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A literature review of analytical techniques for materials characterisation of painted textiles—Part 1: categorising painted textiles, sampling and the use of optical tools

Keywords
textile; painted; conservation; microscopy; sampling; analysis

Introduction

How is a painted textile different to a stretched painted canvas, as Nancy Pollak suggests, 'what is a textile with paint to one conservator is paint with a textile to another'.[1] It may depend on the viewpoint of the conservator working with the object but, for example, the multiple thick layers of paint on stretched canvas can be very different from those on a banner or flag. Painted textiles come in many forms and include processional banners, flags, costume and accessories, theatre scenery, wall coverings, hangings, upholstery top covers, decorative arts, painted and embroidered pictures, religious objects including thangkas, pichhavai and Jain paintings and ancient Egyptian shrouds. These diverse objects are used in many different contexts and have a broad range of social, political, religious and decorative functions as shown in Fig. 1.

In common with stretched paintings, a variety of pigments, binders and preparatory layers are used, depending on the form, function, manufacture and context of the painted textiles. While some painted textiles have thick layers of paint, they often have fewer, thinner layers than stretched paintings on canvas. The texture of the textile may also be visible or masked entirely, indicating something of the paint thickness and number of layers. This is summarised well by Pollak who makes the point that there are many variations.[2] The textiles used are most commonly un-tensioned textiles, designed to be flexible and expected to drape and move, unlike paintings on canvas where the majority are stretched during making and display to produce a rigid support for the paint. The paint may be applied to only part of the surface of a painted textile and this has implications for its appearance, function, degradation and also conservation, as the painted and non-painted areas comprise two distinctly different surfaces. Some examples of typical condition problems of partially painted banners can be seen below in Fig. 2.

However, there is very little available information about the technical analysis of painted textiles nor the materials used and only around 30 readily accessible peer reviewed articles were identified as part of this study. These articles shed more light on the materials used in their making and, especially where supported with evidence from the wider literature, provide the focus for the discussions in this article. Important publications that provide a useful insight into painted textiles include two studies which focus on European painted cloths from the fourteenth to the twenty-first centuries, exploring their different functions, materials and methods of creation.[3] Otherwise, Paulocik and Flaherty carried out an exten-

1 Nancy R. Pollak, 'Moving Pictures: Adapting Painting Conservation Techniques to the Treatment of Painted Textiles', in *Tales in the Textile: The Conservation of Flags and other Symbolic Textiles, Preprints of the NATCC, Albany, 6–8 November 2003*, ed. Jan Vuori (New York: North American Textile Conservation Conference, 2003), 127–34.

2 Pollak, 'Moving Pictures', 128–29.

3 See, Caroline Villers, ed., *The Fabric of Images: European Paintings on Textile Supports in the Fourteenth and Fifteenth Centu-*

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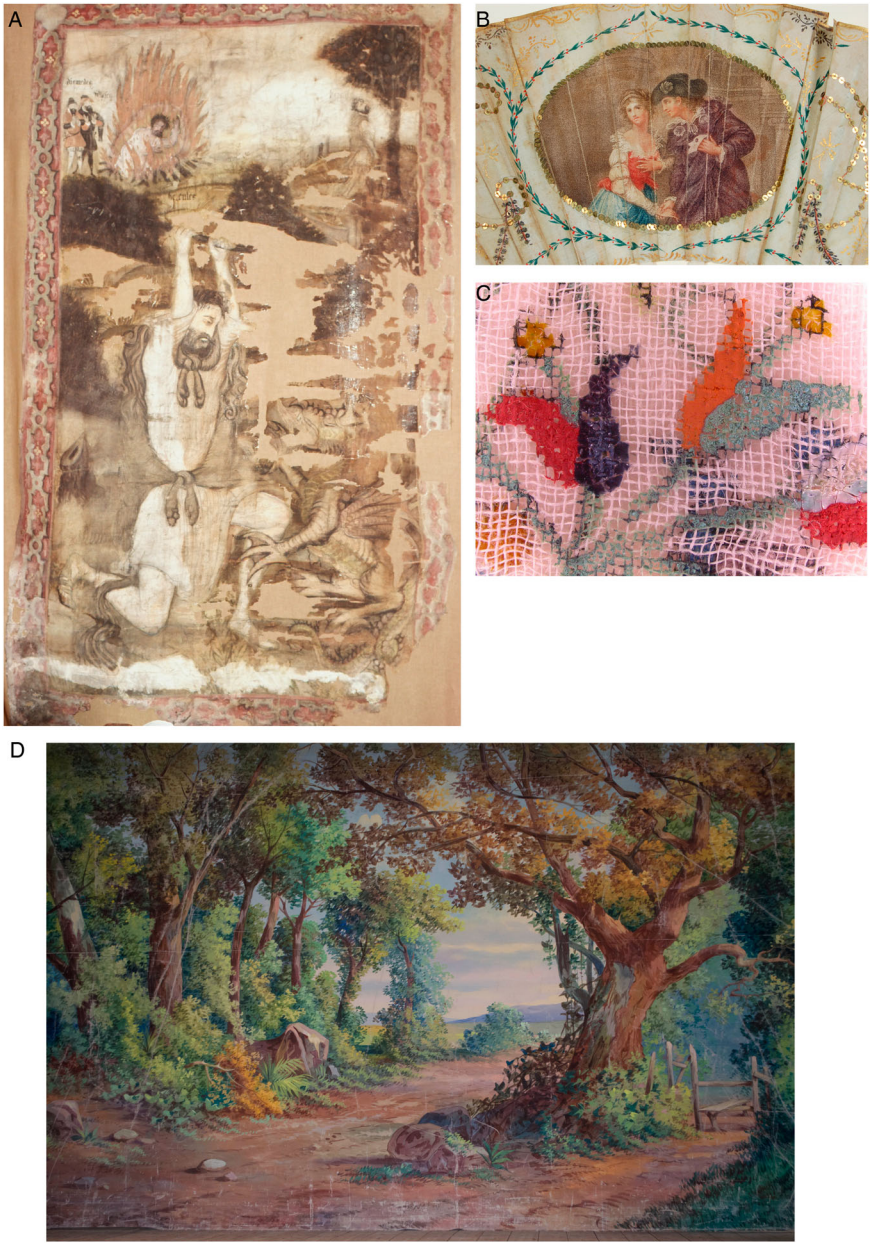

Fig. 1 A—A fifteenth-century painted cloth depicting the labours of Hercules, Colchester and Ipswich Museum Service ©Textile Conservation Foundation; B—Detail of an eighteenth-century fan (object number: N507), Bristol Museums, Galleries & Archives ©Textile Conservation Foundation; C—Detail of painted 1830 muslin apron (object number: T947), Bristol Museums, Galleries & Archives ©Textile Conservation Foundation. D – Woodland scene, backdrop from the Normansfield Theatre Collection, © Normanfield Theatre.

sive technical analysis of an eighteenth-century Chinese painted silk dress and compared it with European painted silks.[4] Furthermore, there have been some technical studies of painted banners,[5] and there is also a review on the conservation of thangkas which summarises studies of materials and techniques and the analysis carried out.[6] While most of the published work is focused on the conservation of painted textiles, some also include discussion about the materials used in their making and their deterioration characteristics.[7]

Developing a better understanding of the materials and methods of making is central to advancing the conservation of painted textiles. While

4 Chris Paulocik and Sean Flaherty, eds., *The Conservation of 18th-Century Painted Silk Dress*, Vol. 1 (New York: The Costume Institute, The Metropolitan Museum of Art/Graduate Program in Costume Studies, 1995).

5 Cordelia E. Rogerson and Frances J. Lennard, 'Billowing Silk and Bendable Binders: Is Flexibility the Key to Understanding Banner Behaviour?', in *Scienti-ries* (London: Archetype, 2000) and Nicola Costaras and Christina Young, eds., *Setting the Scene: European Painted Cloths from the Fourteenth to the Twenty-First Century* (London: Archetype Publications Ltd, 2013).

fic Analysis of Ancient and Historic Textiles: Informing Preservation, Display and Interpretation. First Annual Conference 13–15 July 2004, eds. Paul Wyeth and Rob Janaway, 12–18, 2004 (London: Archetype Publications, 2005), 12–18; Leanne Tonkin, 'Taking the Modern with the Traditional: Introducing the Challenges of Acrylic Emulsion Painted Banners', in *Taking the Rough with the Smooth: Issues and Solutions for Decorated Surfaces*, ed. Alison Fairhurst (London: V&A Museum/Icon Textile Group, 2012), 6–16; Averil M. Macdonald, Cordelia. E. Rogerson, Alun S. Vaughan, and Paul Wyeth, 'Raman Microspectroscopy Interrogating 19th- and 20th-Century Painted Trades Union Banners', in *Scientific Analysis of Ancient and Historic Textiles: Informing Preservation, Display and Interpretation, First Annual Conference 13–15 July 2004*, eds. Rob Janaway and Paul Wyeth (Winchester: Archetype, 2005), 222–9.

6 Sabine Cotte, 'Conservation of Thangkas – A Review of the Literature Since the 1970s', *Studies in Conservation* 56, no. 2 (2011): 81–93.

7 For example: Mika Takami and Dinah Eastop, 'The Conservation of a Korean Painted Silk Banner, C.1800: Paint Analysis and Support Via Solvent-Reactivated Acrylic Adhesive', in *ICOM CC 13th Triennial Meeting, Rio de Janeiro, 22–27 September 2002*, preprints, ed. Roy Vontobel (London: James & James, 2002), 747–54; Frances Lennard and Vivian Lochhead, 'United We Stand! The Conservation of Trade Union Banners', in *Tales in the Textile* (see note 1), 111–8; Jane Wild, 'To Catch an Emerald Thief: An Investigation of Pigments Using Scientific Analysis to Determine the Cause of Substrate Loss in Painted Textiles from Rajasthan', in *Taking the Rough with the Smooth* (see note 5), 33–40; Miriam McLeod, 'Powdery Paint: The Use of Funori with an Indian Jain Painting', in *Taking the Rough with the Smooth* (see note 5), 17–25; Elizabeth-Anne Haldane and Zenzie Tinker, 'Chinese Painted Silks for the European Market in the Victoria and Albert Museum, London: Conservation Treatment Developments', *Studies in Conservation, Supplement 1 (Reviews in Conservation)* 59, no. S1 (2014): S44–S47.

8 Pollak, 'Moving Pictures', 129.

Fig. 2 A—A badly deteriorated nineteenth-century banner with paint cracking and silk degradation; B—Detail of cracking and creasing on a nineteenth-century banner; C—A mid-twentieth-century banner with bloom, paint cracking and creasing; D—Splitting between the painted and unpainted layer on the mid-twentieth-century banner.

much valuable analytical research has been carried out in the study of paintings, there are many differences that need to be addressed: for example, the behaviour of materials on a flexible surface, the way the paint combines with the textile, and the textile and paint interface.[8] There has been comparatively little analytical research on painted textiles and it is rare for even basic characterisation of the materials and techniques to have been carried out so therefore the understanding of their constituent components and subsequent degradation is still limited.

This article is the first of two articles which together categorise painted textiles and review the methods of analysis used in their study. The aim of these articles is to draw together the existing literature on the analysis of painted textiles, highlight the current level of understanding and encourage further research to inform the conservation of painted textiles.

This study will first discuss different types of painted textiles as a starting point for further research before reviewing the analytical techniques. Part 1 covers the use of visual examination, focusing on those techniques that employ optical methods for characterisation of material properties including light microscopy, X-ray and scanning electron microscopy (SEM). Part 1 also details staining, where methods which depend on a material's chemical properties, and sample preparation, including the use of precision methods like ion-milling. Many of the analytical techniques discussed in Part 1 are familiar to conservators and some applications can be comparatively straightforward to carry out and interpret. Part 2, which will be published in the October 2017 issue of this *Journal*, will look at a wide range of spectroscopic and chromatographic techniques which rely on characterisation of chemical composition and are more complex to perform and interpret. Advances in techniques that that would be applicable to the study of painted textiles are also discussed, such as mapping in Fourier transform infrared (FTIR) spectroscopy Raman spectroscopy, surface enhanced Raman spectroscopy (SERS), surface-enhanced resonance

Raman spectroscopy (SERRS) and secondary ion mass spectrometry (SIMS). The principles of these detection methods are explained and include a discussion of their limitations and advantages, as well as how they complement each other. The value of using simple techniques such as low level microscopy and staining is also discussed. These review papers bring together the existing research on the analysis on painted textiles and provide the basis for future research.

Categorising painted textiles

Painted textiles can broadly be described as textiles with paint, where flexibility is a key characteristic. This fundamental premise informs and defines the conservation approaches for many painted textiles. In this study, painted textiles are separated into two groups:

(1) those on which paint covers the entire surface of the textile, and
(2) those where the paint partially covers the textile.

Group (1) textiles, where the paint covers the entire surface, are often referred to as 'paintings on textile supports' and encompass, for example, medieval cloths and banners, thangkas, and theatre scenery. Group (2)'s partially painted textiles include painted banners and flags, and paint-decorated textiles, and encompass a wide range of types of objects including costume, hangings, Chinese textiles, ancient Egyptian textiles, furnishings and pictures.

We believe that this kind of division is important to make because the two types of painted textile pose different conservation challenges. Notably, where the paint partially covers the textile, as in group (2), not only has the conservator to address the paint on textile interactions, but the different interactions of painted and unpainted areas on an object also pose particular issues.

The grouping also provides a starting point from which to assess levels of knowledge and understanding to inform both further areas of study and conservation decision-making. Of course, the divisions are somewhat blurred and there is a great deal of overlap between these two groups and some exceptions. As the division is based on the extent of the painted surface this does mean that certain types of objects can be found in both groups, such as banners. However it was felt that by drawing out some of the themes within a group it is possible to demonstrate some common methods and materials used, thereby both enhancing understanding and identifying some of the gaps in our knowledge.

Where traditional methods of making are well documented or continue to be practiced today, particularly in Asia, such as with thangkas and Chinese painted silks, there is a better understanding of the materials and methods used. Where the traditions of materials and making are no longer practiced, or where records are scant, our understanding of materials to date has been developed primarily through the analytical study and documenting of the conservation of the objects. This is particularly the case with nineteenth- and twentieth-century banners in the west. However, for all categories of painted textiles much more research is needed to better understand the materials, their composition and the factors affecting deterioration so as to inform any conservation plan. The next section provides a more detailed discussion of these categories of painted textile before the analytical techniques are reviewed.

Group (1)—textiles entirely covered with paint

Paintings on textile supports, or painted cloths, include medieval cloths and banners, theatre scenery, thangkas, pichavai, Jain paintings and wall coverings and hangings. The materials and methods of making in group (1) are perhaps the best understood of all painted textiles. These textiles are entirely

covered with paint and it is common to find paints with gums or protein-based binders on cellulose based textiles (generally linen, hemp or cotton) although occasionally silk and oil paints are known to have been used.

Medieval painted cloths from Europe are significant in the history of painting as they reflected the period of change from painting on wood to painting on canvas as the preferred support for western artists.[9] There a few surviving early examples, but there is also written documentary evidence for many of them, and technical studies of a number of those surviving examples are detailed in publications by Villers and Costaras and Young.[10]

Similarly, there are a few surviving European liturgical and processional banners or painted cloths that date back to the fourteenth, fifteenth and sixteenth centuries.[11] These painted textiles tended to be hung from a pole or batten or mounted on a wall, strainer or stretcher. They are more commonly single sided but some examples are double-sided and cellulose-based fabrics such as linen or cotton are commonly found although other textile fibres, such as silk, were used for early processional cloths.[12] They commonly also have a protein binding medium such as animal glue, egg, or a polysaccharide based gum, and oil-based pigments were occasionally used but less often than the proteinaceous mediums.[13] The appearance of the surface is usually matt unless it has been varnished.

The presence of a size and the thickness of a ground layer, if used, are important factors impacting on the degree of flexibility and can help in our understanding of whether these banners were designed to be rolled. This has been discussed in a number of papers and Villers notes that fourteenth-century paintings on a linen support had a thickly applied ground layer of calcium carbonate filling the interstices of the weave to provide a smooth surface for painting that would have made it impossible to roll or fold.[14] A similar observation was made by Kleiner in the analysis of the Spinello banner which was designed to be held in a rigid frame.[15] For rolled cloth the Renaissance artist Cennino Cennini recommended the use of only animal glue size and a very thin layer of gesso sottile (calcium sulphate) mixed with starch, sugar or animal glue as a ground. He also advocated scraping the canvas to ensure the ground layer was not too thick, as thin layers of paint were important to maintain flexibility.[16] On fourteenth- and fifteenth-century painted cloths from Northern Europe, most notably from the Netherlands, it was not uncommon to use only a size of animal glue (with no ground) with the paint applied directly on top.[17] On cloths where paint layers are thinner or fewer in number or there is no ground, the texture of the textile is often evident,[18] and sometimes these cloths are described as stained cloths because the paint penetrates through the textile, indicating few or no ground layers.[19]

Some painted cloths are varnished. This is maybe partly to do with function such as they were to be carried outside and needed to be protected against the elements. Villers suggests that the medium also influenced whether a varnish could be used.[20] Painted cloths from the fourteenth and fifteenth centuries where the binding medium was a gum or glue could not be varnished and have a characteristically matt appearance, whereas those covered with a gesso ground and where the medium was likely to be egg tempera could be varnished. Thus, it was common for Italian painted cloths of this period to be varnished whereas those from Northern Europe were unvarnished, reflecting the different binders used.[21]

The preparation of the textile has an important bearing on the way the object can be used and how it is handled. The tradition for the creation of thangkas is comparatively well documented in the conservation literature. They are briefly mentioned here as methods of making show parallels

9 'Introduction', *The Fabric of Images*, vii (see note 3).

10 Villers, *The Fabric of Images*; Costaras and Young, *Setting the Scene*.

11 Michael Bury, 'Documentary Evidence for the Materials and Handling of Banners, Principally in Umbria, in the Fifteenth and Early Sixteenth Centuries', in *The Fabric of Images* (see note 3), 19–30; Sarah Kleiner, 'A Technical Study of a Late Fourteenth-Century Double-Sided Processional Banner by Spinello Aretino', in *Setting the Scene* (see note 3), 69–76.

12 See, for example, Jo Kirby, 'The Trade and Import of Painted Cloths from the Fifteenth- to the Sixteenth-Century London' and Kleiner, 'Spinello Aretino', in *Setting the Scene*, 58–68, 69–76.

13 Bury, 'Documentary Evidence', 20; Villers, *The Fabric of Images*, vii–ix.

14 Caroline Villers, 'Four Scenes of Passion Painted in Florence around 1400', *The Fabric of Images*, 4 (see note 3).

15 Kleiner, 'Spinello Aretino', 73.

16 Cennini, Cennino, *The Craftman's Handbook: "Il Libro Dell'arte' Cennino d'Andrea Cennini"*, translated by D.V. Thompson (New York: Dover Publications Inc., 1954), 103–4; Villers, *Fabric of Images*, 4.

17 Jo Kirby, 'The Trade and Import of Painted Cloths', 58–68; Villers, *The Fabric of Images*, vii–ix.

18 Charlotte Hale, 'The Technique and Materials of the Intercession of Christ and the Virgin Attributed to Lorenzo Monaco', in *The Fabric of Images*, 31–41; Villers, *The Fabric of Images*, viii.

19 Nicolas Mander, 'The Painted Cloths at Owlpen Manor, Gloucestershire', in *Setting the Scene*, 24–32.

20 Villers, *The Fabric of Images*, vii–ix; Cennini, *The Craftman's Handbook*, 104; Kleiner, 'Spinello Aretino', 75.

21 Villers, *The Fabric of Images*, viii.

with the textiles described above.[22] An animal glue and chalk preparation layer is applied to both sides of the textile (usually cotton) which is then burnished to provide a very smooth surface for the paint. The paint is firmly bound around the textile fibres and provides a flexible textile which can be rolled,[23] and is similar to the methods described by Villers for fourteenth-century painted cloths.

Makers of painted scenery have clearly exploited different methods of preparation for different functions, such as demonstrated in the flats of the nineteenth- and early twentieth-century Normansfield theatre scenery. Cloths that were intended to be rolled have been found to have thinner applications of ground or no ground at all, whereas the flats which were attached to strainers had thicker application of ground.[24] Traditions in theatre scenery painting changed very little from the nineteenth century to the 1970s, so much can be learnt from modern practice which provides valuable insights into the materials, methods of making and the reasons behind these choices.[25] Such traditions are still in living memory and provide an important source of knowledge and understanding. Furthermore, the studies already undertaken on paintings on textile supports, along with written sources and well-established making traditions provide valuable insights and a good foundation for further research and development of conservation methods.

Group (2)—textiles partially covered with paint

This category includes two broad groups: painted banners and flags, and paint-decorated textiles.

1 Banners and flags

Banners and flags include a large proportion that were made to be processed or flown. Banners are designed to be hung from a horizontal top pole and side supports may be used when the banners are processed, whereas flags more commonly hang from the side or hoist edge and are carried on a single pole or staff. They have been used for centuries to proclaim identity and allegiance to societies, religious groups, regiments, etc. and notably from the nineteenth century, by trade unions to promote their quest for social reforms.[26] Often banners and flags are double-sided so that they were visible from all angles when they were carried. The paint may be applied to both faces of a single piece of fabric or sometimes two layers of painted fabric are joined together to make a double-sided banner. However, the paint does not cover the entire surface, leaving unpainted areas of textile.

In the UK banners are one of the most prolific types of painted textiles in museum collections. Over 2500 banners (not including military and religious banners) have been recorded so far in the National Banner Survey, managed by the People's History Museum in Manchester, of which at least a third are painted.[27] These include Scottish covenanting banners from the seventeenth century, and many more friendly society and trade union banners dating from the nineteenth century to the present day.

Despite such a prolificacy it is still very rare to find books, recipes and documents that detail materials and methods of making of nineteenth- and twentieth-century British manufactured banners, unlike in the case of stretched paintings where there is a great deal surviving information.[28] Commercial records are scant, and where seminal publications by Gorman, Edwards and Emery briefly mention details of the production methods of commercially made banners, in particular those made by George Tutill, a prolific banner maker from the late nineteenth and early twentieth centuries, not much is included about the materials.[29] This paucity of information is thought to be in part due to limited research into the surviving archival records, and also the protection of trade secrets.

22 For example, Sabine Cotte, 'An Evaluation of the Role of Semi-transparent Relining in the Conservation of Thangka Paintings', *Studies in Conservation* 52 (2007): 2–12; Cotte, 'Conservation of Thangkas', 81–93; Jacki Elgar, 'Tibetan Thang Kas: An Overview', *The Paper Conservator* 30, no. 1 (2006): 99–114; C.B. Gupta, 'Conservation of Thangka Paintings: A Cultural Heritage from the Himalayan Region', *Proceedings of the Forum on the Conservation of Thangkas, Special Session of the ICOM-CC 15th Triennial Conference, New Delhi, India, September 26, 2008*, eds. Mary Ballard and Carole Dignard (Delhi: ICOM-CC, 2009), 62–72; Huntington, John C, 'The Technique of Tibetan Paintings', *Studies in Conservation* 15, no. 2 (1970): 122–33. Ann Shaftel, 'Notes on the Technique of Tibetan Thangkas', *Journal of the American Institute for Conservation* 25, no. 2 (1986): 97–103.

23 Elgar, 'Tibetan Thang Kas: An Overview,' 99–114.

24 Karen Thompson and Frances Lennard, 'Normansfield Theatre Scenery: Materials and Construction Revealed through Conservation', in *Setting the Scene*, 108–15.

25 F. Lloyds, *Practical Guide to Scene Painting and Painting in Distemper* (London: Sir Issac Pitman & Sons Ltd., 1875); Hilary Vernon-Smith, 'The Changing Practice of Scenic Painters in England', in *Setting the Scene*, 92–8.

26 Nick Mansfield, 'The Contribution of the National Banner Survey to Debates on Nineteenth-Century Popular Politics', *Visual Resources: An International Journal of Documentation* 24, no. 2 (2008): 133–43.

27 Nick Mansfield, Ruth Stevens, Karen Thompson, Sarah Gore and Ian Murray, *National Banner Survey: The Report* (Manchester: National Museum of Labour History, 1999).

28 Arie Wallert, Erma Hermens, and Marja Peek, eds., *Historical Painting Techniques, Materials, and Studio Practice*, Symposium, University of Leiden, The Netherlands, 26–29 June 1995 (Los Angeles, CA: Getty Conservation Institute, 1995), 117–26; Pollak, 'Moving Pictures', 127–34.

Similarly, we are not aware of records of materials and making for flags for large organisations such as the military and many other early banners and flags were made by sign-writers or were homemade so little is known about their making. As a result, much of our understanding of the materials and making of banners and flags comes from a few technical studies and information gleaned during the course of conservation.

Banners and flags were often stored rolled so needed to be flexible. They could be very large and strong textile materials were needed as the paint would add extra weight.

Silk is predominantly used for painted banners and flags and is still used by banner makers today.[30] However, other textile fibres were sometimes used and some early trade society banners were painted on linen, including probably the most well-known, the early Tin-Plate Workers' banners as well as early Italian examples such as the Savonarola banner.[31] There are also examples of banners made of wool, cotton and, later, synthetic and man-made fibres such as polyester or rayon.

The preparation of the surface of a painted banner or flag, whether a size is applied to the textile before the paint layers for example, is little understood. The way the paint bonds with the textile is one factor that is crucial to achieving a flexible but stable painted surface. From research carried out on some examples of oil-painted nineteenth- and twentieth-century banners it appears that little or no size is present as the ground layer coats all surfaces of the fibres. In examples of George Kenning and Sons banners, linseed oil ground layers were thought to be applied directly to the silk.[32] This has also been observed on early banners with tempera paints and modern ones with acrylic paints.[33] Contemporary banner makers suggest that it is very important for flexibility to ensure that the paint combines intimately with the textile rather than forming a distinct layer on the surface as is the case with many stretched paintings.[34] However, this is not the case for all banners, and Rogerson and Lennard identified India rubber, thought also to promote flexibility, on one of the nineteenth-century oil painted Tutill banners examined.[35] This was particularly significant as in 1861 Tutill raised a patent for the use of India rubber as a preparatory layer and such material had not previously been identified—the India rubber coated the fibres ensuring that the paint did not impregnate the weave structure. In other banners, it is apparent that different preparation methods and materials were used on the same banner, as observed by Smith et al. on a 1950s Tutill banner.[36] The presence of an organic layer coating the fibres as the preparation layer or size is evident in some areas of this banner while in others inorganic materials visibly coat the fibres, indicating a thin layer on the silk, and yet in other parts there is no preparation layer at all. This is an important aspect of the making of banners that needs to be investigated further, and, as Pollak describes:

> … the thinner and more saturating paint layers of a painted textile, however, often result in the painted fabric acting as a whole, and aging differences can be seen between the painted and unpainted fabric, as opposed to within the painted structure itself.

She explains that this differs from what she terms easel paintings, where the canvas is separated from the ground and paints layers by the size, meaning that they act together somewhat separately from the canvas.[37]

A wide variety of paints is associated with banners and flags and both traditional and modern pigments and binding media have been used. There is a long tradition of using oil paints for banners, with lead white grounds most frequently found on commercial banners.[38] Commercial banner makers developed their tradition at the time when pigment and binder development was at its peak between 1800 and 1950, and so they would have had access to a huge range of materials and it might be expected that this would be

29 John Gorman, *Banner Bright* (Essex: Scorpion Publishing Ltd, 1986); Hazel Edwards, *Follow the Banner: An Illustrated Catalogue of the Northumberland Miners' Banners* (Northumberland: Carcanet Press Ltd, 1997); Norman Emery, *Banners of the Durham Coalfield* (Gloucestershire: Sutton Publishing Limited, 1998).

30 Rogerson and Lennard, 'Billowing Silk and Bendable Binders', 12–18; Lennard and Lochhead, 'United We Stand! The Conservation of Trade Union Banners', 111–8.

31 Frances Lennard, 'The Conservation of the United Tin Plate Workers' Society Banner', *The Conservator*, no. 13 (1989): 3–7; Peoples' History Museum http://www.phm.org.uk/keemu/display.php?irn=10378 (accessed 1 June 2016); Mary Westerman Bulgarella and Susanna Conti, 'The Conservation of a Savonarola's Painted Banner', in *Tales in the Textile* (see note 1), 135–41.

32 Rogerson and Lennard, 'Billowing Silk and Bendable Binders', 14.

33 Tonkin, 'Taking the Modern with the Traditional'; Pollak, 'Moving Pictures', 135–41.

34 Personal communication with Durham Bannermakers, March 23, 2015.

35 Rogerson and Lennard, 'Billowing Silk and Bendable Binders', 12–18.

36 Margaret Smith, Karen Thompson and Erma Hermens, 'Breaking Down Banners – Analytical Approaches to Determining the Materials of Painted Banners', *Heritage Science* 4, no. 23 (2016): https://heritagesciencejournal.springeropen.com/articles/10.1186/s40494-016-0095-0 (accessed 4 December 2016).

37 Pollak, 'Moving Pictures', 129.

38 Rogerson and Lennard, 'Billowing Silk and Bendable Binders', 12–8; Macdonald et al., 'Raman Microspectroscopy', 222–9.

reflected in banner collections but this has not yet been documented. Modern acrylics are more widely associated with banners from the late twentieth century and are commonly used today. A range of other paint types have also been used including watercolour and gilding. Paints with animal glue and egg binder tend to be used in Asian banners reflecting traditions in choices of materials but, these have not often been identified on British trade union banners from the nineteenth century except where gilding has been used.[39]

Some banners have been varnished to protect them from the elements depending on the nature of the paints used but generally this is uncommon. Rogerson found evidence of a varnish layer in a cotton banner painted with oil paints from 1832 which was thought to have been added as a protective coating for carrying outside but, as Rogerson suggests, this is likely to have rendered it less flexible.[40] Where varnish is not commonly found on oil painted banners of the nineteenth and twentieth centuries except to enhance colour in details of the paint,[41] modern banner makers use acrylic varnishes to provide UV protection as these are more flexible than the earlier resin-based varnishes.[42]

In summary, our understanding of the methods and materials used in European banners and flags is variable and technical analysis has been relatively sparse so it is difficult to gain a clear understanding of the making of these objects. Most evidence comes from the study of nineteenth- and twentieth-century British banners and much can be drawn on for the study of banners and flags more widely.

39 Mika Takami and Paul Wyeth, 'Studies on a Korean Painted Silk Banner: Identification of Layer Structure, Binding Medium and Pigments', *Strengthening the Bond, Science & Textiles Preprints, North American Textile Conservation Conference*, ed. V.J. Whelan (Philadelphia, PA: NATCC, 2003), 133–42.

40 Cordelia Rogerson, 'The Conservation of a "One Side" Painted Cotton Banner', paper presented at *Painted Textiles, Forum of the UKIC textile Section, Museum of London, 21 April 1997*, ed. Vivian Lochhead (London: UKIC, 1997).

41 Rogerson and Lennard, 'Billowing Silk and Bendable Binders', 12–8; Smith et al., 'Breaking Down Banners'.

42 Personal communication with Durham Bannermakers, March 23, 2015.

2 Other paint-decorated textiles

This group comprises of decorated silks in the form of costume, furniture top covers, painted hangings and pictures, including painted and embroidered pictures and hangings, and decorated linen, such as in the form of ancient Egyptian textile shrouds. The paint is usually applied to one side of the textile and does not cover the entire surface. This group can be subdivided into textiles used for clothing and furnishing where flexibility was particularly important to enable these fabrics to be draped, pleated and gathered; hangings where the textile may have needed to be stored rolled and decorated textiles as ornament such as pictures which may be mounted in a frame.

Some of the earliest painted textiles originate from China. Traditions of figure painting on silk date back many thousands of years and examples include painted silk from the Warring States period (475–221BC) and Dunhuang textiles from the eighth century, both representing traditional materials and methods of making still used today.[43] These long established traditions provide useful starting points to develop an understanding of other paint-decorated textiles, and although many of these early painted silk fabrics originated in Asia, there are also later European equivalents.

Differences between the Chinese and European painted silks are discussed in a number of publications on costume.[44] Wider loom width, a softer 'hand' of the fabric and weaving marks such as the 'temple holes' (a tool that keeps the woven fabric evenly spaced) and the use of green and yellow silk selvedge were observed on the Chinese silks when compared to the European silks. Underdrawings have been identified on several silks; these are both printed and painted on Chinese silks whereas only printed underdrawings have been observed on the European ones. The inks on the Chinese textiles tend to seep through to the back whereas this is not found on the European examples. The way the paint is applied over the underdrawings varies too. The use of white grounds, usually lead white but occasionally calcium, is seen on the Chinese silks whereas the European examples do not appear to have a ground and the paint is applied directly to the silk. Thicker

43 Hanyu Gao, *Chinese textile designs*, trans. Rosemary Scott and Susan Whitfield (London: Viking, 1992), 40–1; Helen Wang, Helen Persson, and Frances Wood, *Dunhuang Textiles in London: A History of the Collection* (British Museum), https://www.britishmuseum.org/pdf/19_Wang-Persson-Wood.pdf; The Stein Collection at the Victoria and Albert Museum, London, http://www.vam.ac.uk/page/s/stein-collection/ (accessed 4 December 2016). Documentation of the techniques used in Chinese silk painting is available on the V&A website: http://www.vam.ac.uk/content/exhibitions/masterpieces-of-chinese-painting/video-how-a-silk-painting-was-made/ (accessed 4 December 2016).

pigments and dye pastes were observed on the Chinese examples. Pigment materials used have been identified to include organic dyes, lake pigments, inorganic mineral pigments and metallic paints. Generally, similar pigments were used, with the exception of the type of brown pigment (iron oxide in the Chinese examples and organic minerals in European examples) and silver outlines and accents which were only used on the Chinese examples and are believed to originate from Indian textiles.[45]

From Chinese painting manuals, it would be expected that animal and vegetable glues would be used to prepare the paints.[46] Study of eighteenth-century painted silks has confirmed the presence of animal glue on examples from China, and egg tempera has also been identified on an eighteenth-century painted chair cover of Chinese origin.[47] Plant gum resin has been identified on a painted silk dress thought to be of European origin.[48]

Some ancient Egyptian textiles are decorated with paint. They were used for clothing, or for ceremonial or symbolic purposes such as burial shrouds. They were often painted linen, with a gum, animal glue or egg binder. Chalk and gum ground layers were commonly used as well as a wide range of earth pigments. Lake pigments such as madder as well as gold have been identified through analytical study of these textiles.[49]

An overview of the two groups of painted textiles, showing the types of objects and materials commonly found, are represented below in Fig. 3:

What is clear from this study is that functional use (e.g. carried, rolled, pleated and draped) has a significant bearing on the materials used and how they were applied. This is an important consideration as it has consequences for what kinds of deterioration can take place and also impacts on conservation approaches. Characterising painted textiles in this way can help to bring out common features in terms of materials used in their making and provides useful context in which to place further analysis and study of painted textiles. Whether or not the paint covers the entire surface, the inclusion of ground or preparatory layers or lack of them and the type of paint are significant. It is clear that where knowledge of materials and methods of making are little known, analysis has helped inform our understanding of painted textiles. This understanding of the materials and their condition, both through observation and analytical analysis from macro to nano level, is crucial in order to develop and inform conservation and curatorial practice. This next section of this article will review sampling and optical techniques that have been used to identify materials and agents of deterioration and also identifies new techniques that could improve the study of painted textiles. The techniques detailed are applicable to all painted textiles, although some techniques may be more suitable for study of the textile combined with paint and others for study of the individual components or materials.

Analytical investigation techniques

Table 1 illustrates the range of analytical techniques that has been used to study painted textiles. The mechanisms and scope of the instrumentation have been described in detail below, in order to demonstrate how materials have been identified and measured by specific instruments. A summary of the techniques and their function is shown in Table 2.

1 Visual observation and stereomicroscopy

Visual observation and low level magnification microscopy are invaluable as the first step in assessing the condition of an object and from these observations it is sometimes possible to determine a broad categorisation of materials, the construction, weave and painting techniques used as well as identifying areas for further analysis. Close study of the textile-paint interface can, for example, indicate evidence of a possible preparatory layer.

44 See Paulocik and Flaherty, *The Conservation of 18th-Century Painted Silk Dress*; Haldane and Tinker, 'Chinese Painted Silks', S44–7.

45 Maruta Skelton and Leanna Lee-Whitman, 'A Systematic Method for Differentiating between 18th Century Painted-Printed Chinese and Western Silks', *Advances in Chemistry Series* 212 (1986): 131–51; Paulocik and Flaherty, *The Conservation of 18th-Century Painted Silk Dress*.

46 Maruta Skelton, 'Use of Qualitative Non-destructive X-Ray Fluorescence Analysis in the Characterisation of Chinese of Western Provence for 18th-Century Painted/Printed Silks', in Paulocik and Flaherty, *The Conservation of 18th-Century Painted Silk Dress*, 12.

47 Sara Reiter and Beth Price, 'An 18th-Century Chinese Painted Silk Dress from the Philadelphia Museum of Art: History and Condition Analysis', in Paulocik and Flaherty, eds., *The Conservation of 18th-Century Painted Silk Dress*, 21–36; Macdonald et al., 'Raman Microspectroscopy', 222–9.

48 James Martin, 'Unravelling the Material History of Painted Silk Textiles through Micro-analysis', in Paulocik and Flaherty, *The Conservation of 18th-Century Painted Silk Dress*, 46–50.

49 Pippa Cruickshank, Helene Delaunay and Lynne Harrison, 'Painted Textiles and Canvas Paintings: A Collaborative Approach to Lining and Mounting', *The Conservator* 30 (2007): 5–18; Lee, Lorna, 'Analysis – an aid to conservation' paper presented at *Painted Textiles, Forum of the UKIC textile Section, Museum of London, 21 April 1997*, ed. Vivian Lochhead (London: UKIC, 1997); Lynda Hillyer, 'The Conservation of a Group of Painted Mummy Cloths from Roman Egypt', *Studies in Conservation* 29 (1984): 1–9; Monique Pullen, 'The Conservation of 'The Pink Lady', a Roman Egyptian painted linen shroud', in Lochhead, *Painted Textiles*.

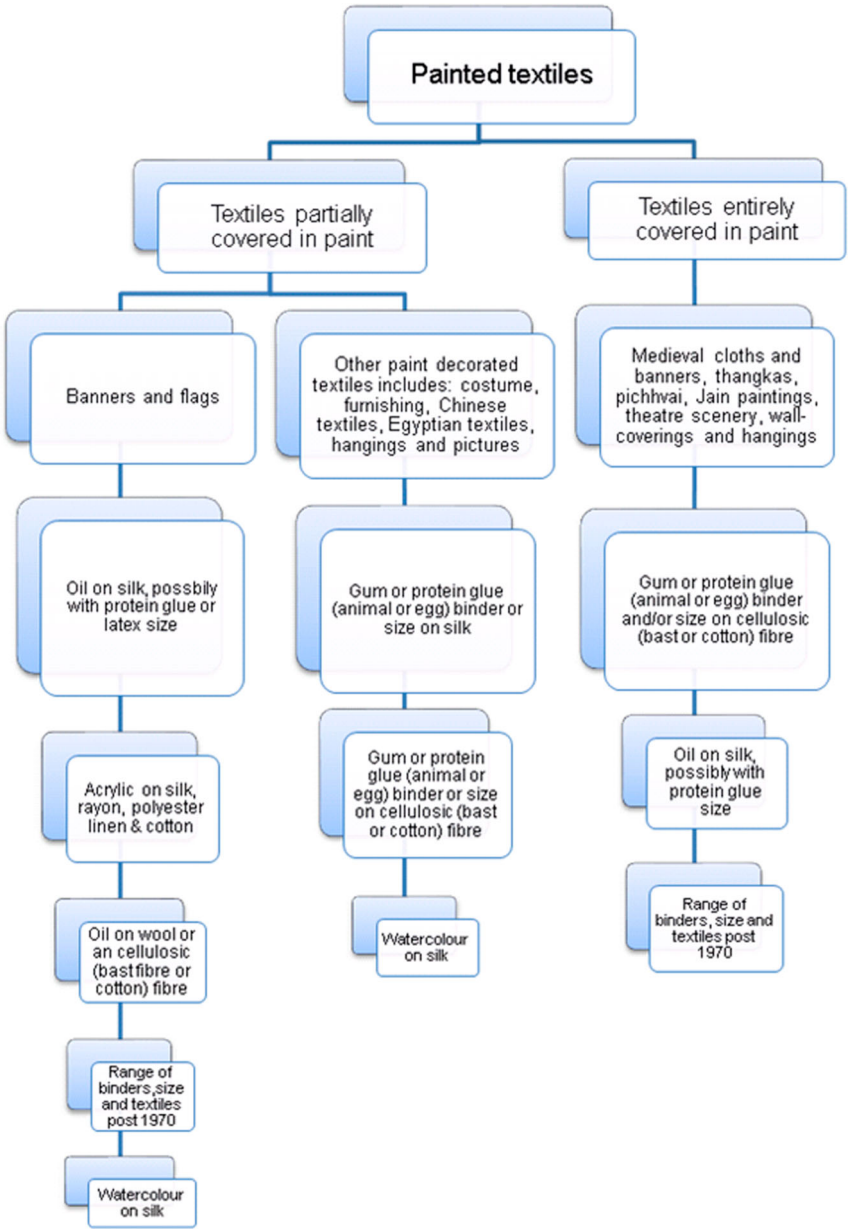

Fig. 3 Classification showing the commonly found textiles, binders and size in the two categories of painted textiles. The size of the boxes for materials indicates their relative prevalence.

The condition of the textile, paint and paint-textile interfaces including presence of soiling, creasing, splits, delamination of paint layers and abrasion can be documented based on visual and low-level microscopy.

Stereomicroscopy is a good next step to give a magnified view of the sample before moving on to more detailed study using light microscopy and SEM. Stereomicroscopy uses reflected light and has a relatively low magnification of typically ×5 to ×70 but can be up to ×250. It provides the opportunity to see in more detail paint techniques as well as the condition of the paint and textile such as cracking, delamination and soiling.

2 Sample preparation

An important aspect of analytical analysis is the consideration of whether to take samples. Sampling may be necessary in order to gain details of the paint

Table 1 Summary of techniques reported in the literature used to study painted textiles cited in article Part 1 and Part 2.

Author	Object	Microscopy	X-radiography	SEM	SEM-EDX/EDS	XRD	XRF	FTIR/FTIR-ATR	Raman	GC	HPLC/TLC	IR-Reflectography
Skelton & Lee-Whitman	painted silk											
Lennard, 1989	banner	✓		✓								
Bilson, 1992	Roman Egyptian shroud	✓	✓	✓	✓							
Pollak, 1993	painted silk dress	✓										
Reiter & Price, 1995	painted silk dress	✓		✓	✓	✓	✓	✓			✓	
Martin, 1995	painted silk dress											
McGlinchey, 1995	painted silk											
Lee, 1997	Egyptian textiles	✓			✓	✓	✓	✓				
Rogerson & Eastop, 1999	textiles inc. painted	✓										
Villers, 2000	painted cloth		✓									
Hale, 2000	painted cloth	✓	✓		✓	✓						
Schießl et al, 2000	painted cloth	✓					✓	✓				
Takami & Eastop, 2002	banner	✓			✓				✓			
Takami & Wyeth, 2002	banner	✓			✓				✓			
Macdonald et al. 2003	painted silk chair cover	✓					✓		✓			
Rode, 2003	banner	✓		✓	✓			✓		✓		
Macdonald et al., 2005	banner	✓							✓			
Rogerson & Lennard, 2005	banner	✓		✓				✓			✓	
Rezić et al., 2006	banner	✓								✓		
Macdonald & Wyeth, 2006	painted silk chair cover	✓							✓			
O'Conner & Brookes, 2007	textile objects		✓									
Abdel-Kareem et al., 2008	Egyptian textiles	✓		✓	✓			✓				
McLeod, 2012	Indian Jain Painting	✓		✓								
Tonkin, 2012	banner						✓					
Wild, 2012	Pichhvai	✓			✓							
Lennard et al., 2013	flag	✓					✓	✓			✓	
Kleiner, 2013	fourteenth-century banner	✓	✓						✓	✓		
Thompson & Lennard, 2013	theatre scenery				✓							
Ernst, 2014	thangka								✓			✓
Smith et al., 2016	banner	✓		✓	✓			✓	✓			

Table 2 Optical and chemical analytical techniques used in the study of painted textiles.

Method/Technique	Preparation	Ease of Use	Information Gained	Qualify/ Quantify
Visual examination	Flat surface and good illumination	Basic to skilled	Overall picture & surface detail	
Staining and solubility tests	Loose or embedded samples	Basic to skilled	Identification of materials classes & fibres	✓
Low level microscopy	Flat surface and good illumination	Basic microscope	Overall picture, surface detail & magnified ×10	✓
High level microscopy (Polarised, ultra-violet)	Small sample sometimes embedded	Skilled	Detail of structure magnified ×1000 Detail down to around 1 μm	✓
SEM	Sample mounted or embedded	Highly skilled	Detail of structure to around 1nm	✓
SEM-EDX	Sample mounted or embedded	Highly skilled	Identification of elements	✓✓

layers and their interaction with the textile. Taking any sample from a painted textile is challenging, due to the fact that the textile is not rigid and also that the paint layers are extremely thin (often around 10 μm). This means that it is difficult to achieve a cross-section of the paint layers alone where the paint layers are thin as it causes the paint to crumble. This contrasts with samples from stretched paintings where the layers are usually much thicker.[50] On an undamaged textile it may be possible to take just a flake of paint from unobtrusive areas. More information can be gleaned if a cross-section sample is taken through all layers including the textile. However, this is usually only possible if there is damage, or where the paint extends to the edges of the textile, which may limit sampling opportunities.

50 Smith et al., 'Breaking Down Banners'.

Traditionally sample fragments from paintings and painted objects are embedded in blocks of a polymer resin. This confers stability on the fragile sample and also allows for easier handing. Such techniques of preparing and embedding samples of painted and unpainted textiles in resin blocks have been reported in the literature both in comparing methodologies of preparation and in preparation for analysis.[51] These techniques were documented and their value highlighted in the 1990s by Rogerson and Eastop for the study of painted textiles. Other work by Rogerson and Lennard has provided, in particular through sampling, the most substantial published work on materials used in nineteenth-century banners by commercial banner makers, as they were able to show paint and preparation layers not previously documented.[52] The effectiveness of sampling the paint layers alone has not been discussed in the painted textile papers but it can be challenging to get meaningful samples because of the thin layers present in painted textiles.

51 Cordelia Rogerson and Dinah Eastop, 'The Application of Cross-sections in the Analysis of Historic Textiles', *The Conservator* 23 (1999): 49–56; Mika Takami and Paul Wyeth, 'Studies on a Korean Painted Silk Banner', 133–42; Macdonald et al., 'Raman Microspectroscopy', 222–9.

52 Rogerson and Eastop, 'The Application of Cross-sections in the Analysis of Historic Textiles'; Rogerson and Lennard, 'Billowing Silk and Bendable Binders', 12–18.

The resin blocks, containing a sample, are polished or cut by a microtome so that the stratigraphy of the sample can be viewed and analysed. Conventional mechanical polishing or cutting techniques can result in scratching or smearing of the resin blocks causing interference during analysis. When full cross-sections are taken, additional challenges resulting from the different hardness of the textile, pigments and resin can make polishing problematic. For example, polishing can damage the soft fibres more easily than the pigments or resin resulting in a distorted fibre layer. However higher quality block faces have been achieved using microtomy,[53] and the use of ion-milling to produce particularly high quality, embedded paint cross-sections was first proposed by Boon and Asahina in 2006,[54] when they reported on greatly improved SEM images of samples with seventeenth-century lead white and modern acrylic paints. This was further demonstrated by Smith et al. where the authors reported on ion-milling followed by SEM with

53 Macdonald et al., 'Raman Microspectroscopy', 225.

54 J. J. Boon and S. Asahina, 'Surface Preparation of Cross Sections from Traditional and Modern Paint Using the Argon Ion Milling Polishing CP

energy-dispersive X-ray spectroscopy (SEM-EDX) analysis of embedded cross-sections from a painted banner.[55] The requirement to achieve a smooth surface is crucial if instrument mapping functions are to be efficiently used[56] and Part 2 of this review provides more detail on these requirements.

In painted textiles, sampling may be difficult where the painted design or area of interest lies in the centre and where no damage is present or where sampling is not possible. The use of *in situ* analysis using portable instrumentation may be desirable or indeed may be the only option for such areas. Portable equipment such as Raman, FTIR, and X-ray fluorescence (XRF) means that an instrument can be taken to an object, negating the need for sampling.[57] However, the depth of analysis and spatial resolution of such portable equipment and the limitations of *in situ* analysis are both well described by Scott et al.[58] They discuss how non-destructive on site analysis yielded useful information about the pigments in a fifteenth-century illuminated manuscript but could not match the level of detail gained through sampling. In the case of painted textiles, the only reference we are aware of on the use of *in situ* analysis is by Tonkin who used portable XRF to examine elemental differences between oil and acrylic painted banners.[59] This enabled the identification of a wide range of materials but not their location and role in the paint and preparation layers, again highlighting the value and also the limitation of portable instrumentation when used in isolation. More recently, Alfeld and Broekaert reviewed the capabilities of depth profiling and sub-surface techniques for historical paintings and Miliani et al. reported on a multi-technique approach to *in situ* non-invasive analysis which gave more information about materials at different depths.[60]

3 Solubility and staining tests

Identification of materials based on solubility tests depend on them being soluble or insoluble in a certain solvent while staining tests usually work by monitoring a change in colour caused by the sample's chemistry on the reagent. These tests require very small samples (usually less than a millimetre of material), either loose or embedded in resin blocks. The samples are put on a microscope slide or in a micro test tube and a few drops of the solvent or reagent added. The reaction can then be monitored by eye or under a microscope.[61] Simple solubility and staining tests frequently used in the study of historic objects are detailed by Plesters and developed further by Martin, although care should be taken as there are safety concerns about some of the chemicals used because of their sometimes corrosive or toxic nature which is unaddressed by these authors.[62] Such tests are limited as they provide a general rather than a specific identification; for example, staining can identify material classes, e.g. lipids and proteins—however it should be noted that newer and more complex and specific staining techniques used in the study of painted and polychrome artworks have recently been reported.[63] Generally staining can suffer from contamination and unexpected side reactions which can lead to misleading results. Furthermore, the combinations of materials such as silk and animal glue, both proteins, also have the potential to interfere with the results. However, although the newer techniques require expertise in both application and interpretation, the findings on the materials and their condition can be extremely valuable in terms of understanding artists' techniques and also the degradation of materials.

The use of stains to identify fibres has not been mentioned in the papers reviewed. Stains, such as the Shirlastain fibre identification stains, can be a relatively inexpensive means to identify different fibres.[64] Although they can be harder to use on dark coloured fibres, as they rely on staining the

System', *Microscopy and Microanalysis* 12, no. S02 (2006): 1322–3.

55 Smith et al., 'Breaking Down Banners'.

56 Boon and Asahina, 'Surface Preparation of Cross Sections', 1322–3.

57 Michael Wheeler, Lucia Burgio and Michelle Shulman, 'Materials and Techniques of Kalighat Paintings: Pigment Analysis of Nine Paintings from the Collections of the Victoria and Albert Museum', *Journal of the Institute of Conservation* 34, no. 2 (2011); Mark Clarke, 'Anglo-Saxon Manuscript Pigments', *Studies in Conservation* 49 (2004): 231–44.

58 David A Scott, Narayan Khandekar, Michael R. Schilling, Nancy Turner, Yoko Taniguchi and Herant Khanjian, 'Technical Examination of a Fifteenth-Century German Illuminated Manuscript on Paper: A Case Study in the Identification of Materials', *Studies in Conservation* 46 (2001): 93–108.

59 Tonkin, 'Taking the Modern with the Traditional', 6–14.

60 M. Alfeld and J.A.C. Broekaert, 'Mobile Depth Profiling and Subsurface Imaging Techniques for Historical Paintings – a Review', *Spectrochim. Acta. B* 88 (2013): 211–30; Costanza Miliani, Francesca Rosi, Brunetto Giovanni Brunetti and Antonio Sgamellotti, 'In- situ Non-invasive Study of Artworks: The MOLAB Multi-Technique Approach', *Accounts of Chemical Research* 43, no. 6 (2010): 728–38.

61 Ágnes Tímár-Balázsy and Dinah Eastop, *Chemical Principles of Textile Conservation* (Oxford: Butterworth-Heinemann, 1988), 385; Barbara Hunt Stuart, *Analytical Techniques in Materials Conservation* (Chichester: John Wiley & Sons 2007), 43–71.

62 Joyce Plesters, 'Cross-sections and Chemical Analysis of Paint Samples', *Studies in Conservation* 2, no. 3 (1956): 110–57; Elisabeth Martin, 'Some Improvements in Techniques of Analysis of Paint Media', *Studies in Conservation* 22, no. 2 (1977): 63–7.

63 Richard C. Wolbers, Susan L. Buck, and Peggy Olley, 'Cross-section Microscopy Analysis and Fluorescent Staining', in *The Conservation of Easel Paintings*, eds. Rebecca Rushfield and J.H. Stoner (London and New York: Routledge, 2012), 326–35; Irina Sandu, M. Helena de

fibre, they may be a useful technique to consider, especially in conjunction with optical light microscopy.

Solubility tests have been used for the identification of the type of binding media used, e.g. proteins and oils, and also for resins.[65] The results can be difficult to interpret and McGlinchey commented that when using staining to identify binding media, the auto fluorescence of the silk protein fibre can interfere with the fluorescence of thinly applied paints found on painted silk costumes.[66]

The use of staining and solubility tests has proved very useful as they are widely available, low cost techniques. Their usefulness is demonstrated in, for example, Takami and Wyeth's work where they used the identification of binders to determine cleaning and consolidation—the presence of proteinaceous binding media and animal glue suggested a cautious approach to the use of water and heat treatments because of concerns of shrinkage and expansion of the paint film.[67] However, as this technique is essentially subjective there can be errors in interpretation.

4 Optical microscopy

Using a compound microscope and visible light, samples can be studied using either transmitted or reflected light depending on the transparency of the sample. In bright field illumination, the light is transmitted through the sample and contrast occurs through the absorbance of light, showing surface and internal features. In dark field illumination, the sample is set against a dark background. Sample contrast comes from light scattered by the sample which is reflected or refracted through the sample and can show different features from those visible in bright field illumination. In cross-polarised light illumination, sample contrast comes from rotation of the stage in relation to the two fixed and right angled polarisers. It is commonly used on birefringent samples where the polarised light interacts strongly with the sample and creates a contrast with the background (double refraction). Polarised light microscopy can be useful for the identification of fibres, including synthetic textile fibres, and pigments.[68]

UV fluorescence microscopy, sometimes abbreviated to UV microscopy, involves the use of a compound microscope with ultra violet radiation instead of visible light. It uses fluorescence and phosphorescence to study the properties of organic or inorganic substances, as materials can show these characteristics, based on their chemical makeup. The use of ultraviolet light, with its shorter wavelength, improves the image quality for example by improving the definition between organic and inorganic layers. It also enables contrast enhancement where the response of individual samples is enhanced relative to their surroundings, due to the interaction of light with the molecules within the sample itself. This makes it easier to differentiate between different layers of materials within a cross-section as shown in Fig. 4.[69]

This technique is widely used in the analysis of paintings, comparing visible and UV fluorescent images of cross-sections to help in the identification of different paint layers and is also key to understanding transparent layers.[70]

Microscopy can provide a really detailed image of paint layers or fibre morphology, for example, and inform the next stage of analysis, although the level of skill and experience of the user will determine the degree of information gained from the findings. Optical microscopy is a relatively low cost analytical technique and many microscopes come with advanced software packages which allow imaging, processing and measuring, all of which greatly enhance their optical information.

Study of surface morphology and cross-sectional analysis of embedded paint samples is most routinely carried out using polarised light and ultraviolet fluorescence to determine the layers, range and quality of pigments, condition of the paint surface, and to gain insight into the making of a

Sa, and Manuel Pereira, 'Ancient Gilded Art Objects From European Cultural Heritage: A Review on Different Scales of Characterisation', *Surface and Interface Analysis* 43, no. 8 (2011): 1134–51; Stepanka Kuckova, Irina Sandu, Michaela Crhova, Radovan Hyneka, Igor Fogas, and Stephan Schafer, 'Protein Identification and Localization using Mass Spectrometry and Staining Tests in Cross-sections of Polychrome Samples', *Journal of Cultural Heritage* 14, no. 1 (2013): 31–7.

64 For Shirlastain stains for fibre identification see, http://www.sdlatlas.com/product/61/Shirlastain-Fiber-Identification-Stains (accessed 2 June 2016).

65 TÍmár-Balázsy and Eastop, *Chemical Principles of Textile Conservation*, 250; Takami and Wyeth, 'Studies on a Korean Painted Silk Banner', 133–42; Thompson and Lennard, 'Normansfield Theatre Scenery: Materials and Construction Revealed through Conservation', 111–2.

66 Christopher McGlinchey, 'The Similarities and Differences in the Technical Examination of Paintings and Painted Silk', in Paulocik and Flaherty, *The Conservation of 18th-Century Painted Silk Dress*, 15–20.

67 Takami and Wyeth, 'Studies on a Korean Painted Silk Banner', 133–42.

68 Nicholas Eastaugh, Valentine Walsh, Tracey Chaplin, and Ruth Siddall, *Pigment Compendium: Optical Microscopy of Historical Pigments* (Oxford: Elsevier Butterworth-Heinemann 2004). Ohio State University, online *Fibre Reference Image Library*, https://fril.osu.edu/index.cfm?fuseaction=site.faq (accessed 20 March 2015).

69 Petria Noble and Annalies van Loon, 'New Insights into Rembrandt's Susanna', *ArtMatters* 2 (2005): 76–96.

70 Maarten R. van Bommel, Ina Vanden Berghe, Alexander M. Wallert, Rene Boitelle, and Jan Wouters, 'High-performance Liquid Chromatography and Non-destructive Three-dimensional Fluorescence Analysis of Early Synthetic Dyes', *Journal of Chromatography A* 1157, no. 1–2 (2007): 260–72; see Eastaugh et al., *Pigment Compendium*.

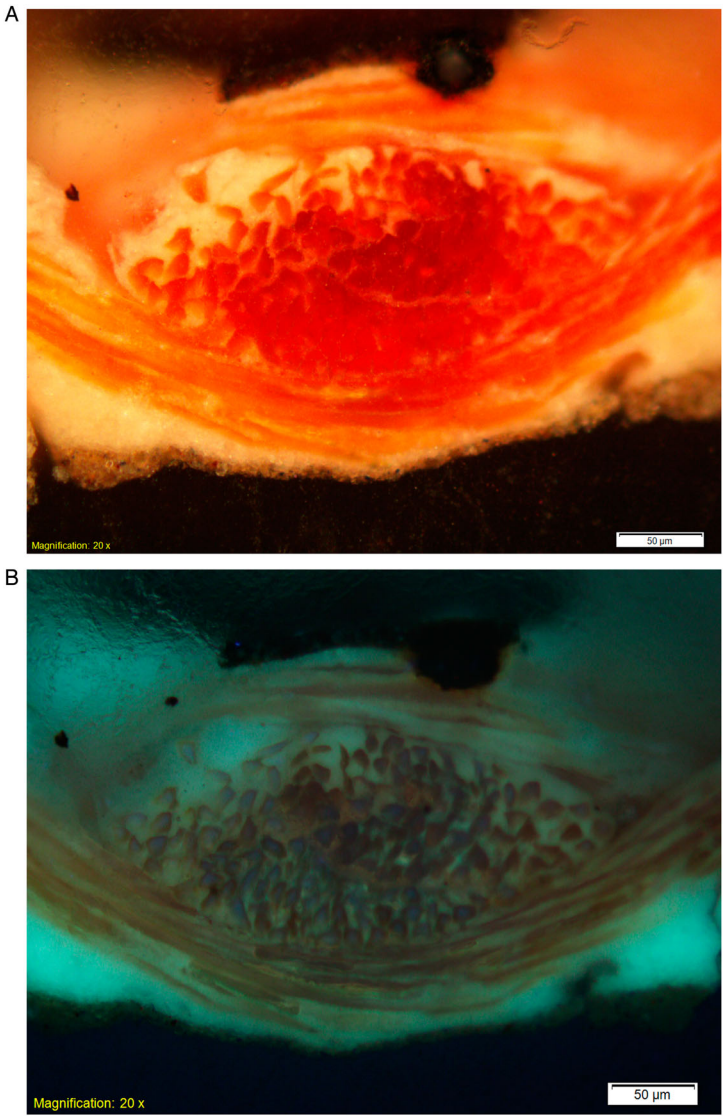

Fig. 4 A Shows darkfield microscopy (×200) for a cross section from a painted banner; B Shows the same sample under UV microscopy (×200).

painted textile.[71] UV fluorescent microscopy has been used to show the presence of a ground layer not seen under visible light,[72] and Lennard et al. analysed samples under normal and ultraviolet light at ×50–×400 magnification to determine differences between pigments and when they were painted to determine later alterations to inform decisions about which repairs should be retained.[73] Furthermore, Takami and Eastop and Takami and Wyeth were able to determine the precise layer sequence on both sides of the textile of a Korean banner using UV microscopy. They found was no sign of sizing and the textile was painted on both sides with a white ground layer thought to be unusual for Asian painting and may have been used to clarify details.[74]

Taking paint samples alone may yield information about the pigment and binding medium but not necessarily about the other preparation layers and their interaction with the textiles. In some cases, a complete cross-section is taken to determine the interaction of the fabric and the paint.[75] and in Rogerson and Lennard's paper the comparison of cross-sections of 15 banners by two different makers showed differences between their production methods with different preparation and paint layers used. This highlighted the rich information that can

71 Kleiner, 'Spinello Aretino', 69–76; Takami and Eastop, 'The Conservation of a Korean Painted Silk Banner', 747–54; Takami and Wyeth, 'Studies on a Korean Painted Silk Banner', 133–42; Macdonald et al., 'Raman Microspectroscopy', 5–7; McGlinchey, 'The Similarities and Differences in the Technical Examination of Paintings and Painted Silk', 15–20.

72 Macdonald et al., 'Raman Microspectroscopy', 5–7.

73 Frances Lennard, Nancy Pollak, Chunmei Lin, and Wang-Ping Chen, 'Blue Flag with Yellow Tiger? Flags, Authenticity and Identity', *Journal of the Institute of Conservation* 36, no. 1 (2013): 3–17.

be gleaned from a study of samples examined using light microscopy and also how it can be used to guide further analysis. This is significant in developing greater understanding of painted textiles. Without sampling and study of cross-sections it would not be possible to fully understand the interactions between different layers. The microscopy investigations demonstrate that low level visual examination would not have been able to provide the quality of information that was made possible with sampling and study of cross-sections.

The works cited here indicate how basic microscopy is often the first, but valuable, step in understanding the sample under investigation and how high magnification microscopy elucidates detailed structure. The levels of information that can be gleaned from microscopy improve as the user becomes more familiar with the instrument and the differing appearance of samples and what information may be had from them.

74 Takami and Eastop, 'The Conservation of a Korean Painted Silk Banner', 747–754 Takami and Wyeth, 'Studies on a Korean Painted Silk Banner', 133–142; Lennard et al., 'Blue Flag with Yellow Tiger?', 3–17.

75 Rogerson and Lennard, 'Billowing Silk and Bendable Binders', 12–18.

5 Scanning electron microscopy

SEM allows for a higher level of detail than light microscopy (more than ×500 greater) and can image in the nanometre and sub nanometre range. SEM produces images by detecting secondary electrons which are emitted from the surface due to excitation by the primary electron beam. In the SEM, the electron beam is scanned across the surface of the sample in a raster pattern with detectors building up an image by mapping the detected signals with beam position.[76] Despite the ubiquitous use of SEM in other areas of historical paintings, there is very little reported use of the technique to study painted textiles. However, in Part 2 of this article its use in combination with EDX is discussed. SEM is particularly useful for detailed imaging of a sample as it also gives a sense of depth by generating a three-dimensional image. Drawbacks are that it requires an expert knowledge to be able to generate the images and to interpret them effectively and is costly to purchase and use.

76 Barbara Hunt Stuart, *Analytical Techniques in Materials Conservation* (Oxford: Wiley, 2007), 72–108.

SEM's use has been cited in papers on a Roman Egyptian shroud and an ancient Egyptian textile where it has been used to study surface morphology and the condition of fibres.[77] It has also been used to study the condition of the painted surface of a Jain painting where the author reported that the topography micro-structure was very broken up and crystalline, indicating the lack of cohesion between the elements and the failure of the binding material.[78] In addition to the microscopy findings by Takami and Wyeth on the materials of the Korean banner, they also used an environmental scanning electron microscope (ESEM) which enabled a more detailed identification of pigments and also the presence of sulfur thought to be from animal glue.[79]

77 Tom Bilson, 'The Conservation of a Roman Egyptian Painted Shroud Fragment', *The Conservator* 16 (1992): 3–11; O. Abdel-Kareem, Y. Zidan, N. Lokma, and H. Ahmed, 'Conservation of a Rare Painted Ancient Egyptian Textile Object from the Egyptian Museum in Kairo', *e-Preservation Science* (2008): 9–16.

78 McLeod, 'Powdery Paint: The Use of Funori with an Indian Jain Painting', 18.

79 Takami and Wyeth, 'Studies on a Korean Painted Silk Banner', 133–42.

6 Atomic force microscopy (AFM)

AFM produces three dimensional images of the surface of the sample. AFM images the topography by scanning over the region of interest. The raised and lowered features on the sampled surface influence the deflection of the cantilever, which is monitored by the position-sensitive photo-detector (PSPD). By using a feedback loop to control the height of the tip above the surface—thus maintaining constant laser position—the AFM can generate an accurate topographic map of the surface features. Sandu et al. reviewed instrumentation including AFM for measuring different scales of characterisation and detailed their advantages and disadvantages,[80] and AFM has also been reported on in the study of fibres by Garside et al. although this study did not include painted textiles.[81] The use of AFM in observing the surface of acrylic paint films and the effects of cleaning on acrylic emulsion paints is detailed by Kampasakali et al. and such applications should prove valuable in the study of conservation treatments of painted textiles.[82]

A combination of complementary microscopy techniques (including light microscopy, SEM and AFM) has proved useful in the study of degraded silk fibres and potentially to study the interactions between paint and textile.

80 Sandu et al., 'Ancient Gilded Art Objects', 1134–51.

81 Paul Garside, Graham Mills, James R. Smith, and Paul Wyeth, 'An Investigation of Weighted and Degraded Silk by Complementary Microscopy Techniques', *e-Preservation Science* 11 (2014): 15–21.

7 Imaging techniques

X-radiography is an imaging technique that is non-invasive and non-destructive. It can be used to reveal layers hidden within an object and can reveal changes and deterioration of a material. It involves the use of X-ray radiation which is beamed onto an object and recorded either on photographic film or digitally. The use of X-rays has been widely used and documented for a range of objects from paintings to metal work and has also been recorded for use with textile objects, including painted textiles, to identify paint and to see differences in paint layers and condition.[83]

Infrared reflectography (IRR) is a technique used to look through the paint layers, a technique commonly used in the study of stretched canvases. The degree of penetration depends on the thickness of the paint, the type of paint used, and the length of the wave of infrared radiation. Many paints will appear partially or completely transparent while others, such as black, will absorb the infrared radiation and appear opaque and dark. An infrared camera captures the radiation reflecting off the surface of the painting, producing a digitised image known as an infrared reflectogram, which can show underdrawings and changes in the paint layers. Alfeld and Broakaert reviewed its application to paintings,[84] and although its use has rarely been reported for painted textiles it is a technique that would be ideal for their study, as detailed by Ernst for the study of thangkas.[85]

Conclusion

The categorisation of painted textiles made here provides a means to draw analogies (and challenge assumptions) of different methods of making which should help to further the study and conservation of painted textiles. Through this broad categorisation it is possible to identify patterns in types of materials and methods of application. Different materials and methods of making have been exploited to produce textiles with different functions and characteristics. Our understanding has been informed by knowledge of traditional materials and techniques and historic records. Where such traditions or records are scant, it is possible to look to other painted textiles and compare the understanding of the materials, making and agents of deterioration as has been informed by analysis.

Looking, visually and microscopically are the first important steps of study. What is learnt from this study can then help inform sampling. Sampling can then provide valuable information about materials and is a familiar conservation technique. In particular, the full cross-section including the textile, albeit destructive, can yield information not only about materials but also their interfaces. This knowledge is crucial in understanding the composition of painted textiles and also to better understand their manufacture and deterioration, all of which are essential for any conservation plan. It should also be noted that whilst non-destructive techniques are important additions to the analytical toolbox, awareness of their scope and limitations is crucial to their effective use.

Understanding the physical properties of a material is also an important factor in determining the construction of an object such as the build-up of layers or the interaction between layers which can clearly be seen in any study of cross-sections, and such an understanding is invaluable in determining the condition of materials. Fibre identification and an understanding of the condition of the textile itself should not be overlooked when studying painted textiles as the effects of interaction of different fibres and paint is crucial to understanding making, deterioration and conservation—it is noteworthy that the analysis of textile materials are reported less than those used to identify the paint, and perhaps this is because fibre identification is a very common procedure for textile conservators. However, delaminating layers, cracks or loss of features on fibres and paint can be indicators of deterioration and so the use of optical techniques on both is invaluable.

82 Elli Kampasakali and Bronwyn Ormsby, 'A Preliminary Study into the Swelling Behaviour of Artists' acrylic emulsion paint films', unpublished report for Tate London and the Getty Conservation Institute, Los Angeles (2009).

83 Bilson, 'The Conservation of a Roman Egyptian Painted Shroud Fragment', 3–11. Sonia O'Connor and Mary M. Brooks, *X-radiography of Textiles, Dress and Related Objects* (Oxford: Elsevier Butterworth-Heinemann, 2007).

84 Matthias Alfeld and José Broekaert, 'Mobile Depth Profiling and Subsurface Imaging Techniques for Historical Paintings – A Review', *Spectrochim. Acta. B* 88 (2013): 211–30.

85 Richard R. Ernst, 'Science and Art – My Two Passions', in *Science and Art The painted Surface*, eds. A. Sgamellotti, B.G. Brunetti, and C. Milani (Croydon: The Royal Society of Chemistry, 2014), 1–27.

Review of the literature indicates the value of these optical techniques as most are relatively simple to use and can be carried out using analytical equipment often seen in conservation labs. When the complexity of techniques increases along with the need for specialised skills to operate and interpret the data, the use of stereo and optical microscopy, staining and solubility tests provide very useful information and should not be overlooked in favour of more sophisticated analysis.

These visual, microscopy and imaging techniques are also important in informing further analysis and Part 2 of this review will focus on spectroscopic and chromatographic techniques and their application to the study of painted textiles.

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Abstract
Many types of painted textile are represented in museum collections. Their flexibility, draping qualities, and heterogeneous, layered nature make painted textiles complex objects to conserve. What do we know about their materials and making? There has been limited research into painted textiles and particularly their analysis. Whilst much valuable information can be gleaned from paintings analysis, there are many distinct differences in materials behaviour between stretched paintings and painted textiles that need to be identified and addressed. This article, together with Part 2, aims to raise the awareness of textile conservators, in particular of potential analytical techniques to identify and characterise the materials, thus enhancing understanding and conservation of painted textiles. Part 1 focuses firstly on the categorisation of different groups of painted textile providing a context for their study and secondly, it reviews sampling and optical techniques that can be used by conservators, highlighting some of the challenges they present.

摘要
有关彩绘织物材料特性分析技术的文献研究（第一部分）：彩绘织物的分类、取样和光学仪器的应用
博物馆收藏了许多类型的彩绘织物。它们内在柔软，具有可悬挂性，由多种成分、多层结构组成，这种复杂性使得我们保存与修复它们变得困难。但对于彩绘织物的材料和制作工艺我们又了解多少呢？这方面的资料很有限，有关它们的分析研究更是少之又少。虽然我们可以从绘画作品的分析中收集许多有价值的信息，但彩绘织物与绷在画框上的绘画作品呈现出很多截然不同的材料特性，而这些特性还有待识别和研究。本文（以及第二部分）旨在提高纺织品保存修复人员使用潜在分析技术研究材料特性的意识，从而提升我们对彩绘织物的理解与保护能力。第一部分首先关注于彩绘织物的分类，为研究它们提供背景资料，其次检视取样过程以及能被修复师所使用的光学技术，并着重介绍其中遇到的挑战。

Resumen
<<Una revisión bibliográfica de técnicas analíticas para la caracterización de los materiales de textiles pintados—Parte 1: Categorización de textiles pintados, muestreo y uso de herramientas ópticas>>
En las colecciones de los museos encontramos representados muchos tipos de textiles pintados. La conservación de textiles pintados es compleja por su flexibilidad, sus cualidades de drapeado y su heterogénea y compleja calidad. ¿Qué sabemos acerca de sus materiales y su fabricación? Existe muy poca investigación sobre textiles pintados y menos aún de análisis de sus materiales. Aunque haya mucho análisis de los materiales usados en pinturas estiradas del que podemos obtener valiosa información, necesitamos identificar y precisar cuáles son las diferencias de comportamiento entre los textiles pintados y las pinturas estiradas. Este trabajo, junto con la Parte 2, tiene como objetivo aumentar la conciencia de los conservadores de textiles, y en particular, el conocimiento de posibles técnicas analíticas para identificar y caracterizar los materiales y de esta manera, mejorar la comprensión y la conservación de los textiles pintados. Parte 1 se centra, en primer lugar, en la categorización de los diferentes grupos de textiles pintados proporcionando el contexto para su estudio y, en segundo lugar, revisa el muestreo y las técnicas ópticas que los conservadores pueden utilizar, resaltando algunos de los desafíos que presentan.

Zuammenfassung
„Eine Analyse der Literatur zu Analytischen Methoden der Materialcharakterisierung bemalter Textilien—Teil 1: Kategorien bemalter Textilien, Probenentnahme und Einsatz optischer Werkzeuge"
Es gibt viele Arten bemalter Textilien in Museumssammlungen. Ihre Flexibilität, Drapiercharakteristika und der heterogene, geschichtete Aufbau machen diese Textilien für die Restaurierung zu komplexen Objekten. Was wissen wir über ihre Materialien und Herstellung? Es gibt nur einen begrenzte Forschung im Bereich bemalter Textilien, insbesondere im Bereich ihrer Analyse. Obwohl viele wertvolle Informationen aus der Analyse von Gemälden übertragen werden können, gibt es viele charakteristische Unterschiede zum Materialverhalten aufgezogener Gemälde, die identifiziert und beachtet werden müssen. Dieser Artikel möchte zusammen mit Teil 2, das Bewusstsein für charakterisierende und identifizierende Analysemethoden schär-

fen, insbesondere unter Textilrestauratoren, um so das Verständnis und die Restaurierung von bemalten Textilien zu verstärken.
Teil 1 konzentriert sich auf die Kategorisierung verschiedener Gruppen von bemalten Textilien um so einen Forschungskontext zu bieten. Zweitens werden hier Methoden zur Probenentnahme und optischer Sichtung zusammengefasst, die Restauratoren zur Verfügung stehen, wobei einige der besonderen Herausforderungen hervorgehoben werden.

Résumé

"Une revue de la littérature sur les techniques d'analyses pour la caractérisation des matériaux des textiles peints—Partie 1 : catégorisation des textiles peints, échantillonnage et utilisation d'outils optiques"
De nombreux types de textiles peints sont représentés dans les collections des musées. Leur souplesse visée, leurs qualités de drapage et leur nature hétérogène et stratifiée font des textiles peints des objets complexes à conserver. Que savons-nous sur leurs matériaux et leur fabrication? Peu de recherches ont eu lieu sur les textiles peints et en particulier sur leur analyse. Alors que beaucoup d'informations précieuses peuvent être tirées de l'analyse des peintures, beaucoup de différences sont sensibles dans le comportement des matériaux par rapport aux peintures tendues et nécessitent d'être identifiées et abordées. Cet article, avec la deuxième partie, vise à sensibiliser les restaurateurs de textiles en particulier sur les techniques d'analyse possibles pour identifier et caractériser les matériaux, améliorant ainsi la compréhension et la conservation des textiles peints. La première partie porte en premier lieu sur la catégorisation des différents groupes de textiles peints en apportant un contexte pour leur étude et examine, en second lieu, l'échantillonnage et les techniques optiques qui peuvent être utilisées par les restaurateurs, mettant en évidence certains des défis présents.

Biographies

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Margaret Smith, BSc, MSc, PhD is a research scientist and lecturer at the Centre for Textile Conservation and Technical Art History, University of Glasgow. Previously, she was a research chemist for 21 years in academia and industry, where she gained extensive experience in analytical techniques and materials behaviour. Her research now focuses on painted textiles including banners and barkcloth and the physical and chemical aspects of tapestry deterioration. Her main research expertise lies in studying the degradation rates of materials, the effects of environmental conditions on those rates, and the interaction of different materials at surfaces and interfaces.

Karen Thompson, BA(Hons), PGCE, PGDip, FHEA, ACR is a lecturer and textile conservator at the Centre for Textile Conservation and Technical Art History, University of Glasgow. Painted textiles is an area of specialism and research, and her work with painted textiles has included: Lead conservator on The National Banner Survey held by the People's Museum, Glasgow; project manager for the conservation of a set of painted theatre scenery and storage of over 100 pieces of scenery for Normansfield Hospital Theatre, Teddington (shortlisted for the Icon Conservation Awards); conservation of painted banners; and research in the making, deterioration and conservation of painted textiles.

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