Twentieth Century Oil Paint. The Interface Between Science and Conservation and the Challenges for Modern Oil Paint Research

Aviva Burnstock and Klaas Jan van den Berg

Abstract This chapter introduces recent research related to aspects of the deterioration of modern paintings in oil media. The research was informed by collaboration between conservators and scientists and utilises phenomenological and experimental methodologies to investigate the causes of optical changes in paint, such as efflorescence and salt formation, and the sensitivity to water that occurs on surface cleaning some unvarnished oil paintings. Examples are given of results based on case studies of paintings and the results of systematic experimental investigation of paint samples, including those supplied by manufacturers and reconstructions based on paint formulations. Results of this research are given including the cause of water sensitivity related to the formation of magnesium sulphate hydrate in selected manufactured oil paints, and criteria for further investigation of the phenomena in other paints. Contributions in this volume that address other classes of material deterioration including the formation of metal soap crusts and treatment approaches are introduced.

Keywords Twentieth century oil paint • Water sensitivity • Efflorescence • Collaborative research

Introduction

The working properties and optical qualities of oil based paints continue to appeal to artists despite the availability of new paint media. A survey from the painting collection at Tate, showed that more than 70 % of its twentieth century painting

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collection is executed in oil (Smithen 2005). Although modern oil paints contain the same oils that were used for paint media in the Middle Ages, the formulation of artists' oil paints have changed significantly (Mayer 1991). While linseed oil continues to be the most widely used medium, other oils such as safflower and sunflower have been introduced to replace the traditional, less-yellowing nut and poppy oils. Artists oil paint tubes, originally invented in the 1840s contain additives to stabilise the paints in the tube whilst controlling the rheology as well as the drying time of the paint once taken from the tube and applied. The archives of artists' paint manufacturers to some extent document these developments (Carlyle and Clarke 2005, Van den Berg et al. 2014). Manufacturers' incorporation of dryers, fillers, dispersion agents and stabilisers has developed in particular during the twentieth century (Izzo et al. 2014; Van den Berg et al. 2014). Concomitantly a range of new pigments, some of improved quality and lower cost have been introduced (de Keijzer 2011, 2014). Economic reasons have driven much of these developments, although more recently health and environmental safety have led to changes in formulations. The restrictions on the production of lead white and other toxic pigments were important changes in relation to the production of artists' paints.

These developments, however, have led to compromises in the stability of some modern oil paints. In some cases the manner in which modern paints are used by artists have influenced the material deterioration of the paint. Preferences for unvarnished surfaces from the later part of the nineteenth century prevailed in the following period of artistic production, rendering the paint surface directly vulnerable to the influences of environmental agents including dirt and pollutants. These developments present challenges for conservators. As many modern paintings are now entering conservation studios for the first time, these issues are now paramount for conservators and curators.

While experience provides the conservator with a solid framework of knowledge, the ability to question standard treatment approaches and recognize problems that require new strategies is an important part of an on-going education in conservation. In these Proceedings, several conservators as well as conservation students present aspects of their research that relates to the condition and treatment of modern oil paintings (Cooper et al. 2014; Sawicka et al. 2014; Franken et al. 2014; Blumenroth et al. 2014; Verissimo Mendes et al. 2014; Volk and van den Berg 2014; Soldano et al. 2014). This research has provided an opportunity to share experiences with professional conservators in museum and private practice, and work in well-equipped scientific laboratories. The problems investigated are important to conservators who deal with them every day in the studio, and thus there is a real desire behind the research to provide guidelines that inform future conservation practice.

The nature of conservation led research is different to scientific research in other fields. Relatively few conservation related studies are undertaken, and many have been based on cumulative evidence from individual case studies. For example, identifying common denominators or causal agents for water sensitivity observed in paintings is difficult given the range of possible materials, in particular where paintings are made using both complex manufacturers' paint formulations and artists' additions, applied heterogeneously.

More recently, collaborations have provided up to date resources for technical and scientific study, at the Netherlands Institute for Cultural Heritage (RCE), the Getty Conservation Institute (GCI), the Natural History Museum, London (NHM) and most recently the synchrotron facility in Grenoble.[1] Participating museums and galleries, notably at the Courtauld Stedelijk Museum and Tate have facilitated paintings-led research that address the condition and treatment of some important works of art made using modern oil paint from the twentieth century to the present. This first chapter in these Proceedings evaluates the approaches to research undertaken so far, gives some further research results and ideas for future study.

Fundamental Research to Inform Conservation

Research in the field of conservation, for modern oil paints and other materials is challenged by the need to design experiments that inform practice. This demands the most difficult kind of experimental work and interpretation. The notion that understanding the chemistry of materials on a molecular level can inform practice requires qualification and necessitates inferences about the macroscopic impact of practical treatment from knowledge of molecular level interactions on the surface and within the paint. This highlights an issue that is at the heart of the interface between conservation science and practice. In the context of cleaning a painting, interpreting the results of semi-standardised experiments on simplified “reconstructed” paint samples, supplemented by in-depth analyses of small and complex samples from paintings, may involve compromises and practical realities. Scientific research and cleaning paintings sometimes feel as different as making art and conserving it.

Nonetheless, with the assumption that understanding the chemical and mechanical properties of painting materials and their deterioration is integral to conservation practice, together with experience and knowledge of historical context we conserve works of art the best we can. This point can be illustrated with regard to deterioration observed in modern oil paints containing ultramarine, and replication of the phenomena in so-called reconstructions or test samples (Fig. 1). Well-prepared reconstructions offer an opportunity to perform comparative cleaning tests and analyses with a degree of confidence that the results will have relevance to cleaning painted art.

Recent research includes investigation of the causes of water sensitive oil paint; dirt removal from sensitive surfaces; causes and treatment of surface efflorescence and evaluation of other kinds of material deterioration. While some phenomena such as whitening of the surface of selected passages of paintings has long been recognized by conservators, recent studies have refined our understanding of different classes of material change that can now be addressed by more specific and

[1] See for an overview of the research undertaken in the 20th Century project: Van den Berg (2013).

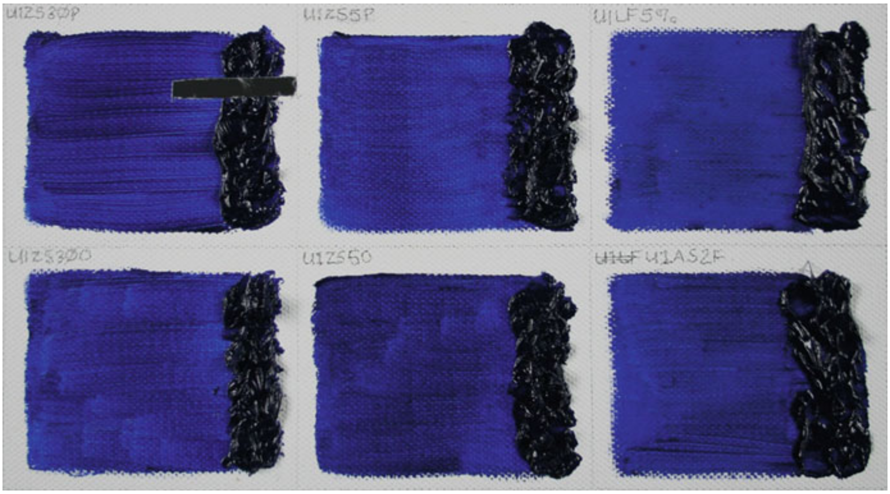

Fig. 1 Test paint samples comprising ultramarine, oil, varying concentrations of metal stearates and other additives. The hydrophilic properties of ultramarine pigment are linked with its sensitivity to swabbing with water (Tempest et al. 2013)

appropriate treatment. Surface deterioration is often evident where efflorescence, medium separation, dripping or flaking paint occur. Sometimes cases such as those of water sensitive paint offer no visual indicators. However, the problem for conservators is to remove superficial material (efflorescence, surface dirt or varnish) or to consolidate flaking paint without affecting the optical or mechanical qualities of the paint.

Classes of Surface Deterioration

Optical Whitening of the Paint Surface: Efflorescence, Salts, Metal Soap Crusts

Recent study of surface whitening in paintings has combined fundamental research and practice that has led to changes in conservation treatment methodologies. The application of new analytical techniques, including high resolution imaging, layer specific analysis and the development of methods for precise characterisation of organic materials and their components has refined understanding of different causes and classes of optical whitening, which can be of organic, inorganic and organometallic (soaps) origin (Burnstock et al. 1993; Sutherland 1995; Akerlund 2012).

Hinde's investigation of surface whitening in a series of twentieth century Spanish paintings at a National Trust property in the UK provides a good example of how research informs conservation practice (Hinde 2010; Hinde et al. 2011).

Hinde's study involved close examination of the causes of whitening, the results of which facilitated her choice of the most appropriate treatment for paintings that she then carried out. This included the removal of the white- appearing deposit of free fatty acids from the surface of the painting using non-polar solvent and or mechanical action, and removal of water soluble salt efflorescence that migrated through cracks from underlying layers. Examination of another painting identified the intentional use of a particulate white material which therefore required no treatment.

Superficially similar optical whitening identified as metal soap crusts that are insoluble in solvents requires a different approach that was subsequently developed by Sawicka and discussed in this volume (Sawicka 2013; Sawicka et al. 2014).

While whitening, or efflorescence in oil paintings may be caused by migration of fatty acids from the oil medium (Fig. 2) and the formation of metal soaps (Fig. 3) there are other examples where efflorescence is caused by reaction with airborne gases or aerosols. The light scattering surface product can consist of metal oxides, carbonates and different types of salts. Examples are sulphates (Van Loon et al. 2012), zinc formates, acetates and sulphides, (Keune and Boeve 2014), carbonates (Sawicka et al. 2014).

The Oil Paint Model

The conditions which influence the formation of efflorescence and metal soaps in oil paintings have been proposed using a model of oil paint (Van den Berg et al. 1999, 2002). The model that incorporates mobile elements, including reactive metal

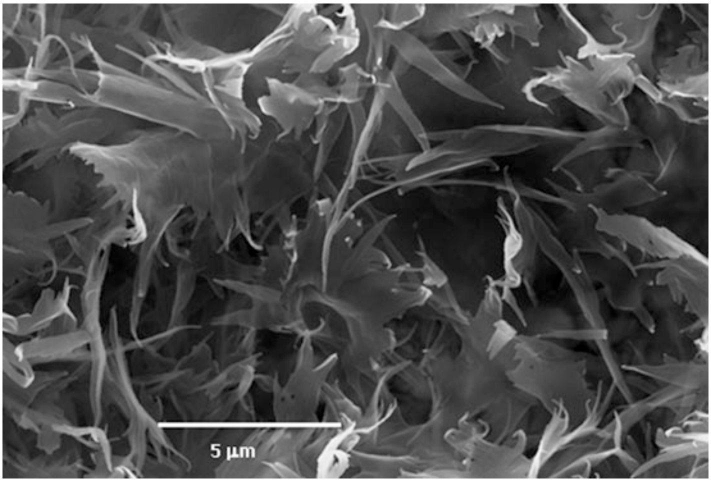

Fig. 2 SEM image of fatty acid efflorescence in a sample from an unvarnished oil painting

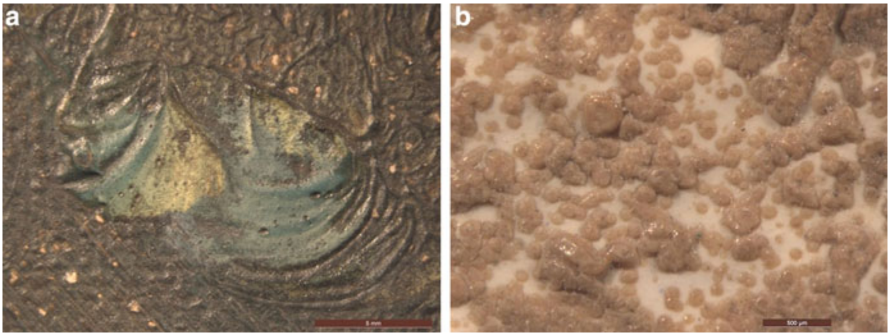

Fig. 3 *Wolmer Wood* by Philip De Lazlo, (c. 1930, private collection) (See treatment report CIA:2093 Luciana Akerlund 2012, Department of Conservation & Technology, Courtauld Institute of Art); (**a**) detail of darkened surface crust composed of zinc soaps formed from zinc ions migrated from the paint and ground reacting with free fatty acids in the oil containing varnish, (**b**) detailed photograph showing zinc soaps on an area of white paint

ions and organic molecular fragments in a cross-linked polymer matrix presents a notional dynamic system for describing the condition of oil paint, as summarised here.

In the development of oil paint drying and ageing, three processes play a role (Fig. 4). Oxidative polymerisation which causes the paint to dry creates a cross-linked network. This process occurs in competition with oxidative degradation, which leads to the formation of smaller molecules which do not participate in polymerisation. The third process is hydrolysis, which will gradually proceed from the first stages of drying of the paint and continue in the longer term.[2] Over time hydrolysis reduces the molecular weight of the binder matrix resulting in a relatively flexible paint that may be vulnerable to extraction of low molecular weight fragments by solvents. If, however, polyvalent ions are present, for example where lead or zinc is present, a more rigid, resistant paint film will be formed.

This model can be used to explain some of the mechanical and optical phenomena in modern oil paints, including aspects of efflorescence (Sawicka et al. 2014). Recent research on the reactivity of in lead and zinc white in oil media has developed a deeper understanding of the processes which involve metal soap formation, including the influence of moisture and temperature.[3]

[2]The presence of drying pigments and driers will promote the oxidative polymerisation process. The presence of alkaline pigments and fillers will promote hydrolysis.

[3]Research is currently carried out within the NWO PAinT project by A. van Loon and K. Keune (http://www.s4a-paint.uva.nl/research-topics), partly in collaboration with the authors. See A. van Loon and K. Keune et al., 'Synchrotron-based studies on the migration of lead soaps in Old Master paintings and model systems', presented at the Synchrotron Radiation and Neutrons in Art and Archeology Conference, Paris, 9–12 Sept. 2014. Manuscript in preparation for the Conference Proceedings.

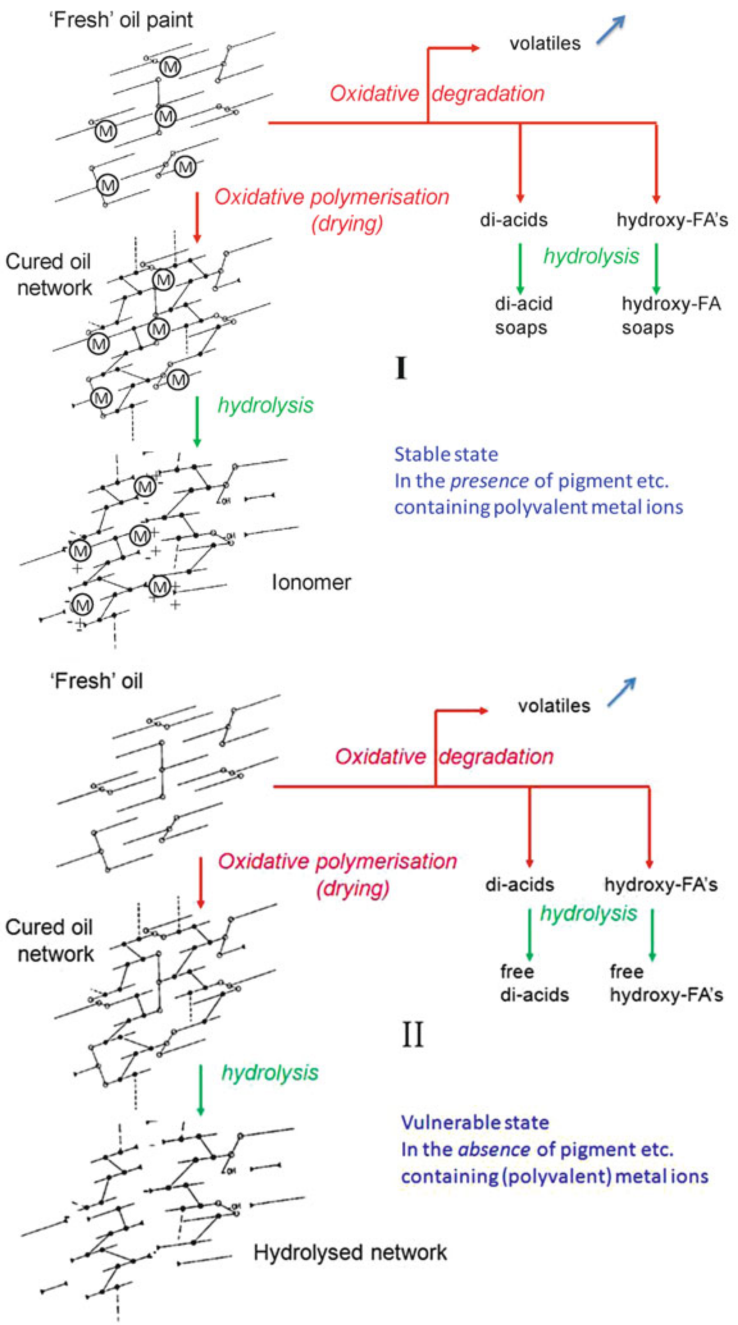

Fig. 4 The oil paint model from Van den Berg et al. (1999) and adapted to illustrate the difference between oil paint, after oxidative drying and hydrolysis, stabilised in the presence of polyvalent metal ions (I), and where the absence of polyvalent metal ions leads to a paint which is more vulnerable to external factors (II)

Water Sensitivity of Modern Oil Paints

Hypotheses based on information given by manufacturers and a review of the literature on the commercial manufacture of oil paint in the twentieth century pointed to manufacturers' addition of excess stearates to modern oil paints as the most likely cause of water sensitivity in paintings by Jasper Johns made in the 1960s (Wijnberg et al. 2007; Burnstock et al. 2006). Sets of samples were prepared following this hypothesis, based on analyses of modern oil paints from different brands with additions of aluminium and zinc stearate (Mills et al. 2008; Saltmarsh et al. 2008). Acknowledging the variable methods used by different conservators, the water sensitivity of the films was tested using a semi-standard swab rolling technique; results suggested that some paints were more sensitive than others. Ultramarine paints were consistently more sensitive to water, as were paints formulated with pre-hydrolysed linseed oil and hydrated alumina. Notable was the presence of a skin of medium on the paint surface in some samples that influenced sensitivity. Contrary to the hypothesis postulated by Burnstock et al. (2006) and Mills et al. (2008), the addition of stearate did not affect water sensitivity and samples that contained both stearate and hydrated alumina were less sensitive (Tempest et al. 2013).

Experiments carried suggested that fatty acid efflorescence in fresh paint films was dependent primarily on the presence of high concentrations of metal stearates (Tempest et al. 2013). In these samples water swabbing produced fatty acid efflorescence within days. These free fatty acids are related to technical stearates which are known to contain high proportions (4-20 %) of free fatty acids; furthermore hydrolysis of the metal stearates may form more fatty acids (Boon and Hoogland 2014; Tempest et al. 2013). Since metal stearates perform an important function both in the paint manufacture, rheology and during ageing, it is important to be able to detect the material. Fourier Transform Infrared Spectroscopy (FTIR) can be used but cannot detect concentrations of stearates below c. 5 %. More sensitive techniques have been developed to detect metal stearates using extraction methods in combination with Gas Chromatography (GC)MS (Izzo 2011) or Evolved Gas Analysis (EGA)MS (Van den Berg et al. 2011). Alternatively, the detection of fatty acids from metal stearates can be done relatively easily using Direct Electrospray Ionisation Mass Spectrometry (ESIMS) (Van den Berg et al. 2011; Van den Berg 2013).

New hypotheses about the causes of water sensitivity in modern oil paintings were developed based on evidence from wider sources. The first was a survey that identified clusters of case studies of oil paintings made in the 1950s–1960s that exhibited water sensitivity were made available for technical study (Tempest 2009). At the same time, the closure of Winsor&Newton's Wealdstone plant in 2012 led to the donation of a set of oil paint swatches painted out from every batch of

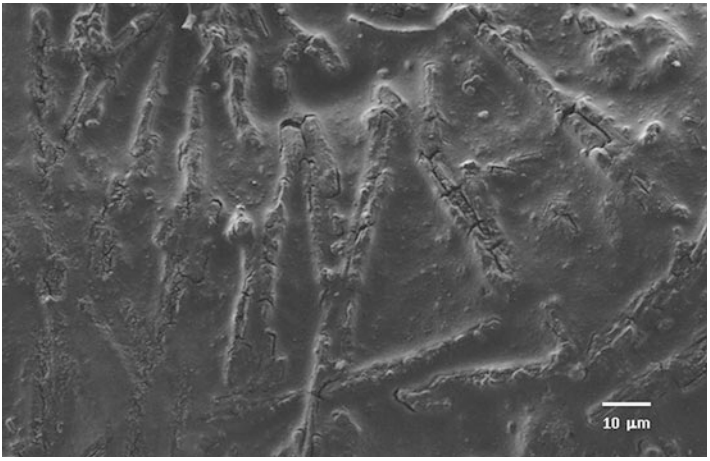

Fig. 5 SEM image of magnesium sulphate heptahydrate (epsomite) under skin of medium of a dry film of Winsor&Newton student quality oil paint (1964/1965) containing cadmium yellow pigment, barium sulphate and magnesium carbonate extenders in oil

oil paint made at the plant between the 1940s and the 1990s.[4] This provided an opportunity to relate the water sensitivity in paintings, in particular where the artists used Winsor&Newton oil paints, to naturally aged samples of the same paints from the manufacturer.

Scanning electron microscope imaging and elemental analysis (SEM-EDX) of some of the most water sensitive paints from both paintings and swatches showed consistent surface features, elongated crystals embedded in the surface of some of the paints that contained elemental Magnesium and Sulphur. The application of non-invasive X-ray diffraction (XRD) identified the crystals as magnesium sulphate hydrate that is highly water sensitive (Fig. 5). A hypothesis for the cause of water sensitivity, at least for the paints that exhibited these crystals on the surface was thus proposed, and the next phase was to try to replicate the formation of the compound by exposure to a sulphurous environment that might reflect the conditions to which paintings were exposed the before the cleaner air of the post-1980s (Silvester et al. 2014). The question of whether the water sensitive compounds were present in the bulk paint or was limited to the surface was subsequently investigated by Cooper et al. (2014).

While the formation of magnesium sulphate heptahydrate may account for water sensitivity in some oil paints (notably those that contain magnesium carbonate) there are a number of cases where water sensitivity cannot be attributed to this kind of chemical change. Friable under-bound paint may also be susceptible to

[4]Oil paint Swatches of batches of paint made by Winsor&Newton from c. 1960–1990 gifted by Ian Garrett to Tate in 2012.

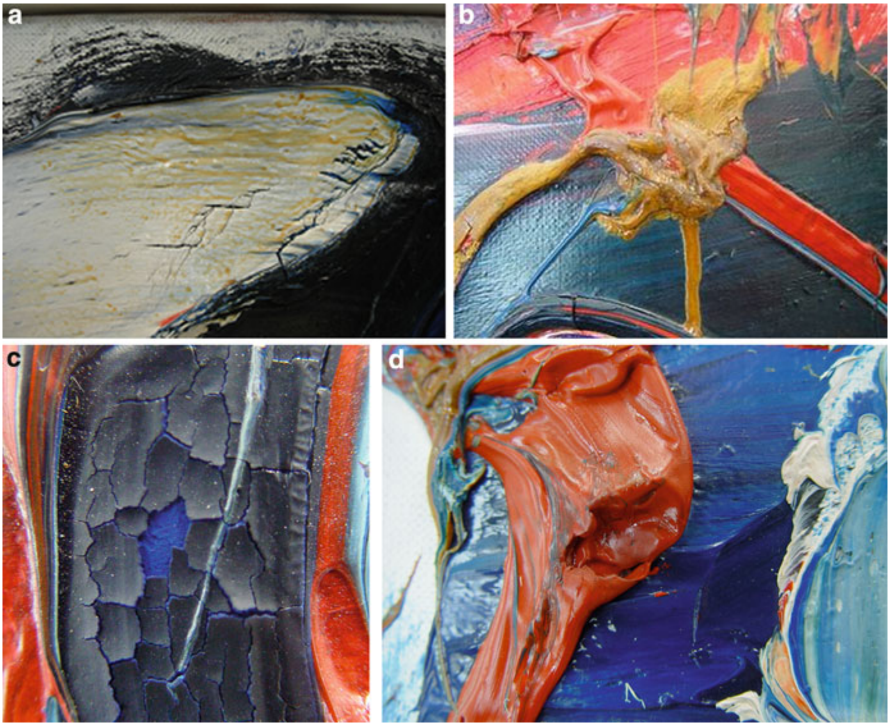

Fig. 6 Water sensitive surfaces associated with medium separation, from Karel Appel, *Les* Animaux 1961. (**a**) *Yellowed* oil medium on a *white* paint passage, (**b**) Drip of medium-rich ochre formed a few years after completion of the painting, (**c**) Flaking ultramarine blue paint with dry powdery paint visible underneath, (**d**) Organic red pigmented paint, medium has leached out into the ground and to the back of the canvas (Photographs Laura Mills 2008)

mechanical abrasion and where the paint appears to be intact there may be other causes linked to the surface deterioration of the paint medium. One example of this class of sensitivity can be seen in paintings by Karel Appel that demonstrate the deterioration of the organic medium at the surface, or separation of the medium from the binder (Fig. 6) (Burnstock et al. 2006; Mills 2008; Volk 2012).

The cause of water sensitivity in well bound paint can be further examined using paint cross sections which show the presence of a skin of medium at the paint surface. In Fig. 7a this is clearly visible in an SEM image. Figure 7b, c illustrates the medium skin in that fluoresces in a cross section photographed in UV light. UV imaging of sections taken before and after treatment has been used in some studies to monitor the effects of different methods of surface cleaning on the paint skin (Daudin et al. 2013).

Analytical results point to surface changes in the organic media in some water sensitive paints. Analysis using GCMS and ESIMS (Van den Berg et al. 2011) indicated that paint surfaces show relatively high organic diacid contents.

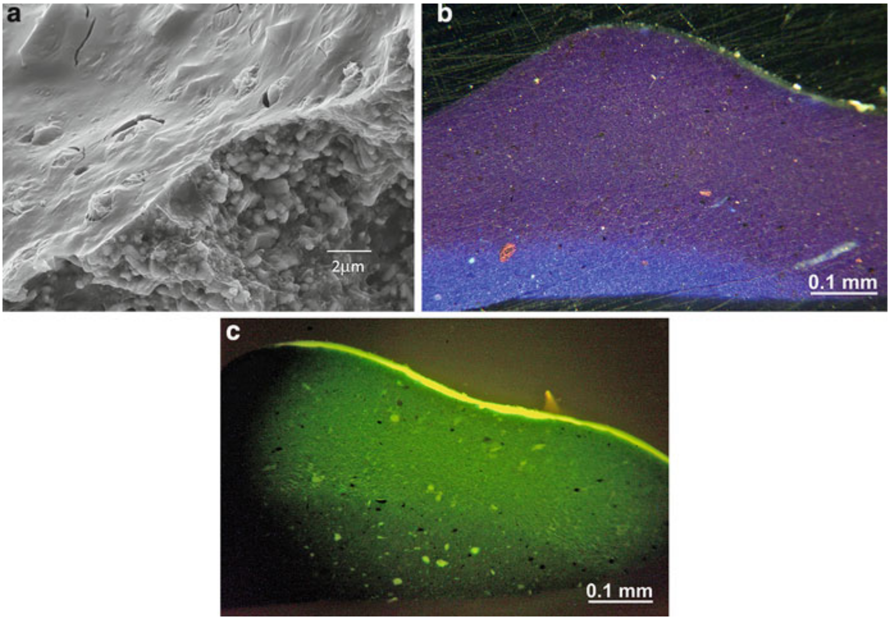

Fig. 7 (**a**) Scanning electron microscope image showing a skin of medium on a paint sample; (**b**) Microphotograph of a cross section taken from a dry film of Winsor&Newton cobalt blue tint student-quality oil paint 1964/1965, containing an organic blue pigment, magnesium carbonate and barium sulphate, (**b**) in ordinary light; (**c**) in ultraviolet light, showing strong fluorescence on the surface of the paint indicating an oxidised and medium rich surface skin (**b**, **c** from Silvester 2011)

These diacids are formed by an oxidative degradation which is in competition with the oxidative polymerisation (see Fig. 4). Following hydrolysis, these free organic diacids may render the surface relatively polar and sensitive to water, especially in medium rich paints and may increase the water sensitivity of the paint surface (Van den Berg et al. 2011; Izzo et al. 2014).

Other evidence has indicated the sensitivity of the paint medium to water increases after exposure to sulphur dioxide. Experiments carried out at the synchrotron facility at Grenoble[5] using K-Edge μ-XANES/XRF mapping of a cross section of a medium rich paint containing natural 'raw Sienna' that comprised hydrated ferric oxides and silicates, with magnesium carbonate filler, aged naturally for 50 years (Fig. 8). Sulphide was detected in a 1–3 μm thick layer on the surface that was not associated with elemental magnesium, suggesting that an organic sulphide is formed due to the reaction of the curing binding medium with atmospheric sulphur (Simendinger and Balik 1994; Silvester et al. 2014). Further research might usefully explore the influence of this reaction on the properties of the oil paint and oil paint surface, and in the bulk paint.

[5](Van den Berg, Burnstock, Pouyet and Cotte, manuscript in preparation).

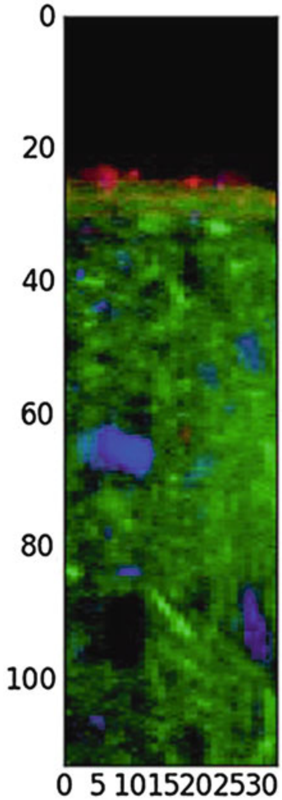

Fig. 8 K-Edge μ-XANES/XRF mapping of the cross section of Winsor&Newton raw Sienna student-quality oil paint 1964/5, indicating that organic sulphide is present on the surface. Numbers in μm. Al (*blue*); Mg (*green*); S, as sulphide (*red*) at 2.4737 keV (Van den Berg et al. manuscript in preparation)

The changes in the organic binding medium that lead to changes in the paint film, including striking examples of dripping that are only evident several years after completion of the painting are discussed by Boon and Hoogland (2014), Bronken and Boon (2014) and Franken et al. (2014).

Foreknowledge that some paints are likely to be water sensitive helps to inform conservation practice. The presence of magnesium sulphate hydrate may be predicted by simple conductivity testing of paintings (Soldano and Van den Berg 2014), a procedure that is used by conservators to adjust concentrations of aqueous cleaning solutions (Ormsby et al. 2013). It is possible, based on the results of research so far, to predict that some paints will be more or less sensitive, though the cause might be explicit where artists have used selected manufacturers' tube paints per se. Mixtures of paint and paints mixed with other materials often employed in making art will behave differently. This is a limiting factor, however some of the most water sensitive paintings comprise fields of colour that are likely to derive from a single tube of manufactured paint, and here the inferences made from reconstruction samples may have direct application.

Designing Treatments

The step that follows fundamental experimental research into the condition of paint is to design methods for treating surfaces sensitive to water and other solvents. The use of new methods that aim to evenly remove surface dirt from real paintings presents a practical challenge. The most useful experimental studies that have addressed the methods for dirt removal from unvarnished oil paint have included an evaluation of the goals for treatment. These include for instance Rachel Morrison's investigation of the use of citrate for cleaning oil paint has informed conservation practice understanding and serve as a model for future study (Burnstock and Van den Berg 2005; Morrison et al. 2007). Experimental evaluation of surface changes has employed a range of imaging methods, such as light and confocal microscopy (Van den Berg et al. 2008), SEM topographic imaging before and after treatment and other profiling techniques such as atomic absorption spectroscopy.

Naturally aged paint surfaces are the most useful for testing but are not widely available and require full characterisation of the painting materials and technique and the nature of surface dirt and its relation to the paint surface. The use of reconstruction samples aged artificially for testing practical treatments present one or more degrees of separation from the qualities of the surface of a naturally aged painting, in particular a painting with a varied physical history of conservation and display. Some experimental studies that involve comparisons between different methods of treatment have introduced artificial surface dirt, of a standardised composition. In theory this reduces the variables by providing a consistent surface for comparison of different methods for removal. Another approach is to use flat surfaces so that interstitial surface materials do not produce other anomalies for evaluation. While the advantages of comparing like with like are obvious, the compromise is that the artificial dirt is unlike the soiling that accumulates under natural conditions, in particular in relation to the interface between the dirt and the paint and the relationship between timing of both the drying of the paint and the soiling. This method is somewhat standard now for cleaning studies of unvarnished paints in different media and experiments using this approach, and the removal of naturally accumulated dirt is discussed by Volk and van den Berg (2014) in relation to selected water sensitive oil paints and by Daudin et al. (2013) for comparing methods of dry cleaning oil paint surfaces.

What has been clear from the studies of water sensitive oil paints is that the top few microns of the paint surface are critical. For paints that exhibit the formation of hygroscopic compounds the question of whether the surface or the bulk paint is likely to be vulnerable during cleaning was the focus of Cooper's research (2014).

There are differences in the nature of the surface of modern oil paints, both from paintings and reconstructed samples, some of which exhibit a skin of organic material that is vulnerable to oxidation or pollutant gasses, and there is another group of paints, perhaps those with poor paint binder interaction, that undergo changes in inorganic compulsion at the surface.

Practical and Ethical Considerations

Conservation approaches are almost always compromises that balance material preservation and aesthetic gains (that result in a more readable image) with the risks for original painting materials. The awareness of deterioration of the original paint and concomitant optical and mechanical changes in original painting materials provides important context for treatment decisions. With regard to the treatment of modern oil paint the surface, the top few micrometers of which present a critical focus, though addressing mechanical and other changes in the painting structure is also important.

Arguably the first cleaning of a painting presents the greatest challenge, in which the paint surface, that may be dirty, aged and perhaps deteriorated, is unaffected by previous treatments. This reality frames the interpretation of data from technical and experimental studies. There are many different approaches to the removal of surface dirt from unvarnished paintings and the visual difference between the results obtained using different methods for surface cleaning can be striking (Wijnberg 2014). In relation to surface cleaning of water sensitive oil paint it is important to define the questions for designing an appropriate research strategy: Is the ultimate goal to remove surface dirt completely, or is it important to do so evenly? Might a compromise be to accept the limitations of selective cleaning? In paints that include imbibed surface dirt, the goal for complete removal presupposes that dry removal of non-embedded surface dirt is unacceptable and the surface aesthetic is compromised by the presence of embedded dirt, necessitating wet or solvent based cleaning methods. Implicit in this approach are more difficult questions: How important is the integrity of the original paint? Can and should we consider cleaning methods which prioritise the clean appearance of the surface but compromise the surface skin of the paint in the pursuit of conservation goals (Fig. 9)?

Decisions about the conservation and presentation of works of art involve a wider range of criteria, may be collection based, consider the artist intention or not, and may also be influenced by the age of the work. In some cases the degradation and soiling of a paint surface might be valued as ‘patina’. Conservators at the Guggenheim Museum remarked after investigation of Ad Reinhardt’s monochrome paintings that we must “begin to accept signs of age on modern paintings, just as we do for historical works” even if this is at odds with the original intention of the artist (Van de Vall et al. 2011).[6]

The conservators’ task to evaluate risks to the oil paint surface and desire to make the image legible is centuries old. Students in painting conservation begin by reading Feller et al. (1985), Hedley, Michalski (1990) and Phenix (1998), and all conservators navigate the practical challenges of exploiting narrow boundary

[6]http://archive-org.com/page/491723/2012-10-21/http://www.guggenheim.org/new-york/collections/conservation/conservation-projects/axa-reinhardt

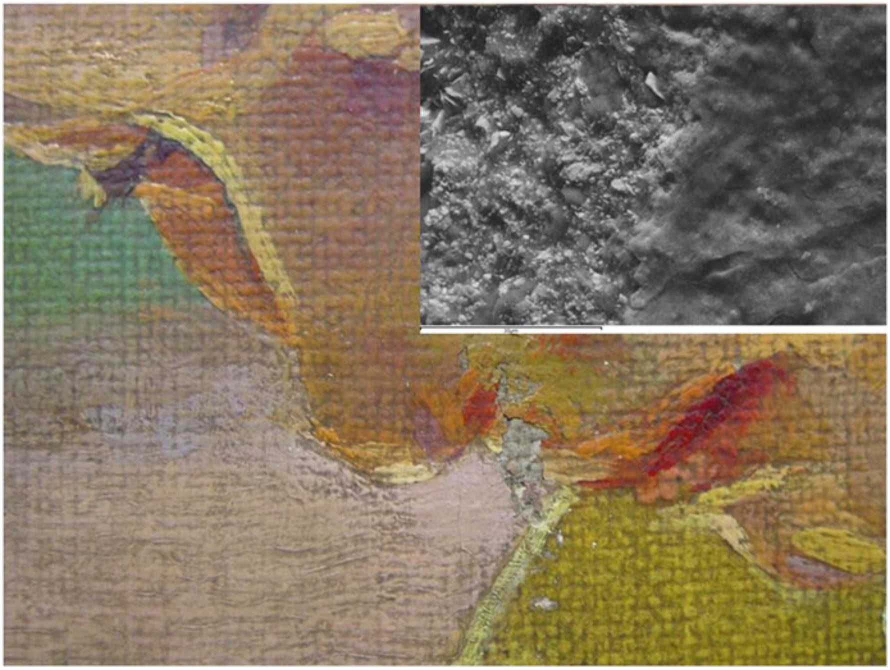

Fig. 9 Cleaning test of a detail from *Girl cleaning a Kettle* by F.G Heath, private collection (See CIA:1837 Painting treatment register, Department of Conservation & Technology, Courtauld Institute of Art.) showing the removal of dirt and medium skin by swabbing with saliva. Insert: SEM image of the surface on the edge of the test

between swelling oil paint during removal of oxidised resin and oil resin coatings, and oily repaint over original paint. The goal is to leave the original paint unaffected, and the cautious approach to cleaning is evidenced by the number of selectively cleaned paintings one encounters in practice. The use of gels that reduce capillary penetration and contain the effects of solvents and reagents to the surface can be a great advantage, and largely thanks to Richard Wolbers we now have an arsenal of methods for cleaning that can be applied to minimise the risks.

Conversely the effects of residues from cleaning reagents may not be immediately visible and require other techniques for analysis that present a whole range of interpretive challenges, and considerations for the longevity of oil paint.

Conclusion

The research described in this introduction that was summarised at the symposium and included in these proceedings serve as a starting point for further studies of the deterioration and treatment of modern oil paintings. Work so far has been based on technical investigation of case studies and experimental study of paint samples and has aimed to characterise the deterioration phenomena and its causes that include paint formulation and the influence of environmental agents. While some of the causal factors have been highlighted, there remain a number of questions that require further study, including the stability of paints in the long term, the influence of painting techniques and the development of practical approaches to treatment.

The detection of magnesium sulphate hydrate as the cause of water sensitivity in paint used by Jasper Johns' for Untitled*, 1964-'65* and other paintings made in the 1960s was useful but didn't solve the problem of how to remove dirt from highly sensitive paint surfaces. The study highlighted the problem associated with ageing of unvarnished paintings that are vulnerable to dirt and other environmental agents that lead to deterioration, and where the quality of the surface is compromised. Superficial changes due to accumulation of surface accretions, of materials that include fatty acid efflorescence, soap crusts and salts may alter the surface colour saturation and gloss, resulting in an overall loss of optical balance in the painting.

Conservation treatment of paintings that include passages of water sensitive paints requires an informed assessment of the condition of the surface and consideration of treatment of the whole surface that necessitates different approaches to passages of paint with the goal of even cleaning.

Water sensitive surfaces and paintings that exhibit recurring fatty acid efflorescence present special concerns for preventive conservation and display. Protection of vulnerable and potentially reactive paint from pollutant gasses and surface dirt is paramount to retain paintings made using these materials in a displayable condition. The arguments for passive preventive framing with glazing, and provision of filtered air conditioned environments present problems, where many works are too large to be glazed and the glazing compromises the aesthetic. Air conditioning is imperfect, increasingly expensive and most paintings are not displayed in clean and controlled environments that may in some cases be critical.

Where a recommendation is made for a possible method for treatment in a Chapter based on technical research, there is an underlying assumption that the methods are deployed with clear aesthetic goals in mind. The skill and judgement of the conservator is the most critical parameter of all. An evaluation of the balance between visual gains and risks to paint are integral to every conservation intervention.

Future study of the treatment of water sensitive oil paints might include an investigation of the efficacy of removing the water sensitive compounds from the surface of paint, consideration of risks to the surface of the paint and its optical qualities, and whether this presents a practical long term solution to water sensitivity. Alternatively, methods for protecting the most vulnerable paints might be considered as a preventive measure that could include application of an aesthetically acceptable coating that offers the most sensitive paints protection from dirt. The question of whether this coating could be removed without changing the surface aesthetic is important to ascertain, and whether this approach prevent the formation of further water soluble deterioration products would be useful to know.

These options remain to be investigated, and so too the mechanical changes in modern oil paints that impact on current and future conservation practice.

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