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DIGITAL NON-METRIC IMAGE-BASED DOCUMENTATION FOR THE PRESERVATION AND RESTORATION OF MURAL PAINTINGS: THE CASE OF THE ÜZÜMLÜ ROCK-HEWN CHURCH, TURKEY

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Abstract:

Digital photography is a valuable documentation technique for the preservation of a cultural heritage site because high-resolution photography presents both general and detailed views of mural paintings and mural condition in a single image. Advanced digital technology is particularly helpful for preserving and restoring mural paintings given that the painting condition is recorded on high-resolution base maps shows how mural paintings are damaged by environmental stresses, mechanical damages and inappropriate treatments, among others. In addition, photogrammetric software technology is rapidly advancing and being applied to the digital documentation of mural paintings or rock art. Nevertheless, human experience and investigation of mural paintings is indispensable for recording the condition of mural paintings, and this highlights that every step of documentation conducted in situ is desirable. However, images by photogrammetric software do not show sufficient resolution because most normal portable computers used on-site are not usually sufficient. Based on our experience at the Üzümlü Church in Cappadocia, Turkey, we propose a new approach to document mural conditions in situ for preservation and restoration. Our method is based on a comparison of a non-metric but approximate high-resolution image with the actual mural paintings. The method does not require special instruments and enables digital documentation of the mural condition in situ at a low cost, in a short time frame and using minimal human resources.

Key words: digital documentation, photography, image processing, mural painting, rock-hewn church, Cappadocia

1. Introduction

Documentation is one of the principal requirements for studies of mural paintings. The iconographic or stylistic analyses of mural paintings and the preservation and restoration of these are based on data derived from documentation. During the 20th century, the main methods of documentation were analogue photography and drawings. The former was disadvantageous due to the fact that only a limited number of shots could be captured because of the numerous heavy instruments used. Additionally, although some murals are painted over small areas, generally speaking photographing an entire painting is impossible with analogue technology. A typical solution is the mosaicking of photographic shots, but this approach presents high costs, entails long periods and requires many human resources. Depicting mural paintings as illustrations can overcome these problems, but such representations do not accurately reflect the actual work of art given that they are usually mediated by the interpretation of an illustrator.

The recent rapid development of digital photography has expanded the possibilities of documentation primarily through digital documentation. The digital camera has paralleled, and in some cases exceeded, the quality of an analogue camera because it produces detailed high-resolution images (Allen & Triantaphollodou, 2010, pp. 279–280). It is easier to manipulate images on a computer compared to photographs from an analogue camera. Moreover, images on the computer can display various kinds of data satisfying the user's needs, whereas analogue images cannot change their printed form. In addition, photogrammetric software is rapidly being introduced specifically for the documentation of

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mural paintings or rock art (Cerrillo-Cuenca et al., 2014; Cosentino et al., 2011; Domingo et al., 2013; Ke et al., 2008). As Doneus *et al.* (2011) clarifed, digital photogrammetry can provide an accuracy that is similar to mid-range laser scanning devices.

However, digital photogrammetry of mural paintings has an avoidable problem. Comprehensive documentation of the mural condition usually consists of two steps: making images of the mural paintings and depicting the condition of the mural paintings on the images by naked eye investigation, as done by Bayerova *et al.* (2011). Documentation of images is best done at the highest resolution possible, and every phase of digital documentation in situ is desirable. Although digital photography can be used with photographic apparatus, laptop and printer, a high-quality digital photogrammetry system still requires a high-performance computer (Koutsoudis et al., 2014). To address this problem, the National Research Institute for Cultural Properties, Tokyo, implemented several missions for the mural conservation project of the Ajanta Buddhist caves (Yamauchi 2013, 2014).

An important feature of recording the mural condition is the high resolution of the images and the comparability between the image and the actual mural paintings. Metric data are not essential, and we therefore tried to make the entire process of digital documentation based on a non-metric approximate image in situ. We used our recent research project, the Üzümlü Church in Cappadocia, Turkey (a UNESCO World Heritage site since 1985), as an example. This method enabled us to make a high-resolution image that is comparable to or surpasses one taken by a multi-shot camera and in addition has a low cost and uses limited human resources. The digital documentation project was conducted in cooperation with Nevşehir Museum, which manages the cultural heritage sites in Cappadocia. More than 400 rock-hewn churches (Turkish Ministry of Culture and Tourism, 1985, p. 22), including the Üzümlü Church, can be found in Cappadocia (Fig. 1).

Figure 1: West façade of the Üzümlü Church

2. Overview of the Üzümlü Church

2.1. Location and architectural style

On the southern side of Aktepe, which is a rock mountain in the northern part of Cappadocia, are two tourist routes from Ortahisar Village: Red Valley and Rose Valley. The rock-hewn church of Üzümlü (üzümlü is Turkish for 'grape') is located west of the middle cross-point of Red Valley and Rose Valley (Fig. 2). We chose this church as our first target for the preservation and restoration of mural paintings in rock-hewn churches because it exhibits typical Cappadocian deterioration caused by environmental factors, rock composition, seismic activity, and biological and human activities, including vandalism.

The structure of the Üzümlü Church is a solitary cone that is approximately 12 m in the east–west direction and approximately 8 m in the north–south direction. The entrance to the church is a cut on the western façade of the rock. In the past, another entrance was on the southern side; however, this entrance is now filled. Although the church comprises two stories, the upper floor was already inaccessible in the 1960s (Schiemenz, 1969, p. 241). The lower story was composed of five chambers (Fig. 3). It is unknown how these chambers were originally used, but we labelled the three consecutive chambers (from west to east) as 'Narthex', 'Nave' and 'Apse', following the method adopted in previous studies (Rodley, 1985, p.184). Two other chambers on the north side of nave and apse were referred to simply as 'Chamber 1' and 'Chamber 2' (from west to east) because these are extra chambers that may have been carved at a later period. The ceiling heights of these chambers were shorter than those of the other three, and no murals were painted on their walls.

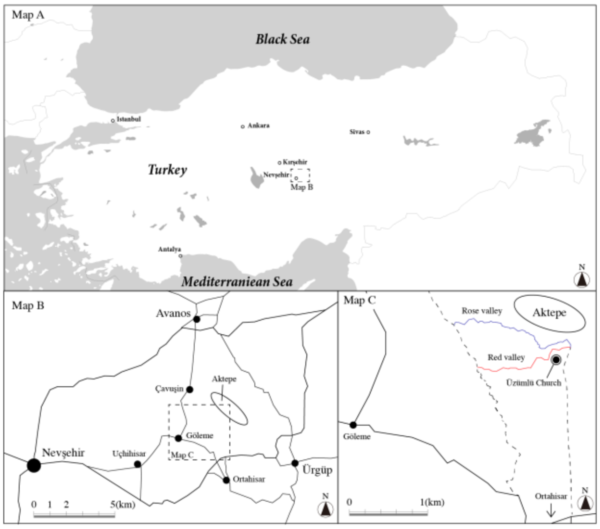
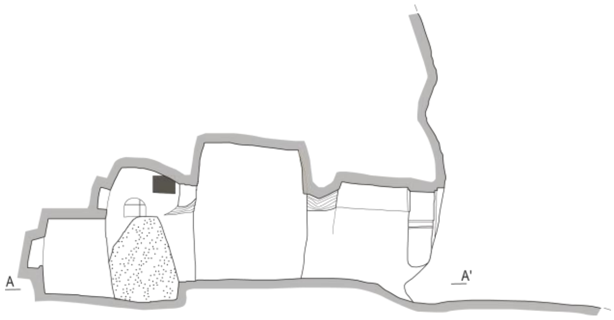
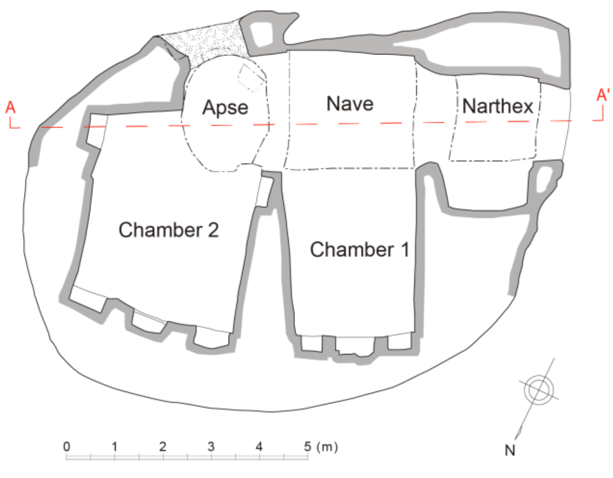


Figure 2: Map of Turkey (A) and the study site (B & C).

The structures of the three main chambers are as follows: Narthex is an imperfect rectangle that spans 1.7 m in the east–west direction and 1.8 m in the north–south direction; Nave is an imperfect rectangle that spans 2.6 m in the east–west direction and 2.4 m in the north–south direction; and Apse is an ellipse with a minor axis of 1.8 m in the east–west direction and a major axis of 2.4 m in the north–south direction. Narthex and Nave are covered by a barrel vault, whereas Apse is covered by a dome. Chamber 1 and Chamber 2 are cuboid structures. Compared with the exposed rock surface of the main chambers, those of Chamber 1 and Chamber 2 are roughly excavated. This suggests that the former three chambers and the latter two were constructed using different techniques. Given that different excavation techniques were used for the main and extra chambers and only the main chambers have mural paintings, Chamber 1 and Chamber 2 appear to have never been painted.



(a)



(b)

Figure 3: The drawings of the Üzümlü Church: a) East-west (AA') section; b) Ground floor plan.

2.2. Dating of mural paintings

Although the Üzümlü Church was known at the time of Jerphanion (1942), who first systematically studied the mural paintings in Cappadocia, he paid minimal attention to this church. Schiemenz (1969) then identified the Üzümlü Church as the chapel of Niketas the Stylite, who is depicted in the mural painting on the east wall of Nave. Little information is available and known about the history of the church due to lack of historical records that can sufficiently shed light on this issue have been found. Absolute dating methods, such as radiocarbon dating, are ineffective because mural paintings do not contain botanical materials, such as thatch. Previous absolute dating is therefore based on iconographic characteristics.

Jerphanion dated the church as going back to the iconoclast period, that is, the 8th to 9th centuries (Jerphanion, 1942, p.404). Schiemenz (1969), who was the first scholar to treat the Üzümlü Church as a primary research object, dated the church's construction to be in the 9th century after 863 A.D. His dating of the church was based on his deduction that the saint painted on the east wall of Narthex, which has now collapsed and is nearly invisible but was visible at that time, is Euthymios the Younger, who died in 863. He interpreted a three-line inscription 'ΠΘ/ΥΜ/ΗΟC', which is on the east side of the saint, as ΕΥΘΥΜΙΟC (this is Euthymios in Greek orthography) based on contemporary Byzantine Greek writing and phonetic manners; he did not discuss which Euthymios this referred to (Schiemenz, 1969, p. 242). Conversely, Thierry (1981, p. 507) dated the mural paintings to a slightly earlier period, specifically the late 7th century or early 8th century A.D., on the basis of iconographic details, style of ornamentation and epigraphy. This argument remains inconclusive to this day. For example, Alioglu *et al.* (2012) assumed the church to be from the 10th century by its decoration programme, but Pelosi *et al*. (2012) supposed 6–7th century by its stylistic and technical characteristics. We believe, similar to Rodley (1985: 189), that the saint on the east wall of Narthex is not Euthymios the Younger but possibly Euthymios the Great (ca. 377–473). Therefore, Schiemenz's dating, which did not consider the earlier Euthymios, cannot be validated, but the church seems to have been built at least during the 9th century A.D. This means it is one of the earliest phase churches in Cappadocia and one of the few representatives of the iconoclast period of Byzantine churches.

2.3. Previous documentation projects

The comprehensive documentation of the rock-hewn churches in Cappadocia was first undertaken by Jerphanion (1942) from the 1920s to the 1940s. However, he regarded the Üzümlü Church as having minimal importance. The first person to publish photographs on the mural paintings of the church was Budde (1958, fig 34), and a number of researchers, including Schiemenz (1969), Thierry (1963, 1981) and Rodley (1985), subsequently recorded and analysed the iconographic schemes of the paintings. The preliminary measurement of the rock-hewn churches around Cappadocia valley was conducted by a research team led by Dr. Masaru Maeno, a professor affiliated with the Tokyo University of the Arts in the early 1970s; during this period, (unpublished) architectural drawings of the Üzümlü Church were made. Since the 1980s, no further documentation has been undertaken, and the mural paintings have been gradually damaged by physical, environmental and biological elements.

2.4. Location of the mural paintings

The mural paintings that were depicted until the 9th century can be seen on the following surfaces of the church: the intrados of the arched entrance, the west, south and east walls and the north arch and barrel-vaulted ceiling in Narthex; the west, south and east walls and the barrel-vaulted ceiling in Nave; the southeast wall and the domed ceiling in Apse; and the transverse arch between Narthex and Apse. All those surfaces were depicted without flattening, i.e. murals are also on the concave point. Although we assume that the intrados of the transverse arch between Narthex and Nave may have been covered with paintings, we cannot identify any remnants of the murals because the lower part of this transverse arch collapsed, and its remains were removed.

3. Documentation methodology

In this project, our aim was to provide a continuous operation of digital documentation for preservation and restoration of mural paintings in situ. Even though we made inner and outer figures of the rock by three-dimensional (3D) laser scanner, the results showed that time and effort were needed for metric accuracy; in addition, the laser scanner was difficult to operate for the whole documentation process in situ. We therefore prioritised the high resolution imagery over metric accuracy because murals were depicted on a highly distorted surface. We used Adobe Photoshop® software due to its easeness for image processing and its availability. These are very important factors that efficiently and effectively advance the documentation of a large number of Cappadocian churches.

Since the murals were painted on large surfaces of the walls, the vaulted ceiling and dome and the small inner space, capturing entire images in a single shot was impossible. We solved this problem by photographing the surfaces in several vertical and horizontal shots and digitally merging the pieces into a single high-resolution image with Adobe Photoshop. Although morphing of the images was required in many cases, approximate images that were comparable to the actual mural paintings were sufficient as a base map, which was the photograph that depicted the current condition of the mural paintings. Details regarding mural condition were recorded on the overhead projector transparent sheets (hereinafter OHP sheet) on the printed base map. After the OHP sheets were digitalised, the condition of the mural paintings was illustrated on the high-resolution base map by Adobe Illustrator®. The documentation generally proceeded in four steps:

1) Taking the shots of the mural paintings;

2) Measurement of the cave and location of the paintings to transform those to be comparable to the actual mural paintings;

3) Image processing: merging photographs into a single high-resolution image, warping the images and creating the base map;

4) Condition assessment and recording.

3.1. Instruments/programmes

We used the following instruments/programmes in our research:

- Digital single-lens reflex (SLR) camera (Canon EOS 60D).
- Wide-angle lens (Canon EF-S10-22mm F 3.5-4.5 USM).
- Tripod (Manfrotto 055 CXPRO3JP).
- Laptop computer (Mac OS 10.9, 4-core Intel i7 processor at 2.30 Ghz, 8 GB of RAM and AMD Radeon HD 6750M 1 GB GDDR5 SDRAM).
- Laser digital distance meter (Leica Disto D210).
- Measuring tape.
- Adobe Photoshop CS6 and Adobe Illustrator CS6.

3.2. Photography of the mural paintings

The mural paintings were photographed by mounting the camera on a tripod horizontally and almost parallel to each mural; then, the distance between the lens and a mural painting was measured by the digital distance meter. As this method was not intended to take metric data, the distance did not require strict accuracy and permited errors. Depending on the dimensions of the mural painting, several shots were taken. Even when the camera was moved horizontally or vertically, the distance between the lens and the painting was kept constant, and we ensured that each shot overlapped with the photographs of adjacent areas. Although it depends on the surroundings, a 10% overlap was usually enough. This approach was designed to guarantee successful digital merging. Figure 4 is an example of a merged photograph. In this example, four photos (two rows of two shots) were taken of the wall painting on the south wall in Nave.

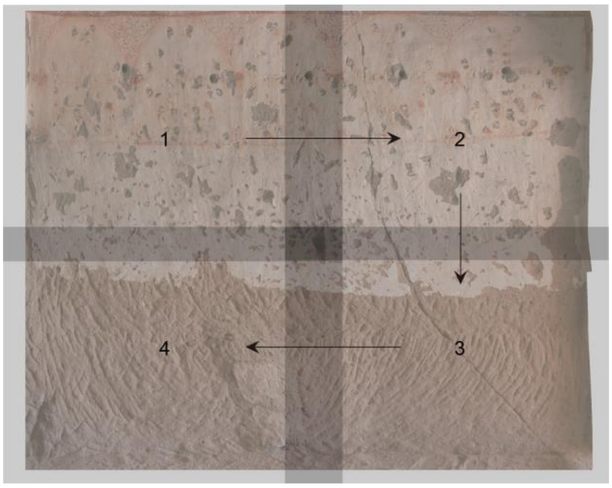


Figure 4: Concept of image merging (south wall in Nave).

3.3. Measurement

The measurement of the cave was based on the architectural plan created by Prof. Maeno in the 1970s because no digital measurement data on this church exist. Additional measurements of the distance between some important figures and features were conducted to morph the merged image being compared to the actual mural painting. First, the heights and widths of the mural paintings were measured using either a digital distance meter or a measuring tape. The distance between distinctive figures, such as saints, was also measured. When we measured curved surfaces, such as the barrel vault or dome, we also measured the inner radius of these to create an approximate planar image from the curved surfaces (Fig. 5).

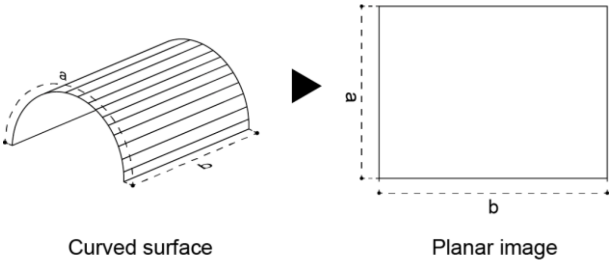


Figure 5: Conversion from curved surface to planar image.

3.4. Image processing

The photographs were merged into a single high-resolution image using the 'photomerge' function of Adobe Photoshop CS6. The merged image was manually morphed using the 'warp' function on the basis of the measurement data and resized to an approximate scale. These images were then imported into Adobe Illustrator CS6 to document the mural condition. We used the following merging and morphing (photomerging) procedure within Adobe Photoshop CS6:

1) Read files (Fig. 6): Read the files to merge. Then select <Automate> in the <File> menu. Click <Photomerge> and select <Add Open Files>.

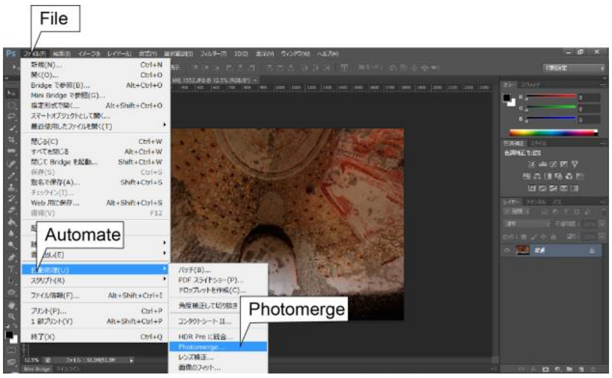


Figure 6: 'Photomerge' on the menu.

2) Merge files (Fig. 7): Check <Blend Images Together>. Also check <Vignette Removal> and <Geometric Distortion Correction> to reduce morphing time after merging as we do not intend to make a metric image. Click <OK>.

3) Check the edge of each of the images (Fig. 8): Upon correct execution of the preceding steps, we checked each end of the reading photographs.If it was wrong, morphed images would not fit each other (such as in Fig 8b). Lack of overlapping images usually induced this error.

4) Combine the layers: Select <Layer> menu and click <Merge Visible>.

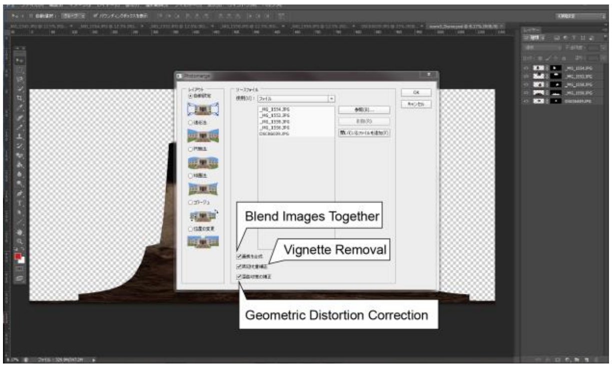
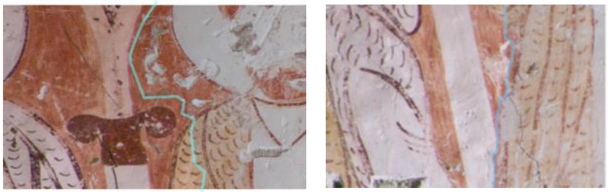


Figure 7: Choosing files to combine.



(a) (b)

Figure 8: Photomerge examples: a) Successful implementation; b) failed photo combination.

5) Set the guidelines for revision: Select <View> menu and click <New Guide...>. Move the guides on the basis of the measured sites, as in Figure 9.

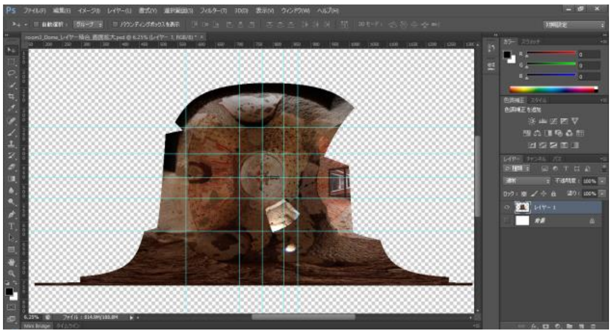


Figure 9: Setting the guidelines.

6) Revise the photograph (Fig. 10): Select <Edit> menu and click <Warp> from the <Transform> menu. Revise the distorted areas of the merged photographs and adjust them to fit the approximate scale.

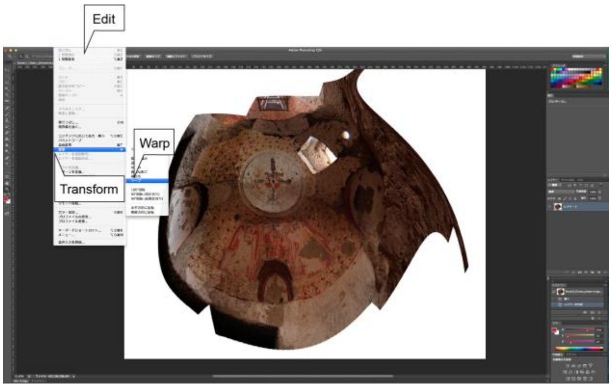


Figure 10: Choosing the 'Warp' tool.

7) Apply the transformation (Fig. 11): After completing the transformation, click <Apply> in the window <'Apply the transform?'>

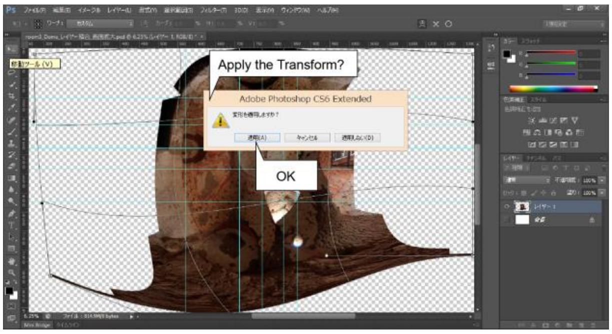


Figure 11: Applying the 'warp' tool.

Figure 12 is an example of the image mosaic of the dome, which was merged from five images. Following this method, we created 13 base maps with resolutions of at least 300 ppi.

3.5. Assessment and documentation of the mural condition

After creating the base maps, the condition of the mural paintings was documented on OHP sheets on the printed base maps. As every site has a different component, specific conditions and unique problems with the mural paintings, naked eye investigation was necessary to preserve and restore the art effectively.

The mural paintings in the Üzümlü Church are composed of three layers: rock, plaster and paint. We recorded the condition of each layer of the mural painting as a separate mural condition sheet. We identified deteriorating items in each layer by naked eye investigation. The following sections present detailed explanations of this process.

3.5.1. Rock layer deterioration

Rock layer deterioration was identified on the basis of four factors: biological activity (Fig. 13a), deposition of dark material (Fig. 13b), structural cracks (Fig. 13c) and spalling (Fig. 13d). Biological activity was evident by animal (e.g. spiders, other insects) inhabitation on a rock. Deposition of dark material pertains to a deposit of dark brown or blackish material on the surface of a rock. Structural cracks are large cracks that run through the body of a rock and are caused by faulting. Spalling refers to the small-scale detachment of a rock parallel to the surface of the rock.

3.5.2. Plaster layer deterioration

Plaster layer deterioration was identified on the basis of five factors: detachment of the lower plaster layer (Fig. 13a), mechanical damage (Fig. 13b), cracking (Fig. 13c), holes (Fig. 13d) and incised graffiti (Fig. 13e). Detachment of the lower plaster layer is the loss of adhesion between the lower plaster layer and a rock substrate, as assessed by visual evidence alone. Mechanical damage refers to the rupture in painting stratigraphy caused by human or animal activity. This type of damage causes a variety of other harmful effects, such as loss of entire stratigraphy; revealing an underlying rock substrate; loss of the paint layer, ground and part of the lower plaster layer, thus leaving the interior of the lower plaster layer exposed; loss of only the upper plaster ground, which leaves the surface of the lower plaster layer intact; and deformation of painting stratigraphy, which otherwise remains intact. Cracking occurs on a plaster layer most often because of the cracking of the rock structure and mechanical damage, although other factors may cause such damage. Holes are small highly circular holes of approximately 5 mm in diameter; these penetrate into a plaster layer but generally do not reach a substrate. Incised graffiti are inscriptions and drawings inscribed onto the surface of a painting, thus affecting the paint, ground and plaster layers.

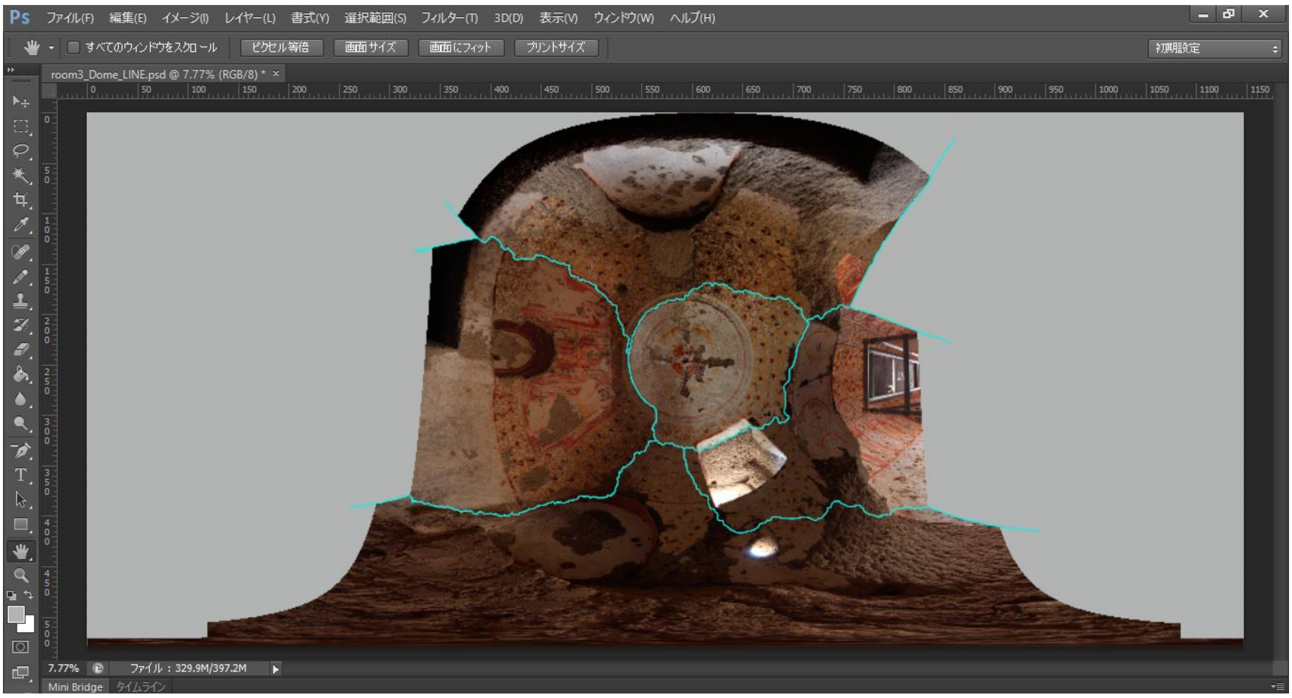


Figure 12: Completed image mosaic from five merged images

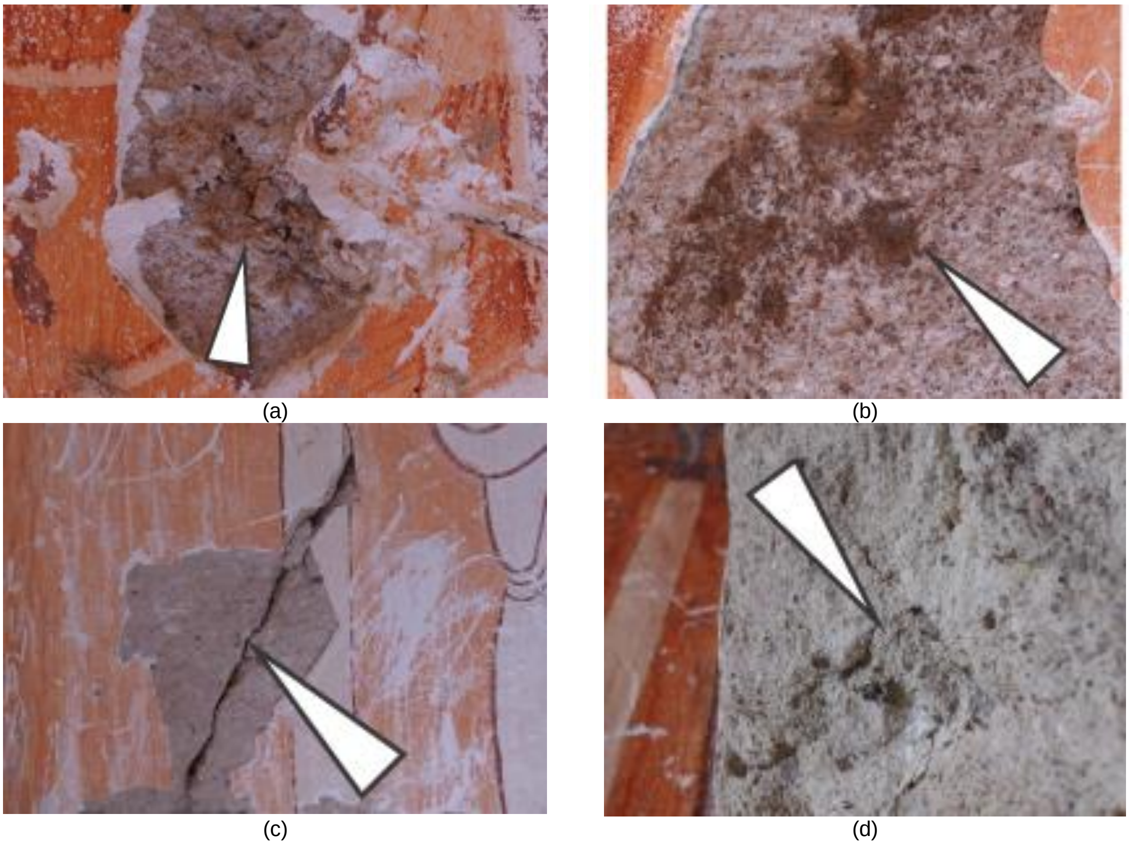


Figure 13: Photos of rock layer deterioration: a) Biological activity; b) Deposition of dark material; c) Structural cracks; d) Spalling.

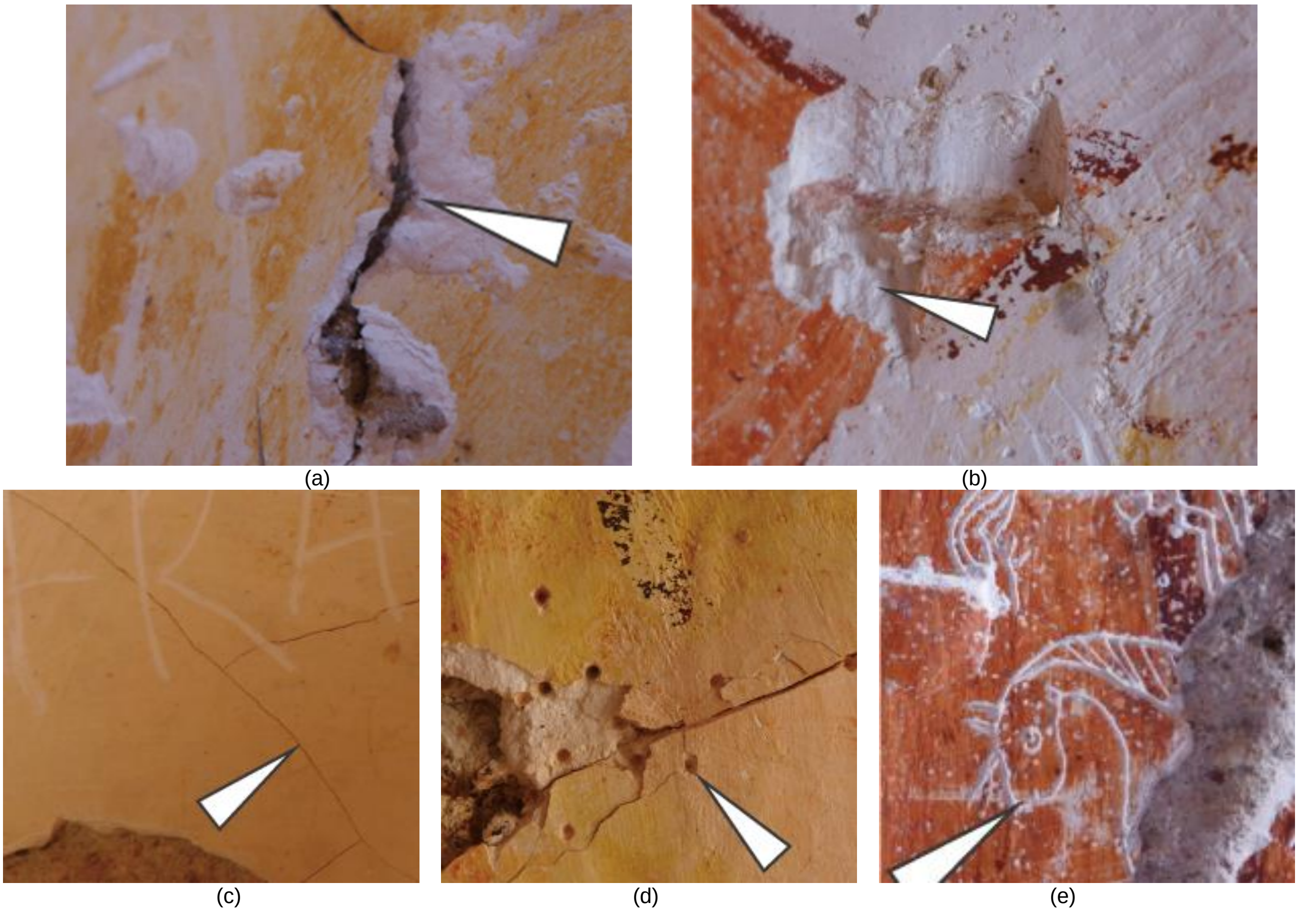


Figure 14: Photos of plaster layer deterioration: a) Detachment of lower plaster layer; b) Mechanical damage; c) Cracking; d) Holes; e) Incised graffiti.

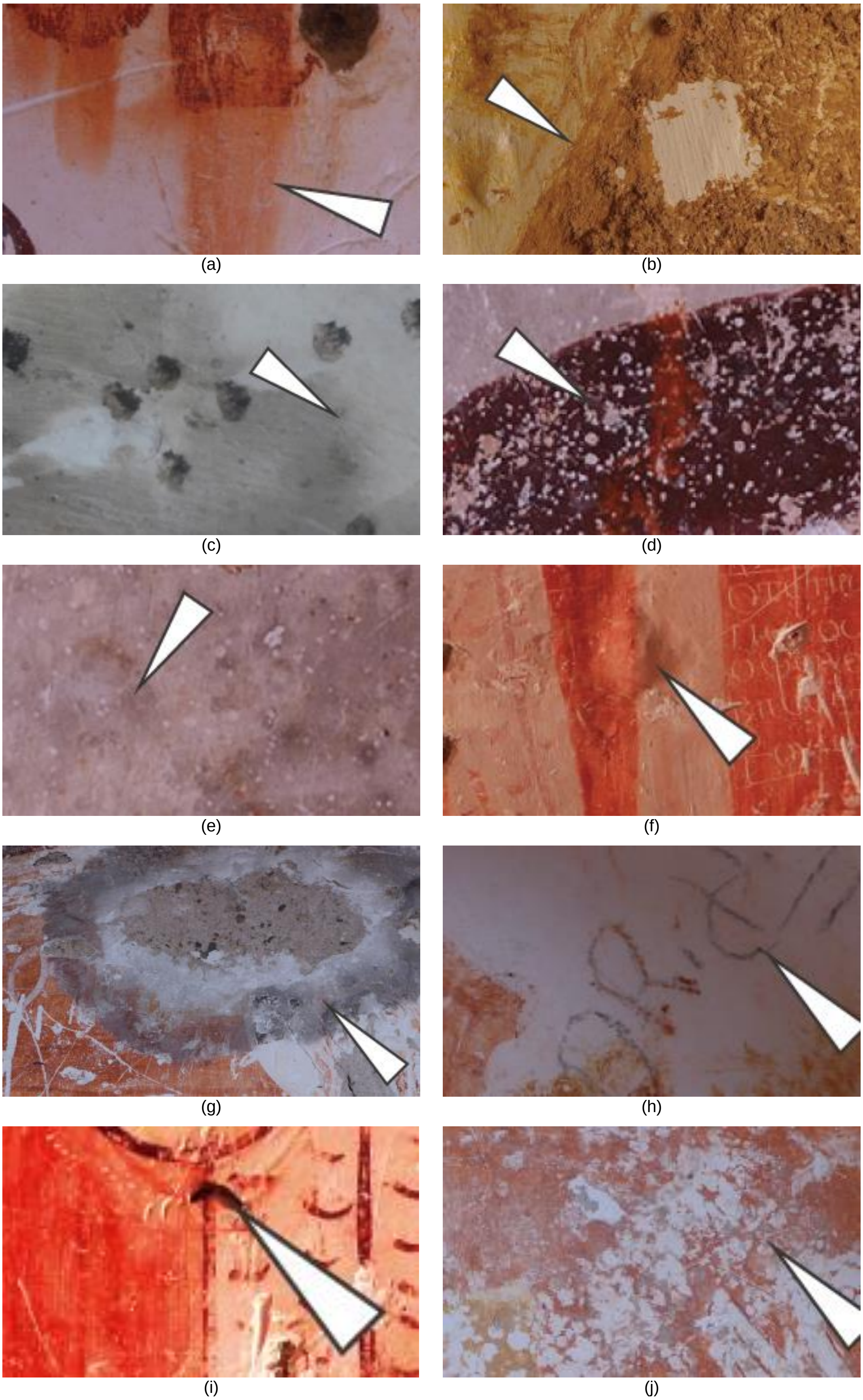


Figure 15: Photographs of paint layer deterioration: a) Smearing; b) Surface deposition; c) Dark grey veiling; d) Micro-losses; e) Grey spotting; f) Original fixing; g) Biological deterioration; h) Superficial graffiti; i) Nail; j) Paint loss due to biological activity.

3.5.3. Paint layer deterioration

Paint layer deterioration was identified on the basis of 10 factors: smearing (Fig. 14a), surface deposition (Fig. 14b), dark grey veiling (Fig. 14c), micro-losses (Fig. 14d), grey spotting (Fig. 14e), original fixing (Fig. 14f), biological deterioration (Fig. 14g), superficial graffiti (Fig. 14h), nail (Fig. 14i) and paint loss due to biological activity (Fig. 14j). Smearing is the mechanically induced displacement of a paint layer beyond its original location, seen as a spreading of paint across a plaster surface. Surface deposition pertains to the deposition of material on the surface of a painting; examples of materials are mud from birds' nests or from later construction in churches (mud plaster). Dark grey veiling is the appearance of a veil that extends over the surface of a painting. The veil is dark grey, somewhat patchy and of unclear origin. Micro-losses are the extremely small rounded losses of a paint layer generally on the order of 0.5–1 mm diameter. Grey spotting is the occurrence of faint circular grey spots (0.5–3 mm diameter) on the surface of a painting. Original fixing refers to traces of fixing that may have been carried out almost at the same period of mural painting depiction because the colours characterising this section and its surrounding area are almost the same. Biological deterioration is the dark grey discoloration of certain areas of a painting and is caused by animal inhabitation. Superficial graffiti refers to graffiti applied to the surface of a painting using a medium, such as paint, ink or graphite. A nail is the part of a nail on a paint layer. Paint layer loss due to biological activity is the loss of a paint layer because of the presence of birds' nests. When materials from the nests are separated from a painting surface, part of the paint layer is removed.

After the state of layer deterioration was documented, an OHP sheet was scanned to create a digital mural condition sheet (Fig. 16). In cases where the number of items was too large for these to be recorded on an OHP sheet, we used more than two OHP sheets to document one layer. Using Adobe Illustrator, we traced the scanned data with a pen tool. The traced deterioration sites were divided into different layers according to each item of deterioration. Therefore, each mural condition sheet can show the deterioration sites of selected items when a pdf file is created and viewed via pdf viewer software. The approximate scale of the mural condition sheets was then adjusted to 1/10, 1/15, 1/20 and 1/25. As we checked the deterioration of each layer of the mural paintings, we produced 39 mural condition sheets and 13 image mosaics of the mural paintings for the digital heritage inventories. An example is Fig. 17, which shows the paint layer deterioration of the ceiling in nave. All the digital inventories of the printed versions (Taniguchi 2015) that we created are available for viewing in Appendix 3 at the following webpage address: http://rcwasia.hass.tsukuba.ac.jp/kaken/contents/content%20images/0_20150723_uzumlu_2014_final_s.pdf.

4. Comparison to previous methods

With the above-described method, we successfully documented the condition of the mural paintings in Üzümlü Church with non-metric images. Although conducting all steps of documentation in situ is desirable for efficient documentation of the mural condition, it is still impossible to create high-resolution images by photogrammetry without high-performance computers,

Figure 16: Scanned OHP sheet of plaster deterioration on the ceiling in narthex.

which are impossible to bring in situ. For instance, Koutsoudis *et al*. (2014) used a computer system equipped with an 8-core Intel i7 processor at 3.50 Ghz, 32 GB of RAM and a NVidia Geforce GTX580 3 GB RAM graphics card running Microsoft Windows 7 64-bit for making a 3D model by Agisoft PhotoScan (Koutsoudis et al., 2014), which is one of the major commercial photogrammetric software. This 3D model would be possible to use as a base map due to its high level of detail; however, the process requires specifications that are too high for laptop computers (PhotoScan Agisoft, 2016). For example, the mural conservation project by the National Research Institute for Cultural Properties, Tokyo, divided the documentation process into work in situ and tasks that require high-performance computers in Japan and conducted each work and task alternately. They required several missions on site (Yamauchi 2013, 2014). Additionally, they used orthoprojection images for recording, which are difficult to use in Cappadocian churches, including Üzümlü Church, because usually murals are depicted on distorted and sometimes concave surfaces.

We do not deny the importance and effectiveness of using photogrammetry in the preservation and restoration of mural paintings. However, taking into account that naked eye investigation is indispensable for the preservation and restoration of mural paintings, this paper reports on a coherent operation of documenting mural paintings in situ. We agree existing problems can be solved by developing specific computers and photogrammetric software. However, we show the usefulness of digital documentation based on non-metric images at the present time.

In addition to our project objective carried out in the Üzümlü Church, the Nevşehir Museum is responsible for managing cultural heritage sites in Cappadocia. However, the large number of these sites is beyond the current management system's capability. Meanwhile, the tourist volume continues to increase, exerting progressive stress on each site. In such situations, as Tsumura (2006) pointed out, the idea is to transform the concept of mural painting preservation from stopping deterioration regardless of how unreasonable this may be to recording the deterioration itself. Our method may facilitate future preservation and restoration projects in the region given that it enables the documentation of the site conditions and requires limited human resources and instruments.

Figure 17: Example of digital image-based documentation of paint layer deterioration on the ceiling in nave

5. Conclusion

This paper summarises the procedure of digital non-metric image-based documentation of mural paintings in Üzümlü Church as a demonstration of our proposed approach. Each of the processes, the photographing of the mural paintings, the image processing of the shots and the description of mural condition was accomplished with the help of simple tools, such as a typical digital SLR camera, tripod, measuring tools, standard laptop computer and Adobe software. The images are non-metric and approximate but can be compared with actual mural paintings; therefore, the approach enables digital documentation for preservation and restoration of mural paintings in situ. This approach is expected to contribute to further documenting preservation and restoration projects in Cappadocia and elsewhere. Compared with conventional digital documentation and despite being non-metric, our method can produce high-resolution images at low cost, in short time frames and with limited human resources.

It is worth noticing that our method is an approximate one and does not address the metric accuracy problem. As we stated, we regard this method as a transitional one until laptop computers can run the photogrammetric software in situ. However, in a next step we should compare our images with accurate metric images undertaken by photogrammetry and clarify their accuracy for effective transitioning from ours to a forthcoming method.

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