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# Advances in Extended Depth of Field Microscopy and Automated Scanning for the Study of Historic Paintings, Calligraphy and Murals

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**Abstract:** Extended depth of field (EDOF) microscopy combines in-focus information from different focal planes within the same field of view. It provides detailed records of surface structures in historic paintings, calligraphy and murals. Integration with automated motion stages and image stitching has extended its use to large-area scanning. This review focuses on published research from October 2021 to October 2026. It examines material and technique studies, surface documentation and conservation treatment assessment in works on paper and silk, cave and tomb murals, and related paintings. It also discusses the technical requirements for developing microscopes into scanning systems. Existing studies show that microscopic morphology, combined with spectroscopic, elemental and tomographic information, can help explain pigment alteration, past repairs and the distribution of conservation materials. Automated multifocus acquisition has also enabled whole-painting two-dimensional microscopic documentation in selected cases. However, most studies still concern local observations and individual objects. Whole-object scanning of paper and silk works, comparisons across instruments, and long-term repeated observations remain insufficiently validated. Future research should strengthen links between raw images and processed outputs. Scale, stitching errors and repeatability also require clearer assessment. These steps would help microscopic scanning provide spatially continuous evidence for conservation research.

**Keywords:** EDOF microscopy; focus stacking; automated scanning; historic paintings and calligraphy; murals; heritage conservation.

## 1. Introduction

Material structures in historic paintings, calligraphy and murals often span very different scales. Macroscopic images show composition and overall condition. Interwoven paper fibres, broken silk threads, pigment particles and fine cracks require microscopic observation. These structures lie at different heights, so images taken at a single focal plane may miss some details. EDOF microscopy combines in-focus regions from multiple focal planes. This allows local structures on uneven surfaces to appear continuously within one image. Its research value depends on the structures that can be observed. It is also constrained by the field of view, spatial sampling and the optical properties of the materials [1].

The development of microscopes into automated scanning systems makes it possible to connect separate observation points while preserving their spatial relationships. A 2019 study of *Girl with a Pearl Earring* compared three-dimensional digital microscopy, optical coherence tomography and fringe-encoded stereo imaging. A 2021 investigation of a painting on paper also used a gantry stage to assist three-dimensional microscopic observation[2,3]. Building on these technical developments, research over the past five years has advanced both local material analysis and large-area digital documentation. This review focuses on Chinese paintings and calligraphy on paper or silk and on murals. It also includes related cases, such as European paintings, to compare applications across materials, acquisition methods and research aims.

## 2. Literature Scope and Review Methods

This thematic narrative review covers research published between 2 October 2021 and 2 October 2026. Earlier studies directly relevant to imaging principles and scanning methods are also included. Searches used publicly accessible academic search tools, journal and publisher websites, and Crossref bibliographic records. Chinese and English search terms included extended depth of field, digital microscopy, focus stacking, automated scanning, image stitching, historic paintings and calligraphy, and murals. References in representative papers were also traced. Selection considered the object studied, the imaging method actually used and the purpose of the results. Instrument brand and open-access status were not used to judge application value.

The review includes 32 publications: 31 journal articles and one conference paper. Of these, 27 fall within the stated period, and five provide methodological principles or earlier technical context. Based on the methods reported, the studies are grouped into direct EDOF applications, related digital microscopic observations, and foundational methods relevant to scanning systems. Original heritage objects, removed samples and mock-up materials are considered separately. This distinction helps compare the roles of microscopic images across studies. As a narrative review, this work does not provide an exhaustive search of subscription databases or a quantitative synthesis. The selected cases are used to analyse advances in application, rather than to estimate the global scale of research.

Local microscopic observation, focus stacking, whole-object image stitching and three-dimensional height measurement are treated as distinct types of evidence. For

recent papers for which only bibliographic records and abstracts could be verified, discussion is limited to the publicly reported objects and broad methods. This approach includes recent work without treating optional instrument capabilities as procedures actually performed in a study. Table 1 summarises representative studies and the scope of their evidence.

# 3. Imaging Principles and Interpretation

EDOF microscopy typically changes the focus along the Z axis and acquires a sequence of images of the same field of view. Focus measures identify the in-focus regions, which are then fused into an all-in-focus image. Depth of field is the range of acceptable sharpness in a single exposure. Focus stacking extends the depth range represented sharply in the final image. Focus measure operators, focal-plane spacing and surface texture jointly affect the fusion result. These factors have been examined in dedicated methodological studies[4]. On heritage surfaces containing fibres, particles and cracks, the main role of an all-in-focus image is to reduce information loss caused by local defocus.

An all-in-focus two-dimensional image and a three-dimensional height map convey different information. The former combines sharp details. The latter also requires height estimation from information such as focal position, together with scale calibration and calibration using reference standards. Surface sharpness does not directly indicate the accuracy of height measurements. Optical coherence tomography (OCT) can reveal internal optical layers in suitable materials, complementing microscopic surface morphology. The comparison of imaging methods applied to *Girl with a Pearl Earring* showed that material properties and measurement conditions impose different limits on each technique [2]. Two-dimensional observations, surface height and internal layering must therefore be interpreted separately.

Large-area microscopic scanning requires adjacent fields of view to be acquired along the X and Y axes, with focusing or stacking along the Z axis. Registration and stitching then recover the spatial relationships between tiles. Outputs may include a whole-object all-in-focus image and calibrated local height data. Magnification, object-space pixel size, optical resolution and motion positioning accuracy describe display scale, sampling, detail resolution and position control, respectively. They are not interchangeable. In particular, a sampling value expressed in micrometres per pixel does not equal the smallest structure that a system can reliably resolve.

Material differences further limit how microscopic information can be interpreted. Observation of works on paper often focuses on fibres and surface deposits. In works on silk, the weave, pigment coverage and colour applied to the reverse may interact. Murals often have rough substrates, coatings and granular surfaces. Shadows, reflections and actual cracks may sometimes produce similar image features. Microscopic morphology must therefore usually be considered alongside macroscopic location, lighting conditions and other analytical results to support material identification or damage assessment. This explains the widespread use of multiple imaging and compositional analysis methods in the studies discussed below.

# 4. Advances in Applications to Historic Paintings, Calligraphy and Murals

## 4.1. Works on Paper and Silk and Painting Techniques

Microscopic studies of paintings and calligraphy on paper or silk mainly aim to identify materials and techniques. A 2026 study of three historic Chinese paintings from the Palace Museum combined optical and three-dimensional video microscopy with technical photography and compositional mapping. It investigated relationships among paper fibres, silk weave structures, pigments, mounting and repairs [5]. The published abstract places microscopic structures within interpretations of painting production and past interventions. Such integrated analysis gives microscopic details a clearer technical meaning than high-magnification photographs alone. However, the abstract does not provide enough information to assess whole-object stacking or height measurement performance.

An earlier study of a painting on paper provides a methodological reference. Couvrat Desvergnes et al. first used ultraviolet imaging to locate suspected repairs. They then compared the textures and cracks of original and later white paint using digital microscopy [3]. Figure 1 shows surface differences between white areas on the forehead. It illustrates how microscopic observation can add detail to locations identified by macroscopic imaging. Material attribution and repair dating still depend on other evidence in the original study. This 2021 case provides methodological context and is discussed separately from the main five-year review period.

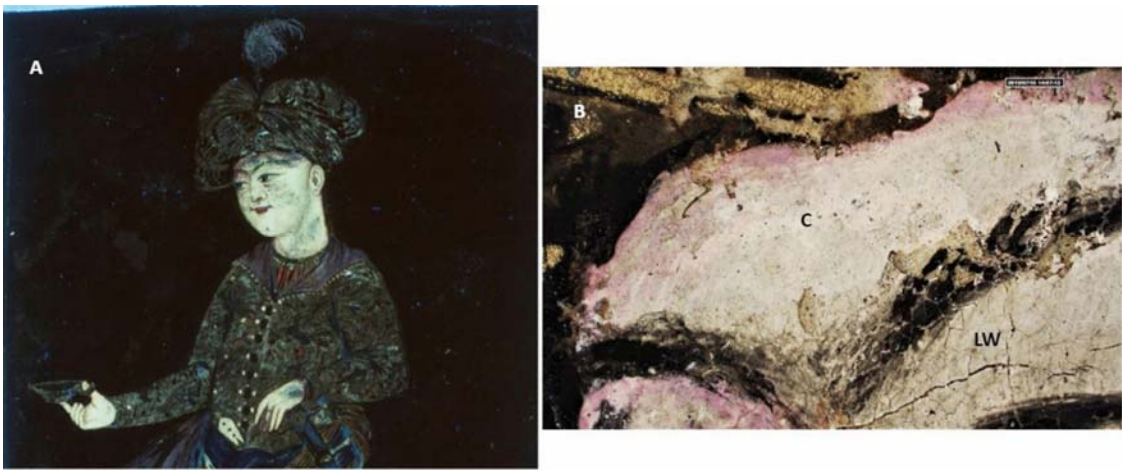



**Figure 1.** Ultraviolet localisation and digital microscopy of repaired areas in a painting on paper

The ultraviolet image is shown on the left, with microscopic details of the forehead on the right. C marks later white paint, and LW marks cracked original white paint. This 2021 case provides methodological context for the main five-year review period.

Source: Couvrat Desvergnes et al. (2021), original Fig. 12 in reference [3]. Reproduced under the CC BY 4.0 licence. The original aspect ratio and labels are retained. Original article.

Studies of the illuminated charter of Évora and a Cypriot composite icon further show how morphology and composition complement each other. The former combined three-dimensional digital microscopy, infrared reflectography and macro X-ray fluorescence to examine painting methods and the order of pigment application [6]. The latter used digital microscopy to observe brushstrokes, overlying layers and repair traces, with spectroscopy supporting material interpretation [7]. The letter stroke in Fig. 2 is shown through both two-dimensional colour and three-dimensional topography. These outputs address different questions. Across these cases, microscopic images reveal local structural relationships. Colour, height and chemical composition nevertheless require interpretation based on their respective measurement evidence.

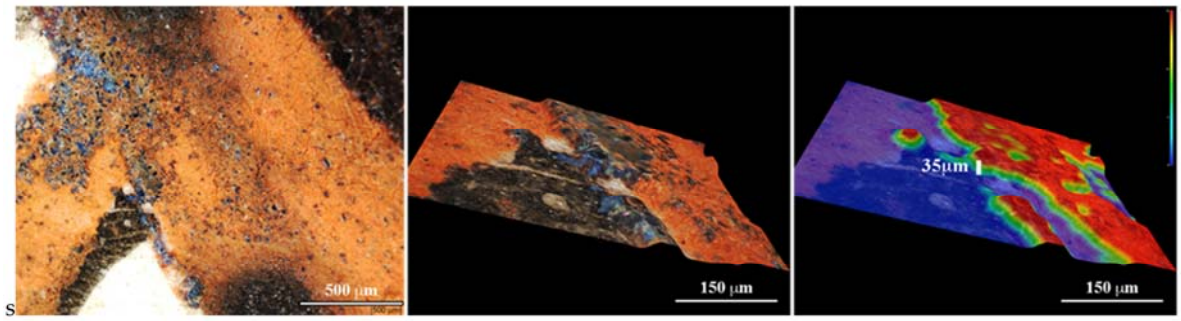



**Figure 2.** Two-dimensional documentation and three-dimensional topography of a letter stroke in an illuminated charter

From left to right: a digital image of the letter A in COLONIA, a three-dimensional display, and a pseudocolour topographic map. The scale bars and the 35 µm height annotation are retained from the original publication. Pseudocolour represents topography.

Source: Miguel et al. (2022), original Fig. 7 in reference [6]. © 2022 by the authors. Licensee MDPI, Basel, Switzerland. Reproduced under the CC BY 4.0 licence. The original aspect ratio and labels are retained. Original article.

## 4.2. Mural Materials and Past Interventions

In mural studies, microscopic observation mainly links surface anomalies to material changes. A study of a discoloured mural in Mogao Cave 254 combined portable digital microscopy, multiband photography, and elemental and molecular analysis. It investigated pigment alteration and virtually reconstructed the original colours [8]. Figure 3 places micrographs from nine colour areas beside the corresponding X-ray fluorescence spectra. Surface structure and elemental information can thus be compared directly. The virtual reconstruction is an interpretation of colour supported by analysis. The microscopic records mainly provide local observations and confirm the locations of analytical areas.

A study of the Dahuting Han Dynasty Tomb applied this approach to previously applied conservation materials. Portable microscopy at 20–200× magnification documented coatings, whitening and local detachment. External-reflection Fourier transform infrared spectroscopy identified conservation materials, while OCT measured the thickness of suitable coatings [9]. Figure 4 preserves the correspondence between macroscopic areas and microscopic details. Unlike the study of pigment alteration in Mogao Cave 254, this case concerns surface conservation materials and their condition. Together, the studies show that microscopic morphology helps locate anomalies. Material identification and layer measurements still require evidence from the relevant analytical methods.

Studies of removed samples and cross-sections shift the focus to pigment stratigraphy and material changes. A study of architectural polychromy in Zhejiang used a VHX-5000 to examine samples and cross-sections. Other analytical methods helped investigate alteration products of copper- and arsenic-containing pigments [10]. A study of pigments from the murals in Murong Zhong's tomb used the same type of instrument to examine paint-layer morphology and stratigraphy [11]. Studies of Mogao Cave 55 and Yuan Dynasty murals at Yongle Palace combined digital microscopy, cross-sections and compositional analysis to investigate gilding techniques [12,13]. These studies reveal relationships between layers that surface observation alone may not show. However, their evidence comes from collected samples or detached fragments and has a different scope from in situ observation.

Studies of gilding materials at the Kizil Grottoes and murals at Guanyin Temple in Suide also used conventional optical microscopy, fluorescence microscopy and material analysis to explain structure and degradation [14,15]. These related studies show that interpretive value depends on the object examined and the combination of evidence. It cannot be classified by instrument name alone. Among the Chinese mural cases reviewed here, the more extensive findings concern local morphology, cross-sectional stratigraphy, and materials and techniques. Continuous whole-mural microscopic scanning is not yet a shared feature of these studies.

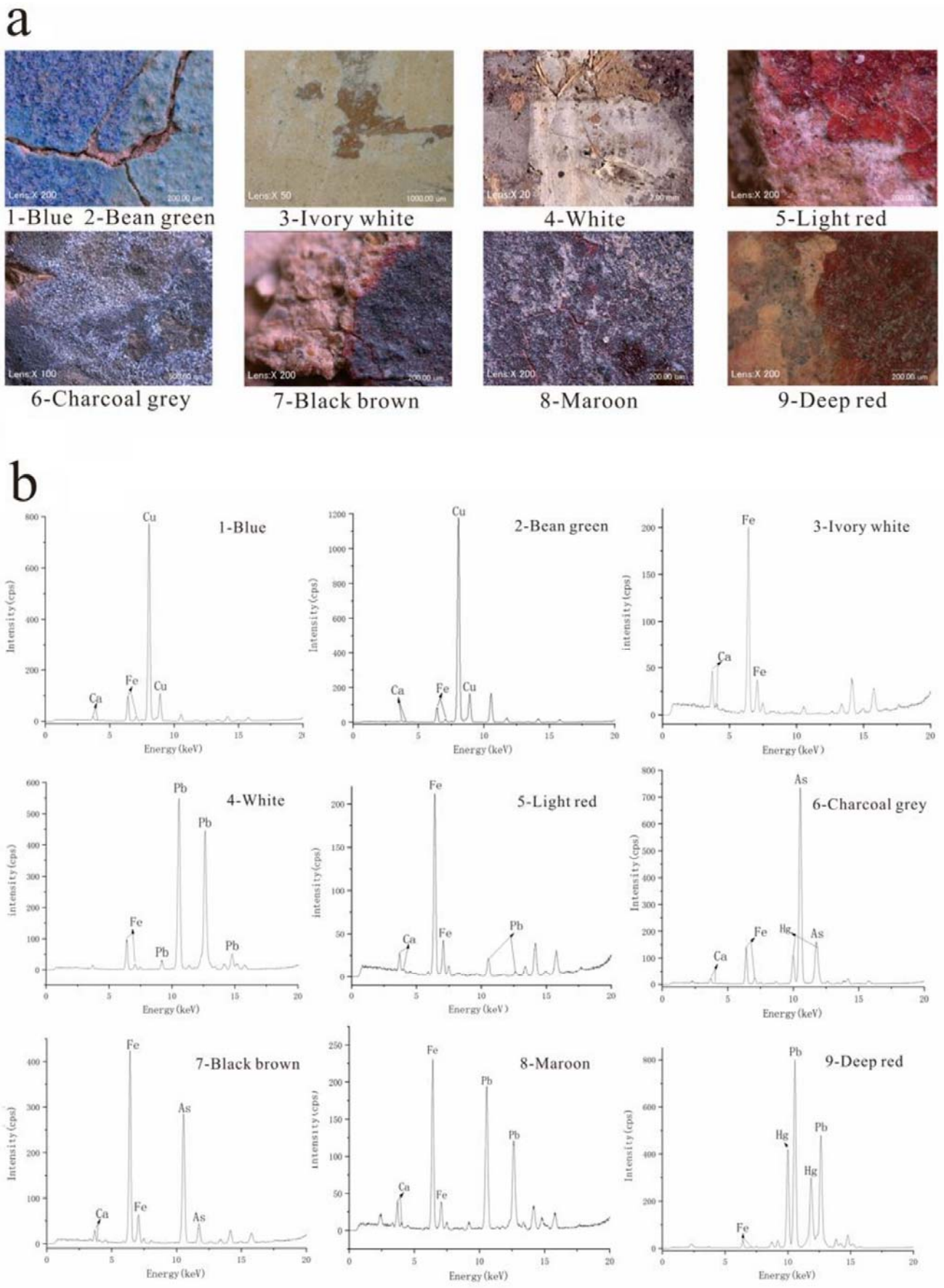



**Figure 3.** Microscopic observation and elemental analysis of colour areas in a mural from Mogao Cave 254

Panel a shows micrographs of nine analytical areas. Panel b shows the corresponding X-ray fluorescence spectra. The two sets provide surface structural and elemental information, respectively.

Source: Chai et al. (2022), original Fig. 7 in reference [8]. Reproduced under the CC BY 4.0 licence. The original aspect ratio and labels are retained. Original article.

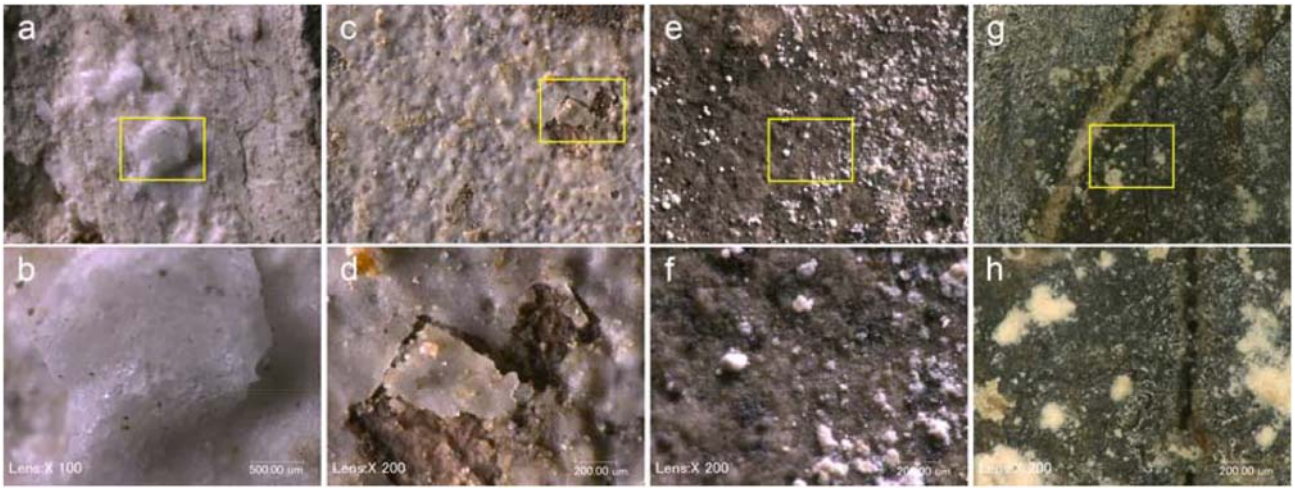



**Figure 4.** Macroscopic locations and microscopic details of conservation materials on murals in the Dahuting Han Dynasty Tomb

Macroscopic images are shown in the upper row. Yellow boxes locate the corresponding microscopic areas in the lower row. Panel b was acquired at 100× magnification, and panels d, f and h at 200×. Interpretation of coatings and deposits draws on spectroscopy in the original study.

Source: Wang et al. (2024), original Fig. 4 in reference [9]. Reproduced under the CC BY 4.0 licence. The original aspect ratio and labels are retained. Original article.

## 4.3. Large Area Scanning and Image Presentation

Research on large paintings has begun to incorporate local microscopic information into broader spatial records. A study of a figure's costume in *The Night Watch* used a Hirox microscope equipped with a motorised XY stage. The microscopic images had a spatial sampling of approximately 1.13 µm/pixel [16]. Figure 5 relates microscopic details to mineral distributions obtained by macro X-ray powder diffraction. Local morphology can thus be interpreted within material distributions over a larger area. This study demonstrates collaboration between microscopic investigation and whole-painting analysis. The sampling and coverage of each instrument nevertheless remain properties of its own dataset.

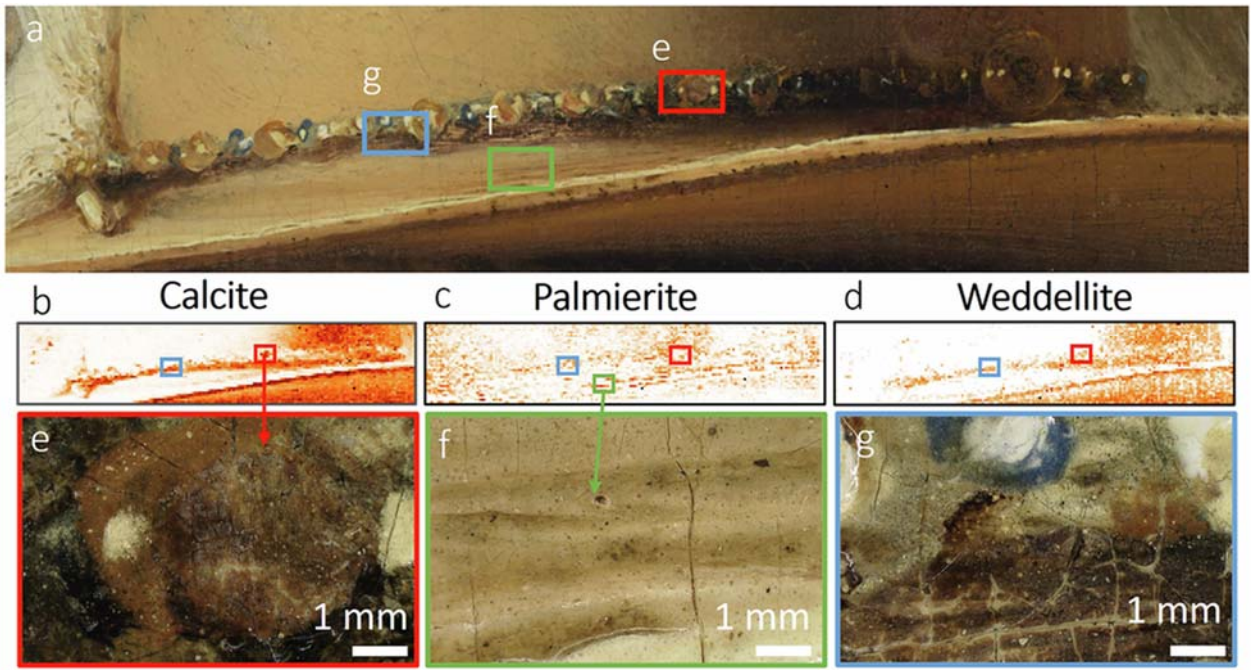



**Figure 5.** Correspondence between local digital micrographs and mineral distributions in *The Night Watch*

Panel a is a visible-light image. Panels b–d show calcite, palmierite and weddellite distributions obtained by macro X-ray powder diffraction. Panels e–g are Hirox micrographs.

Source: De Keyser et al. (2025), original Fig. 11 in reference [16]. Reproduced under the CC BY 4.0 licence. The original aspect ratio and labels are retained. Original article.

A study of *The Scream* provides a clearer example of whole-painting microscopic scanning. In 2024, the researchers used a 1000 × 1000 × 75 mm XYZ gantry to acquire 20,898 multifocus tiles at 30× magnification and 4 µm/pixel. These were stitched into a whole-painting two-dimensional image. The results were published in 2025 [17]. Figure 6 shows the apparatus, and Fig. 7 shows the scanned image and selected regions. This case demonstrates that

automated multifocus acquisition and stitching can produce a spatially continuous microscopic record of a painting. The subsequent tactile model assigns heights to colour regions. This is a conversion for information presentation and differs from directly measured three-dimensional surface topography.




**Figure 6.** Gantry and imaging apparatus for whole-painting microscopic scanning of *The Scream*

The apparatus includes a microscopic imaging head, an XYZ gantry, a painting support, and a control display. Scanning parameters are given in the main text and the original article.

Source: Stavroulakis et al. (2025), original Fig. 4 in reference [17]. © 2025 Stavroulakis, Pagano, Boracchi, Siozos, Sotiropoulou, Leonhardt, Sabatier, Trumpy and Sandu. Reproduced under the CC BY 4.0 licence. The original aspect ratio and labels are retained. Original article.

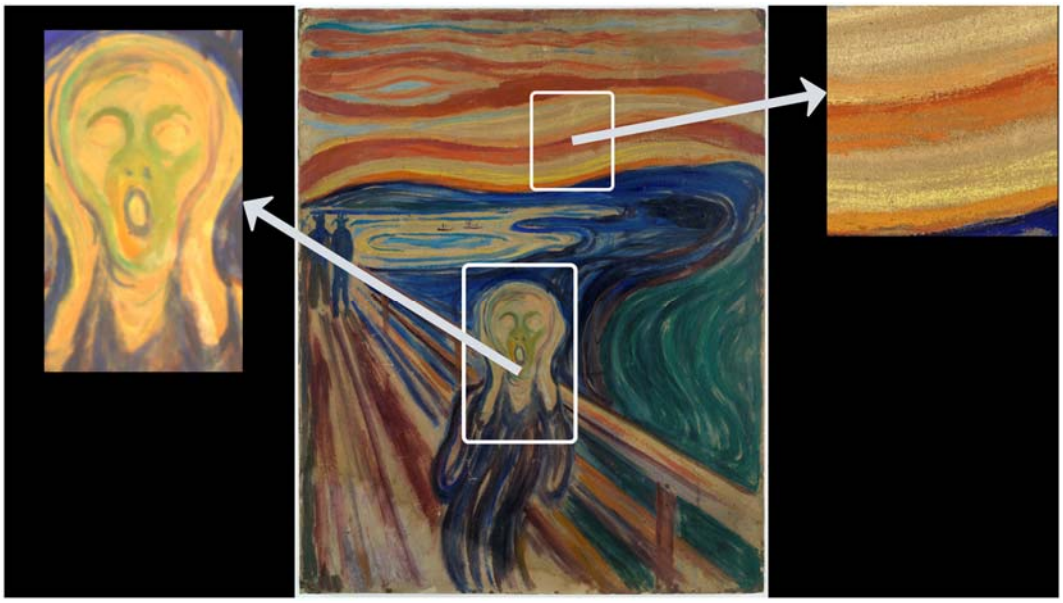


**Figure 7.** Microscopic scan of *The Scream* and selected study regions

The painting is shown in the centre, with selected face and sky regions on either side. Two-dimensional colour information is used for subsequent segmentation and tactile presentation. Heights encoded from colour differ from actual surface heights.

Source: Stavroulakis et al. (2025), original Fig. 5 in reference [17]. © 2025 Stavroulakis, Pagano, Boracchi, Siozos, Sotiropoulou, Leonhardt, Sabatier, Trumpy and Sandu. Reproduced under the CC BY 4.0 licence. The original aspect ratio and labels are retained. Original article.

**Table 1.** Objects and uses of microscopic information in representative studies from the five-year review period

| Year | Study object | Imaging and analytical methods | Recorded information and research use |
|---|---|---|---|
| 2022 | Mogao Cave 254, China | Portable microscopy and multiple analytical methods | Local morphology, pigment alteration and colour interpretation [8] |
| 2024 | Dahuting Han Dynasty Tomb, China | Microscopy, infrared spectroscopy and OCT | Distribution of conservation materials, surface condition and coating thickness [9] |
| 2025 | Murong Zhong's tomb, China | VHX-5000 examination of samples | Morphology and stratigraphy of sampled paint layers [11] |
| 2025 | Mogao Cave 55 and Yongle Palace, China | Digital microscopy, cross-sections and compositional analysis | Gilded-layer structure and production techniques [12,13] |
| 2026 | Paintings on paper and silk, Palace Museum, China | Optical and three-dimensional video microscopy | Relationships among paper or silk, pigments and repairs; based on the published abstract [5] |
| 2022 | Illuminated charter of Évora, Portugal | Three-dimensional microscopy and spectroscopic imaging | Local morphology, painting methods and the sequence of colour application [6] |
| 2024 | Composite icon, Cyprus | Hirox digital microscopy and spectroscopy | Brushstrokes, overlying layers and repair traces [7] |
| 2025 | *The Night Watch*, the Netherlands | Hirox microscopy with a motorised XY stage and multimodal imaging | Local microscopic sampling at approximately 1.13 μm/pixel; links to material distributions [16] |
| 2025 | *The Scream*, Norway | Automated multifocus acquisition and stitching | 20,898 tiles and whole-painting two-dimensional documentation [17] |

Note: Summarised from the cited studies. Local observation, sample analysis and whole-object two-dimensional documentation are distinguished.

## 4.4. Conservation Treatment Assessment and Damage Analysis

Conservation treatment studies use microscopy to compare cleaning and consolidation outcomes. Zhu et al. used EDOF microscopy to help assess mural surface cleaning with a microemulsion-loaded hydrogel. A study of nanocomposite consolidants documented the morphology of treated mural mock-ups [18,19]. Figure 8 shows the cleaning process and microscopic results at different treatment times. Residues, surface structure and treatment extent can thus be compared under the same specimen conditions. Research on fluorescence stress probing also investigated crack detection in laboratory mock-ups [20]. These studies support the use of microscopy in evaluating conservation materials. Safety on original objects and long-term performance still require corresponding evidence.

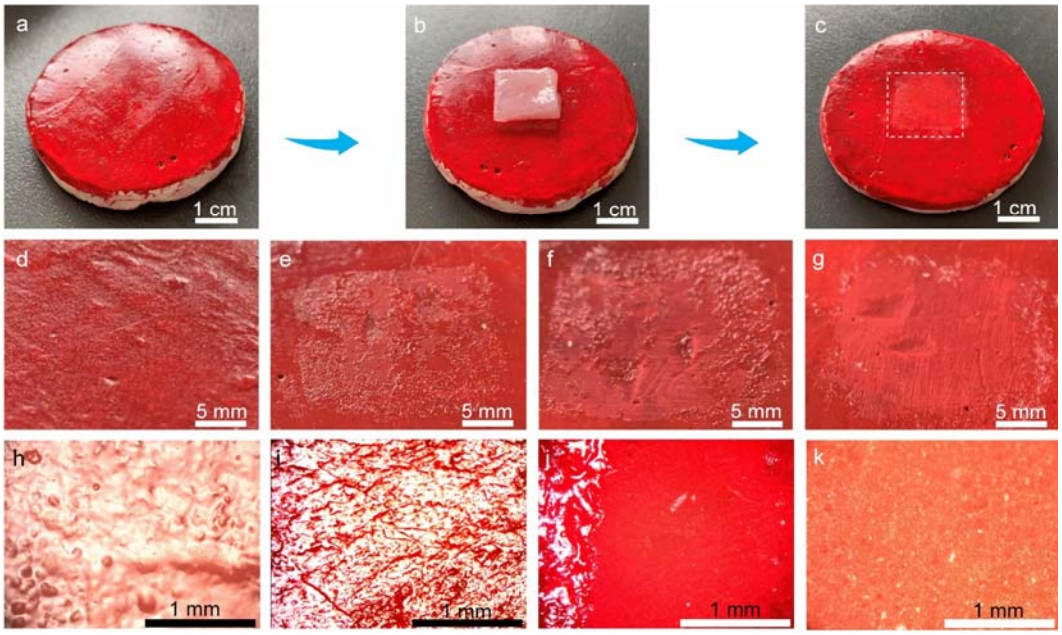



**Figure 8.** Cleaning of mural mock-ups and microscopic results at different treatment times

Panels a–c show the cleaning process, and panels d–g show local surfaces. Panels h–k are optical micrographs acquired before treatment and after 10, 20 and 30 min. These treatment times are experimental conditions for the mock-up specimens.

Source: Zhu et al. (2024), original Fig. 7 in reference [18]. Reproduced under the CC BY 4.0 licence. The original aspect ratio and labels are retained. Original article.

Microscopic records can also be linked to damage analysis and digital archives. PLDS-YOLO detects and segments paint loss in murals and polychrome paintings. A Dunhuang mural dataset provides data for digital restoration, while a review summarises machine learning applications in painting conservation [21,22,23]. These methods extend the use of image information, but their performance cannot be attributed directly to EDOF acquisition. For microscopic tiles, independence between works or regions is particularly important. The high similarity of adjacent tiles may inflate algorithm performance estimates. Conservation experts must still interpret the actual structures before image classification and segmentation results can inform conservation decisions.

# 5. Technical Advances in Automated Microscopic Scanning

## 5.1. Coordination of Imaging and Motion Systems

Developing a microscope into a scanning system requires stable coordination among imaging, motion and data processing. Local observation largely depends on the operator's choice of field of view. Continuous scanning requires recoverable spatial positions for adjacent fields and consistent imaging conditions after movement. Automated acquisition of *The Scream* shows that a gantry and a microscopic imaging unit can produce a whole-painting record [17]. However, experience with planar paintings must be reassessed in relation to support arrangements for paper and silk works, uneven mural surfaces and working distances. For historic paintings, calligraphy and murals, any expansion of scanning coverage must account for the condition of the original object.

Related work on automated photography offers methodological guidance for system development. MosArt uses XYZ motion, autofocus, tiled photography and focus stacking to document two-dimensional and shallow-relief heritage objects. Its imaging unit uses a macro photographic lens [24]. DanqingScan proposes a low-cost three-dimensional scanning approach for Chinese paintings [25]. The former shows how an open automated acquisition system can be organised. The publicly available abstract of the latter describes a recent approach to three-dimensional documentation of traditional paintings. Both relate to EDOF microscopic scanning in their objects and acquisition workflows. Their imaging principles and performance must nevertheless be compared according to their respective methods.

In continuous scanning, motion error becomes a problem of relationships between tiles, rather than isolated positions. Stage position data can provide initial registration estimates. Shared image texture can then correct offsets between adjacent fields. Post-movement vibration, backlash and drift during long acquisitions may affect focus stability and positional consistency. Parallel acquisition with multiple imaging heads is an engineering possibility. However, it also introduces consistency requirements for image scale, colour response and boundaries between scanned regions. The available literature does not yet support a general conclusion about efficiency gains for historic paintings, calligraphy and murals.

## 5.2. Focus Stacking and Image Stitching

Focus stacking extends sharp coverage within one field of view, whereas image stitching connects adjacent fields spatially. Tile overlap provides shared texture. Repetitive patterns, low texture and surface deformation can make matching more difficult. Globally optimal stitching, MIST and ASHLAR provide technical foundations for global position optimisation, stage error modelling and registration across imaging rounds, respectively [26,27,28]. These methods originated in microscopy or tissue imaging. Their application to historic paintings and calligraphy must account for repetitive paper and silk textures, local surface relief, and appearance changes caused by lighting.

Recent multifocus image fusion research has also introduced deep learning. Xia et al. proposed a microscopy image fusion model based on the Swin Transformer. A Chinese-language review compared deep learning fusion methods and discussed focus boundaries, registration errors and limited real-world data [29,30]. In heritage research, fusion quality also depends on whether fine silk threads, crack edges and pigment particles are fully preserved. General image metrics capture some aspects of visual quality. They cannot independently establish whether a material structure is faithfully represented. The original focal sequence therefore remains important for assessing processed results.

Errors in two-dimensional and three-dimensional stitching also differ. Smooth two-dimensional seams mainly indicate visual continuity. Three-dimensional outputs additionally involve height offsets between adjacent regions and cumulative coordinate errors. Reflective, transparent and low-texture regions may lack reliable measurement information. Interpolation can improve display, but it does not add original measurement evidence. Advances in fusion and stitching provide tools for whole-object documentation. Their reliability in heritage research still depends on independent scale checks and verification of local structures.

## 5.3. Complementary Multimodal Imaging

Multimodal imaging broadens the research questions that microscopic scanning can address. A custom infrared scanner has been used for painting reflectography. A portable reflectance transformation imaging (RTI) instrument uses multidirectional lighting to improve interactive observation of surface morphology [31,32]. These methods provide information beneath suitable paint layers and show how texture appears under changing illumination, respectively. Both complement focus stacking. As the cases of *The Night Watch* and Dahuting illustrate, a shared spatial reference can link microscopic morphology, mineral distributions and tomographic results at the same location. This provides a more complete basis for material interpretation.

# 6. Research Limitations and Future Directions

A major limitation of current research is the lack of consistent measurement information and evaluation metrics.

Some studies focus on material identification, others on whole-object documentation, and others provide only local micrographs. Magnification, pixel size and height accuracy are therefore often compared at different levels. Discussion of scanning results should examine optical detail, spatial scale, positional error and processing artefacts separately. Table 2 summarises the main sources of these issues and the aspects requiring assessment. Its purpose is to clarify the basis for comparison across studies, rather than to define universal acceptance thresholds.

The relationship between data volume and information needs also affects technical choices. Denser spatial sampling and more focal planes can increase local information. They also increase acquisition, storage and processing demands. For studies of materials and techniques, a few high-quality fields with clear locations and analytical relevance may be sufficient to support an interpretation. Continuous coverage and positional consistency are more important for mapping damage or repeated observation. Future studies should compare the benefits of detailed local observation and whole-object documentation in relation to specific conservation questions. They should also establish how sampling density relates to structures that can be meaningfully interpreted.

Evidence for applicability across materials and for long-term repeated observation remains limited. Oil paintings, mixed-media works, paper, silk and rough murals differ in texture, reflectivity and support conditions. Experience with whole-painting documentation of European works cannot directly establish suitable parameters for paper, silk or murals. Long-term comparisons must also distinguish actual deterioration from object deformation and changes in imaging conditions. Retaining raw tiles, coordinates, focal sequences and processing versions helps reassess these differences. Comparing only two processed mosaics makes it difficult to determine whether a change arose on the heritage surface or during imaging.

**Table 2.** Main sources of error and aspects to assess in microscopic scanning research

| Research issue | Main influencing factors | Aspects to assess |
|---|---|---|
| Differences in materials and objects | Paper, silk, murals, original objects, samples and mock-ups | Applicability of the evidence to the object studied |
| Scale and detail | Objective lens, working distance and spatial sampling | Separate assessment of scale calibration and resolvable detail |
| Tile positions | Motion drift, repeat positioning and tile overlap | Local registration error and cumulative whole-object error |
| Surface appearance | Lighting direction, exposure, polarisation and reflections | Consistency of imaging conditions and their effects on interpretation |
| Focus fusion | Focal-plane spacing, focus measures and algorithms | Correspondence with raw sequences, ghosting and lost details |
| Three-dimensional information | Height estimation, offsets between adjacent regions and low texture | Height calibration and regions without measurement data |
| Repeated observation | Object deformation, positioning, lighting and processing versions | Distinction between actual changes and imaging changes |

Note: Summarised from the imaging and stitching studies discussed above. These aspects do not define evaluation thresholds applicable to all materials.

# 7. Conclusions

Research over the past five years shows diverse applications of digital and EDOF microscopy to materials, techniques, past repairs and conservation treatments in historic paintings, calligraphy and murals. Their more established role is to provide local morphological and stratigraphic clues. These support material interpretation together with spectroscopic, elemental and tomographic results. Automated multifocus acquisition and image stitching have also enabled whole-painting two-dimensional documentation in selected cases. Microscopic observations can thus retain continuous spatial relationships. These advances provide a practical basis for developing microscopes into scanning systems. However, local observation, whole-object documentation and height measurement still require separate evaluation.

Direct studies of Chinese paintings and calligraphy on paper or silk and of murals still mainly involve individual cases and local observations. Whole-object scanning across materials, comparisons of system errors, and long-term repeat measurements remain insufficiently supported. Future studies should focus on specific material structures and conservation questions. They should establish traceable links among original fields of view, stitched outputs and other analytical data. The technical expansion of EDOF microscopic scanning will make a clear contribution to heritage conservation research when continuous records reliably support interpretation of techniques, comparison of damage or assessment of treatments.

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