

Original Study

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By All Means Necessary – 2.5D and 3D Recording of Surfaces in the Study of Southern Scandinavian Rock Art

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Abstract: Southern Scandinavia is Europe's richest region in terms of figurative rock art. It is imperative to document this cultural heritage for future generations. To achieve this, researchers need to use the most objective recording methods available in order to eliminate human error and bias in the documentation. The ability to collect more data is better, not only for documentation, but also for research purposes. Recent years have seen the wider introduction of image based 2.5D and 3D modelling of rock art surfaces. These methods are Reflectance Transformation Imaging (RTI), Structure from Motion (SfM), and Optical Laser Scanning (OLS). Importantly, these approaches record depth difference and the structure of engraved lines. Therefore, they have clear advantages over older methods such as frottage (rubblings) and tracing. Based on a number of short case studies, this paper argues that 2.5D and 3D methods should be used as a standard documentation techniques, but not in an exclusionary manner. The best documentation, enabling preservation and high-quality research, should employ all methods. Approaching rock art with all the research tools available we can re-appraise older documentation as well as investigate individual action and the transformation of rock art.

Keywords: rock art, documentation, Reflectance Transformation Imaging, Structure from Motion, Optical Laser Scanning, southern Scandinavia, Tanum, Bronze Age

1 Introduction

When the Norwegian priest Peder Alfsön documented the large “Shoemaker” in 1625 in Backa, Brastad (Sweden), the imagery on Scandinavian rock has fascinated people. Over time documentation efforts have evolved into a more systematic and scientific endeavour with the comprehensive recordings by Carl Georg Brunius and Lauritz Balzer (cf. Bertilsson, 2015b). Oscar Almgren's ground-breaking ‘Hällristningar och Kultbruk’ made rock art an essential window into Bronze Age life (Almgren, 1927).

With temporal and spatial variations, rocks were engraved throughout the Nordic Bronze Age (1700–550 BC). The corpus of images comprises cupmarks, canoes, human figures, animals, objects and much more. The largest concentration of petroglyphs can be found in Tanum, West Sweden. The region was designated a World Heritage Site in 1994. Many other regions in Scandinavia, such as Uppland, Sweden

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or Stjørdal in Trøndelag, Norway also contain rock art. It is important to preserve this fascinating cultural heritage for future generations (for a recent overview of sites, interpretations and literature see Goldhahn & Ling, 2013). Most of our work concentrates on Tanum; however, some work has been done in other regions. If not indicated differently, the sites mentioned in the following text are in Tanum. The numbers attributed by the Swedish Heritage Board (Riksantikvarieämbetet) are put in brackets when a site is mentioned first. These numbers can then be located in the online database of the Swedish Heritage Board (<http://www.raa.se/hitta-information/fornsok-fmis/>) and the Swedish Rock Art Research Archive (www.shfa.se).

Period after Montelius	Calendar Dates ¹
Period I	1700/1750–1500 BC
Period II	1500–1300 BC
Period III	1300–1100 BC
Period IV	1100–950/920 BC
Period V	950/920–730/720 BC
Period VI	730/720–550/530 BC

Notably, preservation is not the only aim of documentation. Jarl Nordbladh argued that high-quality documentation is essential for innovative research (Nordbladh, 1981). This also requires methodological innovations to improve the quality. This article highlights work conducted using modern imaging techniques to document rock art in comparison to older methods. Despite criticism of older methods, it should be stressed that all methodologies complement each other and documentation works best when rock art sites are recorded using multiple techniques. Here we demonstrate how our methods can be used to re-assess older documentation. Furthermore, our method is a powerful tool-set to study individual action on the rocks and the transformation of images, enabling us to address rock art biographies.

2 Documentation of Rock Art

Rock art is largely an open-air heritage. Therefore, it is exposed to weathering by the elements such as frost, environmental hazards such as acid rain, and human destruction. A recent incident in Tro (Nordland, Norway) where youths destroyed the famous image of a skier (Orange, 2016), highlights the problem of anthropogenic destruction. The destruction of images can also be seen at other sites, for example, in Finntorp (RAÄ Tanum 89:1) a large chunk of the rock is missing, and the fracture runs through some of the Bronze Age rock art. Photographs from 1935 and 1945 document building activities here, and on a site directly neighbouring this (RAÄ Tanum 90:1), a farmstead partially covered the panel. However, another photo from 1903 indicates that the destruction had already occurred. Both examples vividly demonstrate the need to document rock art. Through recording the images, we are able to preserve them for future generations even if the original should be destroyed. As researchers, we are also interested in the meaning of rock art and what information it contains about past societies. Thus, research is another purpose of documentation (Nordbladh, 1981).

Therefore, it is necessary to record the images on the rocks fully and as close to the original as possible. The aim is to eliminate human error as much as possible. Rock art is mostly very shallow and elusive. Consequently, it can be very hard to discover images with the naked eye. Most steps in the documentation process may require interpretation. This accumulates steps of inference, and thus, introduces potential

¹ Montelius' original calendric dating was largely confirmed by newer radiocarbon and dendro-dating, see Kneisel, Hinz, and Rinne (2014); Randsborg and Christensen (2006). Evidence from burials tends to be somewhat older (Olsen et al., 2011).

sources of error. In the best case, documentation techniques can provide a surplus in visibility, record features previously undiscovered, or settle disputes over contentious features. It follows that documentation techniques should be efficient, storage should be manageable, and it should aim to eliminate steps that require interpretation as they are sources of error.

In the past, many techniques have been employed with varying degrees of success ;for example, drawings, oblique light photography and even casts (Bertilsson, 2015b; Nordbladh, 1981). Tracings and frottage were the most prevalent documentation techniques until recently.

2.1 Frottage

First, the rock is examined by feeling for engraved lines. If such lines are discovered, large sheets of paper are fixed on the panel. For large panels, several sheets of paper are necessary. Then carbon paper is wrapped around a soft sponge and rubbed over the paper. The carbon paper leaves more colour on hard surfaces, elevated parts, and edges. Conversely, in depressions such as engraved lines, less pigment is put on the recording paper. Whether a line is natural or anthropogenic must be decided after the frottage. Naturally occurring lines in the rock's morphology usually possess smooth edges. Fractures have irregular edges. Engraved lines should possess relatively sharp edges that are linear, and therefore, should show up clearer in the rubbing. Afterwards, the carbon is fixed by rubbing the frottage with grass. Frottage contains four documentation steps:

1. Feeling lines
2. Putting the paper sheets up
3. Rubbing carbon on them
4. Fixing the carbon.

2.2 Tracings

The initial step in tracing is a tactile technique. The bedrock in Tanum consists of a particularly hard granite called Bohus granite which was smoothed by the ice masses of the Ice Age (Eliasson & Schöberg, 1991). Most ancient engravers sought out such smooth surfaces (Coles, 2004; Goldhahn & Ling, 2013, pp. 275–77). Naturally occurring lines in the morphology of the rock are also smooth. Fractures occur along the boundaries of the rock crystals. Accordingly, the lines are very rough. Engraved lines break the rock's crystals and the originally smooth surface becomes rough, though not as rough as natural fractures. Documenters feel the rock in an attempt to identify these differences in the lines. Other information may aid the decision of whether a line is engraved or natural, such as the lines overall profile. After an interpretation, the engraved lines are painted with a non-permanent colour such as chalk or chalk paint. Clear plastic sheets are then fixed onto the surface of the rock on which the lines are transcribed. Consequently, tracing is a four-step recording process:

1. Feeling lines
2. Painting the lines
3. Putting up the plastic sheets
4. Transferring the lines.

2.3 Problems with Tracing and Frottage

Both methods have clear advantages over other documentation techniques such as drawing or photography. They record more details of larger areas than photography, and they are more objective than just drawing the images from a visual impression. Tracing and frottage have been standard in the documentation of rock art for decades (Toreld & Andersson, 2015; Nordbladh, 1981). However, both also have severe disadvantages:

1. Researchers have to kneel, sit or lie on the rocks for extended periods of time. Intensive and continued contact is made with the rock surface, especially on larger panels. This can cause damage to the images, particularly, if there is a lot of movement required.

2. Both methods are highly manipulative and human bias is a considerable factor (Bertilsson et al., 2017). Feeling lines in tracings is largely a sensual undertaking and depends on the experience of the researchers as much as on their expectations of what images should look like and where to find them. For example, an engraved line in an unexpected place might be interpreted as natural. Rubbings may be carried out intensely where rock art is expected, but only superficially in other areas. Weathering can also cause a background noise obscuring engraved lines.
3. Although the area of documentation is technically not limited, multiple papers or plastic sheets have to be put together to cover large panels. This makes a continuous documentation improbable. The sheets and paper recordings have to be put together afterwards. This can cause offset on the edges. Tracings usually do not record the entire rock face and frottage tends to flatten out the topography causing erroneous spatial relationships between individual images (Nordbladh, 1981).
4. Both methods are time-consuming. The documentation of large panels takes more than one working day (8+ hours) and generally requires a larger number of people to document areas effectively.
5. Frottage is difficult to carry out in relatively cold and wet climates such as Central Norway (Peacock et al., 2015).
6. While both methods do a decent job of recording rock art in two dimensions, they are less well suited to recording depth differences within engraved lines. Therefore, there is one entire dimension missing in the preservation of this heritage. It is problematic for research because depth differences contain valuable information (see below). Sometimes, documenters denote if figures superimpose each other, but again, this is heavily dependent on individual perception and interpretation.
7. One major disadvantage of both of these methods is that they require careful cleaning of the rock art that precedes the documentation. Both chemical and mechanical cleaning increases abrasion of the rock.

3 New Approaches to Rock Art

New method development needs to take these problems into account and if not solve them, minimise their impact. Fortunately, there has been innovative and active research in the field of 2.5D and 3D imaging in the past two decades which has made techniques such as Reflectance Transformation Imaging (RTI), Structure from Motion (SfM) and Optical Laser Scanning (OLS) accessible and easy to use. A range of open source and commercial software aids the calculation of imaging files. Although they vary in user-friendliness, there is no high-level training necessary to get good first results.

Early attempts to computationally record Scandinavian rock art date to the 1990s, but they were not available to a wider audience (Freij, 1993; Lindqvist, 1994, p. 247). Around 2000, the ATOS scanner technology was developed to document the open-air rock art at Tanum for the National Heritage Board's Rock Care Project (Johansson & Magnusson, 2004). The ATOS scanner's already high accuracy is surpassed by modern laser scanners making them much more powerful documentation tools (see section *Optical Laser Scanning (OLS)*). Some 10 years ago, Joakim Goldhahn tested the technique of documenting petroglyphs using laser scanning at the famous Bredarör grave (Kivik, Simrishamn). However, since the documentation made by Goldhahn has unfortunately never been published, the results remain unknown. In the past five years, rock art researchers in Sweden have embraced image-based and range-based modelling approaches to the documentation of rock art by regularly using SfM, OLS and RTI. The results of the case studies (see below) are stored in the Svenskt Hällristnings Forsknings Arkiv (SHFA). OLS is carried out in cooperation with County Administrative Board of Västmanland. The SHFA uses a Sketchfab Pro account to make OLS files publicly available. Since many contributions in this volume deal with SfM and laser scanning, remarks on these methods are kept very brief, while RTI is discussed in greater detail.

3.1 Reflectance Transformation Imaging (RTI)

RTI was carried out on sites, for example in Tanum, Askum and in the Bredarör tomb, mainly by Rich Potter (RP) and Christian Horn (CH). To avoid damage to the rocks, soft brushes were used to clean the panels before any work (RTI or other documentation) was carried out at the sites. Lichen growth exists variously, but it was minimal and did not affect the engraved lines enough to impair the analysis. Therefore, no attempt to remove lichen was made as it would also risk damaging the panels.

RTI uses Polynomial Texture Maps, invented by Tom Malzbender of Hewlett-Packard in 2000 (c.f. Earl, Martinez, & Malzbender, 2010; Malzbender, Gelb, & Wolters, 2001; Mudge et al., 2006; Mudge et al., 2012). We used the method described as “Highlight RTI” by Mudge (2006). This method computes a pseudo-3D or 2.5D file from the surface reflections. One or two black or red glossy balls record the light direction (Fig. 1a). A remotely controlled static camera set up on a tripod takes a series of images with lighting from oblique angles including raking light (Fig. 1b). Guidelines provided by the Cultural Heritage Imaging group (CHI) describe the appropriate use of the method, with which we complied (Cultural Heritage Imaging 2013). The ideal number of photos is 60–70 (Díaz-Guardamino et al., 2015). However, the weather conditions during our fieldwork seasons necessitated completing the work quickly. We aimed to take as many photos as possible with a Canon 7D DSLR (18 Megapixel), and a Canon Speedlite 430EX flash unit and achieved good results with 40–50 photos. Phottix Stratos 2 triggers were used as the remote control.

The photos were converted into ptm files with RTI Builder Version 2.02 and thereafter analysed with RTI Viewer Version 1.1. Both are open source and can be downloaded from CHI's website. RTI Viewer computes surface normals from the light reflection and creates an artificial representation of the shape of the surface. The application of filters and the dynamic movement of the lighting enhance the visibility of features. We primarily used the diffuse gain and specular enhancement filters. RTI can only be used on small sections of a panel and it is sometimes difficult to identify the correct spot. However, the advantages of RTI compared to SfM are the shorter computing time (up to 5 minutes), files are less storage-intensive, and the quality of the pictures is usually higher. RTI does not produce a real 3D model that can be turned and spun, though it mathematically enhances the surface shape.

3.2 Structure from Motion (SfM)

For SfM, photographs are taken with a 60–70% overlap (Reu et al., 2013). This guarantees high precision of the calculated 3D models enabling measurements as low as 1mm in a 10m scene. This precision can be significantly increased through the use of targets that aid the model calculation (Sapirstein, 2016). The photos have to be processed to calculate the 3D model, which may take up to a day using Agisoft Photoscan®. Calculation time for the models depends heavily on the number of photographs, the specification of the computer, and the software used. There will be substantial improvements to the processing time in the future due to the development of technology. Testing of a new software (Capturing Reality®) indicates that the processing time can be shortened by up to 80%. SfM has been used in various locations in Tanum, the Bredarör tomb and in Nämforsen, Sollefteå, mainly by Johan Ling (JL), Ulf Bertilsson (UB) and Rich Potter (RP).

3.3 Optical Laser Scanning (OLS)

Two qualitatively and very different scanners have been used to record rock art. A project-scanning petroglyphs using advanced digital technology took place in early 2015, when the County Administrative Board of Västra Götaland started to record many engravings at the Tanum World Heritage site. The scanner used in this project was a Handyscan 700 with red lasers provided by the Maskin och Laser Teknik (MLT) Company in Gothenburg. The Handyscan 700 sends out about 480,000 measurement points per second which reproduce the panels with an resolution of 0.05 mm. Thus, the main objective with the Handyscan is to detect “mechanical” impact at 0.05 mm. The other scanner is a 3DSystems Sense scanner. Compared to the Handyscan 700 this is a low-tech, cheap scanner (ca. 300€) providing a spatial x/y resolution of 0.9 mm and a depth resolution of 1.0 mm.

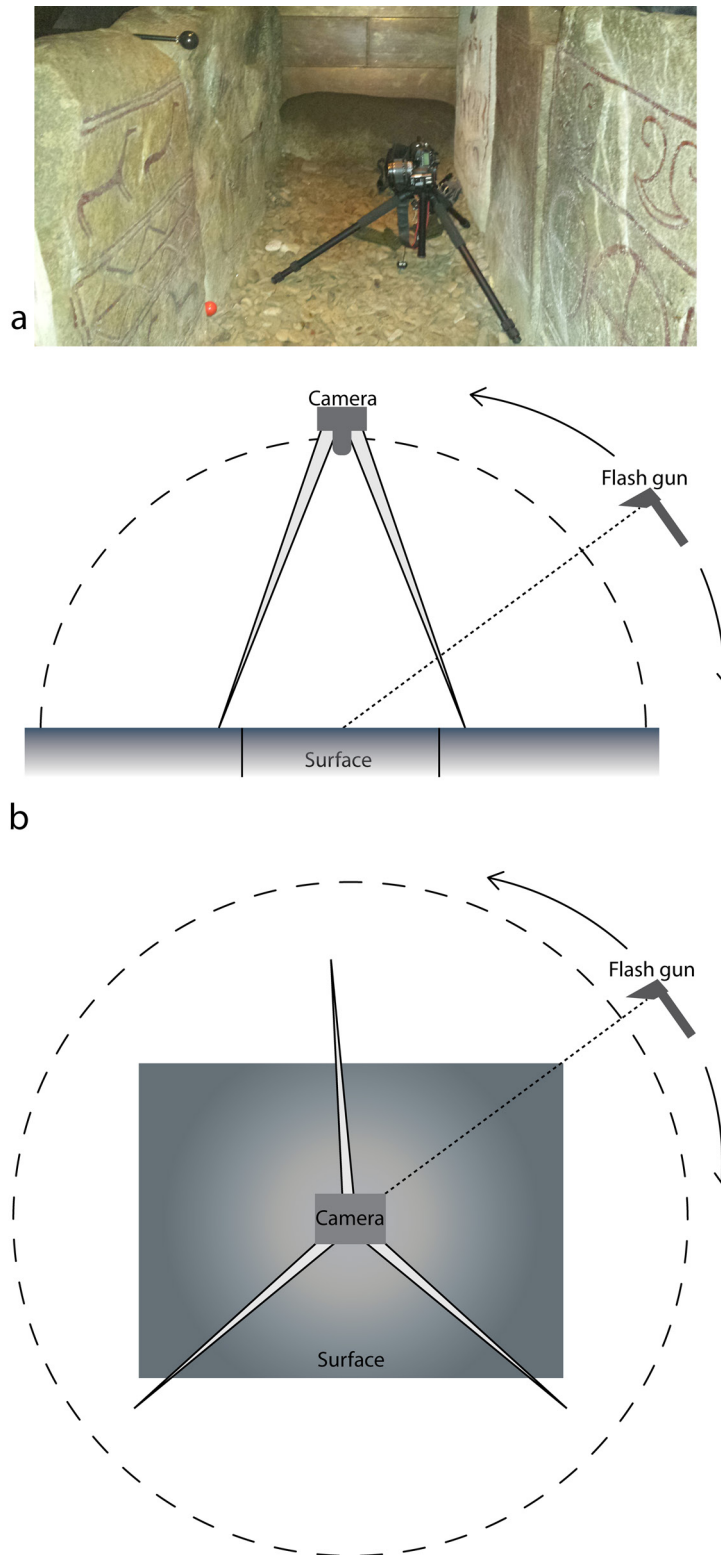


Figure 1. a. camera setup in the Bredarör tomb in Kivik, Sweden; b. schematic camera setup and process to record non-vertical rock art panels.

3.4 Mixed Approaches

As mentioned before, it can be difficult to identify the precise location of images on panels to conduct RTI or close up SfM. This was experienced through the attempt to document a scene in Finntorp (RAÄ Tanum 89:1), which may show a couple engaged in intercourse (Fig. 2a). The scene is very shallow and was not discovered in a previous attempt to record it. To counter this problem a protocol was developed. First, we recorded the area in question with the Sense 3D scanner. This can be done within seconds and the model can be reviewed on a laptop in real-time. The model is of low quality, but it is enough to identify the area of interest. The model of the Finntorp couple shows the basic, blurry outline, but as expected did not record any details (Fig. 2b). Afterwards, the area was marked using string or tape. Then the camera equipment is set up above the marked-out section in a way that captures the markers in the shot for RTI or photographs for SfM which are taken in that area. This ensured that we captured a high-quality model of the intercourse scene in Finntorp (Fig. 2c).

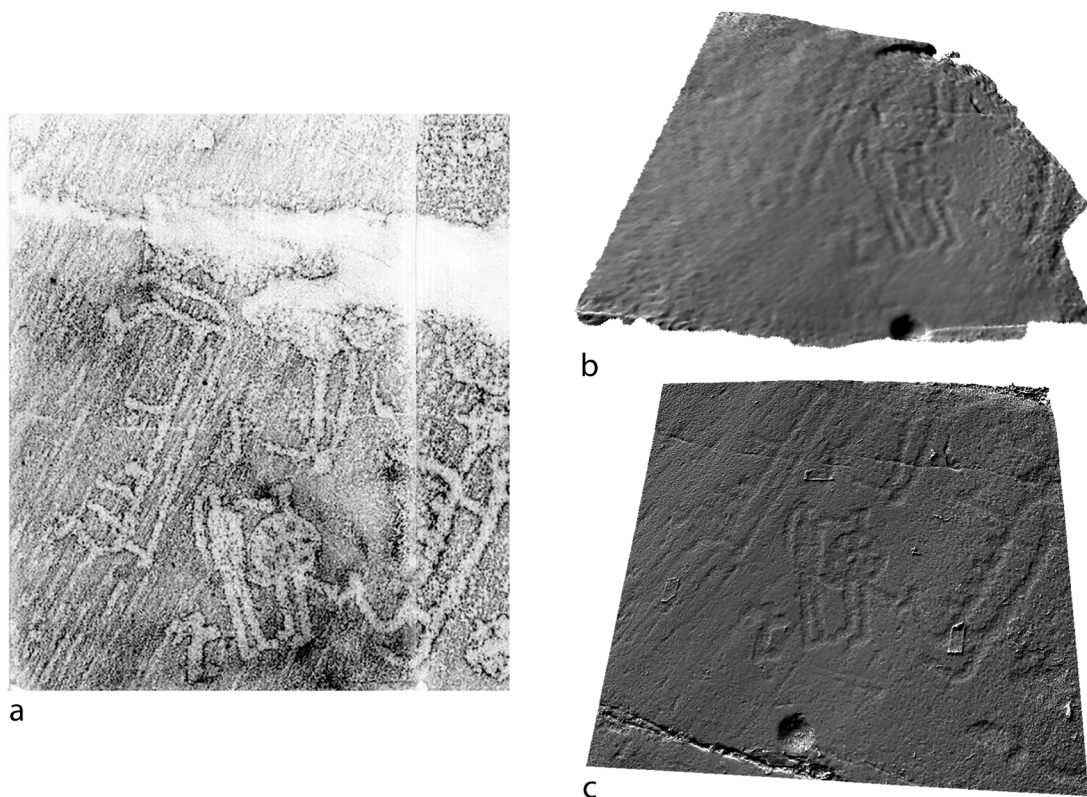


Figure 2. a. Frottage by RockCare of the intercourse scene in Finntorp, RAÄ Tanum 89:1; b. Sense laser scan of the couple by CH; c. SfM of the couple by RP.

4 Advantages in the Documentation of Rock Art Using RTI, SfM and OLS

Before any advantages are described it should be acknowledged that documenting with RTI, SfM and OLS has some disadvantages. The calculation, especially of larger SfM files, takes a very long time and requires high-end computers. The files can be very large, exceeding 1GB on high quality with high-density point clouds. This presents a problem for the storage of high-quality files, so there is usually a trade-off between model quality and size. The area that can be recorded using RTI is limited. RTI and OLS can be difficult in

open air environments. Direct sunlight is detrimental to both techniques. It is also not possible to conduct RTI during strong winds as this causes the camera to shake and makes the images blurry. Finally, laser scanners can be too expensive, especially for smaller projects. However, none of this affects the quality of the documentation directly.

There are some clear advantages of RTI, SfM and OLS compared to tracing and rubbings:

1. There is minimal impact on the engravings and a reduced potential of damaging them during the recording. It is, of course, necessary to step on the rocks as in the older methods, but wearing shoes with soft soles and avoiding stepping on images makes damage less-likely. The tripod for RTI can be set up in a way that does not affect any petroglyphs and plastic or rubber caps on the legs protect unrecognised engravings.
2. Human bias in the recording is minimised because the methods do not rely on experience or perception. They simply record everything including a three-dimensional representation of the topography of the lines. From this, it is easier to judge whether lines are natural depressions, fractures, or were made by humans. The files and models are obviously in need of interpretation. However, they do not leave out features that are within their capability to record, just because they are considered unimportant or are perceived as natural. This increases the visibility of engravings even in largely eroded areas (see Fig. 3a–c).
3. All these new techniques are essentially one or two step processes of documentation, none of which includes interpretation before the final analysis. This further reduces human error, and therefore, potential sources for an incomplete or erroneous documentation.

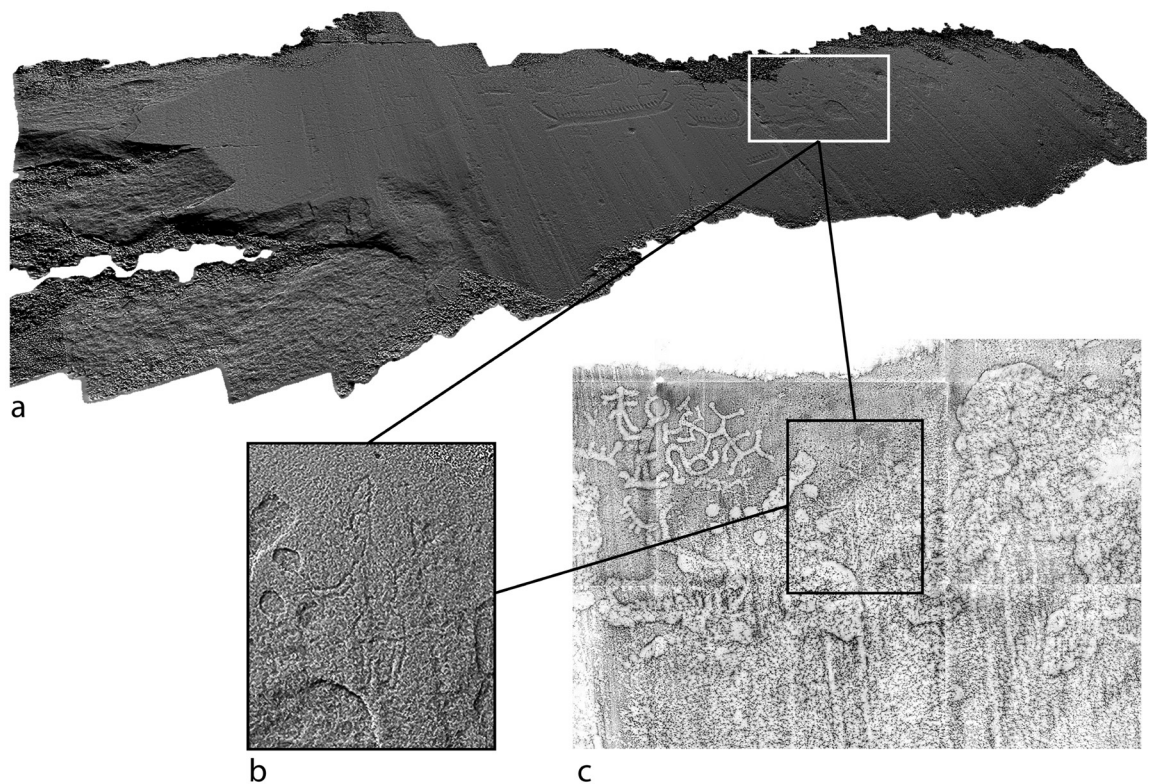


Figure 3. a. SfM of the entire Hoghem, RAÄ Tanum 160:1 panel by RP; b. Anthropomorphic figure in eroded zone, SfM with radiance scaling filter (80%) by RP & CH; c. Frottage by Tanums Hällristningsmuseum Underslös.

4. Given sufficiently powerful hardware, SfM and OLS enable the continuous documentation of large areas in a relatively short time of up to an hour, even for very large panels such as Aspeberget (RAÄ Tanum

- 12:1) at 10.8 x 8 m (<https://tinyurl.com/k953f83>). Since the rock's overall topography is recorded, spatial relationships between images are easier to observe and can be a more central part of the interpretation.
5. The methods allow fast documentation in small teams. The teams that conduct fieldwork usually consist of two people. The process can be completed in 30–40 minutes. Including camera setup and shooting a set of images for RTI. Using the Sense 3D scanner enables the survey of a rock face, depending on its size, in a couple of minutes up to an hour. Usually, the approximate area of the scene that needs to be documented is known so that scanning can take around 5–10 minutes. The necessary images for SfM, even of a large panel of several meters in length such as Hoghem (Sweden, RAÄ Tanum 160:1), can be taken in under an hour. The calculation of the model may take much longer, but during this time, other work can be conducted while the computer calculates.
 6. The results of the OLS recording are visible on the laptop in real-time in the field. Therefore, errors can be readily adjusted. The scans are automatically calibrated, a process that takes 5–10 minutes.
 7. As their biggest advantage, these methods enable us to observe depth differences in the engraved lines. Marking intersections and superimpositions in tracings inscribes the bias directly into the documentation. Conversely, RTI, SfM and OLS record an unbiased documentation that is later interpreted. This means that even if the scientific interpretation of documentation made with RTI, SfM or OLS contains bias or error, there is a chance for other researchers to correct them without having to re-document the rock art.

After detailing the advantages of the documentation of rock art with RTI, SfM and OLS, several case studies are described below to demonstrate how multi-method approaches enable high quality research and the investigation of rock art biographies.

5 Is the Fish not a Fish? – Dietrich Evers and the Documentation of the Rock Art in the Bredarör Tomb, Kivik (RAÄ Stora Melby 42:1)

Dietrich Evers documented rock art at many European sites including Italy and France. In the 1970s he also used his frottage technique in Sweden, amongst other sites, in the Bredarör tomb, Kivik (Fig. 4a). Here he documented a figure that has been interpreted as fish, owing to its form and the many fins or barbels (Fig. 4b). He experimented with the frottage method using several paper formats and ways to apply graphite. Through this he produced several rubbings of the same motif. Recently, his work has been criticised by Andreas Toreld and Tommy Andersson (2015, 2016). Together they re-documented the slabs in the tomb using tracings (Fig. 4c). Their approach was to feel lines in turns and if they both agreed that a line was human made it was drawn; as such if one disagreed then the line was marked as questionable, and finally, lines which both felt were not human made were dismissed or drawn as natural features. Using their documentation, they harshly challenged the results of the frottage done by Dietrich Evers. For example, they denied the existence of multiple lines on the fish that have been interpreted as fins or barbels stating the following:

“Evers has imaginatively created his own motifs on the frottage paper by retouching it using a pencil and eraser. A clear example of this is the two completely different versions that are published of the fish-like figure and a four-legged animal on the slab 7 (Figure 3). Evers’ frottage cannot be said to have any greater scientific value” (Toreld & Andersson, 2015, p. 12, translated here).

From 2015 to early in 2016, the slabs of the stone cist in the Bredarör burial were re-documented on three separate occasions. The methods used were OLS (JL, UB and RP), SfM (UB and Catarina Bertilsson) and RTI (CH and RP). The fins were visible in images produced by all three techniques and all four researchers involved agreed on their presence (Fig. 4d–e; cf. Bertilsson et al., 2017). Thus, Evers recording was validated. If any criticism could be levelled it is that there are potentially even more fins or barbels (Fig. 4d–e). Finally, it was possible to detect some information on how the individual that applied the fish approached the task.

The oval shaped body was made first and the barbels were then added. The tail fin was perhaps engraved last because it seems that it cuts across the body and one of the barbels (Fig. 4d). Similar observations were made for other figures on the slabs (c.f. Bertilsson *et al.*, 2017). These detailed observations introduce the next case study.

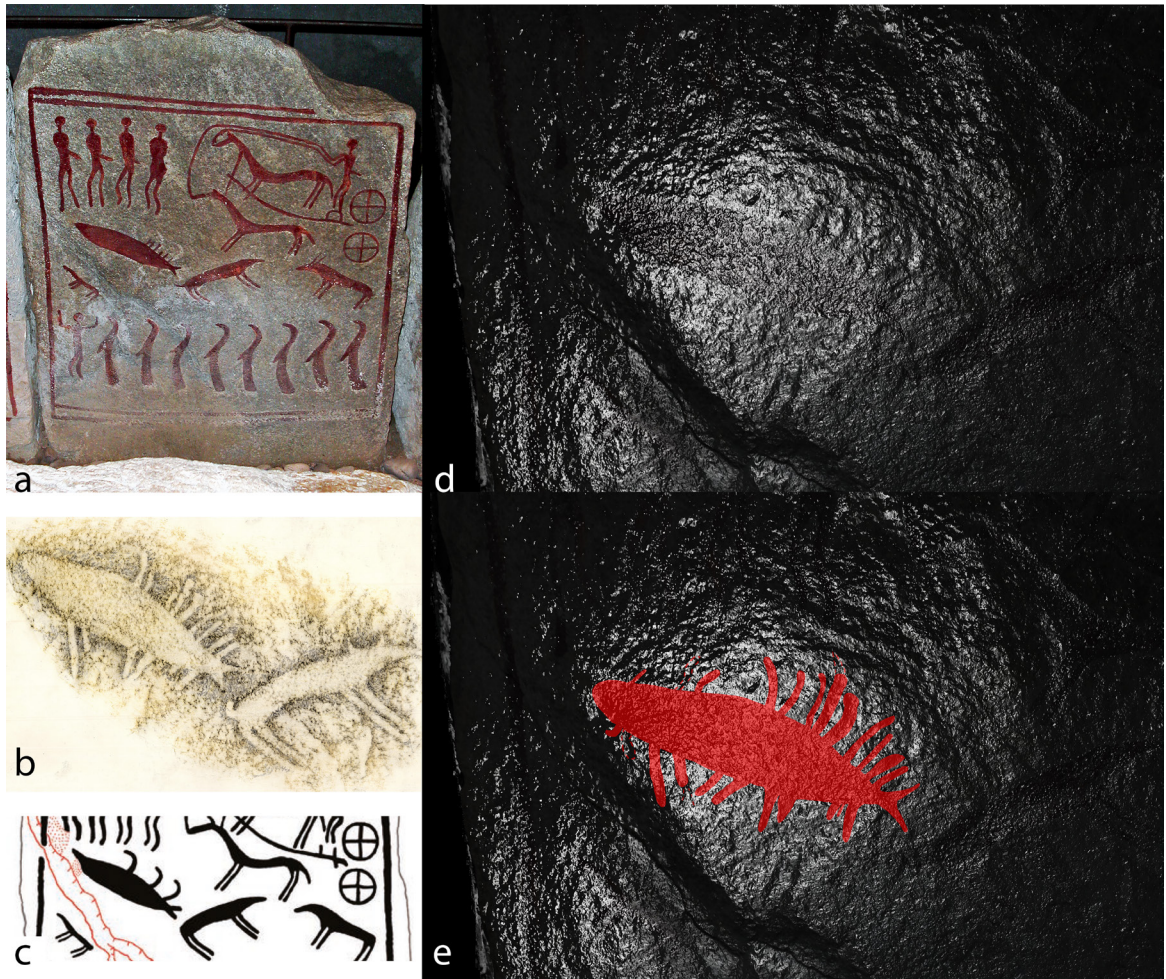


Figure 4. a. Photography of slab 6 in the Bredarör tomb, Kivik by Catarina Bertilsson (the red paint is applied by the heritage service to make the engravings better visible to the public); b. Frottage of the fish by Dietrich Evers; c. Result of the tracing by Andreas Toreld and Tommy Andersson (2015); d. RTI of the fish; e. Fish indicated; Figures 4d–e by RP & CH.

6 At the End of the Longest Line – Individual Action and Transformation of Rock Art

With the capabilities of the various software used for 3D models and RTI files, rock art can be subjected to very detailed analysis by means not available to the human eye alone. The topography of the panel and individual lines gives a sense of the spatial and relative chronological relations of the images. It provides an opportunity to investigate intersections and superimpositions. This allows establishing a relative sequence of transformations on individual figures. The comparison of the production techniques, line depth and width on all kinds of documentation allows for the possibility that different individuals added these lines. Discussing the differences in engraving techniques used on the picture stones in the burial in Sagaholm, Goldhahn suggested that these were used to emphasise aspects of the engraving in the construction of a

narrative (Goldhahn, 2016). However, in the following case study, it is argued that the open context of the panels and the dating of depicted objects supports the notion that several individuals throughout time contributed to the images and scenes final appearance.

On a scenic level, this can be demonstrated with the OLS and SfM documentation of a panel in Finntorp (RAÄ Tanum 184:1). On the frottage of the panel a particular setup of two canoes can be observed (Fig. 5a). The two canoes sit on an axis mirroring each other. Such a position has been interpreted as one canoe representing the living, while the other is the canoe of the dead (Fuglestad, 1999). The argument rests on the observation that one canoe contains humans and the other seems to be empty combined with the perception of both being “mirrored” reflecting the two sides of the human existence: life and death.

We approached the documentation first using the Sense scanner to gain an understanding of the topography (Fig. 5b). We discovered a wide natural depression close to one of the canoes. This first result seemed promising and it was decided that we should document the entire panel using SfM (Fig. 5c). It was discovered by turning the model from a top-down view to an isometric view that the canoes were sitting on opposite sides of the natural depression (Fig. 5d). After sorting through the photographs taken for SfM it was discovered that a black layer runs along the depression (Fig. 5e). This finding indicates that water was frequently flowing through the depression forming a natural water channel.

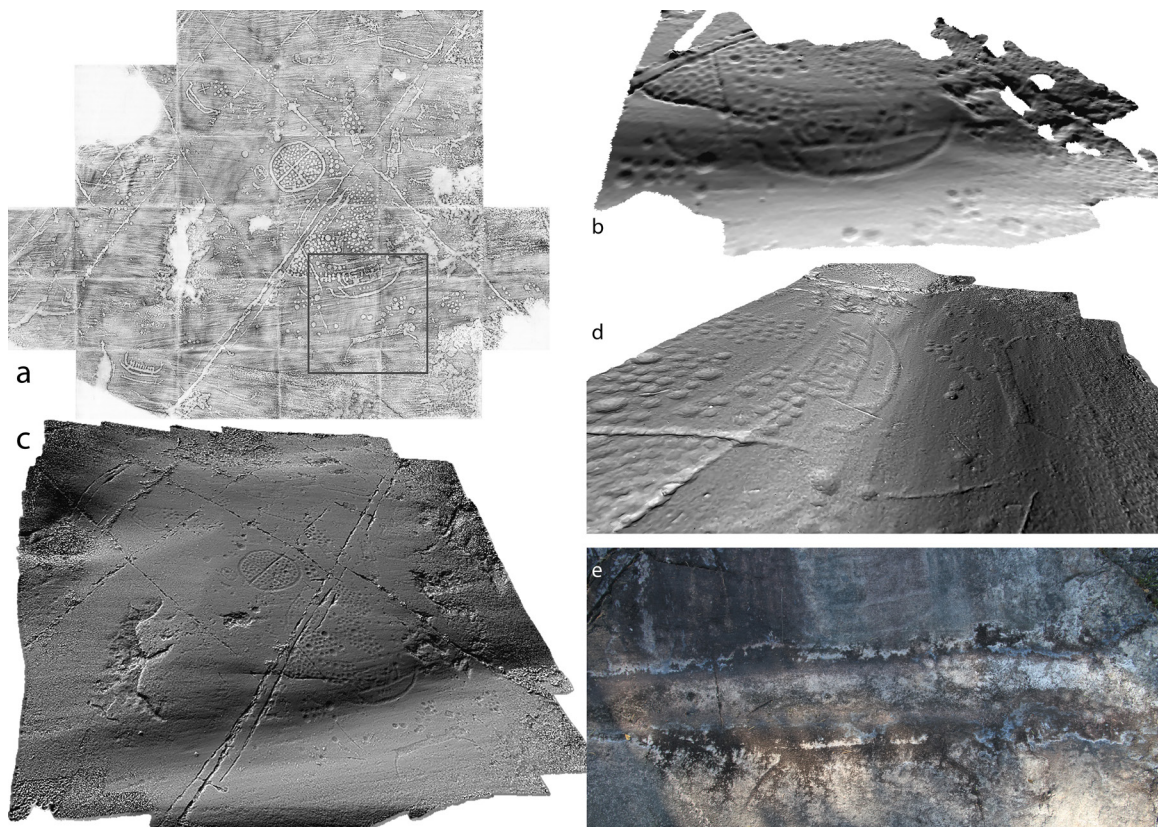


Figure 5. a. Frottage of Finntorp, RAÄ Tanum 184:1 by Tanums Hällristningsmuseum Underslös; b. Sense laser scan of the boat with the spearman by CH; c. SfM of the full site by RP; d. Section with the channel turned, applied radiance scaling filter (80%) taken from the model by RP; e. Photo of the discolored rock in the channel by RP.

This allows for a more elaborate interpretation of the two canoes. Leaving aside whether these are canoes of the living and the dead for the moment, it can be suggested that these canoes do not mirror each other; rather they are depicted as being on either side of a stream, a river, or a fjord. Given that one canoe includes two humans armed with spears this could be interpreted as a canoe crew threatening another crew. The canoe without crew possibly dates to Period III and the canoe with the two spearmen aboard could have

been added in Period V (see Ling, 2008, pp. 102–5). This means both were separated by at least 250 years. The later addition could have turned the scene of a canoe travelling along a fjord into an antagonistic scene emphasised by the raised spears. However, the other canoe does not contain any indication of the crew. This means it could have been perceived as some kind of ethereal or ghost ship to fend off. Alternatively, the raised spears could be a form of greeting and depict a meeting of living warrior crew with their ancestral predecessors. Rock art is a very open medium and more than a single reading of it may have been held by different individuals at different times. Still, the scene was transformed from depicting travel to an engagement of some kind.

That individual figures may have extended chronologies involving many engravers is also demonstrated by, for example the large spearman in Litsleby (RAÄ Tanum 75:1). The warrior's arm, for example, was engraved over some canoe images. The SfM reveals that the hand of the figure is cut across the handle of the spear which indicates that the spear was applied before the hand. The spearhead is morphologically similar to Valsømagle type spears and was perhaps reworked 2–3 times (Fig. 6a–b; Bertilsson, 2015a). The thighs of the figure cut across a Period III canoe (Ling, 2008, pp. 102–5). That could mean that 2–400 years passed between the engraving of the spear and the addition of the human figure. This means several individuals were involved in shaping the scene (see also <https://tinyurl.com/leo8ueg>).

In some instances, the process is more complex and difficult to differentiate. A panel in Fossum (RAÄ Tanum 255:1) was documented using SfM (Fig. 6c) and OLS (Fig. 6d; see for details Ling & Bertilsson, 2016). One figure usually seen as an axeman shows an interesting setup. The figure superimposes a line that forms the phallus and the sword of the figure. An animal superimposes the sword, presumably a dog (Fig. 6d). There are three relative sequence instances, but these cannot be dated because they lack chronological markers. The arm of the human was applied after the body and the hand cuts across something that has been interpreted as an axe (Fig. 6c). This feature superimposes another line that is also superimposed by another human figure. For the second human, this line serves as a sheathed sword. The specific setup of the hand of the first human cutting across it and the attached line make it more likely that this is the representation of a sword (Fig. 6c). In this case, the feature formerly identified as an axehead is more likely a hilt (Fig. 6e). This hilt's form can be compared to period II types.

Lastly, such a build-up has also been observed using RTI on four human figures on another panel in Finntorp (RAÄ Tanum 89:1). A tall warrior (40 cm) carrying a spear was documented three times in two field seasons. The Sense 3D scanner was used to mark the exact extent of the figure. The two other warriors have been documented twice with RTI and the axeman once (cf. Horn & Potter, 2017). In the following, the emphasis is on the spearman and the two warriors.

The pair of warriors displays very pronounced knees (Fig. 6f). These knees have previously been interpreted as representing a connection to posturing and the body image of warriors (Fredell & Quintela, 2010). The documentation results suggest that this may not always have been the case. The lower legs and feet were added after the knees and the thigh indicating that they are later. The thigh and the presumed knee could have regular legs with feet. Similar observations can be made, for example on OLS scans from panels in Aspeberget (RAÄ Tanum 29:1) where one frontal figure to the left has feet that consist of a long line. Two other figures in a central group of three show the similar lines at knee level (see <https://tinyurl.com/l2j7mz6>). There is currently no way of dating the later addition.

This is different for the large spearman. The overall elongated form and the potentially smooth outward swing of the lower part of the blade could suggest a Valsømagle type spear parallel to the discovery in Litsleby (Fig. 6h–i; Horn & Potter, 2017). The shield could be of type Watensted and would date this addition into the transition from Period II to III 2–300 years later (see Uckelmann, 2012). The analysis of the RTI file also indicated that the spear tip was reworked 3–4 times. It also showed that the cup mark used as the head was made in a different style and is marginally superimposed by the spear's handle (Horn & Potter, 2017; Horn, 2016). All this demonstrates that there may be a considerable time-depth for all the discussed case studies.

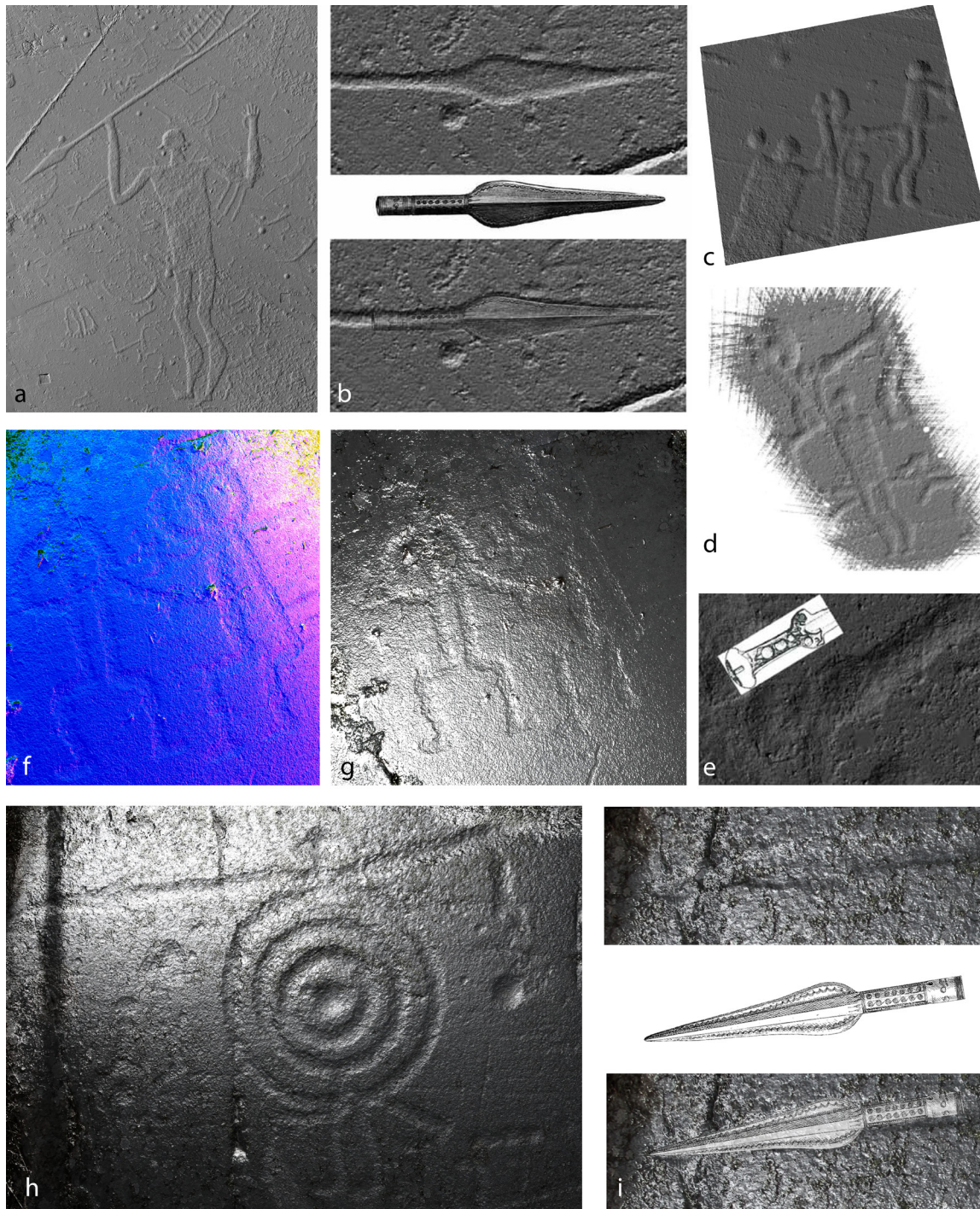


Figure 6. a. SfM of the spearman in Litsleby, RAÄ Tanum 75:1 by SHFA; b. Comparison of the spear point in Litsleby with a Valsømagle spear from Falköping (Bertilsson, 2015); c. SfM of warriors on the Fossum, RAÄ Tanum 255:1 by RP; d. Handyscan 700 scan by Länsstyrelsen i Västra Götland; e. comparison with a flange hilted sword (Ling & Bertilsson, 2016); f. RTI of the two warriors with knees in Finntorp by RP & CH, normals visualized in RTIViewer and enhanced using the DStretch in ImageJ; g. RTI of the two warriors with knees, lighting adjusted to make the feet that form the knees visible on the right figure, specular enhancement filter; h. RTI of the spear man in Finntorp by RP & CH; i. Comparison of the spear point in Finntorp with a Valsømagle spear from Falköping by CH.

7 The Past is Alive – Rock Art Biographies

Identifying transformations and additions in Litsleby, Fossum, and Finntorp has further implications. For example, the spearman on panel RAÄ Tanum 89:1 in Finntorp was transformed at least on five separate occasions. The scene in Litsleby involved at least four transformative events. Rock art research has previously established that images were added on the panels over a long period of time (Bengtsson, 2004; Ling, 2008; Fredell, 2003; Nilsson, 2012). However, this only pertains to the panel level. The results of the new documentation effort indicate that individual figures accrued engraving events. On the example of the Sarsen stones in Stonehenge, it has been argued that repeated human-object interaction provides the stones with a biography (Gillings & Pollard, 1999). This biography provides the stones, or in the Scandinavian case the images, with the power to have an influence on future engagements. We see this for example in Litsleby, where the direction of the handle predetermines the direction of a potentially Late Bronze Age rider. The Period III canoe on the channel in Finntorp influenced the location of the canoe from Period V. The spear and the cup mark on the other panel in Finntorp may have evoked the impression of a human to later prehistoric observers which may have “completed” the figure.

A valid interpretation of the process is perhaps that the presence of rock art allowed humans to engage directly with their predecessors or ancestors on the rocks. That would mean that rock art provided a nexus for whatever rituals the making of rock art was enmeshed in to shrink temporal distance and maybe even break down the barrier between the living and the dead for those who engraved the rocks. This complements other interpretations of rock such as its relation to the dead world (Fuglestad, 1999) or more agency centred interpretations of rock art as intended to change the real world (Ling & Cornell, 2010). Prehistoric communities may have even recognised the age of the images, linked them to certain myths, and imagined engaging with their ancestors or heroes of the past by transforming the images. This could explain why rock art would have been important because it represented a link to the past.

The presented results also have an implication directly impacting archaeological thinking. Figures and scenes are much less stable than previously thought. Most interpretations focus on the completed scene (cf. Goldhahn & Ling, 2013), but they were not finished in one engraving instance. Instead, they evolved over time potentially changing their meaning. That means that interpretations may only apply to the latest phase in the biography of the image or scene. In the future, more biographies should be reconstructed to recognise all variations, the time-scales of transformations and potential common trends.

8 Summary

The wider introduction of RTI, SfM and OLS in combination with each other and older techniques has enhanced our ability to record, store and investigate rock art. Image based 2.5D and 3D modelling should become the new standard of documenting rock art in southern Scandinavia complementing existing methods like frottage and tracing. That way, we can best ensure the preservation of the world heritage in Tanum.

By employing all means necessary it was possible to demonstrate that rock art figures and scenes were transformed and constructed over time involving many individuals. It is an indication that a singular interpretation of rock art, or even a singular figure, are problematic. Researching more rock art biographies will add more complexity to the study and interpretation of Scandinavian rock art.

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