatively relaxed stance. He has placed a small heap of paint in the top right corner of the grinding stone, and to the artist's left a flat square object and something resembling a knife rest on the stone. To his right stands a bottle – the oil he is grinding the pigment in? – and on his right we see two

in all other cases: the assistance of a pestle and mortar being indeed taken in the case of glass, and hard bodies, to prepare them for the mills or stone', Dossie 1758, 164.

11 Bristow 1996, chapter 15, describes patents and early evidence for machine grinding of house-paints in greater detail. For the large-scale manufacture of fine artists' colours, larger machine-driven roller mills came into use during the Industrial Revolution, and Callen 2000, 99 discusses evidence for the availability of machine-prepared oil paints appearing in Paris by 1836.

12 'A stone tablet to grind paints with a stone' ('Een steene tafel om verruwe te vrijven met de steen daer bij') in the attic ('boven opde solder') are mentioned in the estate inventory of Vermeer's widow, Catharina Bolnes, drawn up in 1676 (Roelofs 2023, 295). Bredius 1915, vol. 1, 114, lists 'a porphyry stone with muller' ('een porvier steen met een loper') in the 1649 inventory of Jacob Marrell, drawn up after the death of his wife. Bredius 1916, vol. 2, 408, '2 grinding stones of which one porphyry' ('2 wrijfsteenen, daervan een van puvier steen') in the 1671 inventory of the widow of Bartholomeus van der Helst and his son, Lodewyck van der Helst.

13 A marble muller and grinding stone were recovered from the 'Palm wood shipwreck', a seventeenth-century ship thought to have sunk around 1650 off the coast of the Dutch island of Texels. They are in the collection of the Province of North-Holland and are on display at the Texels Museum Kaap Skil in Oudeschild. An 1816 publication, providing instructions for dimensions and particulars for ships to serve as freight ships for the East India Company, includes in its inventory list, under the header 'colour-man', '1 paint stone, 1 Muller for do', suggesting the standard presence of grinding equipment on such travels. Anonymous 1816, 27.



Figure 8.1 Abraham Bosse, *A Painter in His Studio*, c. 1667, etching, 263x186 mm, New York, Metropolitan Museum of Art, inv. no. 2012.136.173.

dishes, possibly to hold the pigment or the paint. The muller used by the artist has a rounded top and a flat bottom. It somewhat resembles a stone that has been cut in half. A similar cone shape is seen in historical depictions of artist's studios, and the recognizability of the same basic shape, even in an 1827 French source, Bouvier's *Manuel des Jeunes Artistes et Amateurs*, demonstrates its consistency through time (fig. 8.2, mullers O and Q).¹⁴ Yet

¹⁴ Continuity is evident in the shape of a muller found in Thebes, Egypt, 1550–1100 BCE (New Kingdom), British Museum inventory number EA5547, the muller depicted in David Ryckaert III, *Painter's Studio with Paint Grinder and Model*, c. 1638, oil on panel, 59 x 95 cm, MI 146, RMN Grand Palais (Musée du Louvre), and in Andries Both, *The Distressed Painter*, 1624–1640, drawing,

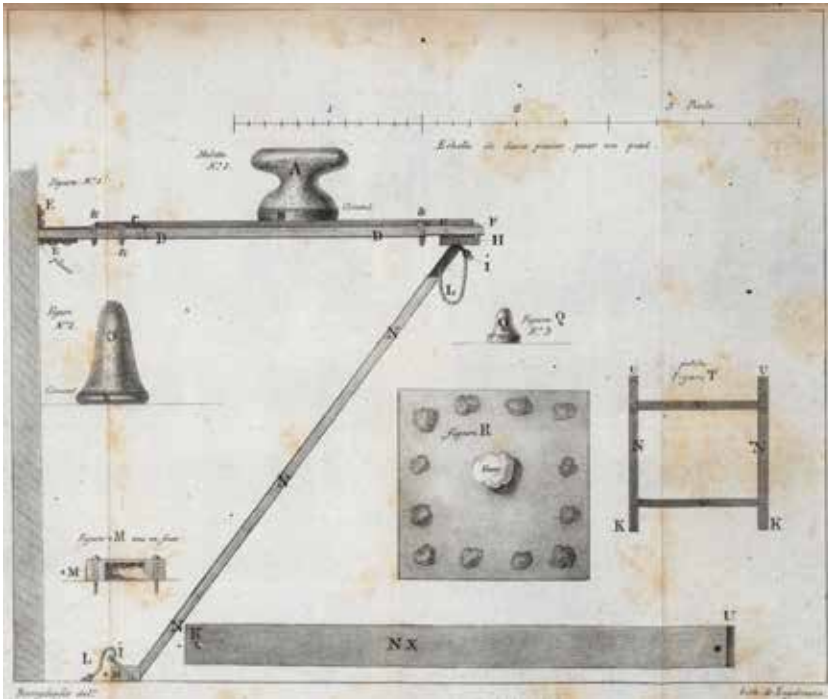


Figure 8.2 Plate 1 from Bouvier's *Manuel des Jeunes Artistes et Amateurs en Peinture*, Paris 1827, showing three types of mullers (A, O and Q).

certain developments in the shape of the muller also seem evident. From the eighteenth century onwards one also encounters cylinder-shaped mullers, as well as mullers with narrower handles and a broad base. The latter shape is closest to that of the glass mullers currently available in art-supply stores. Bouvier's plate 1 (fig. 8.2) illustrates the different mullers he advises for the various stages of paint grinding. A in figure 8.2 depicts the muller used to grind larger amounts of paint. It is the largest one and it has a large, flat top, shaped like a 'bequille' (in English a 'crutch'). Bouvier is very content with this shape, he writes. It allows him to lean into the muller with the whole weight of his upper body without the muller toppling over. And, Bouvier adds, a muller shaped like this has an additional benefit: it does not roll off the table and break when laid on its side – apparently something he experienced with mullers of other shapes.¹⁵ O in Figure 2 is also a fairly

British Museum, 1836, inv.no. 0811.75, on the title page of Bogaart 1692, and in: Anonymous 1886, vol. 4, 523.

¹⁵ Bouvier 1827, 130: 'for my use, I prefer it, because I have found out that one has more force with this one than with no. 2, because one weighs on it not only with the arms, but even more

large-sized muller. It can serve for similar purposes as muller A, but is encircled with both hands during use. The small muller Q, finally, is used to further process small quantities of paint on the palette or on a small glass plate, and can be held with the fingers of a single hand. Bouvier advises it for pigments that cannot be kept and must therefore be freshly ground, or to disperse pigments into oil that do not require much grinding.¹⁶

Bosse's etching cannot tell us what material the muller was made of. A number of written historical sources discuss suitable materials and advise against others. Table 8.1 (at the end of this chapter) provides an overview of materials mentioned through time. While certain developments over time are evident with regard to the shape of the muller, the use of material is surprisingly consistent. Hard stones and glass are mentioned throughout the period, and the only innovation evident from written sources is the introduction of porcelain mullers in the nineteenth century. Porphyry – a particularly hard and evenly grained type of granite – is a favourite with many.¹⁷ However, it was costly, and sufficiently large porphyry was not always available.¹⁸ The anonymous *Nieuwen Verlichter* (1777) and Bouvier (1827) each describe how an artist could use glue to attach a flat sheet of costly hard stone to a handle of a less rare material, a means for painters to grind with porphyry at a lower price.¹⁹ Many authors list what they consider to be

with the whole weight of the body: in addition it has the advantage of resting where one puts it, when one lifts it and places it on the side; while the other rolls of itself, and always risks falling when one does not place it on its base, which is highly annoying' ('pour mon usage, je lui donne la préférence, parce que j'ai éprouvé qu'on a beaucoup plus de force qu'avec celle no. 2, attendu qu'on pèse dessus non-seulement avec les bras, mais encore de toute la pesanteur du haut du corps : elle a en outre l'avantage de rester où on la pose, quand on l'enlève et qu'on la place sur le côté; tandis que l'autre roule d'elle-même, et isqué toujours de tomber quand on ne la pose pas sur sa base, ce qui est fort embarrassant').

16 Bouvier 1827, 123–126.

17 See also footnote 12, which lists two mentions of a porphyry stone in the inventories of seventeenth-century Dutch artists.

18 Hire 1730, 683–685: 'Porphyry is the toughest stone we have, & which as a consequence is the most proper for grinding the colours [...] But it is not easy to secure a piece of porphyry well straight & unified etc. of a reasonable size to grind comfortably; this is why when needed one may use granite from the Orient, which is also very tough, & even an 'ecaille de mer', which is very strong when it is of good quality' ('Le porphyre est la pierre la plus dure que nous aïons, & qui par conséquent est la plus propre pour broïer les couleurs [...] Mais il n'est pas aise de recouvrer une tranche de porphyre bien droite & unie & c de grandeur raisonnable pour broïer commodément ; c'est pourquoi à son défaut on peut se servir de granit d'Orient, qui est aussi fort dur, & même d'une écaille de mer, qui est fort dure quand elle est de la bonne qualité'). Bouvier 1827, 130: 'because the porphyry is a rare and expensive stone' ('... comme le porphyre est une pierre rare et chère').

19 Anonymous 1777, 1718: 'from a flat piece marble attached to a wooden muller' ('uyt een plat stuk marmer tegen eenen houten looper vastgezet'); Bouvier 1827, 131–132, 'How to even the base

suitable alternatives to porphyry, mainly granites and marbles, all stones whose hardness they emphasize. It seems that hardness is important not only because a material must be harder than the substance it is reducing to a powder, but also for another reason: the wearing away of the muller during grinding can seriously reduce paint quality. De la Hire (1730) writes that 'stones that are tender wear away during grinding and mix with the colours, which kills the brilliance if they are lively colours'.²⁰ Such wearing away may be one reason why glass was advised as a substitute from early on.²¹ As discussed by Bouvier (1827), glass particles, when they are worn off the muller and contaminate the paint, add a material that does not endanger the colour, as it has 'no colour and no bulk'. Furthermore, glass, due to the cobalt it contains, could even help oil paint dry.²² Smoothness or fineness of

of a muller with a handle' ('Comme on soude la base d'une molette avec la poignée').

20 'les pierres qui sont tendres s'usent en broiant & se mêlent avec les couleurs, ce qui en ternit l'éclat si ce sont des couleurs vives', Hire 1730, 683–685. See also Bouvier 1827, 123–125: 'There are many other stones which are used by varnishers, and even by merchants of painting colours, but those you should not use; because a certain grès stone, less strong than glass, and also of a grain quite rough, wears away a lot, and always dirties a little the delicate colours; one may thus change them when combining these: this is a risk one does not run when one uses a thick glass' ('Il est beaucoup d'autres pierres dont on fait usage chez les vernisseurs, et même chez les marchands de couleurs pour tableaux, mais qu'il ne faut pas employer; comme un certain grès, moins dur que le verre, et qui d'ailleurs a le grain si rude, qu'il s'use beaucoup, et salit toujours plus ou moins les couleurs délicates; il peut d'ailleurs les altérer en s'y combinant: c'est un risque que l'on ne court point en se servant d'une glace épaisse').

21 Some authors distinguish between crystal glass and other types of glass, crystal being preferred due to its hardness. Sanderson 1658, 54–55 writes that glass is too soft and mixes with the colours, whereas crystal is of good quality but is difficult to find. Bogaart 1692, J verso, advises the artist to order a muller of crystal glass, which due to its hardness is proper both for watercolour and for oil paint grinding.

22 Bouvier 1827, 123–125, discussing materials for the grinding stone – the same materials employed for the muller: 'Glass reduced to an impalpable powder has neither colour nor consistency; it is a white powder, transparent, which, mixed with the colours, even in abundance does not do any harm: it actually has the property, like smalt, to facilitate drying. I do not pretend to insinuate that one should use this means; I only signal that to relax those who believe, strongly, that using glass produces an insensible mixture through the wearing away of glass. Red porphyry or agate stones are, without doubt, better to have: those who can procure one sufficiently large do well to acquire them: but my experience has convinced me that using large glasses has no inconvenience. Besides, agates and porphyries are of an excessive price, and cost at least twenty or thirty times more than a glass of the same size' ('le verre réduit en poudre impalpable n'a ni couleur ni consistance; c'est une poudre blanche, transparente, qui, mêlée dans la couleur, même avec abondance n'y ferait presque aucun tort: elle aurait plutôt la propriété, comme le smalt, de faciliter la dessiccation. Je ne prétends cependant pas insinuer qu'on doive user de ce moyen; je ne le signale que pour tranquilliser ceux qui craindraient, à tort, un mélange insensible produit par l'usure du verre. Les pierres de porphyre rouge ou d'agate sont, sans contredit, ce qu'il y a de meilleur; ceux qui pourront s'en procurer d'assez grandes, feront bien de les acquérir: mais mon

grain was a sought-after quality in mullers and grinding stones, for practical reasons. As Bogaart (1692) explains, uneven sides with pits or pockmarks cannot be cleaned well, and the paint left behind would contaminate the portion of paint that has been ground to sufficient fineness below the muller. As a result, you would have to re-grind your whole batch.²³ Muller dimensions, if given, differ from source to source, reflecting the variation we also encounter in Bouvier (1827), who describes and depicts three different sizes, each with their own use or purpose (table 8.2, fig. 8.2). As early as 1634, there is mention of readymade mullers being available. Henry Peacham explains that in London these mullers could be purchased with ‘those that make toombes’, and the anonymous *Excellency* (1668) directed readers to ‘marblers’ for purchase of a muller. Smith (1687) writes that mullers could be had at the ‘colour-shop’ for prices ranging between eighteen pence and two shillings.²⁴ Bogaart points to glass makers (the ‘glass house’) if one wished to purchase a crystal glass muller, which one should have polished smooth and flat at this same supplier.²⁵ Home-made mullers cannot be ruled

experience m'a convaincu que l'usage des fortes glaces n'a aucun inconvénient. D'ailleurs, les agates et les porphyres sont d'un prix excessif, et coûteraient au moins vingt ou trente fois plus qu'une glace de même dimension'). Cobalt is a siccative used by artists for drying oils (mainly linseed oil, poppy oil or walnut oil). Its catalytic qualities speed up drying. For historical use of cobalt siccatives during the eighteenth and nineteenth centuries, see: Carlyle 2001.

23 Bogaart 1692, L recto: 'And the stone used to grind should be a stone which has been ground smooth and even at its bottom and sides so that one may strike off more easily its paint which because of the grinding stick to the side of the stone, to grind together with the other paint that lays on the stone which if your stone were at its side uneven and full of pits one could not do because how clean could you strike off your paint on the side of the stone, always some course paint would remain within the unevenness or the pits of the stone which afterwards when you have ground your paint sufficiently and want to take it off the stone would easily mix with the rest and this happening you should because of this make all your fine paint completely useless for use or you should at least always be forced to again first grind what you would never have to do if the sides of your stone have been smoothly and evenly ground' ('en de steen die men daer toe gebruijck om te vrijven moet een keij weesen die van onderen en tersijje wel glat en gelijk is gesleepe om dat men sijn verve die door het vrijven tersijje aen de steen blijft hangen soo veel tegeemackelicker altemedt sou konnen af strijcken om met de andere verve die op de steen leijt gelijk fijn te vrijve het t'welck gij anders als uwen steen tersijje ongelijck en vol putten waer soo wel niet sou konnen doen want hoe schoon dat gij uwe verf tesijje van de steen sou [souhe?] af te strijcken soo souder togh altijs noch eenige grofve verf tusse de ongelijckheede of in de putten van de steen blijven steecken die naderhant als gij u verve genogh heb gevreeve en die van de steen sou willen doen dan lichtelijck onder de andere sou geraeck en dat gebeurende sout gij daer deur al u fijne verve ganschelijck onbequaem maecke om te gebruijcke of gij sout voor minste altijs genoot saeck weese die weeder om eerst tewrijfven het t'welck gij nimmer meer sal hoeven dedoen als uwe steen tersijje glat en gelijk is gesleepten').

24 Peacham 1634, 65; Anonymous 1668, 68; Smith 1687, 12.

25 Bogaert 1692, 25: 'have muller made from crystal glass in the glass house and have it ground and polished very smooth and even' ('Wrijver in het glashuijs van kristal glas laeten maken diese dan seer glat en gelijk laeten slijpen en polijsten').

out either, as evidenced in Pictorius's [pen name] 1747 publication. In this Dutch-language handbook, artists are advised to search for a hard, oval pebble along the Rhine or other rivers. They should halve the stone they have found, and grind and polish the flat side until it is smooth and clean (*'glat en suiver'*). When ready, the stone should be immersed in oil before using it to mull paints.²⁶ Drenching somewhat softer stones in oil before use was also mentioned by De Piles (1767).²⁷

Remarks on material and shape underscore the obvious: a muller's materiality is dictated by its function. This includes some of the finer details one may need to be alerted to by reading historical recipes and through trial and error. One example is the edge between the grinding face and the sides of the muller. This edge must be rounded like the edge of a bottle, as noted by the anonymous author of the 1849 *Handbook of Young Artists and Amateurs*. For if the edge were square and sharp, the muller would push away the paint instead of grinding it: 'A muller whose edge touches vertically all round the circle is improperly constructed; the color cannot insinuate itself between the bottom and the slab, and in a few turns you will find yourself grinding little more than the bare glass or stone'.²⁸ Additionally, the same handbook continued, the muller then sticks to the surface of the grinding stone and is extremely difficult to lift off.²⁹ Indeed, in figure 8.3, of a muller that dates to the eighteenth century, the rounded edge is easily recognized once you know to look for it.

Authors of nineteenth-century recipe books discuss the importance of the muller's surface finish. There needs to be some resistance or tooth in order for mullers to work properly, we learn, and the grinding face should be completely flat. The necessary care required is made clear by the several

26 Pictorius 1747, 416–417. Also, in late eighteenth- and nineteenth-century sources, evidence is given of the availability of readymade mullers. The anonymous author of the *Painter's, Gilder's and Varnisher's Guide* (Anonymous 1836, 1–3) writes about stone mullers being available at colour-shops, and in the *Handbook* (1845, 106), published in New York, mention is made of the excellent quality of glass mullers purchased at the 'Office of the New Jersey Glass Works in Cedar-street'.

27 De Piles 1767, 64–65: 'The muller, which serves for grinding, must also be of the same stone. They are sometimes made out of very hard grès, and if it is well made and immersed in oil, it can be of good use' ('La molette, qui sert à broyer, doit être aussi de la même pierre. On en fait quelquefois de grès fort dur, & lorsqu'il est bien préparé & imbibé d'huile, il peut être d'un très bon usage').

28 Anonymous 1849, 106. The *Handbook*, published in New York, is largely based on Bouvier 1827; its title page presents the book as 'a condensed compilation from the celebrated manual of Bouvier'. The passages quoted here summarize certain points made earlier by Bouvier.

29 Anonymous 1849, 106. To this comment, Bouvier 1827, 128 also writes that the rounded edge itself should be polished, so that the paint easily flows past it.



Figure 8.3 A stone muller that is still covered with a crust of old paint, dated to the eighteenth century by its owner: The Table Gallery. Dimensions: 13,5x27,5 cm (diameter x height).

instructions to purchase only unpolished or 'ground' glass mullers, and by instructions for the dressing of the muller's grinding face – it is to be smoothed and flattened on a flat surface using mild abrasives.³⁰

³⁰ Gregory 1815, vol. 2, 338 advises roughening the glass muller with 'fine flour emery, which will give it a surface that will continue a long time'. Bouvier 1827, 127, discusses the dressing of

Using the Muller

Who dressed and held the muller to grind the paint? The introduction to this chapter quoted Van Mander on the role of the pupil or studio assistant. Assistants may have been ‘journeymen’, skilled workers paid by the day.³¹ Of course a role for family members cannot be ruled out. The notebooks of Charles Beale, the husband of English portrait painter Mary Beale (1633–1699), document that he performed some of the paint-grinding for his wife’s studio, though at times he also left this to a local colourman.³² In two amusing drawings, *Andries Both* (attributed, both dating c. 1625–1641) contrasted the circumstances of the happy painter, painting away merrily at his easel while an apprentice or assistant grinds his paints, and the poor painter and his family, all dressed in rags, the wife doing the paint-grinding.³³

Whoever ground the paints, the general procedure was quite uniform and is described in detail by John Smith in his 1687 *Art of Painting in Oyl*:

let your grinding-stone be placed about the height of your middle; let it stand firm and fast, so that it joggle not up and down; then take a small quantity of the colour you intend to grind (two spoonfuls is enough) for the less you grind at a time, the easier and finer will your colour be ground: lay this two spoonfuls of colour on the midst of your stone, and put a little of your linseed oyl to it, (but be sure you put not too much at first) then with your mulier mix it together a little, and turn your mulier three or four times about, and if you find there be not oyl enough, put a little more to it, till it come to the consistence of an oyntment; for then it grinds much better and sooner than when it’s so thin as to run about the stone: you must

the grinding stone, Montabert vol. 9, 1829, 648, advises ‘different glasses that have not yet been polished’ (*glaces different et qui n’ont point encore été polies*), Gandee 1835, 204–205 talks about ‘a ground glass muller’, Anonymous 1849, 106 explains that ‘the interior of the circular superficies is rough, or ground, and more or less course in this grain according to the size of the tool. We have bought them of excellent finish at the “office of the New Jersey Glass Works” in Cedar-street’.

31 ‘Journey’ comes from the French *ournée*, day, not from the English ‘journey’. Someone who travelled from location to location would be referred to as travelling journeyman. Entry ‘Journeyman’, *Oxford English Dictionary* (consulted 4 August 2023).

32 See Draper 2020, 195–196, who describes household involvement in support of Mary Beale’s practice, among others reproducing a text from Charles Beale’s 1677 notebook: ‘ground 1 pellets of Indian Lake, wch was putt up into a Bladder for my Dearest Hearts use upon extraordinary occasions’.

33 *Andries Both*, *The Happy Painter*, parchment and black chalk, 1627–1641, sold by Christie’s in 2001; and *Andries Both*, *The Poor Painter and his Family*, parchment and black chalk, c. 1624–1640, British Museum, London.

oftentimes, in the grinding, bring your colour together with a piece of a lanthorn horn, and with the same keep it together in the middle of your stone; when you find you have ground it fine enough (by the continual motion of your mulier about the stone, holding it down as hard as your strength will permit (which you must also move with such a slight, as to gather the colour under it) and that no knots nor grittiness remains, but be as fine even as the oyl itself, then with your horn cleanse it off the stone into a gally-pot, pan, or what ever else you design to put it into, and then lay more colour on your stone, and proceed to grinding as before: do so thus often till you have ground as much of this same colour as shall serve your occasions; and if you grind other colours after it, let the stone be well cleansed from the first colour with a cloth and fine dry ashes, or sand.³⁴

Smith draws attention to some interesting details. First, the position of the grinding stone at waist height so that it is possible to hold down the stone with hard force. We also learn that the paint should not be too liquid, and Smith emphasizes the importance of working neatly, gathering the paint in between the grinding movements and cleaning the stone between the grinding of different paints to prevent contamination. The Cordoba artist Antonio Palomino (1724) confirms that pigments ‘are ground in portions, picking up the colour of from time to time with the knife, and that what clings to the muller, so that everything is equally well ground’, and explains why: ‘because if it is not, neither does the colour bind well, nor spreads, nor does it give its legitimate colour’.³⁵ The small heap of paint, of the sort we see in the upper right corner of the stone in Bosse’s etching (fig. 8.1), is not mentioned by Smith. However, it features in a number of pictures of artists or assistants grinding paint and therefore appears to be a common procedure.³⁶ Again, Bouvier provides the explanation: after the initial mixing of pigment and oil with the palette knife on the stone, but before the actual grinding with the muller, one should place the mixed paint in a top corner

34 Smith 1687, 33–34. Bristow 1996 used the example of Smith’s description previously in his book on interior house-painting colours and technology.

35 Palomino 1724, vol. 2, 36, ‘se van moliendo à porciones, recogiendo la color de rato en rato con el cuchillo, y lo qua se reboza à la moleta, para que rodo quede igualmente bien molido; porque si no lo està, ni la color empasta bien, ni cunde, ni dà su legitimo color’.

36 For example, in two studio interiors by David Ryckaert III, namely *Paint Making in a Painter’s Studio*, c. 1635–1638, Stadtgeschichtliches Museum ‘Schabbelhaus’, Wismar; and *Painter’s Studio*, 1638, Musée du Louvre, Paris, but also in Stradanus’s famous engraving of Jan van Eyck in his painting studio, we see a blob of paint on the grinding slab of one of the assistants grinding paints.

of the stone, only grinding it small batch by small batch, and placing each finished batch in the other top corner of the plate after grinding. Having worked one's way through all the batches, one collects and transfers them to the dish, bladder or palette.³⁷ The goal of this procedure is to ensure evenly ground paint if quantities are needed that exceed what can be ground in a single batch.

A number of pigments were too rough to be ground immediately into paint and required pre-grinding, the pigment mixed with water at this stage. After the pigment was thus reduced to a fine powder, it was dried and kept for later use.³⁸

Instead of indicating how long one should grind, Smith writes that grinding should be continued until 'no knots nor grittiness remains', and advises continuing until the paint is 'as fine even as the oyl itself'. Such cues indeed seem more useful than an indication of time, as paint-grinding may take shorter or longer depending on the circumstances of grinding, are likely to depend on the experience and posture of the person doing the grinding and, as some authors explain, on the amount an artist grinds in one batch.³⁹ And another crucial factor needs to be considered: the varying properties

37 Bouvier 1827, 139.

38 Norgate 1650, 9–10: 'grind it very fine and with pure water without any Gum, and grind a good quantity together. Being ground, lay the severall grindings on heaps upon a large chalke stone, which you are to have ready for the purpose, wherein having made severall holes or little troughs you are to lay your colour soe ground instantly as soone as you can take it of the stone all wet as it is; where let it dry, for bythismeanes all the greazy and hurtfull quality of the colour wilbe sucked out and drayned away by the hungry and spungie chalke'. Anonymous 1668, 70: 'between your muller and stone grind the colour well together with the water till the colour be very fine, which when you find to be enough, have in a readiness a great chalk-stone, in which make certain troughs or furrows, into which pour your colour thus ground, and there let it rest till it be thorough drie, then take it out and reserve it in papers, and those papers in boxes, for your use'. For similar instructions, see among others: Salmon 1675, 89; Smith 1755, 251; Dossie 1758, 163, which testify to the common application of pre-grinding.

39 Bouvier 1827, 132–133: 'One would make a mistake if one believed one could speed up the matter by putting at once a larger quantity: one would see appear in any case the colour on the edges of the glass and all around the muller, which would necessity continuously using the spatula to reassemble it, without which one would not grind: in a way which would make one lose much time, and one would always dirty the colour through the frequent use of the spatula' ('L'on se tromperait si l'on croyait accélérer la besogne en en mettant à la fois une plus grande quantité: l'on verrait refluer de toute part la couleur sur les bords de la glace et tout autour de la molette, ce qui nécessiterait l'usage continuel de la spatule pour la relever, sans quoi elle ne se broierait pas: en sorte qu'on perdrait beaucoup de temps, et l'on salirait toujours la couleur par l'usage fréquent de la spatule'). Hebert 1836, 228: 'It is not well to have much colour on the stone at one time; it makes it more laborious, and will take a longer time to grind the same quantity equally well'.

of pigments used in the early modern period. Pigments employed by artists differed in size and shape, and this variation influenced the grinding procedures. Successful paint preparation required an intimate knowledge of such properties. The notes Theodore de Mayerne (1620–1644) included from his exchanges with artist Abraham Latombe (1595–1676) hint at what an artist needed to know. Common ceruse, a lead white quality, was to be ground into an ‘impalpable powder’; lamp black should be mixed with oil using a knife on the palette; smalt would lose its colour when ground too long; course masticot should be ground ‘lightly’; and lake needed ‘very strong grinding’. Certain pigments were ground with water first before being dispersed in oil, while for other pigments this was not advisable. For instance, Latombe advised de Mayerne that yellow ochre would whiten if it were first ground with water.⁴⁰

Not only could the grinding procedure differ according to pigment, but the properties of the resulting paint would vary as well, impacting how artists could create the effects they wished to achieve in painting. Pigments thus co-determined an artist’s visual language. Red lake pigments, the darker reds available to early modern artists, are quite translucent in oil, while the bright reds vermilion and minium are opaque. As a consequence, an artist could not paint a deeply coloured opaque red without working in multiple layers (for instance applying a first layer of opaque darkish pigments to set the tonal value, which were then covered with a layer of red lake to provide the red tonality, or, alternatively, covering the area with vermilion or minium, subsequently covered with the darker, transparent lake pigment). Pigments also co-determined paint rheology, i.e. how the paint flowed. Depending on the pigments it contained, paint could be thick or thin, buttery or stringy, smooth or lumpy. Smalt, a cobalt-based blue glass ground up to be used as a blue pigment, would lose its colour when ground too finely, and artists struggled with its grittiness. These struggles translate into quite some attention given to the preparation of smalt paints in historical sources, with authors describing tricks to prepare a manageable paint containing smalt. An example is an anonymous sixteenth-century text from the Toulouse area, where we read that ‘azur d’esmail hates more than any other to be ground’.⁴¹

40 Mayerne 1620–1644, fols. 11r, 11v, 12r. It should be noted that Mayerne’s manuscript provides conflicting information on some topics because he collected information gathered from different sources. For example, in contrast to the information provided by Latombe on the grinding of masticot, in a section with information he obtained from ‘le petit peintre’, De Mayerne notes that masticot cannot be ground on the stone at all, as it would become ‘white as paper’. De Mayerne 1620–1644, fols. 91r, 91v.

41 ‘Lazur desmail haict plus destre broye que nul aultre’, Anonymous 1580–1600, 56v.



Figure 8.4 Cornelis Norbertus Gijsbrechts, *Cut-Out Trompe-l'Oeil Easel with a Painter's Palette and a Fruit Piece*, 1670–1672, oil paint on wood, 226x123 cm (h x w), Statens Museum for Kunst Copenhagen, inv. no. KMS5.

The anonymous author devoted much attention to smalt grinding, offering several options for the best binder; this writer discussed washing – or not washing – the pigment, and the level to which it needed to be ground (see table 8.3).⁴² Some paints were quite liquid, and painters would run the risk of drips if they applied such paint in thick layers or without a binder that contained a drier – a reality Cornelis Gijsbrechts playfully included in the palettes he depicted in his trompe l'oeil paintings (fig. 8.4). The different properties of the paints on Gijsbrechts' palette are evident: some stand stiff while others have less bulk, some pigments are even running off the palette. Paints in the third row on the palette do not present the problem of running off the palette. This is explained by the fact that this row contains the pure colour in mixture with lead white, the white pigment lending its stiffness to the toned mixture. Painters needed to negotiate pigment properties,

42 Difficulties using smalt in oil painting are also discussed in other early modern sources. See for example Eikema Hommes 2004, 20. A comprehensive discussion is beyond the scope of this chapter.

grinding their paints in line with their material affordances, and trying to offset their less desirable characteristics through sensible use, for instance modifying the application method to suit the paint's properties.

To check whether paints had been sufficiently ground, historical authors describe several sensory indicators, including visual and auditory cues (grittiness, evenness, smoothness; Bouvier advises to grind until the paint does not 'cry' under the muller) as well as tactile testing – one could feel the paint between one's fingers to check whether the paint had lost grittiness (table 8.3).

While such indicators may suggest that there exists *one* clear moment when a paint is sufficiently ground and one desirable paint consistency, table 8.3 also reveals that sensory cues differed and thus possibly described a different stage of grinding and consequently a paint with different properties. Microscopic examination of seventeenth-century paintings demonstrates that a single pigment is encountered in varying particle sizes, sometimes within a single painting. A well-researched example is the lead white in Johannes Vermeer's *The Art of Painting* in the Kunsthistorisches Museum in Vienna. As shown by Boon and Oberthaler (2010), some paint layers contain lead white of larger and smaller particle clumps combined, a mixture of larger agglomerates (clumps) mixed with smaller loose particles. Yet in other paint layers hardly any agglomerates are present.⁴³ Fine lead white appears mainly in the upper layers while mixed sizes are present in the lower layers, a difference that can also be observed in Vermeer's *Girl with a Pearl Earring*.⁴⁴ While this seems to hint at a conscious choice, we should not conclude painters only used 'course' lead white in the lower layers. An exploration of cross-sections in the Rembrandt Database (RKD, The Hague) demonstrates that fine lead white is indeed often applied in the final paint layers and course agglomerates are applied in the lower, but there are also instances of paintings by Rembrandt or his circle where such a difference is not present, and courser lead white features in top layers.⁴⁵ Pigment particle sizes in the courser paints range from clumped pigments (agglomerates) of up to 15–20 microns, while fine particles are as

43 Boon et al. 2010.

44 De Meyer 2019 examines chemical differences between the lead white qualities employed by Vermeer. Their figure 2, which compares the chemical composition of a paint cross-section in the lighter areas and one in the shadowy areas of Vermeer's *Girl with a Pearl Earring*, shows differences in lead white particle size in the different layers. A possible link between lead white composition and particle size is currently being investigated; it is a topic relevant to the painting's conservation, as different lead white qualities might exhibit different degradation patterns.

45 See: www.rembrandtdatabase.org (accessed 4 August 2023). Course lead white is found in the upper layers of sample RCE4718 of Rembrandt/Rembrandt studio, *Portrait of a Man*, 1632, collection: Metropolitan Museum of Art; of sample RCE4607, follower of Rembrandt (possibly Samuel van Hoogstraten); *Bust of a Young Woman with a Red Necklace*, c. 1645, collection:

small as tenths of a micron. This difference may be the result of grinding, but it has also been shown to relate to pigment production methods: lead white was available in different qualities. It may furthermore have been influenced by pigment washing and decanting, described in historical recipes and investigated in earlier studies.⁴⁶ This makes it interesting to explore whether use of the muller may have the size-reducing effects observed in paintings. What does paint look like if it has been ground as described in historical sources, the grinding having been steered by the sensory cues described? And how do the paint characteristics observed relate to those of paints encountered in early modern paintings such as those of Vermeer and Rembrandt? As the next paragraphs will demonstrate, reconstructing historical hand-grinding procedures can help answer such questions and thus shed more light on the material complexities that influenced the visual language employed by early modern artists.

Reconstructing the Influence of Grinding as Described in the Recipes

Reconstructing, a term used here for the re-execution of historical procedures according to what we can know about such procedures, is a research method that has been used in art technological studies since the nineteenth century.⁴⁷ In the early 2000s, Carlyle introduced the term 'historical accuracy', later renamed 'historical relevance', for reconstruction as a research method, drawing attention to the importance of using materials and techniques that resemble those employed during the time period being investigated. She argued convincingly that the crucial differences among artists' materials produced according to modern industrial methods and the materials employed in the pre-industrial period need to be taken into account when re-making historical paints, and that researchers should aim to find materials and tools as similar as possible to those that had been available historically.⁴⁸ This is important, for example, when investigating the use of a pigment like lead white.

Metropolitan Museum of Art; and of sample SK-A-4050_RCE4526 of Rembrandt, *Self Portrait as the Apostle Paul*, 1661, collection Rijksmuseum.

46 See Stols-Witlox 2011 and Stols-Witlox 2012 on lead white production and processing methods.

47 Reconstructing, re-performing, re-making or re-doing have been widely applied in fields including archaeology, musicology, anthropology and the history of science. See Dupré 2020 for an introduction to the different 're'-methods in these fields and for essays by experts from these fields, including brief overviews of their introduction and development.

48 See Carlyle in: Dupré et al. 2020.

Lead white was the only opaque white available to artists before the introduction of zinc white during the nineteenth century and of titanium white in the twentieth century. It is omnipresent in early modern paintings, both as a pure pigment and as mixed with other pigments to lighten the tonality or increase the opacity of the colour to which it has been added. Lead white receives considerable attention in current scientific research into paint materials, not just because of its crucial role in early modern painting but also because of its ability to chemically interact with the oil binder. This process is both a blessing and a curse: the chemical reaction between the lead and the oil molecules results in a more solvent-resistant paint and thus contributes to the longevity of a painting, but this same reaction can result in degradation phenomena that can disturb a painting's visual appearance (most notably an increased transparency that darkens a painting or brings into view lower layers that were supposed to be covered by the top paint layer, and the appearance of crusts that seem to add a veil to the painting).

In the seventeenth century this pigment was produced by the 'stack process', in which sheets of lead were exposed to vinegar fumes in a carbon dioxide-rich environment. Because of the serious health risks associated with this method, it was gradually replaced over the course of the nineteenth century by wet precipitation methods, where the ingredients react with each other in a liquid. The differences between the qualities of both types of lead white are huge. Carlyle compared the particle shapes and sizes of lead whites made with both types of processes and showed convincingly that paints made with the modern-method lead white (flattish plate-like particles) behaved very differently than stack-process lead white (larger globules/agglomerates of clumped-together particles mixed with small particles).⁴⁹

Using stack-process lead white prepared according to seventeenth-century methods and a cold-pressed linseed oil, reconstructions investigated the effect of muller grinding for increasing amounts of time.⁵⁰ It was decided beforehand to compare the paint characteristics of three different stages:

49 Carlyle 2005.

50 The lead white was prepared by the Belgian artist Jef Seynaeve according to the stack-process method, the standard lead white production method in the seventeenth century: rolled sheets of roofing lead were placed in an unglazed earthenware jar just above a layer of white vinegar. The jar was closed and placed in horse manure. After three-to-four weeks the jar was opened, and the lead white that resulted from the conversion of the sheet lead to lead carbonate was removed mechanically. Bought during this stage, the pigment was processed further by grinding it and washing it in water until the supernatant water was clear and colourless. This washing process is advised in historical sources and serves to remove impurities resulting from the manufacture process (lead acetate). See Stols-Witlox 2012.

when the pigment and oil were just sufficiently mixed to allow spreading with a brush; after the paint had been ground into a feasible paint (easily spreadable, no large clumps visible); and after grinding much longer than this second stage, to see if we could reach a state similar to what Smith described, a paint 'as fine as the oyl itself'.⁵¹ To be able to compare the effect of grinding only, the reconstruction protocol cannot include other variables. For instance, were the reconstruction to include different mullers, the effects observed could be due both to the muller's material and to the different lengths of time a pigment was ground. Therefore, this experiment was executed with only one type of muller. We chose a glass muller, cone-shaped, with a base 4 centimetres wide, and with a height of about 12 centimetres, comparable to the dimensions described by a number of authors (table 8.4). Out of the grinding stones available, the largest size was selected to allow for full grinding movements not restricted by stone size. The stone in question was a hard black granite. Grinding was performed inside a laboratory fume hood with the researchers wearing personal protection (gloves, a face mask and a laboratory coat) because of the toxicity of the pigment. The observations made during the experiment are written down fieldnote-style, as is optimal for the personal observations and sensory cues I now share:⁵²

With a palette knife, I place a small heap of powdered pigment on the granite slab, careful not to spill any of the toxic powder. The powder feels a little heavy, it is a dirty white, loose powder and clumps. I drip on a few drops of linseed oil and see them running down the heap – the oil does not mix with the pigment by itself. With the palette knife, I move the oil and pigment around. This helps. I add a few more drops, careful not to add more than are needed to wet all the pigment a little – which I see because the wetted pigment has a slightly darker tone and clumps together like a rough batter. I continue turning the mixture with the palette knife until I see hardly any loose powder remaining. The mixture indeed resembles what Bouvier describes as a cement slurry for bricklaying.⁵³

I put down the palette knife, take the muller and press down on the pigment/oil heap. When I lift the muller, I see that the pressure makes the

51 Smith 1687, 33–34.

52 This experiment was designed and executed together with Annelies van Loon, Rijksmuseum Amsterdam, and also serves our joint research into the lead whites employed by Johannes Vermeer. I kindly acknowledge Annelies' contribution and thank her for allowing me to discuss the experiment here. Annelies van Loon and I both ground the pigment, the notes combine our observations. While one was grinding, the other was taking notes and keeping an eye on the clock.

53 Bouvier 1827, 138, 'comme si vous faisiez du mortier de maçon'.

mixture look more oily – I conclude that the muller helps with the mixing. I press down again and start to move the muller up and down a bit. The clumped pigment smears out, but tends to escape from under the muller, clinging to its sides. I lift the muller and scrape off the rim with the palette knife, returning it to the slab. After gathering the smeared-out paint in the middle of the slab, I place the muller on top and move it up and down to spread the paint again. I cannot push too hard, the muller wobbles over the uneven paint heap – it halts and the movements are unpredictable. I continue, and with every round of spreading and gathering, the mixture becomes more oily and smoother. I can now apply more pressure, leaning into the muller with both hands. Less material ends up on its side.

After about six or seven rounds of spreading and gathering, the mixture is quite paint-like. I conclude that I did well not to add more oil. Had I done so, the paint would have been very runny and thin. It now has the consistency of a thick, heavy yogurt, in which I can still see some pigment clumps. I remove a little with the palette knife and apply it with a brush to the plastic sheet we chose as a support. I then continue grinding, turning the muller in circles or in figure-eights, regularly gathering the paint with the palette knife and scraping it off the side of the muller. This I continue doing for 15 minutes. By then, important changes have occurred. I see hardly any clumps of pigment, and the sound of moving the muller, heretofore a slight scratch, is now gone. Only when I push unevenly and the muller touches the stone directly, do I hear a scratch. Moving the muller feels quite smooth and silky – is this the starch-glue feel Bouvier describes?⁵⁴

I remove a second small batch of pigment and brush it onto a plastic sheet. I continue doing what I did before but for a much longer time. I do not immediately notice further changes in the paint. But after some time I see, when gathering the paint between grinding rounds, that it is a bit more fluid. After the first 15 minutes it was rather pasty. When I lifted the spatula it would break off in the shape that butter would, with short peaks. But after an additional 30 minutes of grinding, it pulls longer threads when I lift the spatula. The paint's surface seems smoother and more glossy. Maybe this is Smith's 'as fine as the oil itself'.⁵⁵ To check if longer grinding results in further change, I continue grinding for another 15 minutes. I see no differences, decide that I have ground for a sufficiently long period, and gather the paint in the middle of the stone before applying a little to the plastic sheet and cleaning the muller and stone.

54 Bouvier 1827, 137–138, see table 8.4 for the exact quote.

55 Smith 1687, 33–34.



Figure 8.5 Three paints consisting of lead white ground in linseed oil, observed with a microscope at ten times magnification. The paints have been ground for increasing lengths of time and have been applied with a brush to a plastic sheet (Melinex).

Figure 8.5 provides images of the three paint variations described above, as they appear when viewed through a microscope at 10 times magnification. The proportions of lead white and oil are the same in all images. The only difference is the amount of grinding time.

Comparing the clumps (or agglomerates) of lead white from left to right, the effects noted during the reconstruction and described by historical authors are easily recognized. While the shortly ground paint contains large agglomerates, visible as lumps in the paint, 15 minutes of grinding already strongly reduces the size and number of such large clumps. Continued grinding for another 45 minutes all but removes the larger clumps, and the paint looks increasingly smooth. Such longer grinding has a remarkable effect on the sharpness of the impastos that can be created, as can be noted by a comparison of the paints ground for 15 minutes and those ground for an hour. In the former, the individual brush-marks are visible as sharp lines, while in the paint ground for one hour, some marks fuse together. The paints have a completely different look despite being made from exactly the same materials and in the same proportions, the only difference being the duration of the grinding. The increased elasticity of the paint that was ground for a longer time allows for different spreading techniques than the paint that was ground for a shorter time. One can imagine that if a painter were looking for brisk, stiff and thick impastos, the lead white ground for 15 minutes would be the most suitable option, whereas they would choose the one-hour paint for an even, continuous layer.⁵⁶

⁵⁶ Currently, scientific analysis of the paints is being carried out, investigating the particle size and chemical composition of the differently ground lead whites. Results will be published with

Of course, this reconstruction experiment concerns only a single pigment, ground with a single type of muller, and historical recipe books reveal a much wider range of processing methods for artists to choose from.⁵⁷ But even given its modesty, the reconstruction experiment reveals the muller's huge impact on the qualities of the paints that were made and used by early modern artists. Reconstruction studies like these thus allow us to establish stronger connections between written accounts and the qualities observed when examining paintings. Furthermore, the sensory observations described in the lab notes add to our insights into the meaning and relevance of the cues described by authors of historical recipes, as they help link the paint qualities produced to different stages in grinding with the muller. Reconstructions thus support both the interpretation of historical texts and of painting examinations, and they help connect these modes of interpretation.

Conclusion

Knowledge of paint-grinding strategies, including how to best use the muller, was of great importance for artists painting in the early modern period. Such knowledge continued to be relevant long afterwards, even when commercially produced paints became dominant in the nineteenth century. Different pigments required different grinding protocols, as pointed out in the historical sources discussed in this essay. Furthermore, painting examinations demonstrate that artists varied the level of fineness in the grinding of single pigments, a practice that gave them access to paints of a single colour that nonetheless possessed different spreading properties and varying visual characteristics. This is further evidence of the agency of the muller, whose primary properties of hardness, flatness, weight and shape remained constant throughout the three centuries studied in this essay.

Grinding skills were developed through practice. Therefore, it is no wonder that authors such as Vasari and Van Mander described pupils grinding paints under a master's supervision. While paint-grinding is often understood to be one of the tedious jobs that artists would eagerly leave to their assistants (as

co-authors Annelies Van Loon, Frederik Vanmeert in the postprints to the Vermeer Symposium, held at the Rijksmuseum Amsterdam on 28-29 March 2023.

⁵⁷ Oils could be processed in many different manners to influence their flow and tonality (e.g. by washing, heating, heating with additives), and admixtures of other pigments would influence the quality of the paint (transparency, flow from the brush).

was alluded to in some of the sources discussed in the introduction), there may have been a second reason for this division of labour. Perhaps pupils also ground paint because they needed to master all the intricacies of the process, which would allow them to make use of the full potential for artistic expression offered by oil paints. Masters transferred such experiential knowledge to their pupils, knowledge that we can now aim to unpack with the aid of reconstructions – learning to (re-)do artistic practice by taking the muller in hand ourselves.

Table 8.1 Muller materials, in original spelling

NB: Unless otherwise specified, the paint to be ground is oil paint.

<i>Source, date, page</i>	Bold: material advised. Italics: material advised against
Heraclius 13th century, 230 ⁵⁸	Petra vitrea (glass stone) [glue binder]
Alcherius 1398–1411, 282 ⁵⁹	Lapidem equalem durum (smooth hard stone) [tempera binder]
Peacham 1612, 69 ⁶⁰	Porphyry, white marble, green marble [paint binder unspecified]
Norgate 1650, 9–10	Porphyry, serpentine, pebble, French slate [to grind watercolour]
Sanderson 1658, 54–55	Porphire, serpentine, pebble-stone, chrystall, marble, thick glasse [to grind watercolour]
Smith 1687, 2–3	Pebble stone, spotted marble (hasle colour), hard marble (white or black), slate, any smooth sided stone cemented into a piece of wood
Bogaart 1692, J v	Kristal glas [both for oil paint and watercolour]
Bogaart 1692, L r	Keij [both for oil paint and watercolour]
Hire 1730, 683–685	Porphyry, pierre dur, granit d'orient, écaille de mer (grise plus dur que rouge),⁶¹ grès fort dur imbibé d'huile
Gregory, vol. 2, 1815, 338	Agate, glass [to grind watercolour]
Bouvier 1827, 123–127	Red porphyry, agath, hard glass, some granites – even of grain, porcelaine de Sèvres, grès, marble [both for oil paint and watercolour]
Montabert, vol. 9, 1829, 648	Porphyre, granit d'orient, écaille de mer grise, 'autres substances très dures,' glace non polie

58 Transcription from Merrifield 1849 (1999), dating according to Clarke 2001, 12. Clarke writes that Heraclius is a fictive author to whom three manuscripts of different dates are ascribed. The third manuscript, the one containing the mention of the muller, Clarke dates to thirteenth-century France.

59 Transcription from Merrifield 1849 (1999), manuscript compilation dates according to Clarke 2001, 21.

60 Peacham 1612 reproduced from a quote in the Oxford English Dictionary, entry 'muller, n. 1'.

61 According to Sage 1811, 145, 'écaille de mer' is the name given in the marble trade to a metamorphic rock mined off the French coast between Vire and Caen. It is said to be as hard as porphyry.

<i>Source, date, page</i>	Bold: material advised. Italics: material advised against
Gandee 1835, 204–205	Glass [to grind watercolour]
Kingston 1835, 5	Marble muller [to grind 'Kingstonian colours', which are emulsion paints]
Hebert 1836, 228	Hard stone
Campbell 1841, 25–26	Marble [is] 'inclined to wear more on one side than the other'
Templeton 1845, 9	Porphyry, glass
<i>Scientific American</i> , vol 2, 1847, 248	Block of wood [for house painting as cheap substitution for a stone muller]
Anonymous 1849, 106	Stone, glass, hard white ware, porphyry
Spon 1873, 106	Hard stone
Anonymous 1886, 523	Marble [for grinding ink]

Table 8.2 Muller dimensions

<i>Source, date, page</i>	<i>Muller dimensions in original measurement, translated excerpt from original source</i>	<i>Muller dimensions in cm</i>
Smith 1687, 2–3	c. two inches diameter on the flat end, about five inches high	Diameter: 6.3 cm Height: 12.5 cm
Bouvier 1827, 127	Large muller: 4–5 pouces diameter at basis ⁶²	Diameter: 10.8–13 cm
Bouvier 1827, 127–130	Medium muller: 6–7 pouces high because one surrounds it from top to bottom with two hands, letting the point escape above the hands, which has the advantage of not letting the muller tip over when moved ⁶³	Height: 16.2–18.9 cm
Hebert 1836, 228	Diameter about one-sixth of the grinding stone, cone high enough to get a sufficient hold of it with the hands	
Campbell 1841, 25–26	Five inches in diameter on its face, about three inches across the top, height about six inches	Diameter: 12.5 cm Height: 15 cm
Templeton 1845, 9	Two inches in diameter	Diameter: 5 cm
Spon 1873, 106	Diameter of the base one-sixth of that of the grindstone, cone high enough to get a sufficient hold of it with the hands	
Anonymous 1886, 523	Diameter 2 1/5 inch, height 5 1/4 inch [to grind ink]	Diameter: 5.5 cm Height: 13.1 cm

62 'La grande molette doit avoir de quatre à cinq pouces de diameter a sa base, c'est-à-dire à l'endroit qui sert à broyer, et qui écrase la couleur'.

63 'Six ou sept pouces d'élevation, parce qu'on l'empoigne du haut en bas avec les deux mains, en laissant ressortir la point au-dessus des mains, ce qui a l'avantage de ne pas faire basculer la molette en la maniant'.

Table 8.3 Indicators for grinding times and grinding of specific pigments

Source, date, page	Quote from original source in translation	Pigment and binder – if specified
Anonymous 1580–1600, 11r	The main thing is to grind it well on marble, and before that, to have washed it thoroughly. Some grind it with thoroughly with an egg yolk & then wash it in five or six waters and lay it on not with a paintbrush, which would be too soft, but with a brush thoroughly softened & crimped, & layering it thickly as if one were putting it down with a trowel; settling down it evens out and flattens. I have experienced that grinding azur d'esmail with egg yolk & next washing it in several waters is good. However, it loses a little of its vividness in the grinding of it. [...] ⁶⁴	Smalt in oil
Anonymous 1580-1600, 11r	Azur d'esmail cannot be worked if it is too coarse. Try it, therefore, on the fingernail or the oil palette. If it [illegible] happens to be sandy, do not grind it except with the egg yolk or, better yet, wash it in clear water & with a sponge remove the coloured water after it starts to go to the bottom, and in this manner you will extract the very delicate flower, which will be easy to work with. ⁶⁵	Smalt in water [for watercolour]
Anonymous 1580–1600, 56v	to render it subtle, one ought not to grind it, for this makes it whiten But you have to wash ⁶⁶	Smalt in oil
Anonymous 1580–1600, 58v	Azur d'esmail hates more than any other to be ground, especially with water, for it dies & loses all its colour. However, because it cannot be worked if it is coarse, grind not with water but with oil & grind it thickly, and in this way it will not die as much. ⁶⁷	Smalt in oil

64 'Le principal est de le bien broyer sur le mabre Et plustost lavoire lave fort Aulcuns le broyent avecq fort avecq un jaulne doeuf & puis le lavent en cinq ou six eaulx Et le couchent non avecq un painceau qui seroit trop doux Mays avecq une broisse fort adoulcie & crespie & le coucher espes co[mm]e si on le posoit avecq une truelle en se reposant il sunist et saplatist Jay experimete que broyer lazur desmail avec jaulne doeuf & apres le laver en plusieurs eaulx est bon Toutesfois il perd un peu de sa naifvete en lenroyant'. Transcription and Translation: *Making & Knowing Project 2020* (accessed 21 July 2023).

65 'Lazur desmail sil est trop gros ne se peut travailler Essaye le doncq sur longle ou sur la palette a huile sil se [illegible] trouve areneus Ne le broye pas sinon avecq le jaulne doeuf Ou pour mieulx lave le en eau claire & avecq une esponge retire leau coloree apres quil coma[n] ce daller a fonds Et en ceste sorte tu retireras la fleur fort deliee qui sera aysee a travailler'. Transcription and Translation: *Making & Knowing Project 2020* (accessed 21 July 2023).

66 'Et pour le subtilier il ne fault pas le broyer car cela le fait blancher Mais il le fault laver'. Transcription and Translation: *Making & Knowing Project 2020* (accessed 21 July 2023).

67 'Lazur desmail haict plus destre broye que nul aultre mesmement a leau car il se meurt & perd toute sa couleur Toutefois pourceque il ne se peult travailler sil est gros broye non avecq eau Mays avecq huile & le broye espes et en ceste sorte il ne se mourra pas tant Choisis tousjours le plus delie'. Transcription and Translation: *Making & Knowing Project 2020* (accessed 21 July 2023).

<i>Source, date, page</i>	<i>Quote from original source in translation</i>	<i>Pigment and binder – if specified</i>
Norgate 1650, 9-10	Very fine	[lead] white
Smith 1687, 33–34	No knots nor grittiness remains, as fine even as the oyl itself	Pigments in oil
Bogaart 1692, H v	Quarter half hour also longer depending whether you want to grind much or little paint ⁶⁸	Pigment in water [watercolour]
Bogaart 1692, H v	Temper it [the pigment you have just ground] with gum water ... brush with pinsel onto a clean white paper and observe well whether you can see any remaining coarseness and whether it can be applied to the paper evenly and smooth ⁶⁹	Pigment in water [watercolour]
Bogaart 1682, H v	Try ... on the nail ⁷⁰	Pigment in oil
Hayter 1820, 237	Ten minutes (strong-bodied paints will require more grinding than lakes)	Watercolour-cakes, gum water
Bouvier 1827, 134--37	Grind until the colour becomes sufficiently thick that you can lift it like an ointment ⁷¹	Pigments in water [for watercolour]
Bouvier 1827, 137–138	[until] it does not cry under the muller, but that it passes over, while pressing on, as over starch glue. ⁷²	Pigments in water [for watercolour]
Bouvier 1827, 138	Until it is perfectly at the point you wish it to be ... ⁷³	Pigments in oil
Bouvier 1827, 140	For the rest you follow the directions given in the article on grinding with water, page 134 and following. ⁷⁴	Pigments in oil
Gandee 1835, 204–205	Until all appearance of grittiness has been removed ... ground perfectly fine, having the consistence and smoothness of butter	Pigments in gumwater [for watercolour]
Kingston 1835, 5	Not quite impalpable	Flake white
Anonymous 1856, 4	To reassure oneself that the operation is well done, one takes a little colour between two fingers, and if one does not sense any grain, this means that it has been sufficiently ground ⁷⁵	Pigment in oil
Anonymous 1881, 170	Requires a lot of grinding with the muller	Dutch pink

68 'Kwartier hallif uur oock wel langer na dat gij veel of weijnigh verf wilt wrijven'.

69 'Tempere met om waater, ... strijckse met de pensel op een schoon wit pampiertje en siet wel terdege of gij daer noch eenige grofvigheeden in kan bespeure en ofte sigh welgelijck en gladt op het pampier doen laet leggen'.

70 'Probeeren ... op de nagel'.

71 'broierez jusqu'à ce que la couleur devienne assez épaisse pour qu'on puisse la relever comme de la pommade'.

72 'Elle ne criera plus sous la molette, mais que celle-ci passera dessus, quoqu'en appuyant, comme sur de la colle d'amidon'.

73 'Jusqu'à ce qu'elle soit parfaitement au point où vous la désirez. ...'.

74 'Pour tout le reste vous suivrez les directions continues dans l'article du broyage à l'eau, page 134 et suivantes'.

75 'pour s'assurer que l'opération est bien faite, on prend un peu de couleur entre deux doigts, et, si on n'y sent plus de grain, c'est qu'elle est broyée suffisamment'.

Table 8.4 Consistency during grinding

<i>Source, date, page</i>	<i>Indication</i>	<i>Pigment and binder – if specified</i>
Anonymous 1580–1600, 58v	Azur d'esmail ... grind not with water but with oil & grind it thickly, and in this way it will not die as much. ⁷⁶	Smalt in oil
Bouvier 1827, 134–137	Strong cream [=consistency during grinding], grind until the colour becomes sufficiently thick that you can lift it like an ointment ⁷⁷	Pigments in water [for watercolor] Pigment in oil
Bouvier 1827, 138–140	Wet it little by little, as if you were preparing mason's mortar, by turning and again turning often the powder in the oil that you have applied to your grinding stone, and you do this until the whole mass of colour that you want to put in a bladder is immersed in oil. But take care that this powder, this way dispersed roughly in the oil, should sooner be more thick and firm than soft. This is why: when it has been ground, even when only the muller has made some turns over it, it will appear much less thick to you, because the oil has penetrated everything. In addition, there is always occasion to add a little oil if you find it too thick; while to thicken it one has to mix in non-ground powder, which destroys that which has already been half or completely [ground]. So prepare your colour more thickly than you wish to have it. ⁷⁸	Pigment in oil
Gandee 1835, 204–205	When the colour is on the slab it should be only just wet enough to admit of moving the muller without great labour, because, if made too wet it will never become sufficiently fine.	Pigment in gum water [watercolour]
<i>Scientific American</i> vol. 2 1847, 248	As stiff as can be conveniently stirred with a stick or spatula	Oil paint for house painting

76 'Lazur desmail haict plus destre broye que nul aultre mesmement a leau car il se meurt & perd toute sa couleur Toutefois pour ce que il ne se peult travailler sil est gros broye non avecq eau Mays avecq huile & le broye espes et en ceste sorte il ne se mourra pas tant Choisis tousjours le plus delie.' Transcription and Translation: *Making & Knowing Project 2020* (accessed 21 July 2023).

77 'Forte crème, ... broierez jusqu'à ce que la couleur devienne assez épaisse pour qu'on puisse la relever comme de la pommade'.

78 'L'humectez peu à peu, comme si vous faisiez du mortier de maçon, en tournant et retournant souvent la poudre dans l'huile que vous aurez versée sur votre pierre, et vous ferez cela jusqu'à ce que tout le tas de couleur que vous voulez mettre en vessie soit imbibé d'huile. Mais observez bien que cette poudre, ainsi délayée grossièrement avec de l'huile, doit être trop épaisse et trop ferme plutôt que trop molle. Voici pourquoi: quand elle aura été broyée, et quand seulement la molette aura fait quelques tours dessus, elle vous paraîtra beaucoup moins épaisse, parce que l'huile aura pénétré partout. D'ailleurs, on est toujours à temps d'ajouter un peu d'huile si on la trouve trop épaisse; tandis que pour l'épaissir il faudrait y mêler de la poudre non encore broyée, qui gâterait celle qui l'est déjà à moitié ou entièrement. Préparez donc toute votre couleur plus épaisse que vous ne voudriez l'avoir'.

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