XXVI VALCAMONICA SYMPOSIUM 2015

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PROSPECTS FOR THE PREHISTORIC ART RESEARCH
50 years since the founding of Centro Camuno

PROSPETTIVE SULLA RICERCA DELL'ARTE PREISTORICA
a 50 anni dalla fondazione del Centro Camuno

Centro Camuno
di Studi Preistorici

Proceedings

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Under the auspices and the partecipation of / *Con il patrocinio e la partecipazione di*

United Nations Educational, Scientific and Cultural Organization · World Heritage Centre

ICCROM

ICOMOS Comitato Nazionale Italiano

UNESCO Organizzazione delle Nazioni Unite per l'Educazione, la Scienza e la Cultura · Commissione Nazionale Italiana per l'UNESCO

MiBACT Ministero dei beni e delle attività culturali e del turismo

MiBACT Soprintendenza Archeologia della Lombardia

Regione Lombardia

Consorzio Comuni BIM di Valle Camonica

Comunità Montana di Valle Camonica

Valle Camonica Distretto Culturale

Arte rupestre della Valle Camonica Sito Unesco n. 94

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EXAMPLES OF APPLICATION OF MODERN DIGITAL TECHNIQUES AND METHODS

STRUCTURE FOR MOTION (SFM) AND MULTI-VIEW STEREO (MVS) FOR THREE-DIMENSIONAL DOCUMENTATION OF ROCK CARVINGS IN TANUM CREATING NEW OPPORTUNITIES FOR INTERPRETATION AND DATING

Ulf Bertilsson *

SUMMARY

One goal of the SHFA are applying and improving non-tactile digital documentation techniques, mainly laser scanning and digital photography as means to avoid interventions in the rock carvings like cleaning and painting with increased wear. A pilot study documenting some 20-rock carvings in Tanum with Structure from Motion technology was performed in 2014. One important aim was to compare the result with that of 2D-documentation methods, rubbing and plastic tracing. SfM means that the rock carvings are documented by a number of overlapping photographs taken with a digital SLR camera of suitable quality. A powerful computer, a workstation, is needed to enable processing of the images with the software, Agi Soft and Multi-view Stereo resulting in a high-resolution, three-dimensional image of the photographed hob. In this manner, a picture of the carving is produced, which, also gives the carved surface's structure and topography. The study produced a more detailed result in less time and at lower cost. The results were intriguing and spectacular information was obtained inter alia at the famous rock carving with the mighty spear-carrier at Litsleby. By carefully analyzing details of concerning the spearhead new and sensational information about its type and dating was accomplished showing that the method can provide significant contributions to in-depth interpretation and dating possibilities of rock carvings by creating unprecedented opportunities to analyze actual images and e.g. superimpositions in more detail.

RIASSUNTO:

La SHFA stanno intraducento e applicando tecniche di documentazione digitali, soprattutto scansione laser e fotografia digitale, che riducono al minimo gli interventi sulle incisioni rupestri. Il primo progetto pilota con tecnica SfM sulla r. 20 di Tanum risale al 2014 e ha permesso di confrontare i primi elaborati grafici con le più tradizionali tecniche di rilevamento 2D: rilievo e frottage. SfM permette di documentare le incisioni rupestri con una serie di fotografie scattate con una fotocamera reflex digitale di qualità adeguata, le immagini sono poi elaborate da software come Agi Soft e Multi-view Stereo in grado di restituire immagini tridimensionali del piano fotografato. Lo studio ha dimostrato che si possono ottenere ottimi risultati in poco tempo e a costi contenuti. I risultati più intriganti e spattacolari si sono ottenuti a Litsleby, su una roccia caratterizzata dall'incisione di una grande lancia. Analizzando con attenzione la punta di lancia si sono potute fare importanti considerazioni sulla sua tipologia e datazione. Questo metodo può quindi fornire un contributo significativo all'interpretazione e all'approfondimento delle incisioni rupestri, creando opportunità senza precedenti per analizzare le immagini reali e le sovrapposizioni in modo sempre più dettagliato.

THE BACKGROUND TO THE STUDY

One important goal of the Swedish Rock Art Research Archives is applying and improving non-tactile digital documentation techniques developed in recent decades. This mainly concerns laser scanning and digital 3D-photography as important means to avoid far-reaching interventions on the rock carvings in the form of cleaning with chemical agents and painting with paint containing unsuitable components. Both phenomena through repeated use over, in many cases, two centuries, usually with unknown effects and/or undocumented results. Surely, however, it has meant an increased wear at the carvings with unknown long-term side effects and should, as far as humanly possible, be avoided. Although awareness of the dangers of such interventions today are much greater than before, there is still an opportunity and a risk that they are applied routinely just because "they've always done it" or "It makes sure no harm".

Already in the 1970s, attempts were made by Jarl Nordbladh and Jan Rosvall to carry out documentation work using the 3D technique of photogrammetry on the Kville rock carvings (1978). In the Swedish National Heritage Board-operated Luftföroreningsprojektet [Eng. The Air pollution project], at the beginning of the 1990s, the first attempts to use laser scanning for documentation purposes were made in Norrköping and Tanum. The mutual result of these attempts was that the technique in itself worked but that it was a complicated and costly process in relation to the results achieved. By the end of the 1990s, in the Rock Care project, when the laser scanning technique had been refined, successful attempts were made to carry out documentation work on the Tanum, Foz Côa (Portugal) and Valcamonica (Italy) rock carvings respectively. Then an ATOS-scanner was used in collaboration with the Gothenburg based company Metimur, which normally would use this technique to measure the impact of car crashes on Volvo auto bodies in crash tests. The high level of scanning resolution enabled many details of the rock carving figures and cutting techniques to be documented and analysed (JOHANSSON, MAGNUSSON 2004). The use of the techniques was discontinued mainly due to the high cost of at least 25 000 Swedish Krona a day. Additionally costs added up for the following processing of the attained digital information. (Fig. 1)

During recent years a simpler and more cost-effective 3D technique of rock art documentation has been

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developed and applied. This is the "Structure for Motion"/"SfM"-technique. Briefly, the application of this method, described in short, means that the rock carvings are documented by a number of 60-70 % overlapping photographs taken with a digital camera of suitable quality as an SLR type Nikon 7000 (Fig. 2). The images are then processed in a powerful computer, type the HP Z420 Workstation, with the software, Agi Soft and Multi-view Stereo resulting in a high-resolution, three-dimensional image of the photographed hob. In this manner, a picture is produced, which, also gives the carved surface's structure and topography. These are elements, which traditional two-dimensional methods used, rubbings and tracings; do not give the opportunity to convey. A certain disadvantage is that the amount of high-resolution images required may give rise to a relatively long processing time on the computer. At the same time this part of the work carried out in parallel with the ongoing shooting in the field. (Fig. 2)

The SfM-technique is not only used for rock art documentation purposes but also increasingly regularly at archaeological excavations. Two well-known examples are the archaeological excavations at Tollense, Mecklenburg (Germany) (Jantzen, Terberger 2011) and at Alken Enge at Jutland (Denmark), (see for example: Ancient origins. Reconstructing the story of humanity's past 2013-2015), that has resulted in spectacular findings of skeleton and weapons from the Bronze Age and Iron Age respectively. The technology has also been used in combination with satellite imagery to document threats and damages to archaeological heritage in arid environments (Hesse 2015).

Chris Sevara from Vienna Institute of Archaeological Science - VIAS and Ludwig Bolzmann Institute - LBI at the University of Vienna that SHFA has collaborated with introduced the technique in the initial phase of the process. Sevara had then already tested the SfM-technique for rock carving documentation purposes on a Bronze Age rock art panel and a nearby rock cairn at Törnsfall in Tjust, Småland in cooperation with Joakim Goldhahn (Sevara, Goldhahn 2011 with references). Recently, LBI made documentation work on rock art, using the SfM-technique, in Sudan. Last May, by commission of the Västra Götaland County Administrative Board, a pilot study has commenced, with the aim to carry out documentation work on 20 or so of the Aspeberget rock carvings using the SfM-technique (Bertilsson *et al*. 2014). Hopefully, this modern digital technique can produce a more detailed result in a shorter time frame and at a lower cost as compared with the traditional documentation techniques of frottage ("the rubbing method") and tracing on plastic sheets. Additionally, it can establish, not only the older, rock art documentation on a modern digital arena. During the pilot study, SHFA organized training in the SfM-technique and in which staff from Tanums hällristningsmuseum Underslös (The Tanum Rock Art Museum in Underslös) and Stiftelsen för dokumentation av Bohusläns hällristningar [Eng. the Foundation for the documentation of rock art of Bohuslän] participated.

The purpose was twofold, partly that the work was carried out by competent staff with experience of rock art documentation and partly to provide training in a technique that the involved actors may integrate in their own documentation work. For the training aspect it is also considered to be of vital importance to involve university students in the SfM-technique to ensure competency of staff in future documentation work project. In addition, SHFA has entered an agreement with the Centro Camuno di Studi Preistorici/CCSP, Capo di Ponte in Valcamonica (Italy), targeted training in documentation, research and training, including the SfM-technique in jointly implemented educational courses.

Pros and cons of Structure from Motion

In short, the technology could be characterized by having the following advantages and disadvantages:

Advantages

- Rapid – compared with traditional analogue techniques used
- Low-cost – in comparison with handheld laser
- Accurate – with a resolution of approx. 1 mm used here
- Unordered Images – are ordered automatically
- Archival Images – can be used under certain conditions
- True Ortho-photo Generation
- No Calibration or Positioning Information Needed
- Easy to Implement
- Integration with GIS – using geo-referencing

Disadvantages

- Passive Technology -
- Images Must Be Sharp – and must be selected before being processed
- Intensive Computer Processing – requires for a workstation with a powerful graphics card
- Image Alignment Can Fail – and if so may require new photography lens with different focal lengths

Some further benefits of the SfM-technique, which concerns not only the scientific quality but more the society surrounding the Academy namely its Democratic and Pedagogic effects are also mentioned by Chris Sevara and Joakim Goldhahn. In their Törnsfall study they reached some interesting results concluded in the following way: "While there is no question of the relative density of laser scanning output (e.g. Trinks *et al.* 2005, p. 113) to that of Structure-from-Motion and Multi-view Stero output, the cost involved in the use of laser scanning techniques, principally in the form of hardware, still continues to place laser scanning and its benefits out of reach of the majority of archaeological projects around the world" (Sevara, Goldhahn 2011, p. 262).

The pilot study with the Structure from Motion

For that purpose, a pilot study aimed at documenting some 20rock carvings on Aspeberget in Tanum with this modern and low-cost digital technology Structure for Motion has been performed during 2014 (Bertilsson *et al*. 2014). One important aim was to compare the result with that of more traditional two dimensional documentation methods like rubbing and plastic tracing. The study was expected to produce a more detailed result in less time and at lower cost and to se-

riously establish, the documentation of rock carvings on a modern digital arena. The results were in many ways intriguing and several spectacular examples were obtained, of which one specific will be presented here. The long-term goal of the study, which was done at the County Administrative Board's in Gothenburg mission, was to develop a plan for the documentation of all rock carvings in Tanum World Heritage with this modern 3D technology. The plan is to be carried out, encompassing all 459-rock carvings in the area until the year 2019.

When it comes to large rock carvings one effect of the SfM-technology is that it generates extensive amounts of data e.g. the panel Aspeberget in Tanum requiring for more than 1500 images (Fig. 3). The subsequent processing of which is relatively time-consuming, sometimes lasting more than 24 hours, depending on how powerful the computer on which it is conducted is. But this is compensated by the fact that most data runs can be made in the evening or nighttime and therefore do not affect the record time and presents a detailed view of a rock carving in 3D-format. A complete image of the rock carving can also be presented and used faster than one that has been developed with the traditional methods like rubbing and tracing (cfr. Sevara, Goldhahn 2011). In the pilot study that was conducted in 2014, this and other elements were performed, described and analyzed in more detail (Bertilsson *et al*. 2014). Already at this early stage results show that the method will provide significant contributions to in-depth interpretation and enhanced dating possibilities of rock carvings by creating unprecedented opportunities to analyze actual images and e.g. superimpositions in greater more detail than the traditional techniques used. In the following we will present one specific example to illustrate this.

The mighty spear-carrier at Litsleby - Odin

Our example concerns the supernatural sized spear-carrier on the famous rock carving at Litsleby in Tanum. The high-resolution result of the SfM-documentation revealing surprisingly many details among which is the fact that one can clearly see that the spear is hewn before its carrier since the arm and hand holding it is carved on top of the spear shaft (Fig. 4). The time difference between these two carving elements and events are of course not easy to establish with any certainty but the order of the carving sequence nonetheless interesting to demonstrate. A careful analysis of the SfM-documentation of the spear also shows that there is some highly interesting information hidden in that figure that has not been noted before. A contributing factor to this is the recent practice of painting carving with red paint to the more easily seen by tourists.

But before we take a closer look on that, we will first comment some of the boats represented on the panel. Boats that by its mere type mediates some important information concerning dating and chronology; the first is a small boat superimposed by the shaft of the spear. This boat is of the so-called Nag-type with a general dating to the Late Neolithic sometime between 2100 and 1700 BC (Bengtsson 2014 with references). A similar dating is probable for the three-line boat superimposed by the left upper arm of the spear-carrier. His two thighs superimpose a third boat. That boat is of a type dating to Period II of the Nordic Bronze Age sometime between 1500 and 1300 BC (Ling 2008, p. 105; Kaul 1998).

The spear-carrier himself is normally considered to date to period V, sometime between 900 - 700 BC. It seems reasonable in view of the dating of other similar large human-like carvings such as "Shoemaker" at Backa in Brastad. When it comes to the dating of the spearhead that we promised to return to, the new SfM-documentation shows very clearly that the carving has been re-worked and modified since there is one the longer, slimmer and more pointed tip on top of a shorter one. This gives of course raise to some questions, the most important being; is it possible to determine which proportion of spear head that was carved first; if there is a short, complete one, which later has been equipped with a longer and slimmer tip or how were matters actually? We will now try to sort that out by further analyzing this part of the carving. (Figs. 4-5)

The spear head is deeply carved and detailed designed with a shape in true real spearheads from the Bronze Age to be found and are now kept in museum collections, it was natural to look for parallels there. The first thought then was that the carved head could be of Valsömagletyp type which dates to the early part, period IB of the Nordic Bronze Age. But a direct comparison showed that this might not be completely accurate since the lower bulging part of the spear blade and its transition to the socket does not seem to match perfectly, although Oldeberg (1974) denotes the spearhead as Valsömagle. Therefore, in searching for other possible types a spearhead found in Falköping in earlier times and depicted in the standard work *Minnen från vår forntid* turned out to look much interesting (Montelius 1917; Oldeberg 1974, p. 303, no. 2373; fig. 5a). A comparison made possible by the kind assistance of Dr. Christian Horn from University of Kiel, Germany with this drawing and also with the photo from the National Historical Museum of the original tip shows that those two spearheads fits almost exactly into that of Litslebyristningen (Fig. 5b). Therefore it could definitely have been a model for the carved one. This might be another interesting illustration of the life history and engraved biography of a highly important and prestigious bronze object as suggested by Joakim Goldhahn (2014).

This results of this successful comparison of spearhead types is also some direct chronological implications indicating that the original is of a type from common in period II of the Nordic Bronze Age (Montelius 1917, p. 61, fig. 917). According to Montelius "Spearheads of bronze; many of them adorned with spirals or other ornamentation... or they are also wider, with edges conclusion far from the lower edge. ... Also spears of the latter form are characteristic of the Germanic area. (Montelius 1917, p. 38), translated here". The Falköping spearhead is ca. 37 cm long, and the socket constitutes almost one-third of that, being 9 cm long. The socket is beautifully decorated with spirals form-

ing a running dog pattern and on the blade runs continuous band with double arches. According to Christian Horn spear was the typical weapon of the warrior in the first period of the Bronze Age in Southern Sweden, the sword becoming more common in period II (Horn 2013, p. 22).

Additionally, it shows that the full spearhead the long, narrow tip is the original and the elderly, and can be dated to the Bronze Age second period, 1500 - 1300 BC This tip has been cut over by a shorter, more compact leading-edge, possibly the so-called. Hulterstad type found earlier times in a grave on the island of Öland, which in itself also dated to the second period, but in that case probably the latter part thereof (Fig.6). Before this can be determined with any reasonable certainty, additional comparisons are required and the carving needs to be documented and analysed in more detail. We still, with this simple study of the spearhead of the Litsleby rock carving, have been able to show that the digital Structure from Motion technology can be used, not only, to produce a better and more contemporary documentation, but also that it contributes to the development of research on the rock carvings by providing more detailed information in turn contributing to new questions and interpretations.

The red paint that has been added in recent times helps to smooth out the carved surface and therefore may hide important details such as the spearhead we have dealt with here. That we regardless of this major drawback has been able to discover new an substantial details on he carving has been made possible because of the application of the Structure for Motion- technology that enables you to literally "see through" color. Another example of the negative effects of the paint is that the sun-wheel image, which is located in contact with and superimposed by the phallus of "Odin" (Fig. 4). On the textured, painted version looks the circle while largely complete, but on the non-textured version clearly shows that it is interrupted in several places in the upper left part. The three-dimensional digital technology therefore creates better opportunities to see, document and describe previously overlooked details that may be of great importance for the interpretation and understanding of the carvings. Something that also creates new opportunities for the experience for the visiting tourist to be further be developed and deepened.

References

Ancient origins
2013-2015 *Reconstructing the of humanity's past*: http://www.ancient-origins.net/ancient-places-europe/alken-enge-and-buried-army-002120

Bengtsson L.
2014 *Rock Art Ships as a Method for Dating*, in Bergerbrant S., Sabatini S. (eds), *Counterpoint: essays in Archaeology and Heritage Studies in Honour of Professor Kristian Kristiansen*, in «BAR» International Series 2508, (2013), pp. 253-258.

Bertilsson U., Bertilsson C., Meijer E.
2014 *Dokumentation av Världsarvets Hällristningar med 3D teknik – Structure from Motion. Etapp 1. Pilotstudien på Aspeberget 2014*, Rapport Svenskt Hällristnings Forsknings Arkiv, 106s, Göteborg.

Goldhahn J.
2014 *Engraved biographies – rock art and life-histories of Bronze Age objects*, in «Current Swedish Archaeology» 22, pp. 97-136.

Hesse R.
2015 *Combining Structure from Motion with high and Intermediate resolution satellite images to Document threats to archaeological heritage in arid environments*, in «Journal of Cultural Heritage» Vol.16, Issue 2, March - April 2015, pp. 192-201.

Horn C.
2013 *Danish Journal of Archaeology (2013): Weapons, fighters and combat: spears and swords in Early Bronze Age Scandinavia*, in «Danish Journal of Archaeology» DOI: 10.1080/21662282.2013.838832

Jantzen D., Terberger T.
2011 *Gewaltsamer Tod im Tollensetal vor 3200 Jahren*, in «Archaäologi in Deutschland». 4, Theiss, Stuttgart, pp. 6-11.

Johansson S.-O., Magnusson J.
2004 *Developing new technique for 3D documentation of rock art*, in Bertilsson U., McDermott L. (eds), *The Valcamonica symposiums 2001 and 2002*, Riksantikvarieämbetet, Stockholm, pp. 125-133.

Montelius O.
1917 *Minnen från vår forntid*, I Stenåldern och Bronsåldern, Stockholm.

Nordbladh J., Rosvall J.
1978 *Fotogrammetrisk bestämning av hällristningar - ett försök*, in Nordbladh J., Rosvall J. (eds), *Mått & mål*, Marks & Measures, Institute of Art History. University of Gothenburg, pp. 143-148.

Oldeberg A.
1974 *Die ältere Metallzeit in Schweden I. Kungl. Vitterhets Historie och Antikvitets Akademien*, Stockholm, Sevara C., Goldhahn J.
2011 *Image-based Modelling of the Present Past: Building 3DModels of Archaeological Environments from Digital Photographs* in Al-Qawasmi J., Alshawabkeh Y., Remondino F. (eds.), *Conference Proceedings from Digital Media and its application in Cultural Heritage*, Amman, Jordan, 13-15 March 2011, CSAAR Press, pp. 251-266.

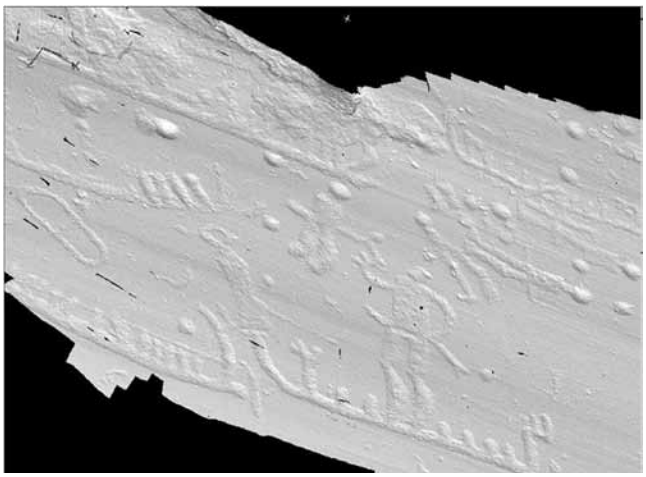

Fig. 1 - Laser-scanned depiction of the rock carving Fossumtorp Tanum 151:1 performed in the year 2000 with ATOS-scanner by Metimur in the Rock Care project of the Swedish National Heritage Board. Source: SHFA.

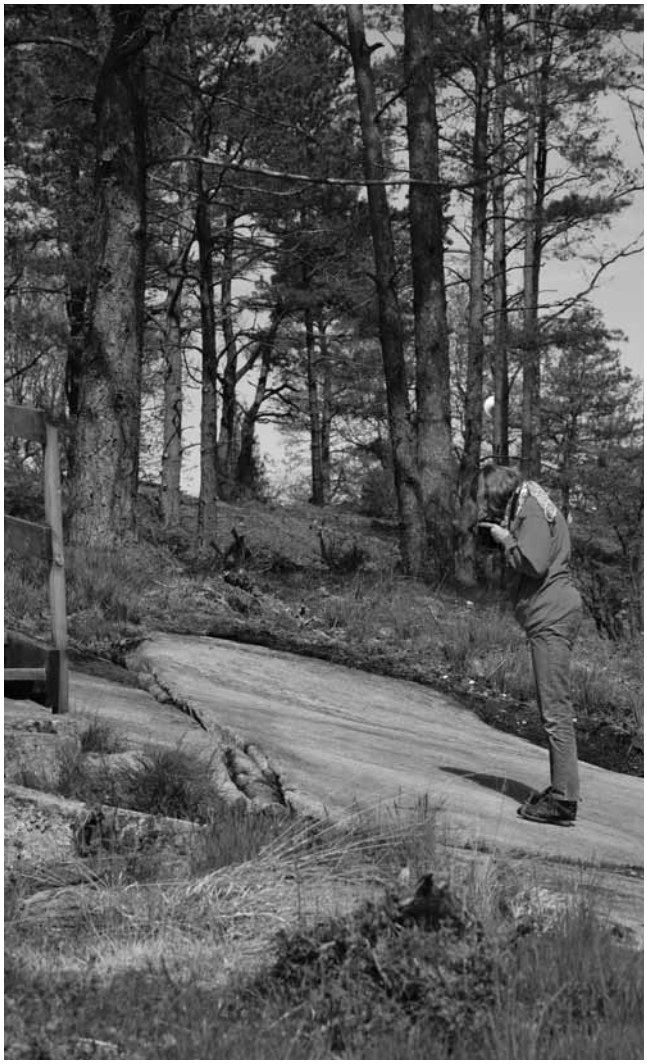

Fig.2 - Catarina Bertilsson photographs Tanum 18:1 on the backside of Aspeberget for Structure from Motion documentation. Source: SHFA. Photo: Ellen Meier.

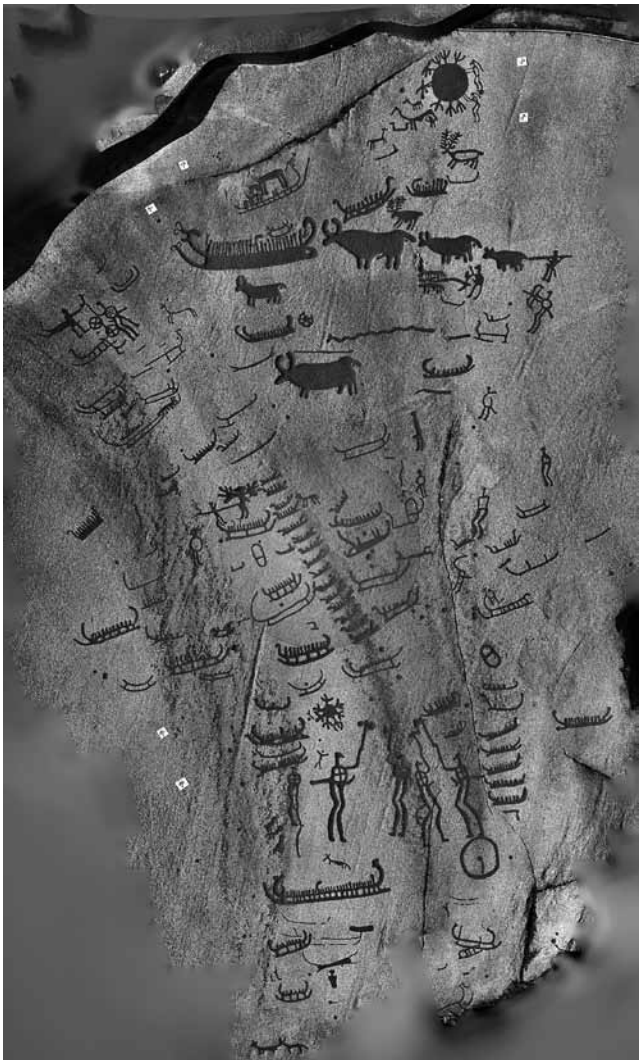

Fig. 3 - The rock carving Tanum 12 at Aspeberget documented by Structure from Motion and here presented with full texture exported as a snapshot from AGI Soft. The surface of the rock carving is approx. 120 square meter and the number of cameras = photos are 1517. Source: SHFA. Photo: Catarina Bertilsson and Ellen Meijer.

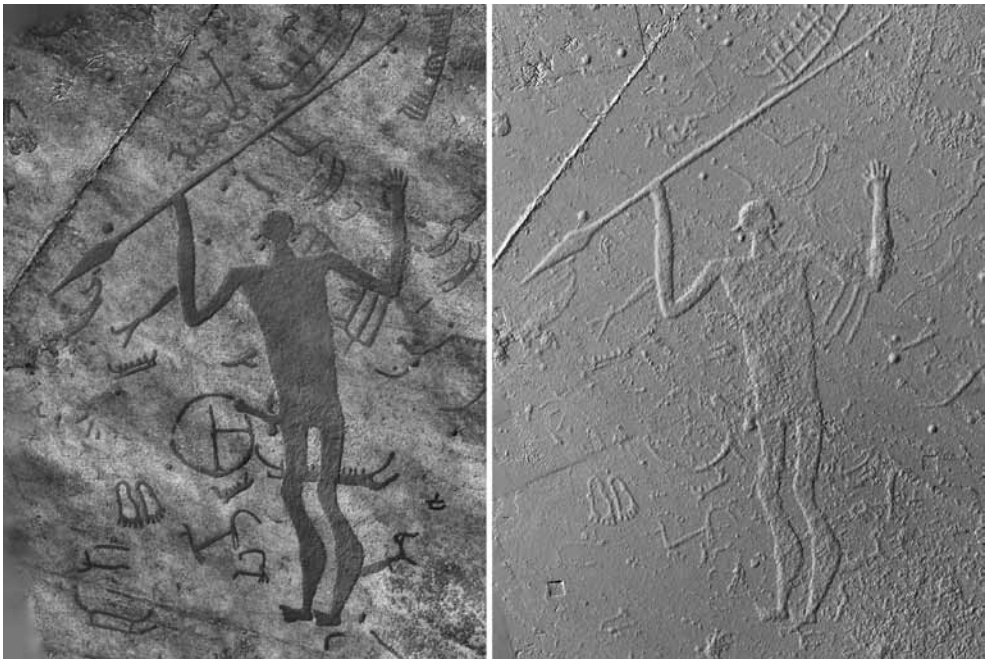

Fig. 4 - SfM-documentation of Litsleby with texture and without – left and right photo. The red paint making the carving more visible to the visiting public still has a major drawback in that it smoothens the carved surfaces and hiding important details. Source: SHFA. Photo: Ellen Meijer.

Fig. 5a - Bronze spearhead from period II of the Nordic Bronze Age found at Gästgivaretomten in Falköping, Västergötland in 1867. Photo: SHM.

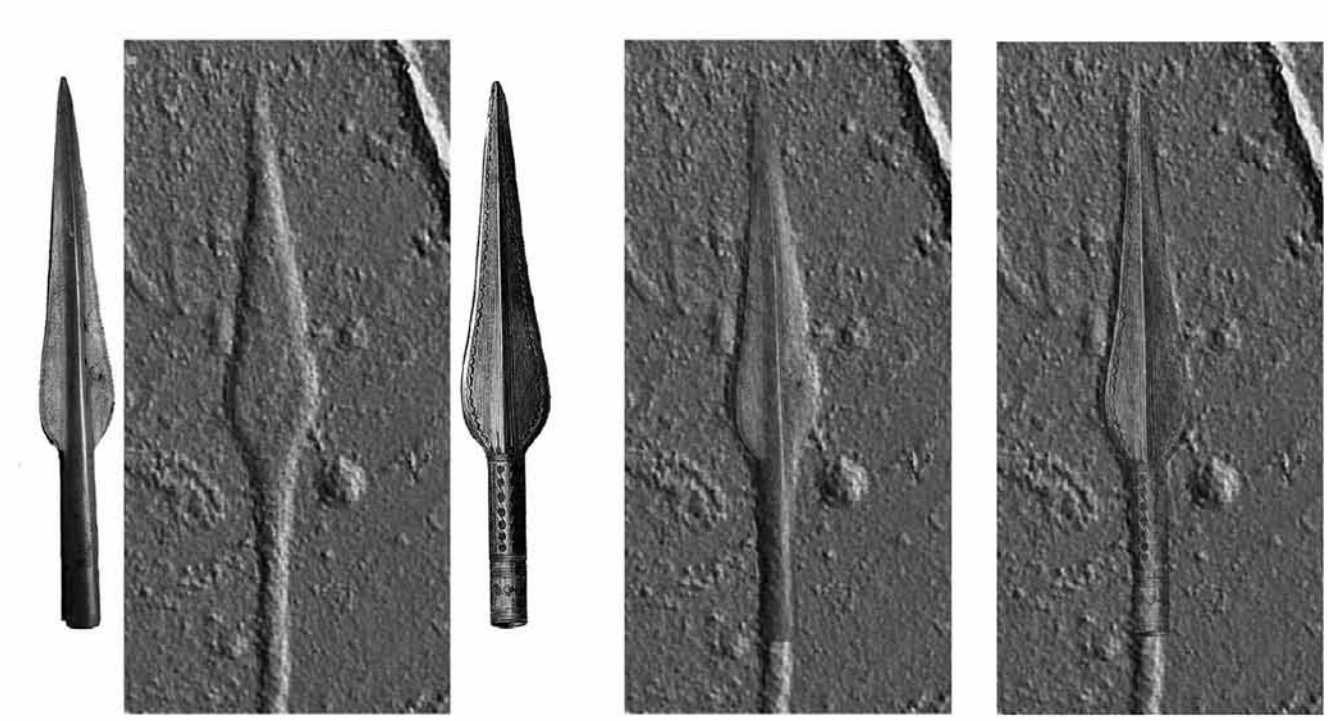

Fig. 5b - SfM photo of Litsleby spearhead with original Falköping spearhead from photo in Historiska museet to the left and drawing in Montelius 1917, to the right. Middle photo with original spearhead fitted into that of the carving and the right with the drawing by Montelius. Processed in Photoshop by Christian Horn, University of Kiel, Germany.

Fig. 6 - Bronze spearhead from period II of the Nordic Bronze Age found in a barrow at Hulterstad, Öland in 1933. Photo: SHM.