Earth Matters

The origin of the material used for the preparation of the Night Watch and many other canvases in Rembrandt's workshop after 1640

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Introduction

Over the years – since the beginning in c. 1972 of technical studies in the framework of the Rembrandt Research Project - knowledge about the composition and build-up of ground layers repeatedly provided useful additional information for the attribution of paintings to Rembrandt and his workshop. Paintings throughout Rembrandt's career were examined, and a total of 61 samples of grounds on panel and 159 of grounds on canvas were included in the evaluation published in the fourth volume of *A Corpus of Rembrandt Paintings* (2005).[1]
This article attempts to answer some questions about the use of grounds on canvas by Rembrandt and his workshop. Special attention is given to the so-called 'quartz ground', a ground preparation first used by Rembrandt when he prepared the canvas for the *Night Watch.* Forty-eight of the paintings on canvas made between 1642 and 1669 by Rembrandt and his circle prove to have been painted on high quartz content grounds.

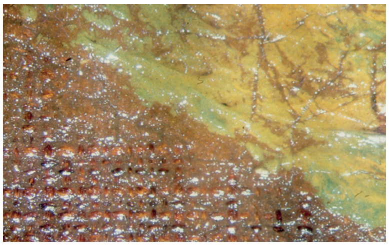
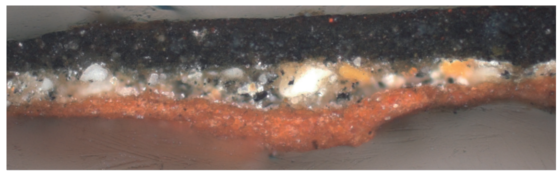


Fig. 1 Microphotograph of an area in the foreground of Rembrandt's *Night Watch*, where the ground is not covered by paint. The original material of the ground is visible in the interstices of the canvas threads. The ground, - originally a mid-tone - has now darkened because of the drying oil medium and relining materials

Fig. 2 Cross section of a paint sample from Rembrandt, *Man standing*, 1639, Schloss Wilhelmshöhe, Staatliche Museen Kassel. The cross section shows the traditional ground of a layer of lead white with a little umber on top of a red earth ground. Thick dark paint covers the ground

Fig. 3 Cross section of a paint sample from Ferdinand Bol, *Self portrait*, 1646, Dordrechts Museum, Dordrecht. The cross section shows the traditional ground of grey over red. The second ground in this painting is darker than the second ground in fig. 2, because in Bol's Self portrait the layer of lead white contains more charcoal black, yellow ochre and very little red ochre. Dark paint covers the ground



In this article the nature of the 'quartz ground' is discussed as well as the suggestion that canvases with such a ground are unique to Rembrandt and his studio.
The article is also a study of methodology: is it possible to identify the provenance of the clay and sand present in the quartz grounds in tiny samples from paintings? Information is drawn not only from analytical results obtained from the paintings but also from the geological build-up of the Dutch soil.

Grounds

Introduction

A ground, or priming, is applied to a support – canvas, wood etc. – to provide a suitable base on which to paint. In general, its composition is comparable to that of the paint layers, namely consisting of one or more pigments in a binding medium applied in one or more layers.
In Rembrandt's paintings, the colour and texture of the ground play a role in the final effect of the painted surface and especially the colour largely determines the choice of painting technique. From the examination of paintings with exposed areas of ground, we can assume that Rembrandt generally appears to have painted on a middle tone, determining the division of light and dark in the composition as a whole at an early stage in the painting process, with the ground functioning as an intermediary (fig. 1). This made it possible to paint rapidly and efficiently, while the chiaroscuro, so important in Baroque painting, was almost instantly achieved.

Grounds on panels

The materials used for the ground differed depending on the type of support. Panels were still mainly used in the Northern Netherlands during the first quarter of the seventeenth century. From c. 1624 on Rembrandt worked on panel, sometimes on paper. Our investigation has shown that, with a few exceptions, there is no significant difference between the grounds on the various panels used by Rembrandt.[2] Only a single type, namely that described in the *De Mayerne Manuscript,* the most important contemporary source regarding the preparation of painting supports, appears to have been used. De Mayerne had obtained the recipe from the Amsterdam painter Latombé (who, like De Mayerne, was working in London): 'For [a ground on] wood, first coat it with the above said glue and chalk. When it has dried scrape and make it even with a knife, then apply a thin layer of lead white and umber.'[3]
This chalk-glue ground was applied thinly and was primarily intended to seal the openings in the wood grain in order to obtain a smooth surface. The oil-containing layer on top isolated the strongly absorbent chalk-glue ground from the subsequent (oil) paint layers and provided a yellowish ochre-coloured surface to work on. Where it functioned as an intermediary tint among the dark and light areas of the composition, the colour of the ground often remained partially exposed. This type of ground also recurs consistently on Rembrandt's later panels.[4] Panels thus prepared were employed on a large scale by Rembrandt and his workshop, as well as other –

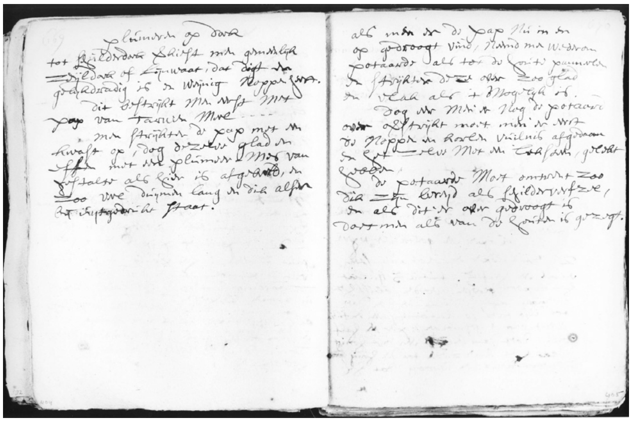


Fig. 4 Simon Eikelenberg, Aantekeningen over schilderkunst, 404 - 405 (modern page nos.)

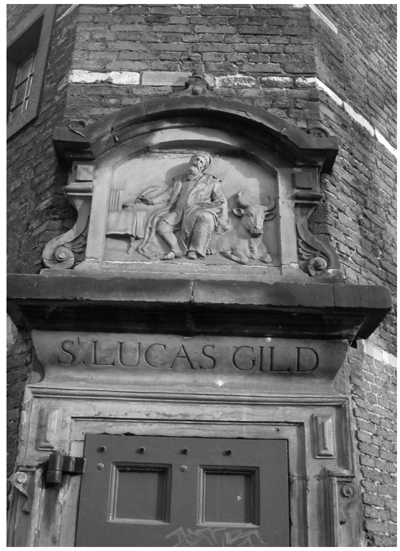


Fig. 5 Stone relief above the entrance of the Chamber of the St Luke's Guild in the Public Weighing House, Amsterdam

Fig. 6 Rembrandt's Funereal Medallion, 1634, 6a recto, 6b verso. Rembrandthuis Amsterdam

not only Dutch – painters in the seventeenth century and earlier. As a rule, painters probably purchased the prepared panels from professional primers.[5]

Grounds on canvas

Double grounds

As far as we know, Rembrandt began working on canvas only in 1631 when he moved to Amsterdam. From the 1630s onwards, double grounds of grey on top of red, (a layer rich in lead white on top of a layer of red earth) were used – with considerable variation – in Rembrandt's workshop (figs. 2-3). Our investigation of the grounds of 159 paintings on canvas formerly or still attributed to Rembrandt (most in Bredius' catalogue)[6], demonstrated that half (80) of the canvases had double grounds. These double grounds were also found when examining seventeenth-century paintings other than Rembrandt's. In our research on the grounds used by painters active in Amsterdam who had no affiliation with Rembrandt's workshop, numerous double grounds were detected as well. However, these double grounds are not all identical. Although the number of pigments artists used was limited and the number of pigments used for the grey-on-red double grounds smaller still, differences could be detected in the paint mixtures used for the top layers.

De Mayerne gives numerous – almost identical – recipes for the treatment of canvas paintings using a ground of grey on red; a confirmation of its frequent use.[7] First the protruding threads and other irregularities were removed after which the canvas was brushed with glue. Then two or three coats of paint were applied to fill any irregularities in the canvas and to provide a smooth surface of a particular colour: 'Having stretched the canvas tightly, apply glue made from the remains of leather or size, which should not be too thick (it is assumed that you have first removed any threads that might be sticking out). When the glue is dry, prime rather lightly with brown-red, or red-brown from England. Let it dry, and make it smooth with pumice stone. Then prime with a second and last layer of lead white and] well-chosen charcoal. Small coals(?) and a little umber earth to make it dry faster. One can give it a third layer, but two is all right, and [such a ground] will never break, nor split.'[8]

A source from 1777, at least in part copied from earlier sources, clarifies the reason for the application of a grey over a red coat. The anonymous writer states that one almost always applies the grey over the red, 'in order to render the right hue, a reddish grey that in general agrees with all the colours in the art of painting'.[9] The mention of double grounds in this source also implies that their use went on in the eighteenth century. They were indeed not unique to the seventeenth century, or the Netherlands. Flemish, French and Italian painters also used double grounds, and continued doing so into the eighteenth century.[10]

Quartz grounds

The quartz grounds began to be used in Rembrandt's workshop in 1640 - when the *Night Watch* was being prepared - frequently alternating with double grounds and a few other types, such as layers of lead white tinted with umber, applied without the initial priming with red earth. Mixtures of lead white and chalk or a dark mixture of earth colours and black were found as well. In general the colour of the grounds is darker towards the end of Rembrandt's career.

It is necessary to clarify the term 'quartz ground'. Although this term has been used for this type of ground since it was first encountered in the 1960s by Kühn, the term is in fact misleading. In the 1960s a controversy surrounded the *Self-portrait* in Stuttgart, which was acquired by the Staatsgalerie in 1961 as an important late Rembrandt. Inspection of the portrait by a few private experts [11] resulted in a negative verdict; their opinion branded it a forgery. The Staatsgalerie decided to submit the painting to an objective examination by an independent laboratory, the *Institut Royal du Patrimoine Artistique* in Brussels. A surprising find was that the preparatory ground layer of this painting consisted largely of finely ground sand, with a substantial quantity of clay minerals.[12] A ground with such a composition had never been encountered before. This sparked-off extensive research by Kühn in Munich on ground layers in relation to Rembrandt's work. Up to Kühn's 1977 publication, this type of ground, then named 'quartz ground', was found in 15 paintings by Rembrandt and his studio.[13] After having evaluated and expanded Kühn's work for many years we have come to the conclusion that canvases with quartz grounds are unique to Rembrandt and his studio. To date the samples of 159 paintings on canvas by Rembrandt and his milieu have been examined and where necessary analysed. Forty-eight of the grounds on these canvases prove to have a high quartz content.[14] To underpin the hypothesis that quartz grounds are unique to Rembrandt and his studio, grounds from paintings by other seventeenth-century masters active in Amsterdam between 1640 (the year Rembrandt must have started work on the *Night Watch*)[15] and 1669 (the year of Rembrandt's death), were examined. These were painters who, as far is known, had no workshop connections with Rembrandt. A total of sixty grounds on Amsterdam canvases were analysed; not one had a quartz ground. Also, none of the numerous Dutch paintings on canvas originating outside Amsterdam in the relevant period, investigated by the author at an earlier date, were found to be prepared with such a ground. Inquiries with colleagues, nationally and internationally, yielded no knowledge of the use of quartz grounds on Dutch paintings originating outside Rembrandt's studio. To date, a comparable ground (in so far as the high quartz content is concerned) has been discovered in two paintings by Aert de Gelder (1645-1727) made after 1680, in eighteenth-century wall hangings by Pieter Barbiers (1749-1842), and in paintings by Italian artists and foreign painters when working in Italy.[16] This underscores the suggestion that quartz grounds must be specific to Rembrandt and his workshop, and provides a strong supplementary criterion for attributing paintings to the master himself and to painters working in his studio around or after 1640.

The quartz ground thanks its name to the high amount of quartz (αquartz) identified in it; percentages of up to 80% or even 100% were recorded. The high figure is in part due to the analytical technique used, as we shall see later. αQuartz is in fact just ordinary sand and it can be found as a constituent in all sorts of paint and ground layers and even as a dust contaminant. Therefore not every ground containing quartz is a 'quartz ground'. Analyses have shown that it consists mainly of ground-up sand and clay minerals. Sand and clay together make clay or loam. Therefore, it would be more appropriate to call the 'quartz ground' a 'ground of clay' or a 'natural earth ground'. However, although a single quartz ground can be distinguished both visually and chemically from the traditional 'double ground', – of which the lower layer is made of a natural earth -, referring to a quartz ground as 'a natural earth ground' would cause confusion. Not only could the quartz ground be confused with other grounds made of earth, but even with a chalk ground, since chalk is also a natural earth. For the sake of clarity, therefore, throughout this article, we use the term 'quartz ground' for the single, greyish ground of an earth with high quartz content.

• *Documentary sources on quartz grounds*

The idea that a canvas with a particular ground was used exclusively in Rembrandt's workshop implies with considerable certainty that it was prepared there. This is supported by the fact that, in Rembrandt's time, Dutch written sources do not contain a single recipe for preparing canvases with clay. Such recipes can, however, be found in notes started in 1679 by the Dutch writer Simon Eikelenberg, and in some French and Italian written sources.

For instance, the French painter Pierre Lebrun describes in his *Collection of essays on the Wonders of Painting*, written in Paris in 1635: 'The canvases are covered with parchment glue or flour paste before they are primed with potter's earth, yellow earth, or ochre ground with linseed or nut oil. The priming is laid on the canvas with the knife or a massette to render it smoother, and this is the work of the boy.'[17] Lebrun seems to distinguish between clay for making pottery and other types of (coloured) earth. Richard Symonds, who travelled around Italy between 1649 and 1651 collecting information on painting technique, writes: 'The earth that bricks are made of is ground & used for imprimatura.' [18]

As early as 1550, the Italian painter and architect Vasari recommended an earth as one of the ingredients in a mixture for making grounds: 'But first there must be made a composition of pigments which possess siccative qualities as white lead, dryers, and earth such as is used for bells....'. This 'earth such as is used for bells' could be the material used for the moulds in bell casting.[19]

The Spanish painter Francisco Pacheco (1564-1654), in 1649 mentioned a ground made with clay: 'The best and smoothest priming is the clay used here in Seville, which is ground to a powder and tempered on the *losa* (stone) with linseed oil.' He adds: 'This is the best priming, and the one I would always use without further modifications, because I see my six canvases in the cloister of the Mercedarians conserved without having cracked nor shown any sign of flaking since the year 1600 when they were begun, which is enough for me to approve the soundness of this clay preparation.'[20]

In Holland, potter's clay for preparing painting supports is first mentioned by Simon Eikelenberg, who ran a brush ware shop in Alkmaar and who was a prospective painter and, later in life, became an historian. Between 1679 and 1704 Eikelenberg collected information on the technique and theory of painting.[21] He states: 'for priming wooden panels, put on size... then with potter's earth, finely ground with linseed oil, instead of with other paint [pigment], because it is cheap. note that I hold it also more durable since it consists of tough and heavy particles etc. when the potter's earth has been applied throw some rain water on it, and rub it with the flat of the hand back and forth, so that it goes in all the pores of the wood and fills them and the panel becomes smooth and closed and so, that the paint can not get soaked in.' On priming canvas supports he states '...for painting one usually chooses sail cloth or linen, that is closed and of even weave and has little knots and this is rubbed with wheat flower... when one finds that the size is dry in and on (the cloth), take again potter's earth as in priming wooden panels, and put this on as smooth and even as possible. But before applying another coat of potter's earth, one should first have removed the knots and other rubbish and gone over it with the pumice stone. The potter's earth should be prepared to more or less the same thickness as paint for painting, and when it is dry one does the same as has been said about the wooden (supports).'[22](fig. 4)

It is interesting to note that Eikelenberg recommends potter's earth not only for priming canvases but also for panels. As far as we know, such a ground has – so far - not been encountered in the analyses of grounds on panel supports.

Eikelenberg's writing is obviously based on (foreign) written sources. As an historian he collected books and therefore had these writings close at hand. One might speculate on whether Rembrandt or someone from his workshop was, like Eikelenberg, aware of these foreign traditions, either from written sources or informed by travelling artists, and developed this kind of ground for use in the master's studio. It remains curious why other painters in the seventeenth century did not use 'potter's earth' (quartz grounds).

In addition, a relation between a ground made with clayish materials and the earthenware industry is likely since 'leywerckers' - the bakers of dishes and the potters - were united in one guild with the painters, namely the St Lucas Guild. The union of these and other professions had been formalised in Amsterdam in 1579.[23] Although the Amsterdam archive of this guild has gone astray, and with it the names of its members, we can be certain that Rembrandt was a member. In the seventeenth century, whoever wished to execute his profession had to be enrolled in the appropriate local guild. It would have been both impossible and disadvantageous for Rembrandt to not do so. The guild rules served as a protection against competitive non-local craftsmen. Proof of his membership is Rembrandt's 'funereal token', one of the two medals issued to members upon joining the guild. The funereal token was to be deposited at the house of a bereaved fellow guild member. Rembrandt's

28 mm diameter brass medaillon - inscribed *Rembrant/Hermans/S* (S stands for *schilder*, which means painter) and *1634* - is kept at the Rembrandthuis in Amsterdam (figs. 5-6).[24] Rembrandt's contact with potters thus could have resulted in trials with potters' clay for preparing canvases.

• *Economics*

The *Night Watch is* the first canvas prepared with a quartz ground. The exceptional size of the painting may have stimulated the development of this evidently new type of ground. It is painted on a canvas that originally measured c. 420 x 500 cm.
Analyses of paint samples has shown that, in contrast to the 'double ground' of grey over red, a quartz ground was usually applied in a single thick layer and rarely in two or more layers (when this is the case, their composition is more or less the same). An anonymous eighteenth-century written source describes how some: '...painters ... prefer their canvases to have only one layer of paint (ground) rather than two layers, because ... the picture can more easily be rolled up for transport; however, since the canvas thread is very visible when only one ground layer is present, it is used only in the case of large works.'[25] It can be presumed that canvases prepared with these grounds were supple. Therefore, the *Night Watch* could safely be rolled-up for transport by boat as was customary for almost all transport in seventeenth-century Amsterdam.[26] The transportation of the rolled-up *Night Watch* during and shortly after the Second World War is a striking demonstration that canvases with quartz grounds are still quite flexible even after hundreds of years.[27]
The brilliant artist Rembrandt was also technically inventive. His technical innovation was based not only on economics but also on sound working practice. However, no link could be made between the dimensions of the canvases and the use of quartz grounds by Rembrandt and his workshop. In addition to the *Night Watch*, they are found in portraits, *tronies* and in history scenes of varying dimensions. It would appear that the *Night Watch*, painted between 1640 and 1642, was the first canvas to be prepared in this manner and that such quartz grounds then occur until the end of Rembrandt's career. This implies that cracking or flaking of the paint when the canvas would be rolled-up was not Rembrandt's main concern since pictures of limited size do not need this treatment. The fact that common sand and clay – the materials constituting the ground - were undoubtedly very inexpensive, could have been the determining factor in the choice of these raw materials for this ground; costly lead white could thus be avoided.[28]
Rembrandt, by choosing clay for the ground for the *Night Watch*, did not need a layer rich in lead white on top of the first ground to tone down its colour. The ground already had the right hue: a greyish brown, more or less the colour of the canvas. If necessary, the tone could be adjusted by adding a small amount of coloured earth pigments. When Rembrandt received the commission for painting the *Night Watch*, he went to the trouble of finding clay that had the right hue to paint on, so that he did not need an additional layer of expensive lead white.

Bricks, tiles and earthenware

Finding many preparatory layers made with clay on canvases deriving from Rembrandt's studio, aroused our curiosity about what sort of clay this was and where it might have come from. In attempting to answer these questions, we tried to compare the composition of the ground layers on the canvases with types of clay found in Holland, especially those types of clay suitable for the manufacture of bricks, tiles and pottery. In the 1960s, after the investigation of the Stuttgart *Self-portrait,* it was suggested that Rembrandt's choice of the quartz ground could have been influenced by pottery makers, who, in his days were frantically searching for clay in order to imitate the much admired Chinese porcelain.[29] These attempts at producing porcelain were not successful in Europe until the eighteenth century, since, in seventeenth-century Holland the *plateelbakkers* (potters or dish makers) did not realise that for making porcelain kaolin was essential. Kaolin or China clay is primary clay, composed principally of the hydrated aluminosilicate clay mineral kaolonite. Kaolin deposits were discovered in the eighteenth century, for instance in Cornwall, from where it had to be imported in Holland.
Seventeenth-century Delfts porcelain is in fact white glazed earthenware. The glaze on both sides of the earthenware body makes that the ware resembles porcelain, as already mentioned by Gerrit Paape in the eighteenth century: 'What is called 'Delfts' in Holland is only a sort of earthenware, *basterd*-Porcelain.'[30]
We know which clays were used for making Delft earthenware from the anonymous writer of the chapter 'De Delfstoffen' in *Natuurlijke Historie,* published in 1781.[31] He must have been very well acquainted with the pottery industry, not only in Holland, but also in other European countries, and with the different types of clays

that were in use for earthenware and porcelain. For the body of Delft earthenware or faience[32], three sorts of clay were mixed together: clay from Doornik (Tournai), clay from along the river Ruhr in Westphalia and a clay dug up locally along the river Rhine, *Ryswyks clay*, (the town of Rijswijk is just east of The Hague). Paape largely repeats this information, adding that the Rhineland clay is black (*swarte aerde*, also mentioned in seventeenth-century potteries' inventories) and that the local clay is *Delfts* and that the three types should be mixed in the proportions 6:3:2 (fig. 7).[33] Black earth derived from the river basin of the Oude Rijn between Woerden and Alphen, which is north of Delft and south of Amsterdam. The Oude Rijn between Utrecht and Leiden, the Vecht and Hollandse IJssel have been the centre of the brick industry for more than 5 or 6 centuries (fig. 8).[34] Already in 1687 there were 16 brickyards in the vicinity of Woerden, in 1724 this number had increased to 26. The clay along the riverbanks has been dug off some three feet deep since at least the 1540s.

If the clay used for priming in Rembrandt's workshop could be just ordinary clay suitable for the manufacture of bricks and tiles and perhaps – with some sand added - for making earthenware, where would it have come from? Supposedly not far from Amsterdam where Rembrandt had his workshop, and where, after 1640, he primed many of his canvases with clay. Vecht and Oude Rijn have the same origin, namely the river Rhine, which branches at Utrecht into Oude Rijn and Vecht. The river Vecht is nearer Amsterdam than the Oude Rijn. The Oude Rijn discharched at Katwijk, until the estuary silted up around the year 1000. [35] The Vecht discharges just east of Amsterdam. And although the largest production of Delftware was indeed in the town of Delft - at least 30 *plateelbakkerijen* (potteries) existed in Delft in the seventeenth century[36] - Delftware was produced in other regions of the Netherlands as well. It was for instance made as a luxury by-product in the tile factories in Amsterdam, Rotterdam and Utrecht and in factories in Friesland.[37] In Amsterdam the manufacture of tiles became the core business in the potteries, and around 1640 seven factories devoted exclusively to tiles were established there.

Bricks and tiles are composed nearly all together of clay. Because of its rich iron content, Dutch clay is especially suitable for the manufacture of bricks and tiles, but for earthenware extra sand needs to be added. Already in Roman times in The Netherlands roof tiles were made from local clay. Roman potteries and ovens for firing roof tiles, the roof tiles them selves and pottery were excavated during archaeological digs in and around Tegelen, a town along the river Maas in Limburg. The town of Tegelen in fact thanks its name to the roman inhabitants who gave the area its name because of the good clay for tiles found there. The Latin word *'Tegula'* meaning roof tile as does the Dutch word *tegel*. The geological era Tiglien (part of the Pliocene, early Pleistocene with many fossil finds) was also named after Tegelen. From archaeology, we know that before the seventeenth century local clay was dug up here and worked in potteries in towns in Holland, for instance in Amsterdam.[38] How local clay was used in potteries can still be seen in one of the ten Frisian earthenware factories in existence in Friesland since 1650, because it is still in use today. This remaining earthenware factory is the *Koninklijke Makkumer Aardewerk en Tegelfabriek Tichelaar* (Royal earthenware and tile factory) in Makkum, in the west of Friesland near the IJsselmeer (the former Zuiderzee). Tichelaar, who claims to produce Delft earthenware in

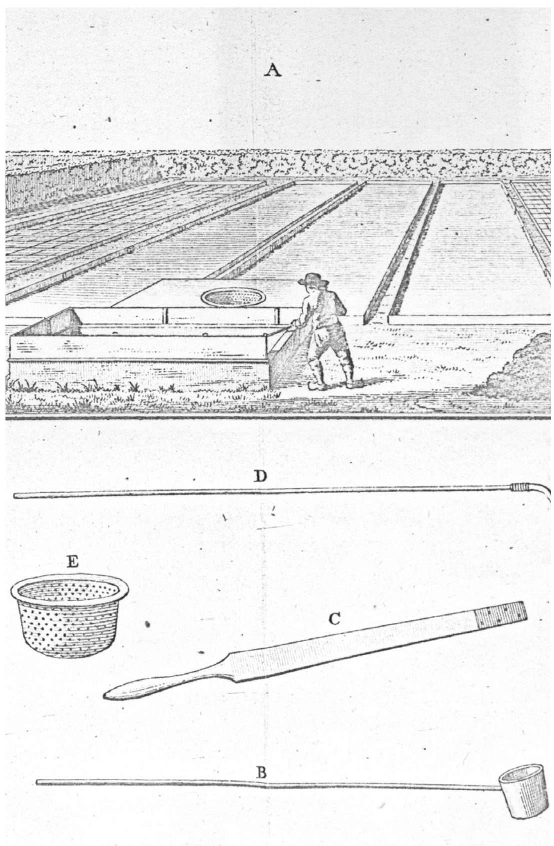


Fig. 7 Illustration from: Gerrit Paape, De plateelbakker of Delftsch aardewerkmaker (Dordrecht, 1794). Washing and straining clay

Fig. 8 Map of the Hoogheemraadschap Rijnland, engraved by Cornelis Danckertsz. in 1647, with indications of stone ovens along the Oude Rijn

the traditional way, was already in full operation in 1572 with brick works and lime kilns. In 1700 the factory was converted to a gallipottery (for notes on the geology of the area see Appendix).
The different clays that were used for the manufacture of earthenware in the seventeenth century, and named by Paape in the eighteenth century, can be compared with the types of clay used by Tichelaar now and in the past. Tichelaar uses local, Frisian clay that, although rich in chalk, is good for roof tiles and bricks only. Therefore, already from the 1650s onwards, it was customary to add extra chalk, from Tournai, to the local Frisian clay. Nowadays *Muschelchalk* is added to make the clay suitable for the manufacture of pottery. Muschelchalk is a dolomitic chalk ($CaMg(CO_3)_2$) from the middle Trias period. It surfaces near Winterswijk in the east of The Netherlands. Without chalk the clay bakes red and yellow if chalk is added. The extra chalk also enables a higher baking temperature of maximal 1000 – 1050 °C, whereby $CaCO_3$ reverts to calcium silicate. For earthenware, extra sand is added as well. Sand increases clay's plastic properties. In Delft, Amsterdam and other places in the west of the country, in the seventeenth century chalk-rich Tournai clay was added to the fluvial Rhineland clay, as mentioned above. River clay lacks chalk. It is possible that the local fluvial clays used in the seventeenth century in Delft and Amsterdam were themselves rich in sand. Alternatively extra sand could have been added as was done in Makkum.

By combining different clays, clay with good physical properties (leanness, colour) was obtained. On its own, clay is 'fat'. It feels fatty to the touch because it consists of layers of minute flaky particles that can slide along each other. In between the layers there are metal ions, for instance potassium or magnesium. These ions attract water, which allow the layers to slide along each other just like glass sheets would slide with water in between them. The water between the layers in the clay is easily released. The take-up and subsequent release of water by clay particles makes that clay is prone to shrinkage and subsequent cracking. Adding sand inhibits the sliding of the clay particles: the clay is said to be lean and less prone to cracking.
Apart from modifying the colour after firing, the addition of chalk to the clay is 'for improving sound and lustre, like the work made from English earth, [which was naturally rich in chalk.'[39]

Analyses and its limitations

In the samples removed from the edge of the canvas paintings by Rembrandt and his workshop we analysed the sand present in the ground and if possible the clay minerals. We also searched for heavy minerals (see Appendix). To decide whether a particular ground is a quartz ground or not, in general sufficient information was obtained by utilising light microscopy observations coupled with SEM-EDX to identify chemical elements in tiny areas of the paint cross section. Quartz was easily identified using XRD as (αquartz or ordinary sand. Quartz grounds cannot be readily recognised in the cross sections when examining them under the optical microscope under incident light. Usually one sees only a semi transparent, yellowish to dark brown mass in which particles are barely visible (figs. 9-10). This is

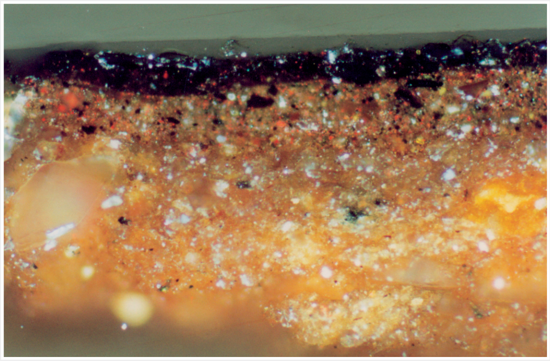


Fig. 9 Cross section of a paint sample from Rembrandt, *Peter denying Christ*, Rijksmuseum, Bredius no. 594, showing a quartz ground with a dark paint layer on top. On the left a particularly large quartz sand particle is to be seen

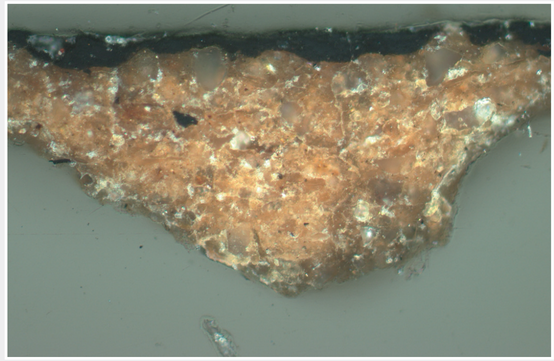


Fig. 11 Cross section (thin-section) from a sample from Rembrandt's *Night Watch*. Colourless quartz particles are clearly visible in the thin-section. The quartz is in a brownish matrix of other minerals and binding medium

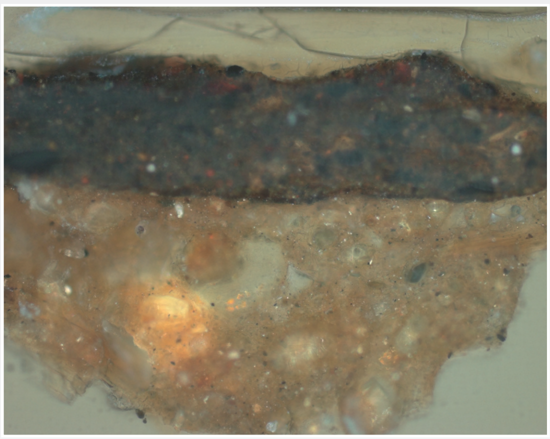


Fig. 10 Cross section of a paint sample from Rembrandt, *Seated woman with a handkerchief*, 1644, Art Gallery of Ontario, Toronto, Bredius no. 369, showing a thick quartz ground with thin dark paint on top

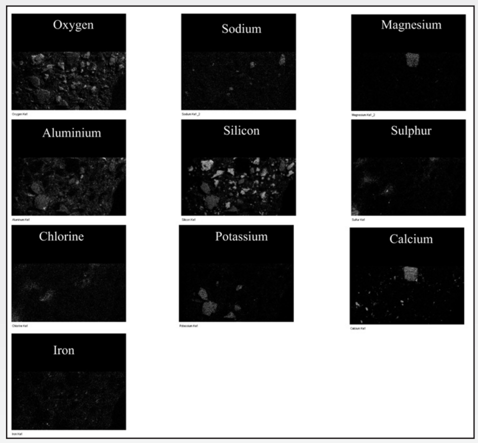


Fig. 12 Mapping of the elemental distribution in a sample from the *Night Watch*. Electron microscopy: Ineke Joosten, ICN

because quartz's low refractive index is very close to that of the surrounding binding medium (a drying oil). In addition, the presence of a large quantity of darkened binding medium in the composition of the ground impedes visual evaluation. For the same reasons, without further analysis, a quartz ground also often cannot be distinguished from some types of oil ground in which chalk is the main ingredient.[40] In order to make the quartz particles clearly visible under a light microscope, an approximately 30 μm thin section was made of some of the embedded paint samples so that they could be examined in transmitted light. In addition, dispersed pigment samples were made (fig.23).

Quartz could be seen in abundance in the dispersed samples and under the electron microscope. Electron microscopic imaging, which shows the distribution of the chemical elements throughout the ground layer in the sample, points to a percentage of quartz of *c.* 50 to 60 % by volume (figs. 12-13). The sand particles in Rembrandt's quartz grounds are very fine, with particles varying from approximately 5 to 60 μm (reduced to silt fraction by grinding before use?) and having sharp edges (fig. 14). The presence of conchoidally fractured particles, particles with smooth, shell-shaped convex or concave surfaces, suggests 'cracking' or breaking of the sand. The sandy earth used for the quartz grounds, like other (mineral) pigments, was apparently ground, probably with a mill.[41] Chalk could be identified in the samples under the optical microscope in polarised light; its presence was confirmed using XRD and SEM-EDX. Particles of feldspar and brown and red iron oxides could be distinguished as well. Sometimes a little black was present.

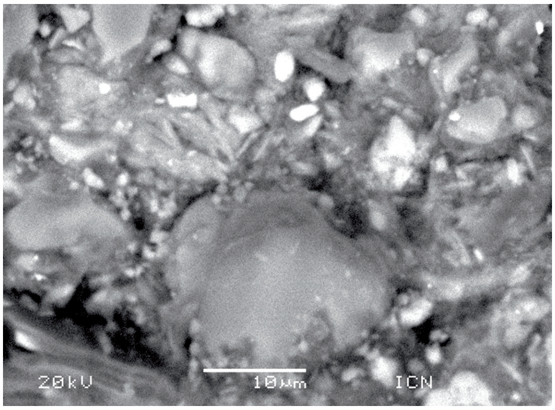


Fig. 13 Electron microphotograph of a sample of the ground in an area in the foreground of the Night Watch, where the ground is not covered by paint (sample from area in fig. 1). Electron microscopy: Ineke Joosten, ICN

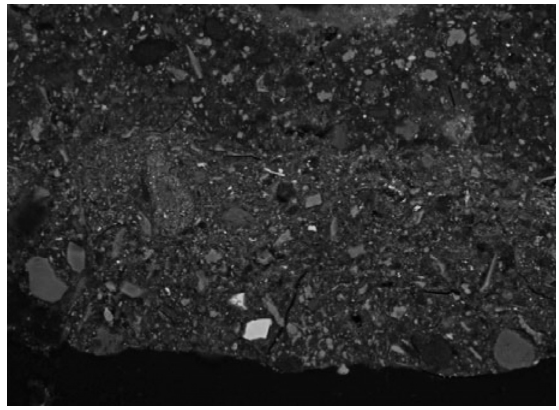


Fig. 14 Electron micrograph of a cross section in a sample from the ground in the *Night Watch*. Large and small fragments of quartz sand can be seen in a matrix of clay minerals. Electron microscopy: David Carson, The Getty Conservation Centre

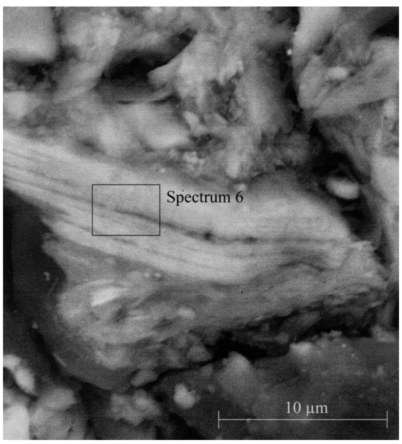
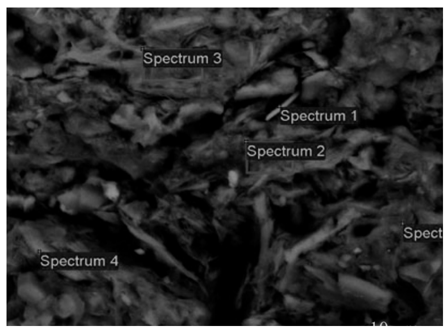


Fig. 15 Electron micrograph of a platy crystal in a sample from the ground in the Night watch. Electron micro-graph: David Carson, The Getty Conservation Centre

Fig. 17 Electron micrograph of a sample of the quartz ground of Rabbi in Berlin, Bredius no. 236, showing platy clay minerals. EDX-analysis spots are indicated. Electron microscopy: David Carson, The Getty Conservation Centre



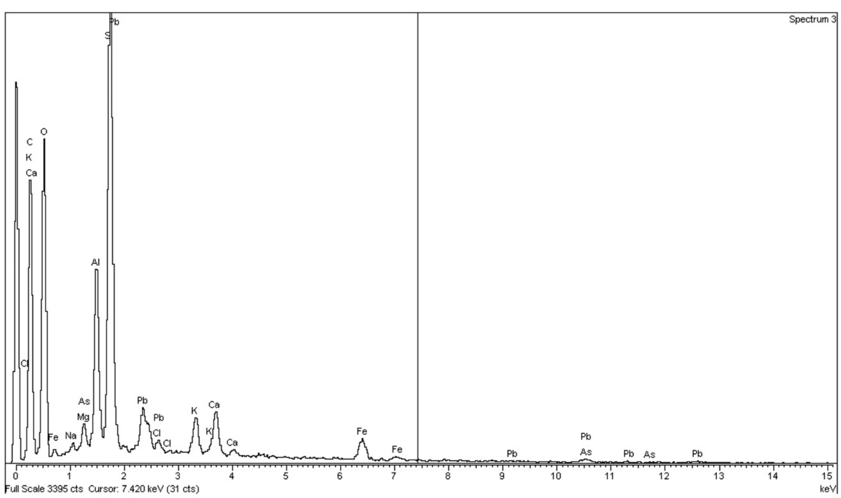


Fig. 16 EDX-spectrum nr 6 of the platy crystal in fig. 15. Electron microscopy with EDX: David Carson, The Getty Conservation Centre

The identification of the clay minerals proved much more difficult. The available research methods proved to have several limitations. The standard techniques for the analyses of soils could hardly be applied to the tiny, inhomogeneous, complex samples from the grounds from paintings. The complex mixtures of tiny sand particles, clay and other minerals, bound in binding medium and – in most cases – soaked in organic restoration materials (drying oil, resin, wax, glue) stretch the analytical techniques to their limit. It proved to be impossible to physically separate the quartz particles from the clay minerals in the samples. Such a separation would have facilitated the analyses.

Thin sections or dispersed samples, together with X-ray diffraction analysis (XRD), would seem the obvious methods for the identification of clay minerals (in theory, micro thermal analysis can be used as well). In the case of paint samples thin sectioning is no option; there is no lump of rock that can be cut. The dispersed samples were of limited use, because most clay minerals do not allow identification under the optical microscope. Their small - often platy - particles have sizes from colloidal to just above the resolution of the optical microscope. Illite, for instance – is extremely fine-grained, its particles measure 0.5–1 μm. SEM-EDX analysis (scanning electron microscopy with energy dispersive X-ray analysis) of clay minerals is of limited use as well: all of

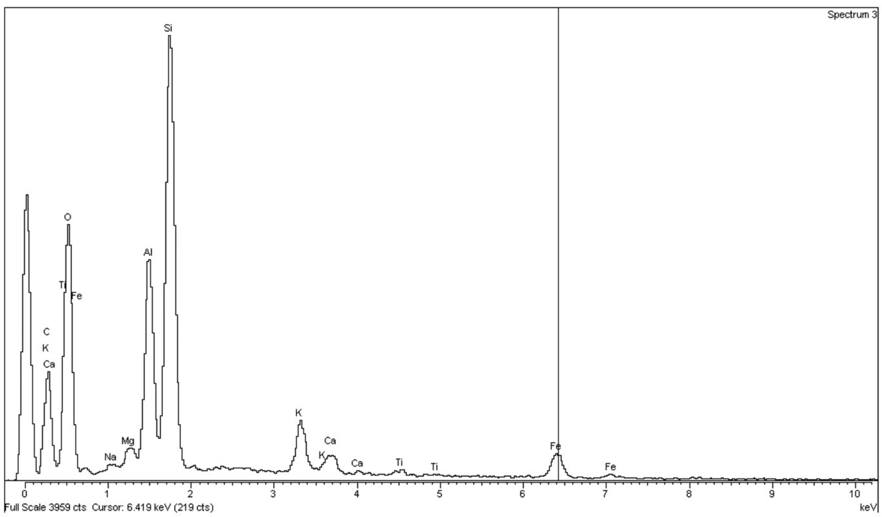


Fig. 18 EDX-spectrum area 3 in fig. 17. Spots 2, 4 and 5 gave very similar spectra. Electron microscopy: David Carson, The Getty Conservation Centre

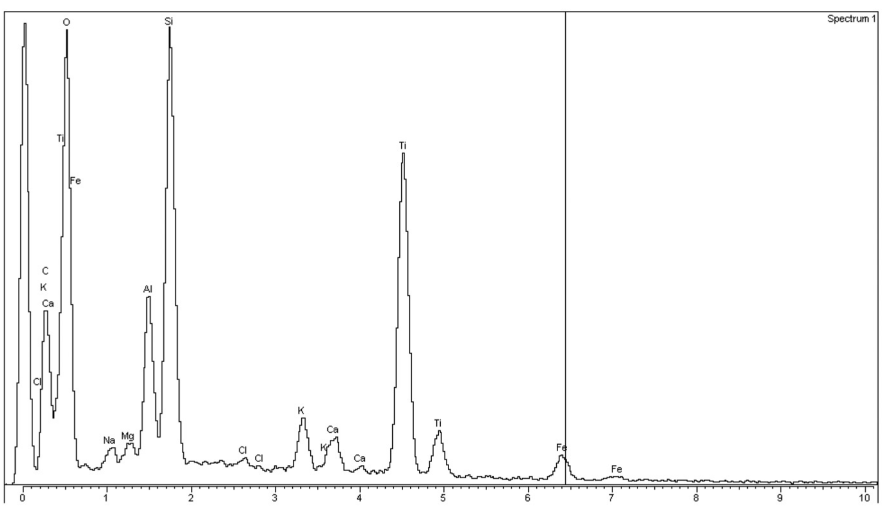


Fig. 19 EDX-spectrum of area 1 in fig. 17: rutile(?) plus minerals surrounding the particle. Electron microscopy: David Carson, The Getty Conservation Centre

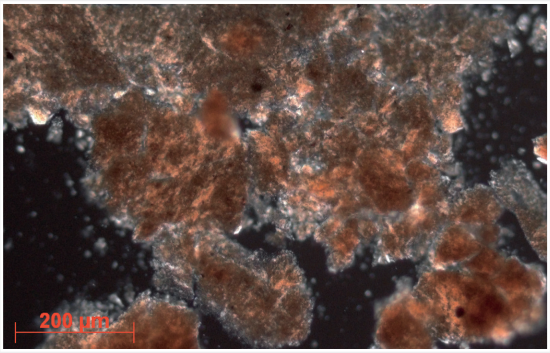


Fig. 20 Dispersed sample of fluvial clay in transmitted, polarised light. Sampled from a brick works quarry. Clay particles can be seen together with quartz, held together with organic material.

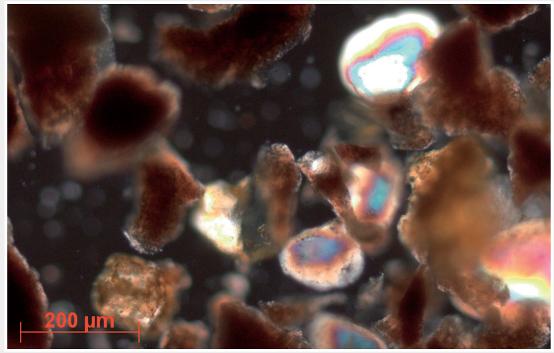


Fig. 21 Dispersed sample of clay in transmitted, polarised light. The sample is an earth used for making bricks, collected at a quarry in Brüggen, Germany. Clay particles and quartz are held together by organic material. The sample is richer in quartz than the sample in fig. 22.

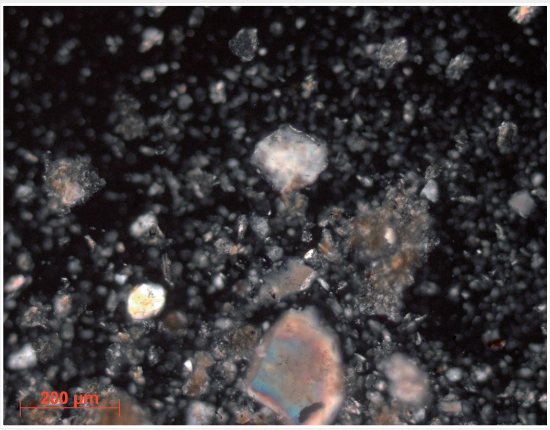


Fig. 22 Dispersed sample of clay from the river Rhine basin. Transmitted, polarised light. Fine particles of clay minerals and different sizes of sand particles

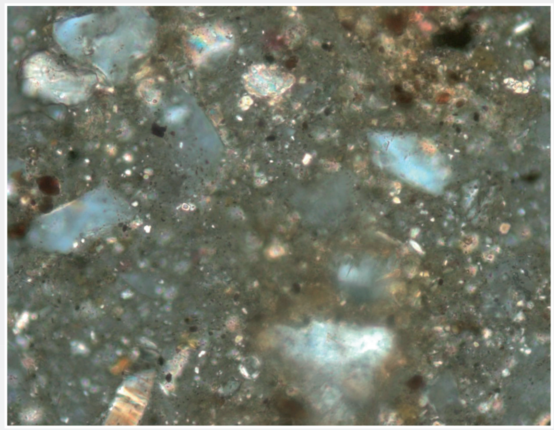


Fig. 23 Dispersed sample in polarised light of the ground of the Night Watch. Clay minerals, quartz and some brown and black organic and inorganic substances

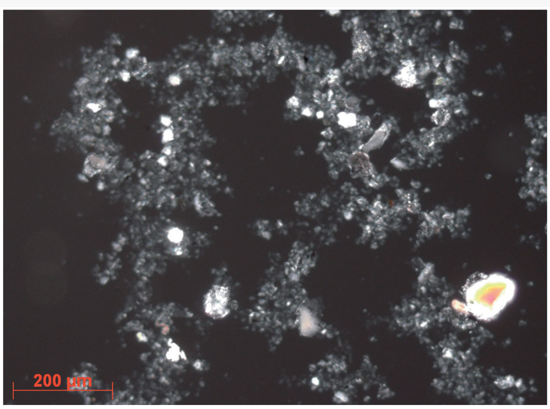


Fig. 24 Marine clay used for earthenware in the Koninklijke Makkumer Aardewerk en Tegelfabriek Tichelaar in Makkum. Transmitted polarised light, quartz, calcite and clay minerals. Fine particles of chalk can be seen clustered around the larger particles of quartz. The tiny needles are clay minerals

the spectra look rather similar. The bulk analytical spectra always contain Al, Si, K, with variable amounts of Na, Mg, Ca, Ti en Fe and sometimes a trace of Pb. Moreover, non-clay minerals present, for instance oxide-pigments, may be made up of the same chemical elements. One reason for the similarity of the spectra is the small size of most of the clay minerals (0.5–1 μm). The resulting EDX-spectra show the chemical elements present in an area of up to c. 5 μm diameter, plus those elements present a few microns below the surface of the embedded sample. Therefore the analytical results show not one, but a collection of particles. As an example, a particular spectrum might be interpreted as muscovite mica ($K_2Al_4[Si_6Al_2O_{20}](OH, F)_4$) plus iron oxide, calcite, or dolomite and/or plagioclase feldspar etc. Image formation using electron microscopy is useful for the sand fraction and for obtaining an overall image; as far as the clay minerals is concerned only the form of the larger ones can be made visible. A single, large, platy, prismatic crystal in the ground of the *Night Watch* suggested that a small amount of kaolinite mineral ($Al_2Si_2O_5(OH)_4$) was present. However, the spectrum of the particle showed O, (Na), (Mg), **Al**, **Si**, ((Pb)), K, (Ca), (Fe), (where **bold** is a main constituent and (( )) means a minor amount), a collection of chemical elements that could indicate that the particle is instead biotite mica ($K(Mg_3Fe)_3(AlSi_3O_{10})(OH)_2$) (figs. 15-16).[42] These examples show that the interpretation of EDX-spectra from quartz grounds is hazardous as far as the clay minerals are concerned. By estimating the relative amounts of chemical elements present in the spectra, we tried to decide on the nature of the minerals present in a sample. Equal amounts of Al and Si present with K would indicate the presence of a degradation product such as illite ($K_yAl_4(Si_8\text{-}y,Al_y)O_{20}(OH)_4$, where y is less than 2 and most commonly around 1.5) (figs. 17-18).[43]

As far as the overall type of clay is concerned, judging from the electron micrographs (the images obtained with the electron microscope) it would appear that different clays were used for different paintings. For instance, the micrograph of a sample from the ground in *Rabbi* in the Staatliche Museen Preussischer Kulturbesitz, Berlin (cat. 828A, Bredius no. 36) shows an illite-type of clay while samples from the *Night Watch* showed the presence of plate-like, lamellar particles indicating a swelling clay (compare figs. 14 and 17).

Sometimes the tentative conclusions based on EDX-results seemed more secure. As an example some individual particles analysed in the ground of the *Night Watch*: C, O, Mg, Ca would be an indication of dolomite, while C, O, Mg would suggest magnesite ($MgCO_3$) and C, O, Ca chalk ($CaCO_3$). A particle showing O, Na, Al and Si might be plagioclase feldspar (albite). Also, a particle showing C, **O**, **Mg**, (Al), **Si**, ((K)), **Ca**, ((Fe)), present for instance in the ground in *Supper at Emmaus*, Statens Museum, Copenhagen, might tentatively be identified as dolomite, rather than vermiculite ($(Mg,Ca)_{0.6\text{-}0.9}(Mg,Fe^{3+},Al)_{6.0}[(Si,Al_8)O_{20}](OH)_{4x}.nH_2O$) plus calcite, because of the relative small amount of Al in the spectrum.

In geological studies another technique used is the determination of the relative abundance of 'stable' and 'unstable' heavy minerals in a sample, which is a measure of mineralogical maturity. Usually, the heavy minerals are first separated from the majority of quartz grains (this can be done using heavy liquid separation) and are then further separated based on their degree of attraction to a strong magnetic field (magnetic separation). In samples from paintings such sample preparation is not possible. Heavy minerals reside in the fine sand fraction of 50–210 μm; paint (ground) samples do not contain an original fine sand fraction, at most a few grains of this size are present in the sample. Since the number of heavy minerals should be counted relative to the number of sand grains present - whereby usually on average only one in every 100 sand grains is a heavy mineral – in the ground samples maybe one or two heavy minerals may be found by a stroke of luck. As for grain size and texture, in geological studies, if sufficient sample material is available, characteristic granular distribution curves can be obtained of river sand, dune sand and wind blown sand. In the examination of paintings obtaining such distribution curves is not possible, because the small, complex sample does not allow separation of the constituent particles into fractions.

We did spot a single particle of the heavy mineral rutile (TiO_2) under the polarising microscope in a dispersed ground sample from the quartz ground of the *Jewish Bride*. Rutile could be recognised by its prismatic shape, high relief, strong red-brown colour and parallel extinction. The particle of rutile identified must be a constituent of the sand fraction in the ground. Stating the provenance of the sand on the basis of a single particle of rutile and, moreover the absence of other heavy minerals in the sample, is impossible (see Appendix). Titanium showed up in most of the EDX-spectra of samples of quartz grounds, often a small peak in the usual spectrum of these samples, but sometimes as a large peak. Since other chemical elements are present besides Ti, it is not always possible to interpret Ti in the EDX-

spectra as rutile, ilmenite ($FeTiO_3$) or brookite (TiO_2), or yet another titanium compound (see spectrum in fig. 19).
XRD of clay minerals in the ground samples is hampered by the presence of a large amount of quartz, among it some large particles which give 'spotty' diffraction patterns. There was too high a background noise for easy identification. Alumino-silicate and clay minerals require special XRD systems to identify them. The samples should be measured with a tube other than the copper tube as is in use at ICN and under a lower angle than possible at ICN.[44] The problem, of course, clearly showed when EDX results were compared with those of XRD-analyses. For instance, *Portrait of an Admiral*, Metropolitan Museum, New York, *Bredius* 223, EDX overall: C, O, (Na), (Mg), Al, **Si**, (Pb), (K), (Ca), (Ti), (Fe). XRD: 10% (coarse) quartz and 90% (estimated) chalk. *Self-portrait*, Cambridge, Mass. *Bredius* 57, EDX overall: Al, **Si**, K, (Ca), ((Ti)), Fe. XRD 80% alpha quartz and 20% K-Al-silicates (estimated).[45]

We asked the help of the Royal Netherlands Institute for Sea Research (NIOZ), based on the isle of Texel, where the XRD instrumentation is optimised for the identification of clay minerals.[46] A sample of the ground in the *Night Watch* was analysed under different low angles and different conditions of temperature and humidity. Results obtained include the following. Certain reflections in the XRD spectrum could be ascribed to the crystallisation of a double layer of linolenic acid. Linolenic acid must be part of the organic binder of the ground. Two other reflections under a low angle seemed to be smaller, organic molecules that, so far, could not be identified. Clay minerals identified are chlorite, mica and a little kaolinite. Feldspar, amphibole, carbonates and of course quartz are present as well. This result is an improvement of the result obtained at ICN using XRD, where it had been possible to only identify alpha quartz and calcite in the same sample. [47]

Discussion

On the basis of analytical results it can be suggested that in the period from 1640-1669 quartz grounds are specific to Rembrandt and his workshop. This provides a strong supplementary criterion for attributing paintings with quartz grounds to the master himself and to painters working in his studio, around or after 1640. Rembrandt's choice of the quartz ground could have been sparked by his contacts with pottery makers. To investigate such a connection, we tried to compare clay used for the manufacture of bricks, tiles and pottery with clay used for the grounds.
Identifying the source of the clay used in the grounds in Rembrandt's studio is a difficult task. Different clays are rarely found separately and sand, feldspars, micas, clay minerals and carbonates are common in all types of clay. Also, it is not possible to state with absolute certainty whether the material used for the quartz ground is a natural clay deposit, or an artificially prepared mixture of sand and clay. However, several of the cross sections show occasional, exceptionally large sand particles in between the much finer material. This means that the sand in the clay is either badly sorted by nature or the clay was made 'lean' artificially by the addition of sand. Even if sand was added, the sand and clay found in the samples could derive from more or less the same area (figs. 20-23).
The clay mineral illite that appeared to be present in some of the samples (not mentioned in the text) is dominant in marine clay, but is present in fluvial clay as well. Kaolinite and chlorite are typically fluvial clay minerals.
Although in some of the samples the amount of calcium encountered suggests marine clay, in the majority of the samples the amount of calcium present seemed too low to substantiate this suggestion. The relatively low percentage of calcium seems to be the original concentration present in the clay, which substantiates the suggestion based on the clay minerals present, that fluvial clay was used for the ground preparations. This is confirmed by the presence of iron. Therefore, the clay would have been fluvial clay, with perhaps some marine influence.
In spite of all the restrictions in the analyses, several factors do point to a type of clay used for the preparation of canvases in Rembrandt's studio that was similar to the clay used for the manufacture of brick and tiles and to the raw clay that was transported to the potters for the manufacture of earthenware. With enough sand present in the clay it was also suitable for making pottery. Extra sand and chalk could easily be added to adjust the clay's properties.
Along the Oude Rijn, from where – for historical reasons - the clay used for the ground could very well have derived, very coarse sand can be found next to clay and loam. Although the loading of ships and subsequent transport of clay away from the Rhine area was (officially) prohibited by ordnance already before 1663 – the danger of loss of arable land was one concern – an exception was made for the transport of clay to potters. The potter's guild only had to fill in a form with the name of the town where the potters were in need of earth for

their work and the name of the skipper of the vessel that would transport it to that town.[48]

Our research does indeed suggest that fluvial clay was used for the preparation of some of the canvases in Rembrandt's workshop after 1640. Extra sand could have been added to the clay. Thus the answer to the question of the origin of Rembrandt's idea of using a 'new' material for the preparation of painting grounds from the 1640s onwards, as well as the origin of the material itself, can be found in matters down to earth and in Rembrandt's inventiveness.

Appendix

Sand, clay, loam in The Netherlands

The Netherlands are covered for 95% by quaternary sediments. These sediments consist of sand, silt, clay, pebbles, shells and organic matter. Therefore, in contrast to most of the pigments used for painting, the clay for the preparation of the canvas could be found in abundance. For comparing types of clay used by potters it seems useful to have a closer look at the composition of the sedimentary layers. Sediments in The Netherlands have been studied extensively by geologists and geo-physicists. From these studies we know that the build-up of the Dutch soil is complex, with alternating and intermingling layers of marine and fluvial (river) deposits. The sediments were deposited in the delta constituting most of north west Holland during thousands of years by large rivers running from different directions, by small streams and the sea. The deposits of clay, sand and loam are the gritty erosion products of rocks. In Holland, the transport of rocks originates in the Eiffel in Germany, the Alps, in the south of The Netherlands and, much earlier in the earth's history, in the northeastern regions.

Clay consists of clay minerals, (which give clay its plastic properties) and 'non-clay' minerals, such as calcite ($CaCO_3$), dolomite ($CaMg(CO_3)_2$), limonite or goethite ('bog ore', hydrated iron oxide, the same composition as rust), sand etc. Clay minerals can be divided into a few groups, of which the principal ones are: 1) kaolinite group, which includes the clay mineral kaolinite; 2) illite group, with among others the clay mineral illite and hydrous mica; 3) smectite group with montmorillonite, nontronite and other clay minerals; 4) vermiculite. Different clay minerals are formed under different conditions. For instance, illite is formed by the weathering of the potassium-feldspar in the parent rock under alkaline conditions, while kaolinite derives from potassium-feldspar as well, but under acid conditions. Muscovite and biotite mica are formed from feldspars as well; they can degrade further to clay minerals with sand as the stable end product of the weathering of all these siliceous minerals. Some of the clay minerals are dominant in marine clay, for instance illites and smectites, however, minerals of these two groups are present in fluvial clays as well, together with kaolinite and chlorite.

Clay minerals are layered, with cations between sheets of silica and aluminium. The chemical composition may vary, according to replacement of cations. The clay minerals show expandability by taking up water or organic molecules between their structural layers. This is most pronounced in the smectite group. After take-up, clay minerals easily release the liquid, causing cracks to form in the clay mass.

The term chlorite is used to denote any member of the chlorite group, which contains at least seventeen members. Differentiation between the different members is not possible. The general formula is $X_{4\text{-}6}Y_4O_{10}(OH,O)_8$, where X represents either aluminium, iron, lithium, magnesium, manganese, nickel, zinc or rarely chromium and Y represents either aluminium, silicon, boron or iron but mostly aluminium and silicon. The chlorite group is not always considered a part of the clays and is sometimes left alone as a separate group within the phyllosilicates. It is a relatively large and common group although its members are not well known.[49]

Sand consists of quartz (SiO_2). Types of sand are distinguished by their grain size which ranges from 63 – 2000 µm. During transport by the rivers the sand grains are broken, rounded etc. The smallest grains are least rounded because they just float in the water. Silt has the smallest grains of 2 – 63 µm (0.002 – 2 mm) and pebbles the largest of 2 mm and more. In between there are the medium, coarse and very coarse sand fractions.

Loam consists of relatively many particles of sand grain size 2 - 63 µm, while clay consists mainly of lutum that is particles smaller than 2 µm. This very fine fraction is rich in platy clay minerals.

Heavy minerals are detrital grains of minerals with high density (>2.9) that occur as accessory minerals in quartz sands. They derive from eroding source rocks as well. Examples are magnetite ($\gamma\text{-}Fe_2O_3$), ilmenite ($FeTiO_3$) , rutile (TiO_2), brookite (TiO_2), hornblendes ($(Na,K)_{0\text{-}1}Ca_2(Mg,Fe^{2+},Fe^{3+})_5Si_{6\text{-}7,5}Al_{2\text{-}0,5}O_{22}(OH)_2$), the unstable, vulcanic mineral augite ($(Ca,Mg,Fe^{2+},Fe^{3+},Ti,Al)_2[(Si,Al)_2O_6]$) etc. Heavy minerals can be good indicators for the provenance (the source region) of sediments - Rhine, Maas, Schelde, (former) Baltic rivers – because they may be distinctive of particular types of rock and of the distance the sediment was transported by rivers. Sediments from the Tegelen formation (see below) are dominated by minerals from the Alpine region; in sediments deriving from the Eiffel region, unstable volcanic minerals could be found, predominantly augite; the Schelde and other small river systems from France are dominated by stable heavy minerals, which means that they are relatively resistant to weathering (zircon, rutile etc.). Because of their stability, they can be found in sand. Quartz is namely a stable mineral as well; it is the stable end product of the weathering of minerals. Rutile was transported to and through Holland by the southern rivers and later by Maas and Rhine together.

Ilmenite is an accessory mineral in many igneous and metamorphic rocks.

Dolomite is typically a mineral of marine sedimentary environments where it is formed from limestone, although exceptions are known.

Geologically, deposits in the Oude Rijn basin are called Duinkerke (so called because the particular deposit was first observed and described in Dunkirk in Belgium), - more precise Duinkerke-Tiel. The name indicates that marine and fluvial (river) clay are mixed here. The town of Tiel is on a branch of the Rhine (now called Waal). Clay was deposited here by the large rivers that transported debris from the Alps to the Dutch coastal estuary. Fluvial clay is naturally less chalky than marine clay.
The local clay used for the Makkum earthenware is Duinkerke as well. In Friesland, this local clay derives from sediments that belong to the Holocene Westland formation of soft marine clays and peat. The sediments were formed from c. 3000 BC onwards during a series of flooding of the moors in the Holocene coastal area in the north. For the manufacture of their earthenware, Tichelaar digs up slightly younger Duinkerke sediments, in Akkrum, to the east of Makkum, where they were deposited 1700 - 900 year B.C and where they surface as a 2 m. thick layer. The deposits are often referred to as 'Young Sea clay'. These yellowish marine sediments are rather rich in chalk (c.15-25%) and sand (20-30%).[50] The chalk in the marine clay contains shells with some of the chalk present in the clay adsorbed onto the clay minerals and the quartz sand (silt fraction, c. 2-63 μm sand particles) naturally present in the clay (fig.24). At the factory the clay goes through a strainer and is washed for the removal of coarse organic material, and then kept in a cellar under the work floor.

Acknowledgements
I want to thank The Netherlands Institute for Cultural Heritage (ICN) for providing time for me to collect data and especially to my colleagues Peter Hallebeek and Ineke Joosten for the instrumental analyses. I thank the Faculty of Earth and Life Sciences at the Vrije Universiteit in Amsterdam for fruitful discussions. The support of colleagues at The Getty Conservation Institute during my scholarship there is also greatly acknowledged. Lastly I am grateful to S. van der Gaast, formerly at NIOZ, who spent time, after his retirement, identifying clay minerals in a ground sample from the *Night Watch.*

Notes

1. C.M. (Karin) Groen, 'Grounds in Rembrandt's workshop and in paintings by his contemporaries', *A Corpus of Rembrandt paintings*, vol. 4, Chapter 4, (Dordrecht, 2005), 318-334. Tables with data on all the pictures examined, 660-677. Since the publication of *Corpus* vol. 4, six pictures on canvas at the Statens Museum in Copenhagen were examined, three of these have a quartz ground. These numbers have been added in the present article, as well as an elaboration on mineralogy and the geology of the Dutch soil, in so far this information is relevant for identifying the origin of the material used in Rembrandt's workshop for priming canvases.

2. K. Groen, 'Schildertechnische aspecten van Rembrandts vroegste schilderijen', *Oud Holland*, 91 (1977), 66-74; E. van de Wetering, 'De jonge Rembrandt aan het werk', *Oud Holland*, 91 (1977), 27-65; J. Bruyn, B. Haak, S.H. Levie, P.J.J. van Thiel, E. van de Wetering; *A Corpus of Rembrandt paintings*, vol. 1, (Dordrecht, 1982), 16-20.

3. E. Berger, *Quellen für Maltechnik der Renaissance und deren Folgezeit*, (Vaduz, 1988), 118: 'Pour le bois. Imprimés premierement auec la colle susditte & croye, estant sec, grattés & equales auec le couteau, puis faites vne couche legere auec blanc de plomb & ombre.'

4. In cases of deviation, for instance in the thickness of the layers or the total absence of one of the two layers, this can, as a rule, be explained by the location from which the sample was taken. For example, the top layer in a sample from the edge of the panel can be thicker than elsewhere because the paint of the ground accumulates along the edges when the panel is prepared. On the other hand, the bottom chalk layer is sometimes so thin that it is not found in a paint cross section: as mentioned in the text, the chalk-glue mixture was used primarily to fill the pores of the wood.

5. E. van de Wetering, *Rembrandt. The Painter at Work*, (Amsterdam, 1997), 21-22.

6. A. Bredius, *Rembrandt Schilderijen*, (Utrecht 1935).

7. J.A. van de Graaf, *Het De Mayerne Manuscript als bron voor de schildertechniek van de Barok*, (Mijdrecht, 1958), 138-142.

8. Berger 1988, 102: 'Ayant bien estendu vostre toile sur un chassis, donnes luy de la colle de retaillons de cuir ou size qui ne soit pas trop espaisse, (presupposé que vous aurez prémierement coupé touts les fils qui auancent). Vostre colle estant seiche imprimés auec Braun rot, ou rouge brun d'Angleterre assez legerement. Laisséz seicher, & applanissés auec la pierre ponce: Puis imprimés auec vne seconde & derniere couche de Blanc de plomb. de Charbon de braise bien choisy. Smale coales & un peu de terre dombre pour faire plus vistement seicher. On peult donner vne troisiesme couche, mais deux font bien, & ne s'escaillent jamais, ny ne se fendent.'

9. Anonymous, *Nieuwen Verlichter der Konst-schilders, vernissers, vergulders en marmelaers, en alle andere liefhebbers dezer lofbaere konsten*, vol. 1, (1777), 167: 'Men legt dan bynaer altyd twee andere grond-laegen op de eerste, d'eene achter d'andere, de naerleste altyd puymende als zy wel droog is, eer men de volgende legt. Deze laetste gronden zyn gemaekt van Lood wit gemengelt met bruyn Rood en een weynig Kol-Zwart, om den grond een roodagtig Grys te geven, het welk generaelyk overeenkomt met alle de koleuren van de Schilderkonst.' Partially translated in: *Valuable Secrets in arts and trades: or, approved directions from the best artists: containing upwards of one thousand approved recipes...*, (London, 1802?), 141: 'When this colour is dry, you are to rub it again with the pounce stone, to render it smoother. Then lay another coat of white lead and charcoal black, to render the ground greyish'.

10. Double grounds in paintings by Canaletto arise in the 1730s: D. Bomford and A. Roy, 'Canaletto's "Stonemason's Yard" and "San Simeone Piccolo"', *National Gallery Technical Bulletin*, 14 (1993), 34-41.

11. P. Coremans and J. Thissen, 'Het wetenschappelijk onderzoek van het "Zelfportret van Stuttgart"', *Bulletin Institut Royal du Patrimoine Artistique*, 7 (1964), 187-195.

12. C. Müller Hofstede, 'Das Stuttgarter Selbstbildnis von Rembrandt', *Pantheon*, 2 (1963), 65-90. P. Coremans, Chr. Wolters, K. Wehlte, 'Bericht über die naturwissenschaftliche Untersuchung des Stuttgarter Rembrandt-Selbstbildnisses', *Pantheon*, 2 (1963), 94-99. H. Kühn, 'Zwischenergebnis der Röntgenfeinstrukturanalyse von Grundierungen' *Pantheon*, 2 (1963), 99-100.

13. H. Kühn, 'Untersuchungen zu den Pigmenten und Malgründen Rembrandts, durchgeführt an den Gemälden der Staatlichen Kunstsammlungen Dresden', *Maltechnik Restauro*, 83 (1977), 223-233. Ten years later the National Gallery London examined 20 works by Rembrandt of which 13 on canvas. Quartz was found in four cases, published in D. Bomford, Ch. Brown, A. Roy, *Art in the Making. Rembrandt*, (London , 1988) esp. 27-31.

14. Groen 2005, 318-334, 660-677.

15. E. Haverkamp-Begemann, *Rembrandt: The Nightwatch*, (Princeton University Press, 1982), 14.

16. Grounds with high quartz content were found in both Aert de Gelder's *Edna blessing Tobias and Sara*, c. 1705 – 1710, Utrecht, Catharijneconvent, and *King David*, c. 1683 in the Rijksmuseum. These grounds differ from Rembrandt's 'quartz grounds' in several ways: 1. their high proportion of lead white; 2. their overall colour; 3. rounded particles of quartz sand. Moreover, stylistically Aert de Gelder cannot be confused with Rembrandt. In eighteenth-century painted wall hangings by Pieter Barbiers (1749-1842) a preparatory layer was found containing approximately 60% quartz, the mineral serpentine and lead white. This sample was analysed through XRD by Peter Hallebeek at ICN.

17. Pierre Lebrun, Peintre, 1635, 'Recueuil des essaies des merveilles de la peinture', in Mrs. M. P. Merrifield, *Original treatises on the arts of painting*, vol. 2, (New York, 1967), 772 (originally published in 1849).

18. M. Beal, *A Study of Richard Symonds, His Italian Notebooks and their Relevance to Seventeenth-Century Painting Techniques*, (London, 1984), 218.

19. Explanation given by the editor of the translation of Vasari's text: G.

Baldwin Brown. See G. Baldwin Brown ed., *Vasari on technique*, (New York, 1960), 230.

20. Z. Veliz, *Artists' techniques in Golden Age Spain*, (Cambridge, 1986), 68-69.

21. Simon Eikelenberg, 'Aantekeningen over schilderkunst', 1679 – 1735, Regionaal Archief Alkmaar, Collection acquisitions nr. 390-394, photographs made at the Central Research Laboratory (now ICN). Several copies of Eikelenberg's notes and photographs of the pages are kept at ICN. Truusje Goedings, 'De "vrijerijboeken" en "pareltjes" van Simon Eikelenberg (1663-1738)', 1, *De Boekenwereld*, 2 (1985-86), 46-57.

22. Eikelenberg MS aquisitions collection nos. 403 - 405 (modern page nos): 'plumeren.

om houten pannelen te plumeren, stryktmen dezelve met Lijm. .. daarna met potaarde twelk met lijnolij fijngewreven is, in plaats van met andere verf, om de goedkoop. Nota maar ik agt dat het ook bestendiger is als uijt taije en sware deeltjes bestaande enz. als er de pot-aard over is werpt men er met de hand wat regen water op, en wrijft het met het vlak der hant her en derwaarts, invoegen dat het in al de pori of pijpjes van 't hout gaat zitten, en hen vervult, en de vlakte van 't panneel glad en digt word, en zoodanig dat er de verfzels niet in komen schieten. Dan laat men het water en de vlugste olij wegdampen, alijas het droogen, en als 't droog is schildert men er over zonder daar meer toe gedaan te hebben.'

'Plamuren op doek Tot schilderdoek verkiest men gemeenlijk Zeijldoek of Lijnwaat, dat digt en gelijkdradig is en weijnig Noppen heeft, dit bestrijkt men eerst met pap van tarwen meel... men strijkter de pap met een kwast op, dog dezelve glad en effen met een plumeer-mes van gestalte als hier is afgebeeld, en zoo veel duijmen lang en dick alser bij uytedrukt staat. Als men er de pap nu in en op gedroogt vind, neemd men wederom potaarde als tot de houte pannelen en strijkter deze over zoo glad en vlak als 't mogelijk is. dog eer men er nog de potaard over overstrijkt moet men er eerst de noppen en korlen vuilnis afgedaan en hetzelve met een leksteen, gelekt hebben, de potaarde moet omtrent zoo dik zijn bereyd als schilderverfzel, en als dit 'er over gedroogt is, doet men als van de houten is gezegt '

Transcription ICN.

23. G.J. Hoogewerff, *De geschiedenis van de St. Lucasgilden in Nederland*, (Amsterdam, 1947), 142, 143.

24. There are a few exceptions regarding membership of the guild. There is some doubt about the authenticity of the medaillon. Oral communication Jaap van der Veen, historian Foundation Rembrandt Research Project, who himself does not doubt its authenticity.

25. Anonymous 1777, 167: 'Daer zyn Schilders die liever hebben dat den doek maer eene laege koleur en heeft, den welken zy prefereren voor den gonnen die'er twee heeft, om dat hy de koleuren min verdooft, en om dat hy gemakkyker oprolt als men hem wilt transporteren; nogtans aengezien den draed van den doek altyd zeer verscheynt op die, de welke maer eenen grond en hebben, men gebruykt dien wynig dan voor groote werken'.

26. Personal communication S.A.C. Dudok van Heel, Gemeentearchief Amsterdam.

27. A. van Schendel and H.H. Mertens, 'De restauraties van Rembrandt's Nachtwacht', *Oud Holland*, 62 (1947),

28. Bruyn et al. vol. 2, 1986, 43, note 90.

29. Coremans 1963, 97.

30. G. Paape, 'De plateelbakker of Delftsch aardewerkmaker', in *Volledige beschrijving van alle konsten, ambachten, handwerken, fabrieken, trafieken, derzelver werkhuizen, gereedschappen, enz.*, (Dordrecht, 1794), 5.

31. J. D. van Dam, *Delfts Aardewerk. Een proeve tot her-ijking*, (Amsterdam, 2004), 23.

32. For nomenclature on Delfts and other earthenware see Van Dam 2004, 10-19.

33. Paape 1794, 5.

34. H.J.A. Berendsen, *De genese van het landschap in het zuiden van de provincie Utrecht*, (Utrecht, 1982), 167. Z. van Doorn, *Kleiland, kleivletten en baksteenindustrie voornamelijk in de Oude-Rijnstreek*, (without name of town, without publisher, 1961), 4.

35. D. Parlevliet, 'De Rijnmond verstopt', *Holland*, 33 (2001), 1-16. P.A. Henderikx, 'The lower delta of the Rhine and the Maas: Landscape and habitation from the Roman period to ca 1000', in: BROB 36, (Amersfoort, 1986), 447-599 [esp. 457].

36. Paape 1794, 2.

37. P. J. Tichelaar, *Fries Aardewerk. Een studie in delen*, (Leiden, 2004).

38. R. van Wageningen, *Ceramiekimporten in Amsterdam, een mineralogisch herkomstonderzoek*, (Amsterdam, 1988), 87.

39. Quoted in J. D. van Dam, 'De majolica- en tegelbakkerijen in de provincie Holland tussen 1620 en 1647', *Mededelingenblad Nederlandse vereniging van vrienden van de ceramiek*, 108 (1982-4), 17: 'omme 't werck daervan gebacken soo goeden klanck ende luystre te geven als 't werck, dat men van Engelse aerde plach te maecken...'

40. For example, the ground in a painting by Caspard Dughet in: K. Groen, 'Scanning electron microscopy as an aid in the study of blanching', *Hamilton Kerr Institute Bulletin*, 1 (Cambridge, 1988), 43, plate 38. The ground in the painting by Dughet is rich in calcite and could be an earth.

41. K. Groen, 'Investigation of the use of the binding medium by Rembrandt', *Zeitschrift für Kunsttechnologie und Konservierung*, 11, (1997), Heft 2, 222-223.

42. Samples from the grounds in the *Night Watch Night Watch Night Watch* were examined using SEM-EDX at The Getty Conservation Institute in Los Angeles. With thanks to Urs Mueller, specialist in clay as a building material, for his remarks on the SEM-images and to David Carson for the use of the Philips-FE7 XL30 ESEM-FEG (Environmental Scanning Electron Microscope-Field Emission Gun) At 20.0 kV, environmental mode at 1.0 torr, uncoated, working distance 10 mm, Oxford Inca System EDX. Additional electron microscopy was done by Ineke Joosten at ICN, using the variable pressure electron microscope JEOL 5910LV with.EDS system Vantage, ThermoNoran.

43. W.A. Deer, R.A. Howie & J. Zussman, *An introduction to rock forming minerals*, (Harlow, 1992), 369-376.

44. With many thanks to Peter Hallebeek, ICN. Hallebeek analysed samples using X-ray diffraction (XRD), A minute amount of solid material, size 0.5 mm^2 is put on the tip of a glass fibre, diameter 0.1 mm. The tip of the glass fibre is coated with a thin layer of cedar oil. The fibre with sample is attached to a small piece of wax on top of a copper tube with a hole. The copper tube is fixed in the centre of the back of the microdiffractometer. Debye-Scherrer powder patterns were obtained using Philips type PW 1026/10 camera, X-ray film CEA REFLEX 25, double coated, X-ray generator Philips PW 1010. Samples were also analysed using a new instrument, the GADDS microdiffractometer (Siemens-Bruker). GADDS means Area Detector Diffraction System. The HI-STAR detector is a gas-filled multiwire proportional counter. It is a true photon counter, which makes it extremely sensitive for weakly diffracting materials.

45. Results XRD Peter Hallebeek and SEM-EDX Ineke Joosten, both at ICN.

46. We are very grateful to Dr S. van der Gaast, who, on the last days before his retirement – and the last days before the submission of my manuscript - enthusiastically managed to tackle the difficult problem of the identification of clay minerals. It is our intention to present the technical details of the XRD-analyses in a joint publication.

47. In the ground in the Stuttgart *Self-portrait* (pyro?) phyllite (a smectite), with some chlorite and sericite present in smaller proportions were identified. Coremans 1963, 97.

48. Van Doorn 1961, 61: Beperking uitvoer van potaarde uit Holland. Archief Hoogheemraadschap Rijnland. Extract uyt het register der resolutien van de Heeren Staaten van Holland in haar Ed. Groot Mog. Vergaderinge genomen op Donderdags den 20 November 1704 (deze beperkingen golden reeds vóór 1663 en tot ná 1793).

Formulieren van de voors. acte.

Wij onderges Hooftman ende Deekens van het pottebakkersgilde binnen de stad................certificeeren by desen, dat den schipper.................is gedestineert na den Rijn om vandaar af te haalen aarde, die gebruijckt sal worden bij de pottebakkers in dese stadt gedaan etc.

Daar geen gilde is diergelijke acte te passeeren bij den pottebakker die aarde nodig heeft. Onderstont accordeert met het voors. register ende was geteekent, Simon van Beaumont. Missive van de Staaten van Hollandt ende West Vrieslandt.

49. http://mineral.galleries.com/minerals/silicate/clays.htm.

50. Oral communication J.Lieverdink, Makkum.