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Front cover: *The Virgin and Child before a Firescreen*, detail of Plate 1, p. 20.

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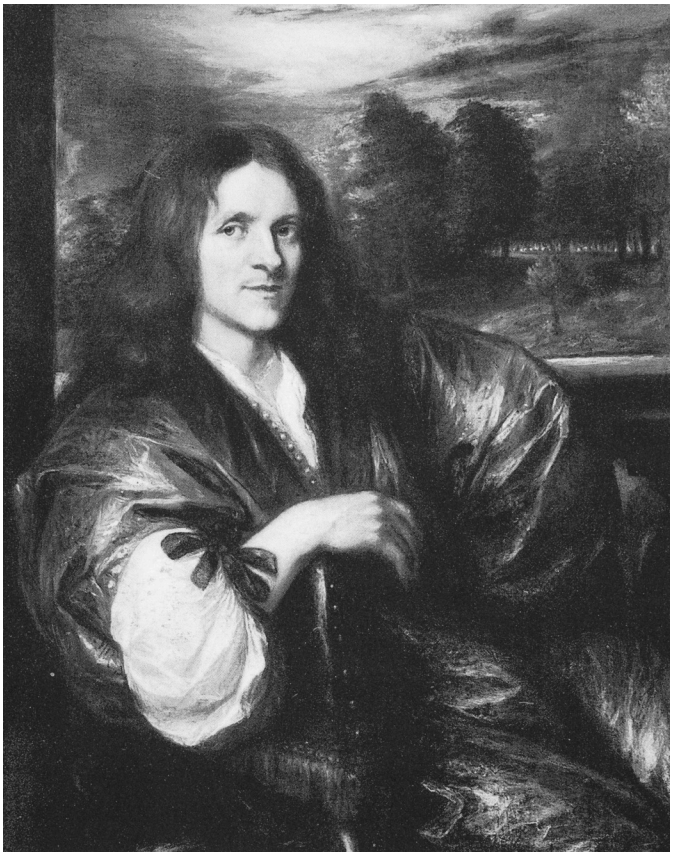


Fig. 1 Jan Lievens, *Self Portrait* (NG 2864), *c.* 1638. Canvas, 96.2 × 77 cm.

Rembrandt and his Circle: Seventeenth-Century Dutch Paint Media Re-examined

RAYMOND WHITE AND JO KIRBY

Seventeenth-century commentators, writing shortly after Rembrandt's death in 1669, noted certain features of the artist's painting practice; disappointingly few had anything to say about his painting methods or materials. This is perhaps not too surprising: treatises on painting, like those of Joachim von Sandrart[1] or Samuel van Hoogstraten,[2] whose books date from 1675 and 1678 respectively, were far more concerned with the academic and theoretical aspects of painting, such as Rembrandt's use of chiaroscuro and colour, for example, than with the practical. Although there are interesting comments on materials and other technical matters in Samuel van Hoogstraten's book, he made no detailed observations on Rembrandt's painting practice, despite the fact that he was Rembrandt's pupil during the 1640s.

The features of Rembrandt's painting technique most frequently remarked upon, apart from colour and chiaroscuro, were his brushwork and his impasto. Filippo Baldinucci, writing in 1686, drew on the words of another of Rembrandt's pupils, the Dane Bernhardt Keil (who studied with him between 1642 and 1644), for his information to describe these characteristics. According to Baldinucci, Rembrandt sometimes spent two or three months on a portrait because, as soon as the first work was dry, he would work on it again until, in some places, the paint was little less than half a finger thick.[3] Arnold Houbraken, himself a pupil of Hoogstraten between 1675 and 1678, ascribed the thickness of the impasto, particularly in Rembrandt's late works, to excessive speed of working.[4] Whatever the speed at which Rembrandt worked, the precise nature of his materials and methods played their part in the effects which so impressed contemporary critics. The slowness of working described by Baldinucci, and thus Keil, might indicate careful practice as well as the artist's labouring towards a particular effect.

Not one of these authors, Rembrandt's pupils among them, commented on the overall soundness of his technique in terms of the way in which he combined his ingredients. Rembrandt used linseed, or occasionally walnut, oil, sometimes heat-bodied: analysis has revealed no incompatible medium mixtures, no additions of resinous materials to give added transparency or gloss, or to aid drying.[5] As a result very few, if any, paint film disturbances are apparent in his paintings. The pigments he used regularly were not in themselves remarkable; the combination of pigments, however, played a significant part in the translucency of his glazes, the quality of his impasto and, indeed, the soundness of the paint film. Chalk was occasionally used to give body and translucency to glaze-like layers without altering their colour. Small quantities of azurite or smalt, which are good driers, were added to pigments, like the red and yellow lakes or bone black, which are poor driers, without affecting the overall colour of the paint layer. Smalt appears to have been used to give bulk to thick glazes containing lake pigments as well

Fig. 2 Pieter Lastman, *Juno discovering Jupiter with Io* (NG 6272), 1618. Wood, 54.3 × 77.8 cm.

as to assist in their drying, which would otherwise be extremely slow. Rembrandt did use the poorly drying Cassel earth, which is obtained from lignite or peat deposits, but it was always mixed with other pigments including ochres, which are good driers.[6]

Translucent shadows and impastoed highlights are just two of the features occurring in Rembrandt's work which could have been accomplished by additions or modifications to the paint medium rather than by – or in addition to – careful combination of pigments. These same features may be found in the work of other Dutch painters; they may or may not have been achieved by methods similar to those of Rembrandt. In order to set his practice in context, it is logical to look at the work of other painters in his immediate circle.

Painters in Rembrandt's circle

Both Rembrandt and Jan Lievens studied with the Amsterdam painter Pieter Lastman, Lievens for about two years before 1621, Rembrandt for only about six months, perhaps around 1623–4. Lievens was closely associated with Rembrandt in Leiden during the late 1620s and up to 1631 or so. During this period his works are difficult to distinguish from those of Rembrandt stylistically and they may on occasion have worked together. After 1631–2, when Rembrandt moved to Amsterdam and Lievens went to England and subsequently Antwerp, their styles became very different. *Anna and the Blind Tobit* (NG 4189), dating from about 1630, is one of the earliest of Rembrandt's works examined, as far as analysis of the paint medium is concerned.[7] Both the works by Lievens examined during the current study date from the period when he was in Antwerp (1635 to early 1644): the *Self Portrait* (NG 2864; Fig. 1) was probably painted in about 1638; *A Landscape with Tobias and the Angel* (NG 72) dates from his last years there.[8]

Lastman was a renowned painter in his day, painting principally religious and mythological subjects; *Juno discovering Jupiter with Io* (NG 6272), signed and dated 1618, shows the careful detail typical of the work from his studio (Fig. 2).[9] He influenced the work of both Rembrandt and Lievens, but these painters would have learnt the basic elements of their craft from their first masters in Leiden. Similarly, many of Rembrandt's own pupils had already received their preliminary training with another master. In Rembrandt's studio they assisted in the production of paintings in his style and assimilated his manner of painting (as Rembrandt and Lievens had done in their turn in Lastman's studio); later on in their careers, when they were masters in their own right, their styles frequently changed.[10] It is thus debatable how long-lasting the influence from master to pupil would be as far as details of technical procedure are concerned.

Of the painters whose works are discussed in the present study, Ferdinand Bol, Govert Flinck, Gerbrand van den Eeckhout and Jan Victors all seem to have been in Rembrandt's studio in the 1630s.

Plate 1 Ferdinand Bol, *Portrait of a Young Lady with a Fan* (NG 5656), 1645–50. Canvas, 83.5 × 69.5 cm.

Plate 2 Follower of Rembrandt, *A Young Man and a Girl playing Cards* (NG 1247), early 1650s. Canvas, 123.5 × 104 cm.

Ferdinand Bol may have acquired his basic skills as a painter in Dordrecht with Jacob Gerritsz. Cuyp, or possibly in Utrecht with Abraham Bloemaert. He was already describing himself as a painter in Dordrecht in 1635, shortly before he entered Rembrandt's studio in Amsterdam.[11] It is assumed that he worked there until about 1641–2, becoming an independent painter shortly thereafter. Of the two paintings studied, *An Astronomer* (NG 679; Fig. 3) dates from 1652, some ten years after his period of work with Rembrandt. The *Portrait of a Young Lady with a Fan* (NG 5656; Plate 1) is slightly earlier, dating from the mid to late 1640s. Like Bol, Govert Flinck had trained elsewhere, in Leeuwarden with Lambert Jacobsz., before joining Rembrandt's studio as an assistant in the early 1630s. By 1636, roughly when Bol joined Rembrandt's studio, Flinck was signing paintings in his own right; *Self Portrait aged Twenty-four* (NG 4068) was painted in 1639.[12]

It is not known exactly when Gerbrand van den Eeckhout and Jan Victors were pupils in Rembrandt's studio. Eeckhout's earliest surviving painting dates from 1641, thus he probably served his apprenticeship with Rembrandt, with whom he seems to have developed a friendship, from the middle of the 1630s until about 1640/1.[13] If so, he would have been Bol's contemporary. The guild portrait, *Four Officers of the Amsterdam Coopers' and Wine-rackers' Guild* (NG 1459), dated 1657, and the somewhat later *Rebekah and Eliezer at the Well* (NG 6535),[14] dated 1661, were both painted perhaps as much as twenty years after Eeckhout had left Rembrandt's studio. Victors similarly was probably a member of Rembrandt's studio at much the same time, during the second half of the 1630s.[15] *A Village Scene with a Cobbler* (NG 1312) dates from between 1648 and 1651.

Unlike Bol or Flinck, for example, who came to Rembrandt as assistants, Nicolaes Maes learnt the major part of the craft of painting from him. He was probably with Rembrandt from the late 1640s as he returned to Dordrecht, his place of birth, by 1653.[16] *A Woman scraping Parsnips, with a Child standing by her* (NG 159) and *Interior with a Sleeping Maid and her Mistress* (NG 207) both date from 1655. Little is known about the life and career of Willem Drost, but it is thought that he trained with Rembrandt towards the end of the 1640s and the first part of the 1650s, that is, at approximately the same time as Maes. His early works are strongly influenced by Rembrandt; *Portrait of a Young Woman with her Hands Folded on a Book* (NG 237), which is attributed to the artist, is probably dated around 1653/4.[17]

Not all the paintings which, from stylistic evidence, appear to have been produced by artists working within Rembrandt's circle have a firm attribution. *A Young Man and a Girl playing Cards* (NG 1247;

Plate 2), which may date from the early to mid-1650s, was previously ascribed to Nicolaes Maes, but this is now thought to be incorrect. *A Study of an Elderly Man in a Cap* (NG 2539) was painted by a seventeenth-century artist with, apparently, some understanding of Rembrandt's painting methods: the brown silica-containing ground is similar to that found in several paintings by Rembrandt. The artists responsible for *A Man seated reading at a Table in a Lofty Room* (NG 3214) and *A Seated Man with a Stick* (NG 51) are also unknown.[18]

The choice of drying oil

The drying oils most widely used during the seventeenth century appear to have been linseed and walnut oils. The use of poppyseed oil is mentioned more than once in the compilation of practical information obtained by Theodore Turquet de Mayerne from painters, including some from the Low Countries, visiting the English court where he was a physician between 1620 and 1646. According to de Mayerne, poppyseed oil was used there for flower pieces and similar works; it was particularly good for white or blue pigments.[19] At the end of the century the painter Wilhelm Beurs described poppyseed oil as being better than either walnut or linseed oil for whites.[20] Despite this, its presence has yet to be confirmed in a seventeenth-century Dutch school painting.[21]

Walnut oil was recommended for use with white pigments in particular because it did not yellow so much, in the early stages of drying at least.[22] For the same reason, it was also recommended for blues and for use with light colours such as flesh paint.[23]

Analysis has suggested that Rembrandt himself tended to use linseed oil to a far greater extent than walnut, for pale colours and dark; when walnut oil was used it was not necessarily restricted to paler or cooler colours, although this is the case in perhaps the majority of instances.[24] Unmodified linseed oil was used in all the samples from *Anna and the Blind Tobit* examined, although the possibility of the presence of some walnut oil in the white paint of the sky cannot be ruled out. Linseed oil was also the preferred medium of other artists in Rembrandt's circle, including both Lastman and Lievens, as the results summarised in the Table show (p. 78). Linseed oil, not heat-bodied, was found in a highlight of the sitter's yellow garment near the lower right-hand side of Lievens's *Self Portrait*, for example; it was also used in a cool white highlight on the chair's seat (Fig. 1).

Among Rembrandt's former pupils, too, linseed oil was used to a far greater extent than walnut. Govert Flinck's *Self Portrait aged Twenty-four* dates from a period when he had been established as an independent painter for some three years, but his practice still resembles that of Rembrandt himself in

Fig. 3 Ferdinand Bol, *An Astronomer* (NG 679), 1652. Canvas, 127 × 135 cm.

that linseed oil alone was found in areas of both the olive-green background and the sitter's black robe. Gerbrand van den Eeckhout, Nicolaes Maes and Jan Victors, too, appear to have shared the general preference for its use, even in areas of white or light-coloured paint.[25] In the case of the dark brown paint of the wooden shed housing the cobbler's work-bench on the left of Jan Victors's *Village Scene with a Cobbler*, not only was the medium found to be linseed oil, but the chromatogram obtained also showed the enhanced formation of an azelaic acid scission product and reduced oleate peaks typical of the presence of iron oxide minerals. Examination of a sample of the paint under the microscope had indeed suggested the presence of brown ferruginous earth pigments.

Few instances of the use of walnut oil were observed in the paintings examined. Unlike Rembrandt himself, the painters of his circle appear to have followed the recommendations of the literary sources to a far greater extent, as walnut oil was generally only found in white and light-coloured paints. It was detected in both the paintings by Ferdinand Bol examined, in the white paint of the sleeve cuffs of the sitter in each case. The somewhat warmer white paint of the cuff in *An Astronomer* (see Fig. 3) might conceivably contain a little linseed oil also: perhaps the lead white pigment was ground with walnut oil as prescribed, but a little linseed was added during painting.

Extraction and further treatment of drying oils

As a background to a study of the paint medium, it is useful to consider the methods by which oils and

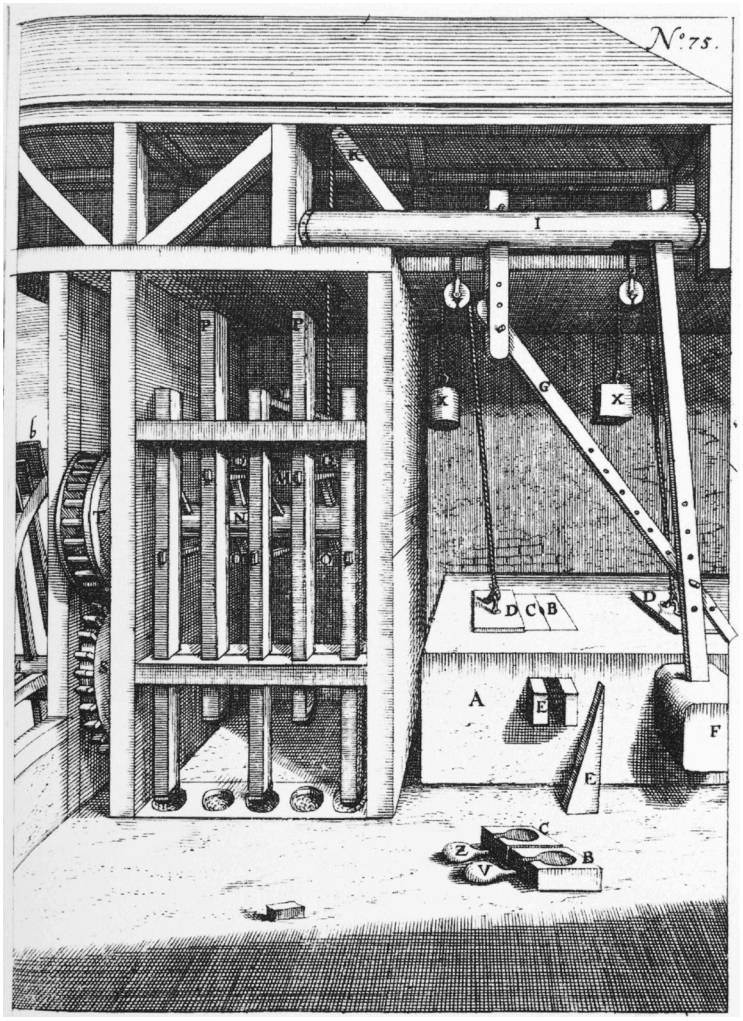


Fig. 4 Oil press, from Georg Andreas Boeckler's *Theatrum machinarum novum*, Cologne, 1662: the raw material is crushed by five iron-tipped pestles (P) on the left, then wrapped and placed in containers (B, C) in an oak chest (A). The wedges (E) on either side of the containers are forced together by the pressure of the wedge F driven against them by the action of a falling hammer, thus expressing the oil.

other possible ingredients were prepared in the seventeenth century. The first step in the process was the expression of the oil. Linseed and walnuts, like most of the kernels used for medicinal or culinary purposes, yielded their oil relatively easily. The oil could be expressed using a screw press after grinding the raw material in a mortar; the pulverised matter was then wrapped in a cloth and placed (according to some sources in a loose-bottomed box) between the two plates of the press. The expressed oil was collected in a vessel below the press. It was recommended that everything should be warmed beforehand.[26] This is not a particularly efficient process and the yield of oil is not large; for the production of oil on a larger scale a 'stamper' press, rather like that illustrated by Georg Andreas Boeckler in his *Theatrum machinarum novum* of 1662 and first developed in the seventeenth century, might have been used (Fig. 4). The process of extraction was essentially the same: the seed was pounded by the iron-tipped pestles powered by a water wheel or windmill. Bags of the warmed, crushed seed were placed between two wedge-shaped plates inserted into an oak chest, which were forced together by the pressure of a wedge driven against them by the action of a falling hammer, thus expressing the oil.[27] This, too, gave a low yield, but the method was in use until the development of the hydraulic press in the nineteenth century.

Further treatment of the oil was usual before it was ready for use. A number of writers, including de Mayerne, describe the washing of the oil.[28] The oil was shaken with water, preferably rain water, in a separating vessel with a tap and left to settle; the oil layer was taken off and the process was repeated. This would remove by hydration material ('break' material in modern terminology) that would otherwise precipitate during any subsequent heat treatment, by rendering it less soluble in the oil. Such nitrogen-containing substances would also be likely to form yellow-brown condensation products.[29] In a number of recipes cited by de Mayerne, the oil was first filtered through, or added to, sand, which would no doubt remove a certain amount of plant mucilage.[30] Salt and alum might be added with the water; the addition of alum to water would produce a weakly acidic solution which could have the property of coagulating suspended mucilaginous material.[31] Bread might be added to absorb the water, as described by Christopher Love Morley in a recipe for linseed oil for use in varnish preparation. Morley's book, *Collectanea Chymica Leydensia*, published in 1684, is based on lectures he attended while studying in Leiden; the recipe for linseed oil is ascribed to the chemist Jacobus Le Mort.[32]

Heat pre-polymerised oils

Further treatments included bleaching and thickening the oil, processes which are not necessarily separate: if the oil was left in the sun to bleach for any length of time it would also thicken, as the instructions quoted by de Mayerne and other authors make plain. Bleaching (essentially fading by light) affects chiefly the fugitive plant colouring matters, such as carotenoids and chlorophyll, present in the virgin oil as a result of the extraction process. This is a separate phenomenon from the yellowing processes that occur during the ageing of oil films.[33] Thickening of the oil was carried out by two, chemically quite distinct, processes. Oil placed in direct sunlight for a reasonable length of time, with periodic stirring, thickens by a process akin to the natural thickening or drying process which takes place when a drying oil is mixed with pigment and spread out in a thin film; that is, polymerisation is carried out by joining the individ-

ual glyceride molecules through peroxy linkages.[34] Stirring the oil allows air, and thus oxygen, to be readily available. The polymerisation process thus begins before the oil is used for painting.

If a thickened oil was not desired, it was necessary either to remove the bleached oil before it had thickened too much, or to carry out the bleaching process at a time of year when the sun was not too strong: March was suggested in some sources.[35] Otherwise, in the words of a recipe in a manuscript associated with Edward Norgate's *Miniatura*, compiled around 1650, 'Fatt Oyle is but Lynseed Oyle exposed to the Ayer and soe it becometh thicker, yet somtimes you shall see it soe thick that you may cutt it almost like butter.'[36]

Sometimes quicklime, calcium oxide, was added to the oil before bleaching or heat treatment; this would neutralise free fatty acids.[37] It would also have the beneficial side-effect of removing any plant colouring materials present, if these had not been removed earlier. During heat treatment, the most common additives were lead salts, incorporated to improve the drying properties of the oil. Norgate, in a recipe quoted by de Mayerne, recommended that lead white should be mixed with the oil, together with breadcrumbs and sawdust (which would absorb any remaining plant mucilage and lecithin), stirring the ingredients together five or six times a day for the four or five days that the oil was to be left in the sun.[38] John Smith obtained a pale, clear oil by adding two ounces of litharge to a quart of linseed oil and leaving it in the sun for a month, stirring it twice a week.[39]

The other method of bodying the oil was to heat it, usually with the addition of lead salts or other driers: John Smith, for example, recommended heating the oil with finely powdered litharge for one hour until it was 'almost of the thickness of Treacle'. The mixture was cooled and allowed to settle before the clear, but quite strongly coloured, oil was poured off.[40] Other sources recommended suspending the litharge or other drier in a bag above the bottom of the vessel in which heating was carried out so that it did not burn.[41] Lead salts were not the only driers recommended: walnut oil might be boiled with azurite or smalt for use with whites.[42] Oil bodied by direct heating, without stirring, relies upon bond formation between the glyceride molecules under circumstances which essentially exclude the wholesale participation of oxygen molecules. The bonds formed are thus essentially carbon–carbon, rather than carbon–oxygen.[43] A modern stand oil is a refinement of this process in that it is carried out on a larger scale and under more closely anaerobic conditions, quite often under nitrogen; conditions and length of processing can be varied to give oils of specific viscosities.[44] According to seventeenth-century sources, no more than a quart (just over a litre) of oil appears to have been heated at a time, usually over gentle heat for roughly half an hour to an hour. Care was generally taken not to heat the oil too strongly, which would deepen the colour.[45]

In documentary sources such modified oils are described as drying oils. Heat pre-polymerisation has several effects on the oil. Drying properties are improved and are further enhanced by the addition of metal salts (usually those of lead) during the process. The refractive index of the oil is increased, thus reducing light scattering at the pigment-medium interface and thereby increasing the saturation of the pigment colour; the paint film may also have a glossier appearance. The pigment is less liable to sink in the oil film, which itself decreases less in volume than a conventional oil film, reducing the amount of wrinkling that may occur. White paints appear less discoloured because, as the polyunsaturated fatty acids initially present in the paint film are destroyed by the formation of carbon–carbon single bonds, there is less scope for the formation of chromophoric and auxochromic groups, the presence of which give the yellow appearance to the film.

Analysis has suggested that the artists of Rembrandt's circle used heat-bodied oils principally in two circumstances: to obtain an impasto (in a highlight, for example) and to aid the drying of pigments, like lake pigments and black, which were poor driers.

The relatively stiff paint needed for an impasto could be obtained by using an oil thickened as described above, which gives a soft appearance and a relatively yielding paint: it could be also be obtained by using a high proportion of pigment with unmodified oil, which, over a period of time, results in a dry, hard paint. In Rembrandt's *Belshazzar's Feast* (NG 6350), painted around 1635, a detail of which is shown in Fig. 5, examples of both can be seen in the paint of Belshazzar's cloak. A heat-bodied linseed oil was used for the white impastoed paint near Belshazzar's brooch, while the hard, brittle, yellow impasto of the cloak trimmings gave no indication of such pre-polymerisation (Figs. 6a and 6b).[46]

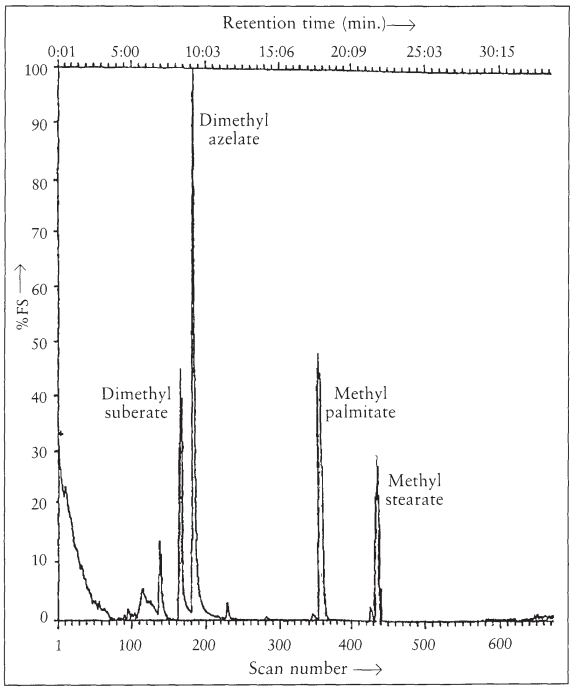
The painters of Rembrandt's circle also obtained a desired impasto or textured paint by the use of a heat-bodied oil, or by bodying with pigment, or, indeed, both. A heat-bodied oil was used for a cream-coloured, rounded highlight on the path in the foreground on the left of Lievens's *Landscape with Tobias and the Angel*. On the other hand, the white lace scarf of the young woman in *A Young Man and a Girl playing Cards* (Plate 2, p. 66) had quite a thick, textured appearance, but contained unmodified linseed oil: in this case the pigment used gave the paint the necessary body. The yellow highlight paint of the orange-brown silk curtain on the extreme right-hand

Fig. 5 Rembrandt, *Belshazzar's Feast* (NG 6350), *c.* 1635. Canvas, 167.6 × 209.2 cm. Detail showing Belshazzar's cloak.

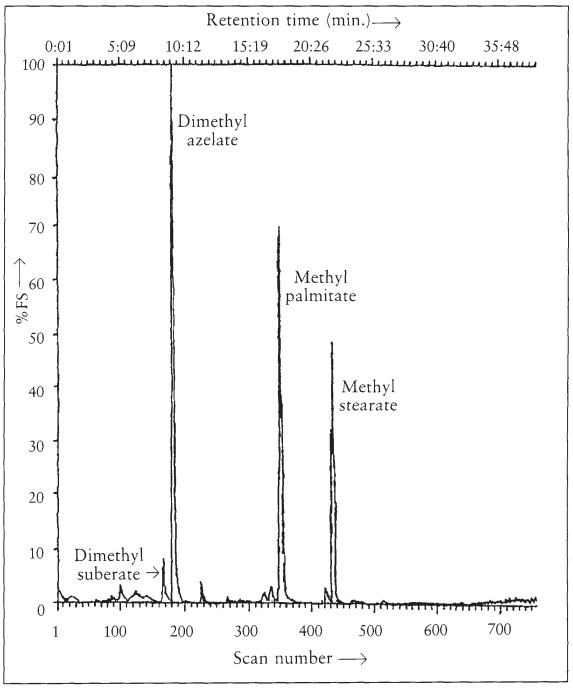
side of Ferdinand Bol's *Lady with a Fan* (Plate 1, p. 66) was observed to have been bound with heat pre-polymerised linseed oil, but the paint of the curtain has quite a pronounced texture in some areas and examination of a sample taken from a pale greyish-yellow impasto in the foreground indicated that the thick, rather poorly bound paint contained smalt mixed with lead-tin yellow. It is possible that, like Rembrandt, Bol added smalt for its textural qualities: its properties as a drier would hardly have been required.

Occasionally the results of medium analysis suggest the use of a partially heat-bodied oil; an example is the thick blue-grey sky paint near the top edge of Jan Victors's *Village Scene with a Cobbler*. This result could be interpreted in several different ways. One explanation might be that the pigments were indeed ground with a partially heat-bodied linseed oil. A more likely explanation is that the pigments were ground in ordinary unmodified linseed oil; the heat-bodied oil was added during painting. Examination of a sample of the paint under the microscope showed that the greyish-blue paint layer was composed of

Fig. 6 Total ion chromatograms (TIC) of saponified and methylated samples of paint from Rembrandt's *Belshazzar's Feast*. The instrument was a Kratos MS25 Gas Chromatograph-Mass Spectrometer System (GC–MS); electron impact mode (EI+), 70 eV, 1 sec/decade scan-rate, 25 metre 0.53mm bore silica column (bonded phase methyl silicone type); temperature programmed 110°C × 7°C min^{-1} to 310°C. Helium carrier gas.



(a) White impasto paint of Belshazzar's cloak, near brooch. The dimethyl suberate peak is more pronounced (relative to dimethyl azelate) in comparison to that in chromatogram (b). The azelate-suberate ratio of 2.73 indicates the probable use of a heat pre-polymerised drying oil.



(b) TIC of yellow impasto of trimmings of cloak.

lead white mixed with fragments of very discoloured smalt and bone black. It is therefore conceivable that, assuming that the colours had been ground in oil separately and then mixed for use, the heat-bodied oil had been added to the black paint to help it to dry. Marshall Smith describes how certain pigments, including lakes and bone black, should be ground in linseed oil, but tempered on the palette using drying oil.[47] There is also some documentary evidence for the use of a mixture of oils: John Smith, for example, describes the mixing of ordinary linseed and heat-bodied linseed oils in certain proportions; the mixture was then used to temper the prepared colours.[48]

Among the paintings studied, several instances were found of pre-polymerised oil being used with pigments that are poor driers: Pierre Lebrun, in the Brussels manuscript, wrote that drying oil heated with litharge was very good for drying pigments such as lake and black.[49] While it must be assumed that often the oil would have been heated with a lead salt, for example, to increase its drying properties, it is not easy to detect the driers themselves, particularly when the paint includes lead-containing pigments. It has apparently been possible to detect the presence of lead driers in the grounds of certain French paintings of the seventeenth and eighteenth centuries.[50]

Driers might also be incorporated into the paint on the palette, as Rembrandt's practice indicates: both de Mayerne and John Smith refer to the use of powdered calcined copperas (de Mayerne specifically mentions white copperas, zinc sulphate, $ZnSO_4.7H_2O$; 'copperas' nowadays generally refers to the iron (II) sulphate, $FeSO_4.7H_2O$, which is white when calcined).[51] Verdigris, minium and umber were also recommended.[52] Marshall Smith recommended the use of ground glass, which was a not uncommon suggestion and interesting in view of Rembrandt's use of smalt in pigment mixtures for its drying properties, mentioned above.[53] A drier, mixed into the paint or incorporated with the oil during preparation, must have been used in the black paint of the sitter's sleeve in the *Portrait of a Young Woman with her Hands Folded on a Book*, attributed to Willem Drost. The paint was in good condition, with no evidence of cold flow or shrinkage, yet the linseed oil identified as the binding material had not undergone any significant heat-bodying to assist in the drying of the pigment.

Certain pigments still did not dry successfully even with the aid of a heat-bodied oil. Asphaltic or bituminous pigments are notoriously bad driers, encouraging long-term cold flow of the paint film; this results in a characteristic craquelure or 'crocodiling'. These defects can be seen in the black paint of the sitter's gown in Ferdinand Bol's *Astronomer* (Fig. 3). The principal component of the medium was heat pre-polymerised linseed oil, with a small amount of conifer resin. The treatment the oil had received, however, was insufficient on its own to assist drying, for the paint was also found to contain chemical components associated with triterpanes, suggesting the presence of asphaltum or bitumen (Figs. 7a–d). Under the microscope, brown translucent particles of low refractive index, characteristic of asphaltum, were indeed found to be present in a sample of the paint, mixed with bone black. Philippe de La Hyre, writing at the beginning of the eighteenth century, comments that asphaltum is convenient to use, but never dries without a strong drier; for this reason, once it has been prepared it can be kept for several years.[54]

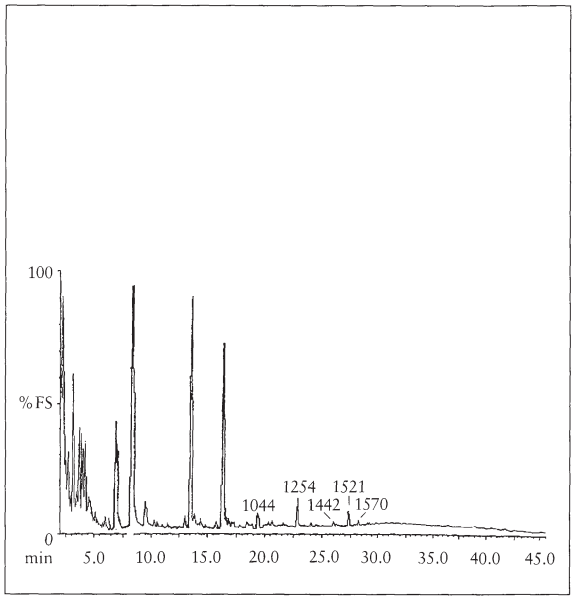
The black paint of the background of Jan Lievens's *Self Portrait* (Fig. 1), which shows rather similar cold-flow defects, was found to contain a significant amount of a softwood pitch: fragments of an organic brown pigment (presumably pitch) could be seen, mixed with black pigment, in a sample of the paint examined under the microscope and the paint medium, heat-bodied linseed oil, had a distinctly yellowish appearance. Like asphaltum, pitch is a particularly poor drier and the use of this pigment was undoubtedly responsible for the shrinkage.[55]

Additions of resinous compounds to the paint medium

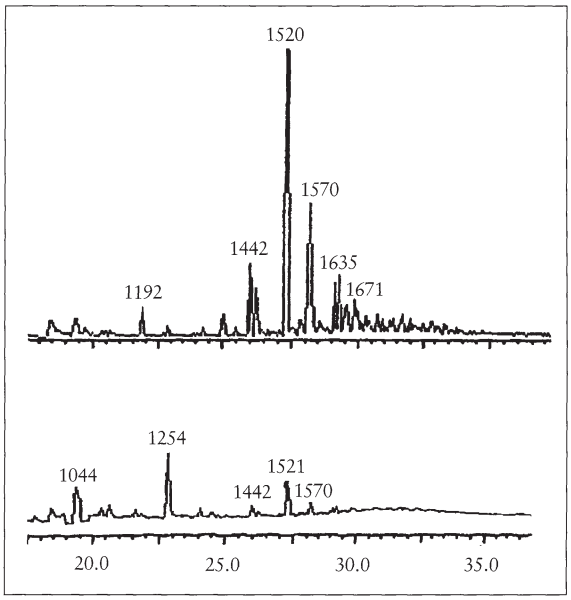
Unlike Rembrandt, several of the painters in his circle appear occasionally to have added small amounts of pine resin, in the form of varnish, to the medium. Many of the recipes for varnish preparation given by de Mayerne refer to the use of Venice turpentine (obtained from the larch, *Larix decidua* Miller) rather than colophony (pine rosin, the solid material remaining after the distillation of spirits or oil of turpentine); the use of Venice turpentine by painters in the Netherlands in the mid-seventeenth century has yet to be confirmed, however. Later in the century, Nicolas L'Emery writes that the turpentine commonly used was 'called, improperly, Venice Turpentine', but it was, in France at least, obtained from species of pine (*Pinus* spp.) and fir (*Abies alba* Miller), as well as larch.[56] Small quantities of other resins, such as sandarac or mastic, are sometimes mentioned in the recipes collected by de Mayerne, but as yet these have not been identified in the paint medium. Both spirit varnishes and those prepared using linseed or walnut oil were available; given the tiny quantities in which the additions of varnish, and thus pine resin, were made to the paint medium, however, it is impossible to say which would have been used in any particular case where resin has been detected.[57]

The principal reason for adding turpentine resin varnish to the paint appears to have been to give increased transparency and gloss to the paint film,

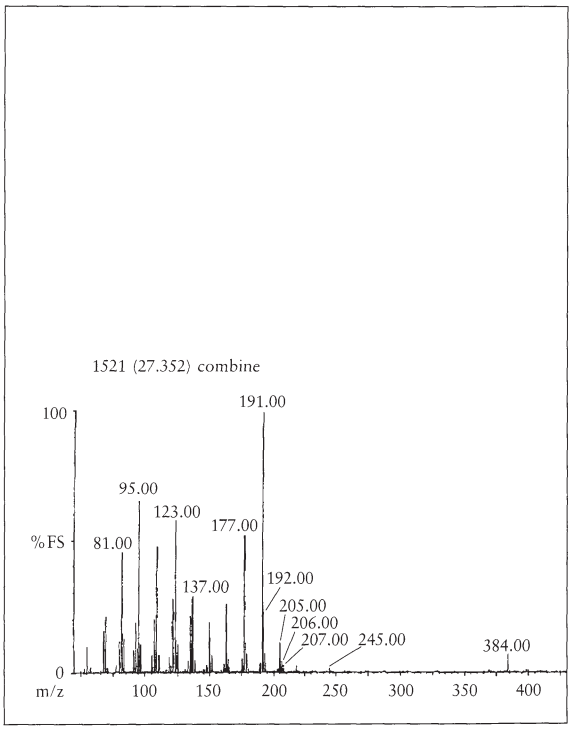
Fig. 7 Sample of saponified and methylated black paint, exhibiting shrinkage, from Ferdinand Bol's *Astronomer*, examined using a VG Biotech Trio 2000 GC–MS. A 25 metre SGE *HT5* bonded phase, 0.53 mm bore capillary column was used (column temperature: 35°C (0.5 min) × 25°C min^{-1} to 120°C (1.0 min) × 7°C min^{-1} to 300°C). MS detection was carried out with a source temperature of 280°C, EI+ mode at 70 eV, 0.9 a.m.u. sec^{-1} mass scan (m/z range: 650–40).



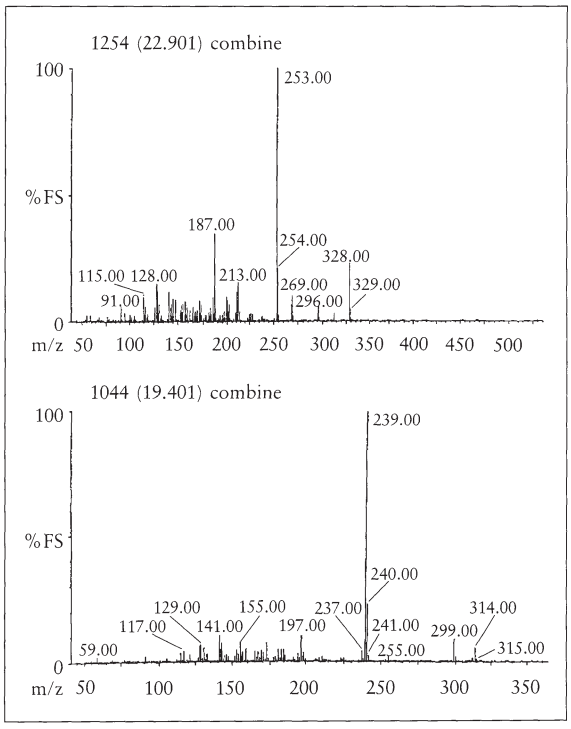
(a) TIC showing fatty acid methyl ester profile suggesting a heat-bodied linseed oil, together with minor components in the diterpenoid resin region and the triterpane area.



(b) (Above) Hopanogram (ion trace for m/z = 191, a typical base peak in the fragmentation pattern of hopanes) and (below) TIC detail of the diterpenoid and triterpane regions.



(c) Mass spectrum of a component at scan number 1521, indicating a triterpane bisnorhopane of molecular weight 384. The component at scan number 1570 gave a similar spectrum, but with a molecular ion of m/z = 398, clearly indicating a higher carbon number homologue, norhopane.



(d) Lower spectrum: mass spectrum of component at scan number 1044, indicating the presence of methyl dehydroabietate, molecular weight 314. Upper spectrum: mass spectrum of component at scan number 1254, indicating the presence of methyl 7-oxodehydroabietate, molecular weight 328.

particularly in glazes and for areas of shadow. John Smith (admittedly referring to house painting) describes how the addition of turpentine (that is, rosin), dissolved in oil of turpentine, to pigments ground in oil enabled them to dry with a shiny, smooth, glass-like surface.[58] Marshall Smith recommends the use of walnut oil mixed with varnish for glazing draperies, specifically with red lake pigments, although varnish or drying oil could also be used.[59] The addition of varnish was also said to speed up or improve drying. In the short term this might be so; the film would gel more rapidly, but its long-term effect might be more equivocal. Only a very small amount of varnish (a few drops to the paint as it was mixed for use, perhaps) appears to have been added.

A good example of this practice is the final glaze on the red dress of the girl in *A Young Man and a Girl playing Cards* (Plate 2), which was found to contain linseed oil, with some pine resin (indicated by the presence of 7-oxodehydroabietic acid) to provide extra gloss and richness. The main body colour of the dress appears to be painted in a mixture of red pigments, including transparent red lake pigment, a mixture similar to that often used by Rembrandt himself.[60]

Similarly, the dark green foliage paint on the right-hand side of Pieter Lastman's *Juno discovering Jupiter with Io* (Fig. 2) was found to contain some pine resin as well as unmodified linseed oil. The paint, which was quite rich and lustrous, contained the blue basic copper carbonate pigment azurite, with some lead-tin yellow and a little translucent yellow lake pigment; the apparent fading of the latter contributed to the pronounced blue-green colour of the foliage. The use of a little resin in the paint of a shadow, to give increased depth and translucency, is seen in Eeckhout's *Rebekah and Eliezer at the Well*.[61]

Because only small additions of resinous material were made to the paint it is necessary to ensure that residual traces of any varnish removed during conservation treatment, for example, are not mistaken for constituents of the paint medium. Conifer resin components apparently present in the white paint of a handkerchief tassel in the *Portrait of a Young Woman* attributed to Willem Drost were found to derive from traces of varnish on the paint surface.[62]

The addition of resinous components to the medium did not always result in a stable paint film. The thick, very dark brownish-green paint of Lievens's *Landscape with Tobias and the Angel* showed slight shrinkage. The uppermost layer of paint was found to contain a mixture of pigments, including large particles of azurite, with ochres, black and other pigments, in a distinctly brownish-yellow medium. Gas-chromatography gave evidence for the use of pine resin in the paint, but was unable to characterise it any further. The shrinkage could be explained by the presence of softwood pitch, the cause of the shrinkage in the background of Lievens's *Self Portrait*, which might also account for the discoloured medium. It could also be due to the presence of crude pine oleoresin – that is, as bled from the tree, rich in essential oil – in the medium. This would be equivalent to diluting the medium with turpentine oil, which would diffuse from the matrix and be lost by surface evaporation. The drying oil-rich film, containing the residual pine resin solids, would gradually shrink as a result. Hoogstraten wrote that Lievens 'was expert in seeking wonders in the mixed pigments, varnishes and oils'; if this is true, it seems that, on this occasion, his experimentation did not lead to a technically sound conclusion.[63]

Ferdinand Bol made use of a rather more unusual resinous material in his *Portrait of a Young Lady with a Fan* (Plate 1). The rich, glaze-like paint of the brownish shadow at the top edge of the orange-brown curtain was in some ways reminiscent of an oleo-asphaltic glaze, but without the paint-film defects associated with the liberal use of such a material. The gas chromatogram (Fig. 8) showed that the principal component of the paint medium was heat-bodied linseed oil; the diterpenoid components, including methyl Δ8-isopimarate, also present suggested that Bol used amber varnish in the paint.[64]

Amber, like many other painters' materials, was used to alleviate the symptoms of a number of unpleasant medical disorders. The tincture – the alcohol-soluble fraction – of amber (which de Mayerne used in the preparation of a varnish with oil of lavender)[65] and the oil distilled from the solid resin were said to be good for apoplexy, epilepsy and similar maladies.[66] Amber varnish was not particularly easy to prepare because of the hardness of the resin; the recipe noted by Christopher Love Morley during his studies in Leiden consisted of heating the coarsely powdered amber with either linseed or walnut oil until it had liquefied and was black in colour. It was then poured onto a damp stone and allowed to cool, after which it was powdered and cooked with oil, previously heated with bread (to remove water) and chalk (to remove free acids). After filtering, the varnish was ready for use.[67] De Mayerne, who made a number of attempts at preparing amber varnishes, gives a very similar recipe; the resulting varnish, he said, was red in colour and used by lute makers.[68]

Because of its strong colour, amber varnish appears to have been used mostly for musical instruments and similar items. De Mayerne referred to its use in Italian painting practice (specifically by Orazio Gentileschi and his daughter Artemisia): because it flowed well, it was apparently mixed with two or three parts of walnut oil and applied over the first layer of paint, or dead colouring, thus helping the

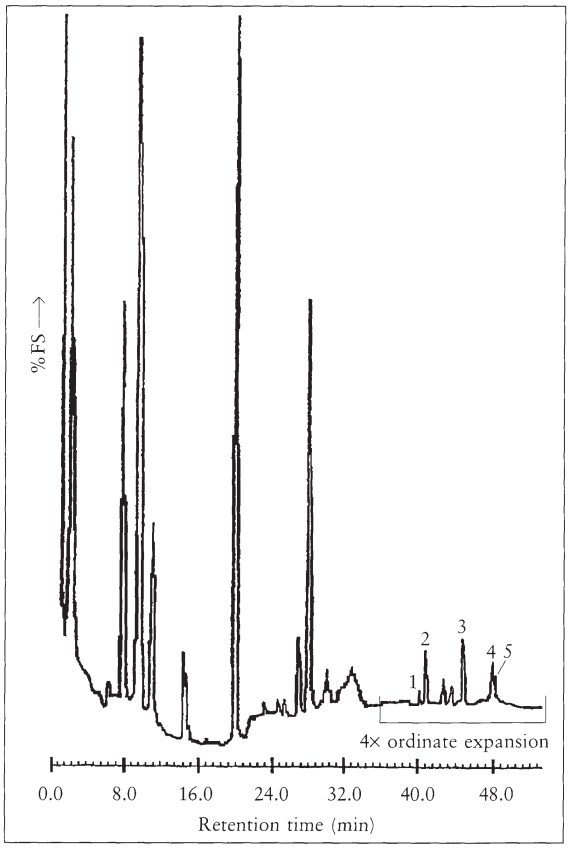


Fig. 8 Gas chromatogram of sample from brownish shadow on curtain in Bol's *Portrait of a Young Lady with a Fan*, saponified and methylated using diazomethane gas and examined on a Perkin Elmer F30 gas chromatograph (GC), fitted with on-column injector and wide bore quartz capillary column. Helium was used as carrier gas with a FID (flame ionisation detector). The diterpenoid region of the chromatogram displayed has undergone a 4-fold expansion of the ordinates. The following peaks were identified, by means of a comparison run: (1) 13-methylpodocarpatrien-19-oic acid, methyl ester; (2) Δ8-isopimaric acid, methyl ester; (3) Dehydroabietic acid, methyl ester; (4) 7-oxodehydroabietic acid, methyl ester; (5) Δ13-isoagathic acid, methyl ester, probably.

paint applied subsequently to spread.[69] Similarly, a drop of oil of amber mixed with the colours already ground in oil on the palette allowed them to spread more easily and gave them a glass-like lustre.[70] The strong red colour was said not to affect the light flesh colours to which it was added. In the case of Bol's portrait, it seems likely that the varnish was used for its red colour, rather than for its spreading properties.

Diluents

Although it is not possible to detect the remains of volatile diluents, such as oil or spirits of turpentine and lavender, essential oils of this type would undoubtedly have been used for moistening or cleaning brushes, if not for diluting paint. Turpentine was easily distilled from the crude resin over a gentle fire, or even hot water.[71] On a larger scale, as would be needed for painting purposes, the oil was distilled by heating the crude gum turpentine in a large copper kettle: Fig. 9 shows the apparatus used by Willem Pekstok in Amsterdam, who distilled turpentine from 1658. Great care appears to have been taken to regulate the temperature of the distillation, using a gentle heat and adding water to the gum resin so that the turpentine oil distilled over at a lower temperature; cold water was also used as a coolant for the collecting vat. The process was monitored by testing the resin at intervals. Ninety pounds of turpentine oil and 470 pounds of residual colophony were obtained from 570 pounds of starting material.[72] De Mayerne recommended that the solvent be redistilled before use.[73] Lavender, or spike, oil had slightly different solvent properties – it would, according to Pomet, dissolve sandarac resin – but its recommended uses in painting were similar to those of turpentine.[74]

During painting, volatile solvents might be used to moisten the brush, particularly if the paint was too stiff.[75] They also appear to have been employed to dilute blues, in particular, and also whites, so that the paint flowed from the brush easily while retaining a clean colour because the solvent evaporated so rapidly.[76] It is quite possible that a diluent of this type was used in the rather thin greyish-blue paint of the cloudy sky over Juno's head in Pieter Lastman's *Juno discovering Jupiter with Io* (Fig. 2). The paint was much leaner than the white highlight paint on a trailing stem of foliage on the right of the painting, although both contained linseed oil.

Conclusion

It must be remembered that this is a comparatively limited study; nevertheless, certain features of painting practice appear to be common to Rembrandt and to the circle of painters associated with him. It seems that Rembrandt largely relied on the use of a simple oil medium, generally linseed oil, occasionally modified by heat-bodying; linseed oil was also that most commonly used by his associates and pupils. The production of an impasto by the use of heat-bodied oil or, alternatively, by bodying the paint with pigment, also appears to be general.

Rembrandt generally achieved his desired effects of translucency or body in the paint by mixtures of pigments; painters in his circle were inclined to employ small additions of pine resin varnish instead – or, perhaps, as well – to obtain the translucency and gloss they desired. This is the principal difference between Rembrandt's practice and that of many of the other painters in his circle. There is no evidence so far to suggest the addition of substantial quantities of resin to the oil medium.

Any painter would have been aware that certain pigments were poor driers. Rembrandt offset this by including pigments that dried well in his mixture.

Occasionally painters of his circle, for example Lievens and Bol, seem not to have taken adequate precautions to ensure drying of pigments like asphaltum and pitch (which Rembrandt appears not to have used), resulting in the paint film defects that are apparent today.

Note

Some of these analytical results were first presented in a paper given at *Rembrandt: The Master and his Workshop. A Symposium on Recent Technical Research*, held at the National Gallery on 22–23 May 1992.

Acknowledgements

The paintings discussed in this article were sampled by Ashok Roy for examination of the layer structure and materials used. Thanks are due to Sara Hattrick and Colin Harvey of the Photographic Department for the illustration of the turpentine still obtained from the original microfilm, and to Christopher Brown for useful discussions and comments.

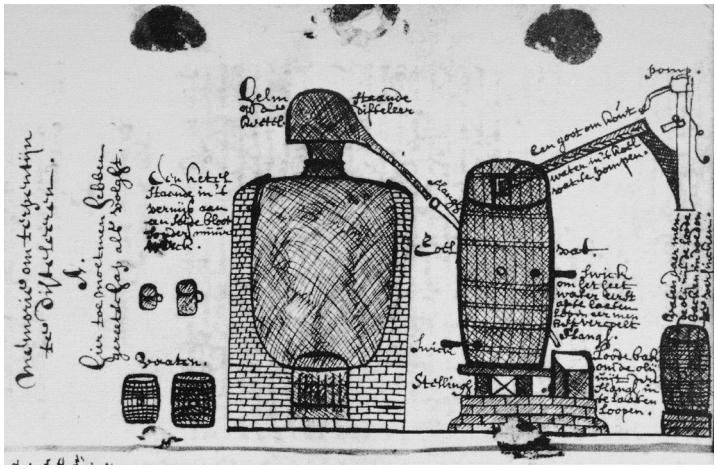


Fig. 9 Willem Pekstok's apparatus for the distillation of turpentine: crude gum turpentine was placed in the kettle (on the left of the figure), the 'helm' was placed in position and the kettle heated. The distillate was carried over into the collecting vat on the right, cooled by cold water from a pump. *Memorie om terpentijn te disteleeren*, from notes made by Willem Pekstok on the preparation of colours and other materials, Gemeente-Archief, Amsterdam, Ms. no. N 09 23, f. 8r.[72]

Notes and references

1. J. von Sandrart, *L'Academia todesca della architectura, scultura e pittura, oder Teutsche Academie der edlen bau-, Bild- und Mahlerey-Künste*, Nuremberg 1675, Vol. 1, 1679, Vol. 2: for his discussion of Rembrandt see Vol. 1, Part II, Book III, pp. 326–7; for Rembrandt's colour see Part I, Book III, Chap. 13, p. 85.
2. S. van Hoogstraten, *Inleyding tot de hooge Schoole der Schilderkonst*, Rotterdam 1678 (facsimile edn. Davaco Publishers 1969); for Rembrandt's colour see pp. 291 and 306; for his flesh tints pp. 227–8; for his chiaroscuro pp. 176, 273, 305–6. Ernst van de Wetering asserts that echoes of Rembrandt's practice may have found their way into other chapters of his book: see E. van de Wetering, 'Rembrandt's Manner: Technique in the Service of Illusion', C. Brown, J. Kelch and P. van Thiel, *Rembrandt: The Master & his Workshop. Paintings*, exhibition catalogue, Berlin/Amsterdam/London 1991–2, pp. 12–39. For a discussion of Hoogstraten's treatise and his remarks on painting materials see C. Brown, D. Bomford, J. Plesters and J. Mills, 'Samuel van Hoogstraten: Perspective and Painting', *National Gallery Technical Bulletin*, 11, 1987, pp. 60–85.
3. F. Baldinucci, *Cominciamento e progresso dell'arte dell'intagliare in rame, colle vite di molti de'più eccellenti Maestri della stessa Professione*, Florence 1686, p. 79.
4. A. Houbraken, *De Groote Schouburgh der Nederlantsche Konstschilders en Schilderessen*, 3 vols., Amsterdam 1718–21, Vol. 1, p. 269.
5. D. Bomford, C. Brown and A. Roy, *Art in the Making: Rembrandt*, with contributions by J. Kirby and R. White, exhibition catalogue, London 1988, pp. 26, 28–9; J. Mills and R. White, 'Paint Media Analyses', *National Gallery Technical Bulletin*, 13, 1989, pp. 69–71.
6. Bomford, Brown and Roy, op. cit., pp. 21–6.
7. *Anna and the Blind Tobit* was until recently attributed to Gerrit Dou. During the 1992 *Rembrandt: The Master and his Workshop* exhibition at the National Gallery, it was possible to make a direct comparison between this painting and Rembrandt's *An Old Woman at Prayer* (*c.* 1629/30, Salzburg, Salzburger Landessammlungen-Residenzgalerie), and early works by Dou. On the basis of these comparisons, and of the (probably contemporary) engraving after the painting by Willem van der Leeuw, in which it is said to be by Rembrandt, Christopher Brown felt that the attribution to Dou could no longer be upheld. The painting has thus been re-attributed to Rembrandt. See N. MacLaren, *The Dutch School 1600–1900*, revised by C. Brown, 2 vols., National Gallery Catalogues, London 1991, Vol. 1 (text), pp. 109–12, 319–20; Vol. 2 (plates), plate 93; Brown, Kelch and van Thiel, op. cit. (note 2), catalogue no. 6, pp. 139–41 and nos. 55–7, pp. 300–7.
8. MacLaren/Brown, op. cit., pp. 228–33, plates 194, 196; Brown, Kelch and van Thiel, op. cit, p. 294.
9. MacLaren/Brown, op. cit., pp. 224–5, plate 192.
10. J. Bruyn, 'Rembrandt's workshop: its function & production', in Brown, Kelch and van Thiel, op. cit., pp. 68–89.
11. MacLaren/Brown, op. cit., pp. 29–31, plates 25–6; Brown, Kelch and van Thiel, op. cit., p. 322.
12. MacLaren/Brown, op. cit., pp. 140–1, plate 118; Brown, Kelch and van Thiel, op. cit., p. 314.
13. MacLaren/Brown, op. cit., pp. 127–30, plate 111; Brown, Kelch and van Thiel, op. cit., p. 344.
14. *The National Gallery Report: April 1990–March 1991*, London 1991, pp. 22–3.
15. MacLaren/Brown, op. cit., pp. 471–2, plate 397; Brown, Kelch and van Thiel, op. cit., p. 334.
16. MacLaren/Brown, op. cit., pp. 239–42, plates 201–2; Brown, Kelch and van Thiel, op. cit., p. 366.
17. MacLaren/Brown, op. cit., pp. 114–15, plate 95; Brown, Kelch and van Thiel, op. cit., p. 384.

18. For these four paintings see MacLaren/Brown, op. cit., pp. 371–2, plate 299 (NG 1247); pp. 377–8, plate 303 (NG 2539); pp. 373–6, plate 301 (NG 3214); pp. 370–1, plate 298 (NG 51).
19. T.T. de Mayerne, *Pictoria, sculptoria, tinctoria et quae subalternarum artium spectantia*, 1620–46, British Library (British Museum) Ms. Sloane 2052. The edition used is that annotated by J.A. van de Graaf, *Het de Mayerne Manuscript als Bron voor de Schildertechniek van de Barok*, diss., Utrecht 1958. A useful commentary is given in M.K. Talley, *Portrait Painting in England: Studies in the Technical Literature before 1700,* published privately by the Paul Mellon Centre for Studies in British Art, London 1981, pp. 72–149, 431–41. There is a paucity of seventeenth-century Dutch documentary sources on materials and methods; those extant are particularly uncommunicative as far as the paint medium is concerned. For this reason the de Mayerne mauscript, although not, strictly speaking, a Dutch source, is particularly valuable: it reflects many aspects of northern European practice. Reference has also been made to English and other northern European documentary sources where information from Dutch sources is lacking. De Mayerne usually gives the name of his informant with a recipe; this has been omitted and all references are cited under his name. For references to poppyseed oil see de Mayerne no. 86a, p. 178; no. 88, p. 179; no. 90, p. 180; no. 119, p. 190.
20. W. Beurs, *Die grosse Welt ins klein abgemahlet*, Amsterdam 1693, p. 9. (Original Dutch edn., *De groote Werelt in't kleyn*, 1692.)
21. Similarly, hempseed oil, which de Mayerne suggested could be used for varnishes despite its greenish colour, has not been detected; see de Mayerne, op. cit., no. 124, p. 192.
22. See, for example, J. Smith, *The Art of Painting in Oyl*, 2nd edn., London 1687, pp. 40–1; E. Norgate, *Miniatura, or The Art of Limning*, ed. M. Hardie, Oxford 1919, pp. 92–3; von Sandrart, op. cit. (note 1), Vol. 1, Part I, Book III, Chap. VII, p. 73.
23. De Mayerne, op. cit., no. 87, p. 178; no. 90, p. 180; M. Smith, *The Art of Painting according to the Theory and Practise [sic] of the best Italian, French and Germane Masters*, 2nd edn., London 1693, p. 71 (1st edn. 1692).
24. Mills and White 1989 op. cit. (note 5), pp. 69–71; Bomford, Brown and Roy, op. cit. (note 5), pp. 28–9.
25. For Eeckhout's *Rebekah and Eliezer at the Well* see R. White and J. Pilc, 'Analyses of Paint Media', *National Gallery Technical Bulletin*, 14, 1993, pp. 89, 93. The paint of Eeckhout's *Four Officers of the Amsterdam Coopers' and Wine-rackers' Guild* was contaminated with wax adhesive applied during conservation treatment; as a result, the use of linseed oil in the black paint of the officers' cloaks remains a probability rather than a certainty.
26. A screw press is illustrated in Sir Hugh Plat's *The Jewel House of Art and Nature*, London 1653 (first published in the 1590s; the woodcut is probably of this date), pp. 163–4. See also N. L'Emery, *Cours de chymie, contenant la maniere de faire les operations qui sont en usage dans la medecine, par une methode facile*, 9th edn., Paris 1697, pp. 469–72; P. Pomet, *Histoire générale des drogues, traitant des plantes, des animaux & des mineraux*, Paris 1694, pp. 229–30.
27. G.A. Boeckler, *Theatrum machinarum novum*, Cologne 1662, pp. 23–4 and fig. 75. A nineteenth-century description of the process is given in J.-S.-E. Julia de Fontenelle, *Manuel du fabricant et de l'épurateur d'huiles*, 2nd edn., Paris 1836 (Encyclopédie Roret: Manuels Roret, 1st edn. 1828), pp. 125–9.
28. De Mayerne, op. cit., nos. 91–7, pp. 180–2 (some of which also include bleaching). For a modern discussion of the refining and bleaching of oils, including treatment with acid and alkali, see *Bailey's Industrial Oil and Fat Products*, ed. D. Swern, 4th edn., Vol. 2, New York and Chichester 1982, pp. 253–314.
29. These products would be formed by the Maillard reaction: see *Autoxidation in Food and Biological Systems*, eds. M.G. Simic and M. Karel, New York and London 1980, pp. 367–85.
30. De Mayerne, op. cit., no 96, pp. 181–2; no. 106, p. 185.
31. De Mayerne, op. cit., nos. 93–5, p. 181; no. 100, p. 183. The addition of onion, mentioned in several recipes, might have the same effect as it is weakly acidic; see, for example, A. Félibien, *Des principes de l'architecture, de la sculpture, de la peinture et des autres arts qui en dépendent*, Paris 1676, p. 413. Vinegar is occasionally mentioned also; see de Mayerne, no. 100, p. 183.
32. C.L. Morley, *Collectanea Chymica Leydensia, id est Maetsiana, Margraviana, Le Mortiana*, Leiden 1684, p. 466; J.R. Partington, *A History of Chemistry*, Vol. 2, London 1961 (1969 reprint), pp. 736–7.
33. J.S. Mills and R. White, *The Organic Chemistry of Museum Objects*, London 1987, p. 34; Talley, op. cit. (note 19), p. 79.
34. Mills and White 1987, op. cit., pp. 30–5
35. De Mayerne, op. cit., no. 96, pp. 181–2; no. 106, p. 185.
36. Norgate, op. cit. (note 22), p. 93.
37. De Mayerne, op. cit., no. 98, pp. 182–3; see also Morley, op. cit. (note 32), p. 466.
38. De Mayerne, op. cit., no. 89a, pp. 179–80.
39. J. Smith, op. cit. (note 22), p. 40: metric equivalents would be approximately 56 g litharge to 1.1 litres oil.
40. J. Smith, op. cit., pp. 38–9.
41. See, for example, P. Lebrun, *Recueuil des essaies des merveilles de la peinture*, 1635, in M.P. Merrifield, *Original Treatises Dating from the XIIth to XVIIIth Centuries on the Arts of Painting*, London 1849, Vol. 2, pp. 816–17.
42. Félibien, op. cit. (note 31), p. 413.
43. During heating it would probably be necessary to stir the oil periodically, before the so-called 'boiling', that is, evolution of carbon dioxide (see note 45), to prevent the material at the bottom of the vessel burning, with consequent darkening of the oil. This would not make any essential difference to the bond type formed. See, for example, de Mayerne, op. cit., nos. 113, 115, p. 187.
44. *Bailey's Industrial Oil and Fat products*, ed. D. Swern, 4th edn., Vol. 1, New York and Chichester 1979, pp. 730–3.
45. See, for example, de Mayerne, op. cit., no. 113 p. 187, where the oil is removed from the heat when it boils and replaced on cooling. 'Boiling' implies the evolution of carbon dioxide, which would inhibit oxidation by removal of dissolved oxygen by degassing. The formation of a skin, or covering the oil during cooling, would restrict access of oxygen. The oil does not actually boil without considerable decomposition taking place at the same time. Heating the oil to such a high temperature that it smoked is rarely mentioned: see de Mayerne, op. cit., no. 118, p. 189.

46. Mills and White 1989, op. cit. (note 5), p. 69 no. 4 and p. 70; Bomford, Brown and Roy, op. cit. (note 5), pp. 74–9, esp. p. 75 and plates 34–5, p. 79. The use of a heat-bodied oil in the white paint, but not the yellow, may account for the noticeably different behaviour of the paints during sampling: the smoothly contoured white impasto yielded in a plastic manner; the brittle yellow impasto did not.
47. M. Smith, op. cit. (note 23), pp. 71–2. If prepared colours were to be stored in a bladder for any length of time it would be inappropriate to grind them with a modified oil as they would then harden; see J. Smith, op. cit. (note 22), pp. 4–5.
48. J. Smith, op. cit. (note 22), pp. 38–9: three parts plain linseed oil, one part heat-bodied oil with a drier, a mixture he calls 'fat' drying oil. Lebrun describes the oil cooked with litharge as 'fat'; 'drying' oil is that cooked with minium and umber: Lebrun, op. cit. (note 41) nos. 23–4, pp. 816–17.
49. Lebrun, op. cit., no. 26, pp. 818–19.
50. A.R. Duval, 'Les préparations colorées des tableaux de l'Ecole Française des dix-septième et dix-huitième siècles', *Studies in Conservation*, 37, 4, 1992, p. 252.
51. De Mayerne, op. cit., no. 119, pp. 189–90; Talley, op. cit. (note 19), pp. 75–7; J. Smith, op. cit. (note 22), p. 39.
52. De Mayerne, op. cit., no. 120a, p. 190.
53. M. Smith, op. cit. (note 23), p. 73; see also Lebrun, op. cit. (note 41), no. 29, pp. 818–19. Glass in general could well have contained traces of iron, manganese or lead, for example; smalt contains cobalt, which is responsible for its blue colour. Compounds of all these metals encourage drying.
54. R. White, 'Brown and Black Organic Glazes, Pigments and Paints', *National Gallery Technical Bulletin*, 10, 1986, pp. 62–5; P. de La Hyre, 'Traité de la pratique de peinture', *Mémoires de l'Académie Royale des Sciences depuis 1666 jusqu'à 1699*, IX, Paris 1730, pp. 680–1. For the use of asphaltum by Gerrit Dou see L. Struick van der Loeff and K. Groen, 'The Restoration and Technical Examination of Gerard Dou's *The Young Mother* in the Mauritshuis', *ICOM Committee for Conservation 10th Triennial Meeting, Washington, DC, USA, 22–27 August 1993. Preprints*, 2 vols., Paris 1993, Vol. 1, pp. 98–103.
55. White, op. cit. (note 54), pp. 65–7.
56. L'Emery, op. cit. (note 26), pp. 603–5. What he describes as the best turpentine, that of Chio, was extremely expensive; its use was limited to certain branches of medicine. This was in fact the original true turpentine or terebinth from *Pistacia atlantica* Desf. (a variety of another member of the same genus, *P. lentiscus* L., gives mastic resin): see J.S. Mills and R. White, 'The identity of the resins from the late Bronze age shipwreck at Ulu Burun (Kas)', *Archaeometry*, 31, 1, 1989, p. 38; Pomet, op. cit. (note 26), p. 112.
57. For recipes see Morley, op. cit. (note 32), p. 465; de Mayerne, op. cit., no. 124, p. 192, and nos. 142–3, 145 and 147–59 pp. 201–6.
58. J. Smith, op. cit. (note 22), pp. 41–2. There appears to have been a long tradition for the addition of resin, in the form of varnish, to green glazes in particular; see, for example, G.B. Armenini, *De' veri precetti della pittura*, Ravenna 1587, p. 126.
59. M. Smith, op. cit. (note 23), pp. 71, 84.
60. Analysis by high-performance liquid chromatography suggests that the glaze consists of a mixture of red and yellow lake pigments (including a cochineal lake), also common in Rembrandt's work; see Bomford, Brown and Roy, op. cit. (note 5), pp. 24, 30, 111, 142; C. Brown and A. Roy, 'Rembrandt's "Alexander the Great"', *The Burlington Magazine*, CXXXIV, May 1992, pp. 293–4.
61. White and Pilc, op. cit. (note 25), pp. 89, 93.
62. Two samples of white paint were taken from the same area, one after a limited cleaning, the second after a more thorough cleaning. Analysis of the first suggested the presence of conifer resin in the medium: both methyl dehydroabietate and 7-oxodehydroabietate were detected. The second gave the same results for the principal binding component – walnut oil – but no resin was detected. Residual varnish on the paint surface had been removed by the more thorough cleaning. To minimise the risk of contamination by varnish, the immediate surface of the paint to be sampled should be removed.
63. Hoogstraten, op. cit. (note 2), p. 238; Van de Wetering, op. cit. (note 2), p. 29.
64. White, op. cit. (note 54), pp. 59–60.
65. De Mayerne, op. cit., no. 138, p. 200.
66. L'Emery, op. cit. (note 26), pp. 424–33.
67. Morley, op. cit. (note 32), p. 466.
68. De Mayerne, op. cit., nos. 131–2, pp. 195–6.
69. De Mayerne, op. cit., no. 131, pp. 195–6.
70. De Mayerne, op. cit., no. 121, pp. 190–1; no. 133, p. 196.
71. L'Emery, op. cit. (note 26), pp. 603–7; Pomet, op. cit. (note 26), p. 283; Plat, op. cit. (note 26), p. 162.
72. W. Pekstok, untitled manuscript on the preparation of colours, etc. [the 'Pekstok Papers'], Gemeente-Archief, Amsterdam, Ms. N 09 23, ff. 8 recto – 9 recto (counting from the first written folio: the leaves are unnumbered).
73. De Mayerne, op. cit., no. 120b, p. 190.
74. Pomet, op. cit. (note 26), p. 184.
75. De Mayerne, op. cit., no. 121, p. 191; M. Smith, op. cit. (note 23), p. 73.
76. Félibien, op. cit. (note 31), p. 300.

Table Circle of Rembrandt: analysis of paint media

Artist	*Picture*	*Date*	*Sample*	*Oil*	*Treatment/Additives*
Pieter Lastman	*Juno discovering Jupiter with Io* NG 6272	*c.* 1618	1. White highlight on stalk of foliage	Linseed	None
			2. Dark green foliage, right-hand edge	Linseed	Pine resin
			3. Thin, greyish blue of clouds	Linseed	None
Rembrandt	*Anna and the Blind Tobit* NG 4189	*c.* 1630	1. Dark brown paint of Anna's chair	Linseed	None
			2. Brownish purple of Tobit's robe	Linseed	None
			3. Green leaf on branch outside window	Linseed	None
			4. White paint of sky through window	Probably linseed	None
Jan Lievens	*Self Portrait* NG 2864	*c.* 1638	1. Yellow highlight of silk garment, right-hand edge	Linseed	None
			2. Black background paint, heavy shrinkage	Linseed	Softwood pitch; heat-bodied
			3. Blue-white highlight of seat of chair	Linseed	None
	A Landscape with Tobias and the Angel NG 72	early 1640s	1. Mustard earth, left-hand edge (hard and compact)	Linseed	None
			2. Dark brownish green of trees, thick with signs of shrinkage	Linseed	Pine resin; heat-bodied
			3. Impasto lump of cream highlight of rocky path	Linseed	Heat-bodied
Ferdinand Bol	*Portrait of a Young Lady with a Fan* NG 5656	1645–50	1. White, left cuff	Walnut	None
			2. Yellow highlight on curtain, slight impasto	Linseed	Heat-bodied
			3. Brownish-black shadow on curtain	Linseed	Heat-bodied; amber varnish
	An Astronomer NG 679	1652	1. Warm white of sleeve	Walnut	None
			2. Orange tunic	Linseed	None
			3. Black gown (shrinkage)	Linseed	Heat-bodied; asphaltum; pine resin
Govert Flinck	*Self Portrait aged Twenty-four* NG 4068	1639	1. Olive-green background, left-hand edge	Linseed	None
			2. Black paint of sitter's coat, bottom edge	Linseed	None
Gerbrand van den Eeckhout	*Four Officers of the Amsterdam Coopers' and Wine-rackers' Guild* NG 1459	1657	1. Grey background	Linseed	None
			2. Black paint of cloak	Probably linseed	None (beeswax contamination)
Jan Victors	*A Village Scene with a Cobbler* NG 1312	*c.* 1648–51	1. Warm white impasted highlight on earth, lower edge	Linseed	Heat-bodied
			2. Dark brown shed	Linseed	None
			3. Blue-grey sky	Linseed	Partially heat-bodied
Nicolaes Maes	*Interior with a Sleeping Maid and her Mistress* NG 207	*c.* 1655	1. Thin white paint of plate	Linseed	None, possible diluent?
			2. Red-brown floor tile	Linseed	None
	A Woman scraping Parsnips, with a Child standing by her NG 159	*c.* 1655	1. Dark brown shadow of sideboard	Linseed	None
Attributed to **Willem Drost**	*Portrait of a Young Woman with her Hands folded on a Book* NG 237	*c.* 1653–4	1. White impasted highlight of tassel	Walnut	None; bodied with pigment
			2. Black of dress, no shrinkage	Linseed	None
Follower of **Rembrandt**	*A Young Man and a Girl playing Cards* NG 1247	1650s	1. Red of dress	Linseed	Some pine resin
			2. White dry impasto of scarf	Linseed	None; bodied with pigment
			3. Mustard highlight, chair's fitment	Linseed	None
Imitator of **Rembrandt**	*A Study of an Elderly Man in a Cap* NG 2539	1650–1700	1. Greenish-brown background	Linseed	None
			2. Buff paint of highlight on sitter's right shoulder	Walnut	None
Follower of **Rembrandt**	*A Man seated reading at a Table in a Lofty Room* NG 3214	1650–1720	1. Rich white impasto of illuminated wall	Walnut	Pine resin; heat-bodied
			2. Rich, thick black paint from tablecloth	Linseed	Pine resin; heat-bodied
Follower of **Rembrandt**	*A Seated Man with a Stick* NG 51	1660–80	1. Pinkish-brown fur on robe, mid left-hand edge	Linseed	None; partially heat-bodied
			2. Pale buff impasto stroke, same area	Linseed	None; partially heat-bodied
			3. Black background, left-hand edge	Linseed	Trace of pine resin; heat-bodied