Studies in Conservation

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/ysic20

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To cite this article: Ângela Santos, Vanessa Otero & Márcia Vilarigues (04 Apr 2023): Production of Hand-painted Magic Lantern Glass Slides: A Literature Review, Studies in Conservation, DOI: 10.1080/00393630.2023.2194080

To link to this article: https://doi.org/10.1080/00393630.2023.2194080

Published online: 04 Apr 2023.

STUDIES IN CONSERVATION
https://doi.org/10.1080/00393630.2023.2194080

REVIEW PAPER

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Production of Hand-painted Magic Lantern Glass Slides: A Literature Review

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ABSTRACT

Hand-painted magic lantern glass slides frequently present significant conservation problems, mainly due to the painting's deterioration and detachment from the glass support surface. However, the study of these objects is a very recent field. This work reviews the materials and techniques applied to hand-painted slides until the nineteenth century in Europe and North America to follow their evolution throughout time and place, aiming to further our understanding of the slides' historical, cultural, and artistic impact. This review identifies 22 historical sources from five countries, written between the eighteenth and nineteenth centuries, containing information on the production of hand-painted slides, from the glass support to the painting materials and techniques. The production processes changed from the mid-seventeenth to the eighteenth century with the apparent transition from *fired paints* (enamels) to *cold paints* (watercolours, oil colours, and varnish colours). Different stages of eighteenth- and nineteenth-century production processes are explored. Concerning the glass support, *crown* and *plate* or *ground-polished* glass (later *patent plate*) were commonly advised. Although the paintings' palette was mainly restricted to transparent colours, around 70 colourants and 25 binding medium components are listed. Their chronological distribution unveiled a possible correlation between their evolution and the advent of the Industrial Revolution. The knowledge of the original materials and techniques will not only contribute to understanding the differences between locations, periods, and slides' producers, helping in future attributions, but will also support further investigations on the key factors and mechanisms that lead to the degradation of historical hand-painted slides, enabling the improvement of current conservation practices.

ARTICLE HISTORY
Received August 2022
Accepted March 2023

KEYWORDS
Magic lantern; glass slides; painting on glass; eighteenth century; nineteenth century

Introduction

The magic lantern slide is the name used to designate positive and transparent images depicted on glass plates for projections with 'magic' (or optical) lantern instruments. The invention of this apparatus in the mid-seventeenth century allowed, for the first time, the projection of illuminated and magnified images onto a white screen or wall to be viewed by collective audiences. The person responsible for creating the magic lantern is not agreed upon between twentieth-century authors; the German Jesuit priest Athanasius Kircher and the renowned physicist Christiaan Huygens are frequently referred to as inventors (Frutos 2010). Even though Kircher, in 1646, described a projection system close to a magic lantern, Huygens is recognised as the most probable creator (Mannoni 1994; Frutos 2010). Huygens, in 1659, besides first drawing and describing the working principles of a magic lantern, had already demonstrated the illusion of movement created by glass slides (Figure 1) (Mannoni 1991; Robinson, Herbert, and Crangle 2001). The functioning of a magic lantern can be observed in more detail in the scheme of Figure 2.

The history of the progress of this instrument is extraordinarily rich and has developed for more than two thousand years. Since the beginning, projectionists have tried to fully explore the movement of the images projected, the abstraction, and the rapture of those who attended magic lantern shows (Bernardo 2009). The magic lantern soon became the most popular device for social communication until cinema. It was used to disseminate science, religion, and advertisement, illustrate lectures (e.g. chemistry, astronomy, zoology, history, and art) and entertain children and adults with tales, adventures, burlesque, and phantasmagoria animations, not only in large theatres but also in more intimate environments (Campagnoni 1996; Schlosser 1980; Frutos 2010). By projecting colourful moving animated images in combination with audio performances, the magic lantern achieved its apogee during the eighteenth and nineteenth

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This article has been corrected with minor changes. These changes do not impact the academic content of the article.

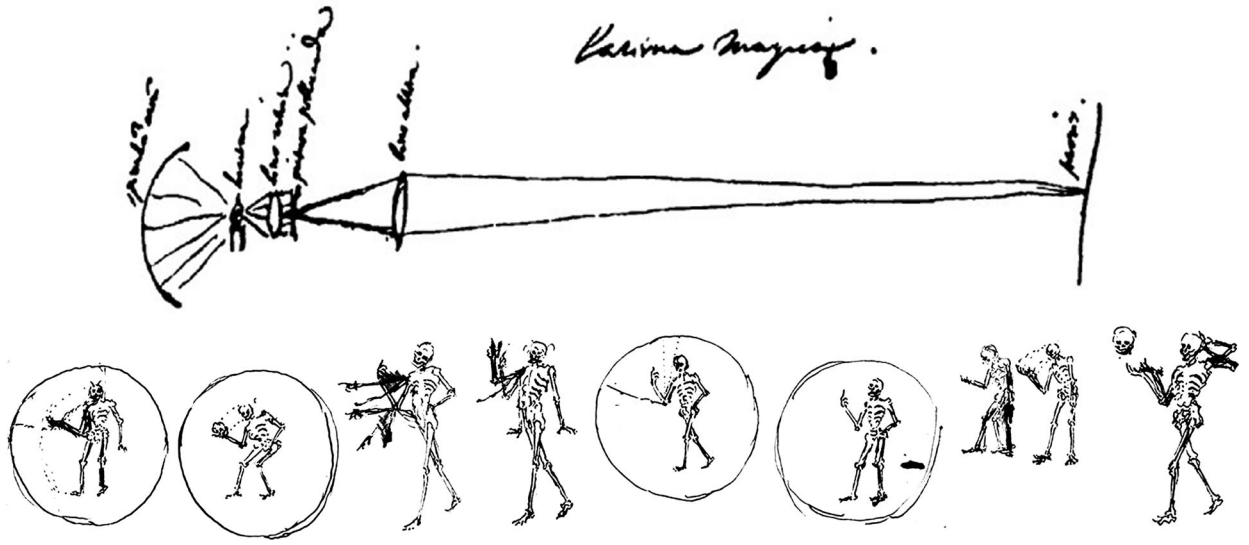

Figure 1. Composition of drawings by Christiaan Huygens, representing: the working principles of a magic lantern (*laterna magica*), with the same configuration (without a slide) from a Huygens' letter to Pierre Petit (11 December 1664) (Société Hollandaise Des Sciences 1893), where a concave mirror (*speculum cavum*), a lantern (*lucerna*), a vitreous lens (*lens vitrea*), a transparent image (*pictura pellucida*), another lens (*lens altera*), and a wall (*paries*) can be observed (1694); and a set of skeleton figures illustrating animated glass slides showing the illusion of movement (1659). Adapted by the authors from Bibliothèque nationale de France (public domain) (Huygens 1685–1692, 1950).

centuries and marked the beginning of the 'pre-cinema' period (Robinson et al. 2001; Frutos 2010).

During that time, the lanterns developed from the simplest models to the most sophisticated instruments with two or three objectives (*biunial* or *triple lanterns*, respectively), allowing for the creation of dissolving effects by juxtaposing complementary images (*dissolving views*) and other techniques that produced almost continuous moving images (e.g. from day to night, winter to spring, and illusions as snow falling or water running) (Alves Costa 1988).

Besides the lanterns, the production of glass slides had also evolved, and over time, three main techniques were used to produce them: hand painting, printing, and photography (Figure 3). Various documents from the eighteenth and nineteenth centuries include not only information on the different types of magic lanterns and how to operate them but also instructions on the production of magic lantern slides, from the choice of the glass support to the depicting techniques, providing invaluable information on their artistic and manufacturing practices (Frutos 2013). The production methods used to represent the coloured figures on the glass slides drastically changed, from *fired paints* to *cold paints* in the transition from the seventeenth to the eighteenth century. Both Hertel (1716) and Nollet (1770) point out the production of earlier magic lantern slides painted with enamels fired at low temperatures as in stained-glass tradition (Figure 3a), warning that although these were much more durable, it was difficult to find people that could do this type of work; it was very expensive; and the result was not as beautiful as those painted in watercolours or varnish colours (Hertel 1716; Nollet 1770; Mannoni 1994). For those reasons, after carefully choosing the glass plates for the support, the standard procedure was to paint the images by hand with watercolours, oils, and varnishes referred to as *cold paints*, which, when projected, revealed their magic by playing with the colours' transparency and light (Figure 3b). During the second half of the nineteenth century, manufacturers transitioned to printing techniques to create the images' outlines (e.g. copper-plate) and later the whole picture with printing processes alone (e.g. chromolithographs or transfer slides) (Figure 3c and d). By the end of the century, most glass slides were produced by photographic methods that could also be hand-coloured (Figure 3e) (Frutos 2013).

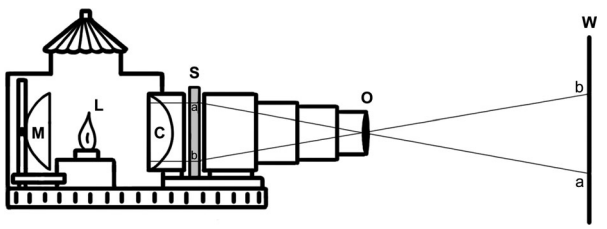

Figure 2. Scheme of the working principle of a magic lantern with a concave mirror (M), a light source (L), a condenser lens (C), a glass slide (S) with a transparent image (a-b orientation), an objective lens (O), and a wall (W) with the projected image inverted (b-a orientation). © Drawing by Ângela Santos.

Written documents are considered one of the most valuable sources of information for studying technical aspects of art production. However, the processes and materials used to produce historical hand-painted magic lantern slides for over two centuries are still little studied. To the extent of the

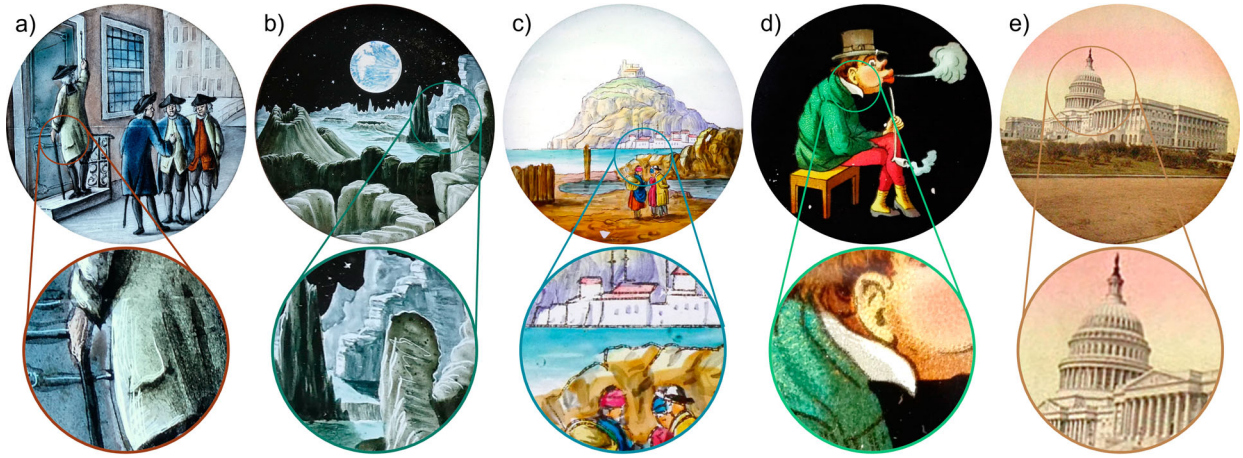

Figure 3. Examples of slides produced with the four main production techniques identified: (a) hand-painted, possibly with fired paints (e.g. with grisaille and enamels), possibly eighteenth century, Holland (?) (inv. PC1); (b) hand-painted slide by Carpenter & Westley, nineteenth century, England (inv. PC3301/008); (c) slide hand-painted over printed outlines by Carpenter & Westley, ca. 1850-1875, England (inv. PC189/009); (d) chromolithograph slide, 1850-1899, England (inv. PC183); and (e) hand-coloured photography by T.H. McAllister, end of nineteenth century, USA (inv. PC411/011). © Portuguese Cinematheque – Museum of Cinema, photos by Ângela Santos.

author's knowledge, only a study by the University of Turin focused on the materials characterisation of slides, resulting in three publications, more than 10 years ago (Scalarone et al. 2006; Ploeger et al. 2008, 2020).

More recently, Portuguese collections of painted slides have been studied as part of the PhD '*Lanterna Magica* – Technology and preservation of painted glass slides for projection with magic lanterns' within the MAGICA project ('Magic Lantern – Study, safeguard, uses and reuses in nineteenth-century Portugal'). This investigation has brought to light the conservation problems and the fragility of these objects by exploring these questions from the material point of view. Technical and compositional characterisation studies on glass and paintings used to produce eighteenth- and nineteenth-century hand-painted slides have shown a correlation between the materials listed in the historical written sources and those identified in original slides (Rodrigues et al. 2019; Santos et al. 2019, 2020, 2021a, 2023). The colour palette appeared to have changed in the transition from the eighteenth to the nineteenth century, and in the mid-nineteenth century, the variety of colourants used increased, accompanying developments in the artists' materials manufacturing industry (Santos et al. 2021a, 2022). The same tendency has also been observed regarding the glass support (Rodrigues et al. 2019; Santos et al. 2023).

In the context of these projects, this research intends to present a critical literature review regarding the materials and techniques used to produce glass slides entirely hand-painted and hand-painted over printed outlines until the end of the nineteenth century in Europe and North America to study its geographical and chronological evolution. In addition, the present review intends to detail a correlation between the materials and techniques described by historical literature and those identified in analytical studies. Mannoni and Frutos have previously explored the production of slides based on historical literature, presenting an excellent foundation for developing the present work (Mannoni 1994; Frutos 2010, 2013). This knowledge is fundamental to understanding these artefacts in terms of their materiality, allowing not only for an in-depth comprehension of the slides' historical, cultural, and artistic impact but also aiding in their analytical characterisation and unveiling the key factors and mechanisms that lead to the degradation of the historical hand-painted slides, subsequently enabling the development of better preventive and interventive conservation strategies to assure their accessibility to future generations.

Methodology

The present work considers documents written until the end of the nineteenth century in Europe and North America. Adding to the references compiled by Mannoni and Frutos (Mannoni 1994; Frutos 2010, 2013), the search was performed, mostly on digitised archives, in English, French, German, Italian, Portuguese, and Spanish. From the sources available to the public, different types of publications that informed on the glass support and painting materials used in the production of magic lantern slides were included: manuscripts, treatises, books, catalogues or business periodicals, and articles from magazines. Written sources with instructions for colouring photographic slides were only included when there was an

explicit indication that the materials and techniques presented could be applied or adapted to produce slides entirely hand-painted or painted over printed outlines.

Results and discussion

Written historical sources on hand-painted magic lantern slide production

A total of 22 documents mentioning the best types of glass and the materials applied to produce hand-painted, and hand-coloured magic lantern glass slides were identified and can be consulted in Table 1.

As observed in Figure 4a, most of the documents were produced in England, the United States of America (USA), Germany, and France, which was expected given that these countries were important centres of production of magic lanterns and glass slides. In particular, it should also be taken into consideration that there was an increased interest in rediscovering these documents England and the USA, promoted by The Magic Lantern Society of the United Kingdom and the Magic Lantern Society of the United States and Canada.

Furthermore, most of the sources belong to the second half of the nineteenth century (Figure 4b), which corresponds to the magic lantern apogee, with technological developments in both instrument and depiction techniques allowing its consolidation as a communication and entertainment medium and consequent mass production of glass slides and demand for painting instructions by students, amateurs, and private lecturers (Bielfeld 1855; Frutos 2010). Additionally, books published during this period had more printed copies and, therefore, can be more easily found than eighteenth-century ones.

The earliest documents in which instructions for magic lantern slide painting were identified are treatises from the eighteenth century that concern facts and principles mostly related to the construction of scientific instruments and the study of sciences such as mathematics, chemistry, and physics, in particular optics, written by academics possibly for dissemination and lecturing purposes (Hertel 1716; Nollet 1770; Wiedeburg 1735; Denecke 1757). The only exception is the bifolium from a Portuguese manuscript that contains information about the positioning of the magic lantern parts and the colours to paint figures on the slides, from which the author and context information are currently unknown (Distribuiçam das partes da Lanterna Magica 2018).

On the other hand, the books from the second half of the nineteenth century are predominantly handbooks and manuals. Several, written by artists, provide detailed information about different painting techniques, including painting on glass for magic lanterns, from the materials (e.g. pallets, brushes, type of glass, colours, mediums) to the application processes step-by-step (Bielfeld 1855; Groom 1855; M. J. Whipple & Co. 1856; Rintoul 1867; Urbino and Day 1873; Middleton 1876). In some cases, these books were published by renowned manufacturers of artist's materials (e.g. Winsor & Newton and George Rowney & Co.) and suppliers (e.g. Whipple & Co.) and frequently included trade catalogues listing painting materials for magic lantern glass slides that were also considered (Groom 1855; M. J. Whipple & Co. 1856; Winsor & Newton 1896). Another group of publications dedicated to explaining how to operate magic lanterns and related instruments, presenting the accessories available on the market (e.g. types of lanterns, light sources, condensers, supports), and explaining how to paint glass slides, was predominantly published by lecturers, lanternists, and magic lantern and slide manufacturers and dealers (Chadwick 1878, 1886; Hepworth 1889; "An Expert" [W. C. Hughes] 1893). Finally, a magazine article written by the artist Underhill (1892), specifically with instructions for magic lantern slide painting, was also found (Underhill 1892).

The production of hand-painted slides has been reported since the earliest documents reviewed for this research; they enlighten us on the difficulty of producing good quality glass slides without the complete mastery of the technique and best quality materials (Hertel 1716; Nollet 1770; Wiedeburg 1735; Denecke 1757; Bielfeld 1855; Groom 1855; M. J. Whipple & Co. 1856; Winsor & Newton 1863; Distribuiçam das partes da Lanterna Magica 2018). Besides early references to painting with fired enamels, hand-painting with *cold paints* was the only technique explored by the literature until 1866, when Negretti & Zambra explained how to paint slides for magic lanterns and included recommendations for printing on glass and colouring photographic slides (Negretti & Zambra 1866).

Although photography was the most used image production technique in the second half of the nineteenth century, some authors of this time argued that hand-painted slides should continue being produced because they were more artistically interesting and appealing to the public than photographic ones ("A Mere Phantom," 1874). For specific purposes, photography could not be of aid, for example, to represent grotesque and comic figures or educational diagrams (e.g. astronomical) ("A Mere Phantom," 1874). Even at the end of the nineteenth century, besides buying or producing photographs on glass and colouring them, lanternists and amateurs could easily buy clear glass plates to produce their slides from scratch or obtain outlines already printed on glass (with black varnish or fired enamel) to be painted and buy different types of frames and mechanical devices suitable for animated slides (Chadwick 1878). In this way, books comprehending the hand-painting technique solely

Table 1. Consulted written sources on the production of hand-painted magic lantern slides, chronologically organised.

Author	Date	Title	Printer / Publisher	City
Hertel	1716	*Vollständige Anweisung zum Glasschleifen*	Rengerschen Buchhandlung	Halle
Wiedeburg	1735	*Einleitung zu den Mathematischen Wissenschaften*	Berlegtens Johann Meners	Jena
Denecke	1757	*Vollständiges Lehr-Gebäude der ganzen Optik*	David Iversen	Altona
Nollet	1770	*L'Art des Expériences*	-	Paris
-	17–	*Distribuiçam Das Partes Da Lanterna Magica*	-	Lisbon
Groom	1855	*The Art of Transparent Painting on Glass*	Winsor & Newton	London
Bielfeld	1855	*A Guide to Painting on Glass*	George Rowney & Co.	London
Whipple & Co.	1856	*Directions for the Graduation and Mixture of Colors*	M.J. Whipple & Co.	Boston
Winsor & Newton	1863	*Winsor & Newton's Trade Catalogue*	Winsor & Newton	London
Negretti & Zambra	1866	*The Magic Lantern, Dissolving Views, and Oxy-Hydrogen Microscope (…)*	Negretti & Zambra	London
Rintoul	1867	*Transparent Painting on Glass for the Magic Lantern in Water, Oil & Varnish Colours*	Brodie & Middleton	London
Urbino & Day	1873	*Art recreations: being a complete guide*	Shepard and Gill	Boston
"A Mere Phantom"	1874	*The Magic Lantern, How to Buy and How to Use it (…)*	Houlston and Sons	London
Middleton	1876	*Magic Lantern Dissolving View Painting*	Brodie & Middleton	London
Marcy	1877	*The Sciopticon Manual (…)*	James A. Moore	Philadelphia
Chadwick	1878	*The Magic Lantern Manual* (1st ed)	Frederick Warne & Co.	London
Molteni	1881	*Intructions Pratiques sur L'emploi des Appareils de Projection*	F. Aureau	Paris
Chadwick	1886	*The Magic Lantern Manual* (2nd ed)	Scovill Manufacturing Co.	New York
Hepworth	1889	*The Book of The Lantern*	Edward L. Wilson	New York
Underhill	1892	"Artistic Lantern Slides No. 1-2" in *The Optical Magic Lantern Journal and Photographic Enlarger*	-	London
"An Expert" [Hughes?]	1893	*The Art of Projection and Complete Magic Lantern Manual*	E.A. Beckett	London
Winsor & Newton	1896	*Winsor & Newton's Trade Catalogue*	Winsor & Newton	London

(with or without the aid of printed outlines) continued being published by Rintoul (1867), Urbino & Day (1873), 'A Mere Phantom' (1874), Middleton (1876), and Underhill (1892) (Rintoul 1867; Urbino and Day 1873; "A Mere Phantom," 1874; Middleton 1876; Underhill 1892).

In addition to Negretti & Zambra (1866), the authors Marcy (1877), Molteni (1878), Chadwick (1886), Hepworth (1889), and 'An Expert', possibly Hughes (1893) also wrote instructions for hand-painting slides apart from those for colouring photographic slides (Marcy 1877; Molteni 1878; Chadwick 1886; Hepworth 1889; "An Expert" [W. C. Hughes] 1893). Finally, Winsor & Newton's Trade Catalogue from 1896 included painting materials specific for magic lantern glass painting without specifying the slides' production technique, which was interpreted as being transferable to all hand-painted slides (Winsor & Newton 1896).

Techniques for producing hand-painted slides

During the eighteenth and nineteenth centuries, the production of hand-painted slides generally included four main stages: selecting and preparing the glass support, outlining and painting the image, and framing the slide (Figure 5). To produce the images, from the glass preparation to the outlining and colour application, several authors advise choosing a place free of dust and working under an artificial light source (e.g. gaslight or paraffin lamp with green shade) so that when the figures were projected, the colours would reflect the intended hues and be free of dust that would ruin the work when magnified (Groom 1855; M. J. Whipple & Co. 1856; Rintoul 1867; "A Mere Phantom," 1874; Middleton 1876; Chadwick 1886).

Many authors emphasise the importance of carefully selecting good quality glass for the magic lantern slides to obtain the best result, with characteristics such as colourless, flat, very thin, uniform thickness, and perfectly free from any specks, veins, bubbles, and other flaws (Nollet 1770; Bielfeld 1855; Groom 1855; M. J. Whipple & Co. 1856; Negretti & Zambra 1866; Marcy 1877; Hepworth 1889; Underhill 1892). Before drawing or painting, the glass would be cut with the desired shape and size and perfectly cleaned to remove dust and grease from the surface. Among the strategies used by the authors are rubbing the glass with gall water on a piece of linen followed by turpentine (Bielfeld 1855); cleaning with a solution of water and ammonia (Negretti & Zambra 1866; Marcy 1877); cleaning with ox-gall to 'give the colours more bite', which possibly means to improve the colour adhesion to the surface by removing any grease and stains from the surface (Middleton 1876); and cleaning with *blanc d'Espagne* (possibly a whitewash), a product similarly advised to give a final polishing to the glass and increase paint adhesion (Molteni 1878). After the cleaning, other substances, such as weak solutions of gelatine in water, watercolour medium, solutions of sugar, and varnishes, could be used to coat the surface as a preparatory layer to enhance the glass transparency and the paints' adhesion (Hepworth 1889).

After having the desired composition drawn on paper, the prepared glass was placed over a retouching desk (Figure 5), or an adapted easel for glass painting, with the drawing underneath (Chadwick 1878,

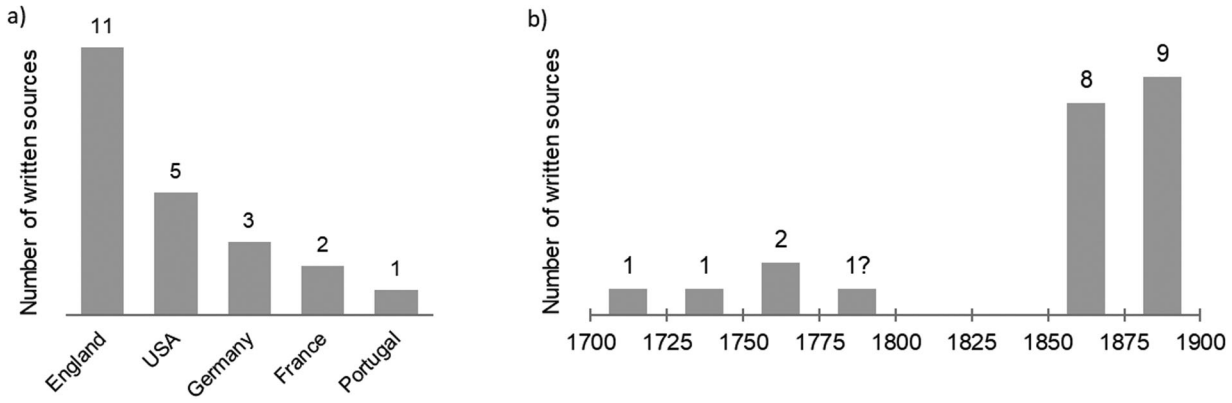

Figure 4. Geographical (a) and chronological (b) distribution of the 22 historical written sources consulted. Note: The source between 1775 and 1800 (with '?') corresponds to the one attributed to the end of eighteenth-century Lisbon.

1886), and the outlines or guidelines would be copied to the glass with a pencil, brush, or lithographic pen with dark paint, varnish colour, or watercolours matching the tone of each area depending on the desired effect (Groom 1855; M. J. Whipple & Co. 1856; Negretti & Zambra 1866; Middleton 1876). Several options are presented regarding the outline: it could be done on the opposite side of the glass to keep the drawing steady during the painting process, and they would be rubbed off after the painting was completed (e.g. with a vinegar solution); they could be done on different glass than the one on which the painting would be executed and, when finished, they would be attached with the paints facing inwards for protection; the outline could be done and receive the painting directly over it; or be covered with a protective layer of varnish to assure it remained untouched during the colour's application (Hertel 1716; Groom 1855). If the glass slides were bought with the outlines already printed, the process would start with colour application (Chadwick 1878, 1886).

Regarding the painting method, it is advised to have a coloured illustration for reference. Most of the authors indicate that the background (e.g. sky, clouds, and mountains) and distant elements should be painted first using dimmed shades of colours, then the figures and finally the details would be added with more concentrated colours (Groom 1855; M. J. Whipple & Co. 1856; Middleton 1876). In addition, the authors advised watercolours, oil, and varnish colours. Watercolours and oils were sometimes combined; watercolours created delicate and shiny effects, whereas the strength of the oils conferred intensity on certain parts of the painting that were intended to stand out (Groom 1855). The figures would be painted with strong colours, so these would remain visible when magnified under intense light (Urbino and Day 1873). After painting them, their surrounding background could be covered with opaque black oil paint to make them stand out, and needles could be used to scratch details and write (Hertel 1716; Denecke 1757). Varnishes were applied at different stages, either between paint layers, mixed with the colourants, or as a final layer (Groom 1855). Some authors advise painting two slides simultaneously, alternating between them to give time for each layer to dry completely before applying the following layer of colours (Rintoul 1867).

Another glass could be placed over the painted surface as an alternative to varnishing the painting or an additional layer of protection. A rim of glued/gummed paper was placed around the edge of the

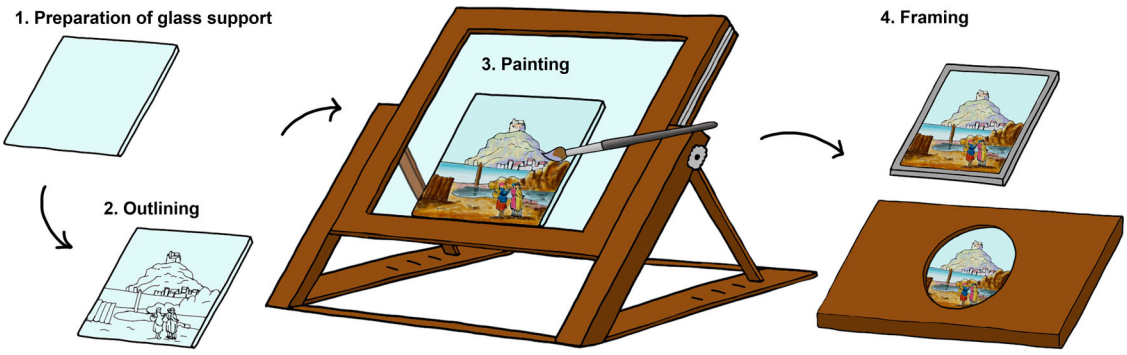

Figure 5. Main production stages of hand-painted magic lantern slides: (1) preparation of glass support, (2) outlining, (3) painting, and (4) framing. © Drawings by Ângela Santos.

glass to keep this cover glass from touching the painting (Groom 1855; M. J. Whipple & Co. 1856). Furthermore, to prepare the glass to be safely handled and placed in the magic lantern to be projected, they would be framed using adhesive paper or wood with or without movement mechanisms (Chadwick 1878).

To the extent of the authors' understanding, these transparent paintings appear to descend from the stained-glass tradition, as implied by the reference to seventeenth-century or earlier slides being painted with transparent low-fired enamels (Hertel 1716; Nollet 1770). Similarly to stained glass, these were observed in transparency, departing from reverse glass paintings that, even though they use cold paints on glass, are opaque and were painted in reverse order (starting with details and finishing with the foreground) to be installed on walls (Fakuč 2007).

Materials used on hand-painted slides

Glass support

The period of interest, from the mid-seventeenth century to the end of the nineteenth century, has covered significant changes in the flat glass industry. Around half of the written sources consulted indicate preferred types of glass to make magic lantern slides with the desired quality, which appear to follow the developments in flat glass production (Table 2).

The earliest reference, by Hertel (1716), specifies thin 'discs' of pure glass, which can indicate the use of *crown* glass, one of the most predominantly used hand-blowing techniques to obtain transparent sheets of glass until the early nineteenth century, along with *broad* or *cylinder* glass. In a few words, the *crown* method created a circular panel or disc of glass by spinning an opened glass bubble in the pontil using centrifugal force. As the glass furthest away from the centre was flatter than the area surrounding the 'bullseye', it was probably the part used for the slides. On the other hand, the *cylinder* technique consisted of blowing a bubble and elongating it until a long cylinder was formed, which was then cut along its length, reheated, and opened into a sheet of glass, resulting in glass from 0.25 mm or less to 0.3 mm thickness (Navarro 2003; Cable 2004). Often these glasses have imperfections. For example, *crown* glass presented air bubbles with a concentric orientation and wavy surfaces, and the cylinder method resulted in glass with elongated bubbles, marks of flattening instruments, and rough surfaces (Navarro 2003).

Denecke (1757) refers to a glass that is poured, milled, or rolled on tables and ground by glass manufacturers, suggesting the *plate* or *ground-polished* glass that should be homogeneous in thickness and with one smoother side (Hertel 1716; Denecke 1757). This flat glass production technique was developed in Saint-Gobain (France) at the end of the seventeenth century as a reinvention of the Roman *cast (plate)* glass method, and it was produced by pouring and casting the molten glass from a special pot onto a flat polished metal table and passing a heavy metal roller on movable sidebars with the thickness of the intended glass plate (Navarro 2003; Cable 2004). With this process, a thick sheet of glass was obtained, which had to be ground and polished on both sides after annealing to reduce the thickness and remove the surface irregularities (Navarro 2003; Cable 2004; Dungworth 2011). Even though this technique produced high-quality flat glass, the long hand-polishing process made the *plate* glass more expensive than *crown* or *cylinder* glass (Dungworth 2011).

During the nineteenth century, both *crown* and *plate* glass were highly recommended. Groom (1855) and Bielfeld (1855) suggest both types of glass, and Groom adds that the flatted *crown* glass is suitable for common subjects, but the *plate* glass is better for refined executions (Bielfeld 1855; Groom 1855). The latest is likewise mentioned by Whipple & Co (1856) as *plate* glass, by Marcy (1877) as *ground-polished* glass, and by Hepworth (1889) as a 'very finely-ground glass'. Hepworth emphasises that ground

Table 2. Types of glass techniques advised by the written sources consulted for magic lantern slides.

Author	Date	Country	Crown	Plate or Ground-Polished	Broad or Cylinder	Patent Plate
Hertel	1716	Germany	●			
Denecke	1757	Germany		●		
Groom	1855	England	●	●	?	
Bielfeld	1855	England	●	●	?	
Whipple & Co.	1856	USA		●	?	
Negretti & Zambra	1866	England				●
"A Mere Phantom"	1874	England	●			●
Marcy	1877	USA		●		?
Hepworth	1889	USA		●		?
Underhill	1892	England				●

Note: ● – Identified by this classification; **?** – Not identified by this name but cannot be excluded. © Drawings by Ângela Santos.

glass fine enough for making lantern slides, with no bubbles and other flaws, would be possibly difficult to find, and encourages the reader to grind and polish the glass themself, using flour and thin cream with water, repeatedly, until the glass is clear under transmitted light (Hepworth 1889). Groom (1855) and Marcy (1877) also point out that the glass had a smooth and a rough side, explain how to distinguish them by drawing a fingernail over the surface, and indicate that the smoothest should be chosen to draw and paint to avoid irregularities. Although none of the authors explicitly mentioned *broad* or *cylinder* glass, after the improvements made from around the 1830s onwards, this production method gained strength; the resulting glass sheet tended to be rough on one or both sides, and when grinding and polishing processes were applied, it could similarly be referred to as *plate* glass (Cable 2008; Dungworth 2012; Brostoff et al. 2020). Considering this observation, the three references to *plate* glass from 1855 and 1856 could also point to the improved cylinder glass method.

In 1838, Chance patented a mechanised grinding method for *plate* glass (made with the *cylinder* technique) and improved the process by supporting the cold glass sheets on chamois leather, allowing the achievement of much thinner glass that became known as *patent plate* glass (Cable 2004, 2008). This type of glass was first mentioned by Negretti & Zambra (1866), and this technique was later suggested by 'A Mere Phantom' (1874), along with *crown glass* (advised for most purposes) and by Underhill (1892) (Negretti & Zambra 1866; "A Mere Phantom," 1874; Underhill 1892). Given that *patent plate* glass became widely available in various thicknesses and qualities, it is possible that Marcy (1877) and Hepworth (1889) were already referring to this type of glass when mentioning *ground-polished* glass.

Insights into the glass composition are mostly given by earlier literature. The eighteenth-century authors Hertel (1716), Denecke (1757), and Nollet (1770) advise the use of pure glass from France or Bohemia (Hertel 1716; Nollet 1770; Denecke 1757). Chadwick (1886) states that the glass should not be 'too cold in tone', which may imply lower amounts of iron, an element responsible for giving green or blue–green tints to the glass, or other decolourising agents (Dungworth 2012).

Recent analyses of eighteenth-century magic lantern slides have identified a potassium-rich or potassium-lime glass composition similar to white/chalk glass objects produced in Central Europe during the seventeenth and eighteenth centuries (Santos et al. 2023), which may correspond to the referenced pure French or Bohemian glass. In addition, these glasses present round-shaped bubbles slightly tilted to the same side, possibly indicating the use of the *crown* technique, and Central European *crown* potash glass has also been reported in other studies (Caen 2009; Santos et al. 2023). Regarding early nineteenth-century slides, kelp-based mixed alkali *crown* glass with concentric ripples produced in England was identified in slides before ca.1835 (Santos et al. 2023). From the second half of the century, English and French slides presented high-lime low-alkali (HLLA) and soda-lime glass showing the elongated bubbles typical of the *cylinder* or *patent plate* glass (Santos et al. 2023). The identified techniques correspond to those suggested by the coeval literature.

Paints

To paint magic lantern glass slides, the authors frequently listed the painting materials necessary, including various resinous and oil binding mediums and the best colourants for that purpose, which can be consulted in Table 3.

To paint glass slides, most authors mentioned watercolours, given their brilliance and transparency, and their use goes from the beginning of the eighteenth century to the end of the nineteenth century. Several authors recommend mixing the watercolours with varnish before applying the paint; when watercolours were applied alone, it was frequently advised to coat the painting with a layer of clear varnish to protect it and prevent it from cracks when heated by the lantern (Groom 1855; Negretti & Zambra 1866; Middleton 1876). Gum water is only advised when watercolours are used or mixed with Indian ink (Middleton 1876).

Oil colours were usually not recommended during the eighteenth century. In his testimony, Hertel (1716) stated that he had tried to use oils but mentioned they would become dark and opaque in time (Hertel 1716). Darkening of green colours, such as verdigris, in the possible presence of oils and resins, was detected in eighteenth-century slides (Santos et al. 2019). The only source from the eighteenth century referring to the use of oil colours, the Portuguese manuscript, states they should be applied mixed with a thin varnish that should also be used to coat the painting at the end to give transparency and adhesion to the glass (Distribuiçam das partes da Lanterna Magica 2018). Nevertheless, the nineteenth century was a period of changes in the production of painting materials, with alchemy giving place to chemistry and the discovery of new elements that triggered the development of different compounds and colourants (Harley 2001). Due to this period's significant improvements, new oil colours suitable for transparent glass painting were produced and started being advised in the second half of the nineteenth century by almost all authors (Bielfeld 1855; Groom 1855; M. J. Whipple & Co. 1856; Rintoul 1867; Urbino and Day 1873; "A Mere Phantom," 1874; Marcy 1877; Chadwick 1878;

Table 3. Binding medium components, and colourants for painting magic lantern glass slides advised by written historical sources, chronologically distributed.[§]

Written Sources	Hertel	Wiedeburg	Denecke	Nollet	Anon.	Groom	Bielfeld	Whipple & Co.	Winsor & Newton	Negretti & Zambra	Rintoul	Urbino & Day	"A Mere Phantom"	Middleton	Marcy	Molteni	Chadwick	Hepworth	Underhill	"An Expert"	Winsor & Newton
	1716	1735	1757	1770	17--	1855	1855	1856	1863	1866	1867	1873	1874	1876	1877	1878	1886	1889	1892	1893	1896
Resinous Binders																					
Gum water	•		•											M	M				•		
Mastic varnish	•	•	•	•		M	O			MT	•			•	•		•	•	•	•	
Sandarac varnish	•	•	•	•												•		•			
Shellac/Lac varnish				•		MT															
Copal varnish				•			O					M?				•		•			•
Gum anime				•																	
Varnish					MT		W	•	•				•		•	•					
(Japanners') Gold Size						M	O				•			•			•	•			•
Canada balsam						•				•			•	•	•			•			•
Outside varnish												•									
Opaque black varnish														•							
Water-colour medium														M							
Megilp[1]																		•			•
Crystal varnish																				•	
Solvents / Essences																					
Lavender oil	•	•	•	•									•								
Spirits of wine	•	•	•	•		•										•		•			
Turpentine	•	•				•	B	•		•	•	•	•	•	•	•	•	•	•	•	•
Ox-gall						•	W		•	•			•	•		•	•	•			
Essence of lemon										•											
Oil of cloves															•						
Oils																					
Oil			•		•								•								
Boiled oil					•															•	
[Pale] Drying oil							O	•			•			•			•				
Almond oil																				•	
Colourants																					
Goma guta/gamboge	W	•	•		O	W	O		W	W	BV			WV					W		O
Saffron	W	•																			
[Berry juice] yellow			•																		
Yellow lake					O		W	•				O			B		BV	B			O
Italian pink						B	O		W				O		B			B		O	O
Gallstone						B			W												
Indian yellow						B			W		BV			WV	B						O
Raw sienna							O			W		O		WV				B	W		O
Aureolin									W												
Yellow carmine																		B			O
Brown pink																					O
Burnt sienna						B	B	•	W	W	BV	O	O	WV	B		BV	B	W	O	O
Chinese orange																		B			O
Raw umber	W	•									BV			WV					W		
Brown from walnuts			•																		
Madder brown						B		•	W	W					B			B			O
Vandyke brown						B			W		BV	O		WV	B				W	O	O
Intense brown							W														
Warm brown							W														
Burnt umber							O	•		W	BV			WV	B					O	
Asphalt								•		W											O
Sepia															B				W		
Bitumen																					O
Caledonian brown																					O
Mummy																					O
Carmine	W	W	W								BV		O	WV							O
Dragon's blood	W	W																			
Florentine lake	W	W	W																		

Written Sources	Hertel	Wiedeburg	Denecke	Nollet	Anon.	Groom	Bielfeld	Whipple & Co.	Winsor & Newton	Negretti & Zambra	Rintoul	Urbino & Day	"A Mere Phantom"	Middleton	Marcy	Molteni	Chadwick	Hepworth	Underhill	"An Expert"	Winsor & Newton
	1716	1735	1757	1770	17--	1855	1855	1856	1863	1866	1867	1873	1874	1876	1877	1878	1886	1889	1892	1893	1896
Pernambuco wood			W																		
[Light/Thin] red					O																
Crimson lake						B	B		W		BV	O	O	WV	B		BV	B	W	O	O
Rose/pink madder lake						B	O	•	W	W		O			B			B		O	O
Scarlet lake							W			W	BV				B					O	
Madder carmine								•													
Venetian red											BV										
Alizarin crimson																					O
Crimson madder																					O
Geranium lake																					O
Magenta																					O
Rembrandt's madder																					O
Ruben's madder																					O
Scarlet madder																					O
Mauve											BV				B						O
Purple lake															B					O	O
Purple madder																		B			O
Violet carmine																					O
Indigo	W	•	•			B			W		BV			?	B			B			O
Litmus	W	•																			
Ultramarine blue	W	•			O																
Prussian blue			•			B		•	W	W	BV		O	?	B		BV	B	W	O	O
Light blue							W														
Chinese blue							O														O
Payne's gray																			W		
Verdigris	W		•		O					W											O
Green lily			•																		
Light green							W														
Dark green							W														
Emerald green												O									
French Veronese green																					O
Olive green																					O
Prussian green																					O
Sap green																					O
Viridian																					O
Bone/ivory black	W	•	?		O						BV			WV				B		O	O
Lamp black				V	O	B			W	W	BV	O		WV	B				W		O
Opaque black					O		B														
Transparent black							?										BV				
(Opaque) blue-black								•													
Neutral tint																		B			O
Other Materials																					
Indian ink							W							L	•	L					
Prout's brown ink									L												
Sugar of lead															D						•

[§]It should be noted that various historical material terms listed are ambiguous and possibly redundant, limiting their correspondence to specific materials (e.g. varnish and oil).

Notes: ● – not specified; **M** – mixed with colours; **T –** applied on top; **W** – watercolour; **O** – oil colour; **B** – both W and O; **V** – varnish colour; **L** – outlines; **D** – drier; **?** – possibly referred. [1] mastic varnish + pale drying oil.

Molteni 1878; Chadwick 1886; Hepworth 1889; "An Expert" [W. C. Hughes] 1893; Winsor & Newton 1896).

Besides being added to oil colours, oils were also used along with varnishes. More expressively than what is observed with the colourants, many authors mentioned using a varnish without attributing a name that could identify them. Nevertheless, it is possible to ascertain that the most used varnish throughout both centuries was by far mastic varnish diluted with turpentine, which was also the most listed solvent, and/or with spirits of wine (alcohol), a varnish frequently used along with oil colours (Groom 1855; Urbino and Day 1873; Marcy 1877). Japanners' Gold Size, characterised as an oil-gum

varnish, and Canada balsam are also much advised, followed by copal and sandarac varnishes. The latter, and shellac varnish, appear to have been replaced during the nineteenth century.

Regarding solvents and essences, apart from turpentine and spirits of wine, Canada balsam and oxgall were often recommended in the nineteenth century. In opposition, lavender oil appears to have during this period. Besides solvents and essences, oils were added to the varnishes, not only when oil colours were used but also with watercolours to improve the handling properties.

As mentioned, varnishes could be used as a preparation layer, applied between layers of colour, mixed with watercolours and oil colours, or on top of the painting. The intention was to enhance the colours' intensity and transparency, improve the paints' adhesion to the glass, and protect the painting from, for example, cleaning, impacts, abrasion, and high temperature during the projections (Groom 1855; Frutos 2013; Distribuiçam das partes da Lanterna Magica 2018).

Varnish colours were first advised at the end of the eighteenth century by Nollet (1770). These were prepared by grinding the powder pigments with varnish (e.g. mastic or Canada balsam with turpentine), and during the nineteenth century, these colours were being sold already prepared. Besides being also mentioned by Rintoul (1867), Middleton (1876), Chadwick (1878, 1886), and Molteni (1878), most authors that suggested oil colours advised mixing them with varnishes before applying the paint, which would give similar results in terms of transparency, adhesion, and shine, and would also accelerate the paints' drying time (Bielfeld 1855; Groom 1855; M. J. Whipple & Co. 1856; Rintoul 1867; Urbino and Day 1873; Middleton 1876; Marcy 1877; Chadwick 1878; Molteni 1878; Chadwick 1886; Distribuiçam das partes da Lanterna Magica 2018).

The drying time of the oil paints was undoubtedly an issue they tried to overcome. Rintoul (1867) advised painting two slides simultaneously, alternating between layers of paint to allow them to dry before adding the next layer (Rintoul 1867). Also, Chadwick (1878), who indicated all three types of paints were suitable, affirmed that watercolours were easy for amateurs to paint since less time was required for them to dry (Chadwick 1878). Marcy (1877) also mentions that the sugar of lead could be added to the paints and the mastic varnish diluted with turpentine (Marcy 1877).

During the nineteenth century, a few authors indicated that both watercolours and oil colours should be obtained in tubes, and several authors revealed their preference for Winsor & Newton, one of the leading artists' colourmen worldwide at the time (Groom 1855; M. J. Whipple & Co. 1856; Urbino and Day 1873; Hepworth 1889).

Material studies undertaken on historical slides have revealed the presence of natural resins in almost all eighteenth- and nineteenth-century hand-painted slides analysed (Scalarone et al. 2006; Ploeger et al. 2008, 2010; Rodrigues et al. 2019; Santos et al. 2019, 2020, 2021b). The terpenoid mastic and shellac resins were identified in several of them, corresponding to the instructions given by the historical literature (Rodrigues et al. 2019; Santos et al. 2019, 2020). A few studies also detected the possible presence of oils and gums, in some cases, in combination with the resins (Scalarone et al. 2006; Ploeger et al. 2008, 2010). The presence of animal glue has also been detected in two nineteenth-century hand-painted slides (Scalarone et al. 2006).

Regarding the colourants listed by the authors, summarised in Table 3, it is noteworthy that the number is considerably restricted due to the importance of transparency (Groom 1855). The majority are primary colours (yellows, pinks/reds, and blues), and the authors frequently mentioned that these should be mixed to produce the rest of the necessary hues, which corroborates the results from previous analytical studies of historical slides ("A Mere Phantom," 1874; Santos et al. 2021a). Furthermore, some authors only mentioned the type of paints and binding mediums that should be used and did not specify the colourants. Additionally, others did not list some of the colourants with an identifiable term (e.g. yellow lake, light blue, and dark green), which increases the difficulty in ascertaining a trend in the choice of colourants over time.

In general, most of the colourants used were organic and transparent, and there was some consistency in the colour choice since the authors frequently referred to the same colourants.

Various yellows were frequently advised; however, gamboge was the most listed, followed by Italian pink, an unidentified yellow lake, raw sienna, and Indian yellow. Additionally, the 'yellow from berry juice' mentioned by Denecke (1757) may be related to Italian pink since this colourant was also extracted from berries. Burnt sienna was repeatedly advised as a valuable orange to be used by itself and to mix with other colourants. Nevertheless, since it is a semi-transparent colourant, authors often mention the mixture of a yellow lake with a red/pink colourant (Bielfeld 1855; M. J. Whipple & Co. 1856). Finally, various browns were listed, from lakes to earth pigments, Vandyke brown, madder brown, and burnt umber being the most common.

Regarding the red and pink hues, cochineal lakes were by far the most mentioned and appeared to have been used throughout both centuries under the names of carmine and crimson lake (which was confirmed by analytical studies (Rodrigues et al. 2019, Santos et al. 2021a), followed by rose or pink madder lake. The blue colourants were the most

consistent since mainly indigo and Prussian blue were preferred, the latter being the most used after it became available to artists (ca. 1724) (Coles 2018).

Purples and greens were scarcely mentioned and as stated by the authors, were frequently obtained by mixing primary colours, as verified in previous historical slides analysis (Groom 1855; M. J. Whipple & Co. 1856; Rintoul 1867; Frutos 2013; Santos et al. 2021a). Nevertheless, the green verdigris was mostly advised in the first half of the nineteenth century and purple lake only in the second half. Finally, as black colourants, lamp black, followed by bone/ivory black, were, without doubt, the most frequently used.

Over time, changes in the colour palette can be perceived. The variety of colourants advised increased considerably from the mid-nineteenth century onwards. Through Winsor & Newton's Trade Catalogue from the end of the century, it became clear that the advances in the pigment manufacturing industry continued to allow the development of new transparent colourants (Winsor & Newton 1896). A few colourants notoriously stopped being listed in the nineteenth century, which was the case of the yellow saffron, gallstone, and aureolin, the reds dragon's blood (a resinous colourant), Florentine lake (a cochineal-based lake), and Pernambuco wood (known as brazilwood), the bluish-violet litmus and ultramarine blue, and 'green lily' (that could mean green earth). It was also interesting to notice that, in the nineteenth century, fewer green colourants were listed, increasing the references to mixtures to produce greens, and the opposite occurred with purples since more purple colourants became available (M. J. Whipple & Co. 1856).

It should be noted that no white colourants were listed since this was achieved by the absence of paint that allowed the light to pass through the glass (Bielfeld 1855; M. J. Whipple & Co. 1856; Negretti & Zambra 1866). On the other hand, opaque black colourants were advised for background masks, and these, along with inks, were also indicated for outlines (Bielfeld 1855; M. J. Whipple & Co. 1856; Rintoul 1867).

In a systematic study on the colours applied on eighteenth- and nineteenth-century slides, the colourants identified correspond mostly to those advised by coeval literature; nevertheless, the palette identified thus far is much more limited. Slides from the eighteenth century showed the presence of colourants and mixtures advised, such as yellow, brown, and red ochres (respectively corresponding to, e.g. raw sienna, raw umber, and burnt sienna), an anthraquinone lake of animal origin (possibly cochineal-based, e.g. carmine and crimson lake), Prussian blue, purple made of the pink animal lake and Prussian blue, copper-based green (e.g. verdigris), carbon-based black (e.g. lamp black and bone black) and unidentified organic yellows, oranges, and browns (Scalarone et al. 2006; Rodrigues et al. 2019; Santos et al. 2019, 2021a). Analysis of nineteenth-century slides demonstrated, as the historical literature implied, an increase in the variety of colourants and mixtures. Colours such as gamboge, an eosin-based lake (e.g. geranium lake), ultramarine blue (mixed with Prussian blue), and greens made of organic yellows and blues were identified (Rodrigues et al. 2019; Santos et al. 2021a, 2022). Unexpectedly, in a few orange and pink colours, vermilion was also detected in mixtures with yellows and pink lakes (Santos et al. 2021a).

The choice of painting materials has implications for the long-term preservation of these objects. The material analyses have detected deterioration products at the molecular level (e.g. presence of metal carboxylates and oxalates), which result in the binders' failure, correspondng to the lack of paint cohesion and adhesion to the glass and, ultimately, the loss of the painting layer, visible on numerous slides (Rodrigues et al. 2019; Santos et al. 2019, 2021b). Also, colour alterations were observed, such as the darkening of copper-based green and fading of yellow and pink lakes (Santos et al. 2019, 2021b).

Concluding remarks

In this investigation, 22 written sources from eighteenth- and nineteenth-century Europe and the United States of America were found to have instructions on producing magic lantern slides entirely hand-painted and with printed outlines. A significant part belonged to the nineteenth century, which coincided with the period when the magic lantern achieved higher popularity, and the demand for magic lantern slides considerably increased. It was possible to observe a tendency to transition the information on the production of slides from broad scientific treatises to specialised books over time.

The slides' production processes drastically changed from the mid-seventeenth to the eighteenth century with the apparent transition from *fired paints* (enamels) to *cold paints* (watercolours, oil colours, and varnish colours) and from the eighteenth to the nineteenth century, it evolved with the development of the glass industry and painting materials manufacture during the Industrial Revolution.

The quality of the glass and increased palette with refined transparent colourants and binding mediums allowed the production of slides with much higher quality. Regarding the glass support, the importance of choosing the thinnest and most transparent glass sheets without imperfections became clear. This glass was mainly produced by *crown*, *plate,* or *ground-polished*, and later, the *patent plate* method. The macroscopic characteristics of the slides' chosen glass can help in attributions when allied with analytical methods since flat glass production centres used specific techniques and chemical compositions that changed over time. Since

only a few sources indicated possible compositions, further research should be undertaken to uncover if particular glass compositions were valued by slides' manufacturers. In this regard, the material analyses verified a preference for high-quality glass compositions with low contents of impurities and follow the technological evolution of flat glass production.

Painting methods did not considerably change between authors, given that the variations observed appear to be mainly related to the image's composition and the choice of colourants and binding mediums. Watercolours mixed or protected with varnishes were the binding mediums preferred in the eighteenth century, and the nineteenth century saw increased references to oil colours. In general, these types of binders correspond to those detected on the slides analysed. A list of around 70 transparent and semi-transparent colours was identified in historical literature. The colours identified through analytical studies of historical slides belong to this list; however, it revealed a more limited palette.

Identifying the materials and techniques applied to these slides contributes to their understanding and appreciation. Further characterisation studies on historic painted magic lantern glass slides should be performed, allowing further correlations between the written historical sources and the artefacts according to time and place of production. It would be very interesting to verify the survival of slides with *fired paints* from earlier periods.

In-depth knowledge of hand-painted slide production will aid the understanding of degradation mechanisms that lead to the conservation problems observed in these objects and aid the development of better conservation practices (preventive, interventive, and restoration). Furthermore, given the need for efficient solutions to replicate original glass slides, the present work will help develop future proposals to protect historical slides while ensuring access to them as performative and educational artefacts by present and coming generations.

Acknowledgements

The authors would like to thank the Portuguese Cinematheque – Museum of Cinema for the collaboration and Beatriz Rodrigues for helping in the collection of historical literature.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work was supported by the Portuguese Foundation for Science and Technology (FCT) of the Ministry of Science, Technology and Higher Education (MCTES), Portugal, through the doctoral program CORES-PD/00253/2012 (Ângela Santos' grant PD/BD/136694/2018; COVID/BD/152617/2022), Vanessa Otero's 2020.00647.CEECIND, Research Units VICARTE (UIDB/00729/2020; UIDP/00729/2020) and LAQV-REQUIMTE (UIDB/50006/2020; UIDP/50006/2020), and the project MAGICA, PTDC/ART-PER/1702/2021.

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