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The rock, the whole rock, and everything about the rock

3D-scanning of Bronze Age rock art sites in central-eastern Sweden using Leica MS60 and RTC360

The different documentation methods of rock art all have their pros and cons in recording petroglyphs. Traditionally it is the figurative content that has been in focus, but because Bronze Age motifs often relate to and incorporate the topography and mineral composition of the rock there is a need to also capture these aspects to a higher degree. The new 3D-techniques offer interesting possibilities to achieve this. Hitherto, handheld scanners and photogrammetrical approaches have been employed to record smaller areas of rock art but they are only rarely capable of capturing a larger part of an outcrop. To capture a fuller context of the petroglyphs, we have evaluated the potential of other types of 3D-scanners; a Multistation scanner, Leica MS60 and a dedicated dome-scanner, Leica RTC360, to record seven whole rock outcrops with rock art in central-eastern Sweden. Our tests conclude that although the scanners perform parts of the recording process differently, they both are capable of capturing even faint petroglyphs as well as the curvature and topography of a whole outcrop, including textures in colour.

Introduction

Rock art research has experienced substantial reorientations during the last decades in terms of both new documentation methods and new theoretical approaches. Traditionally, Bronze Age (1700–500 BCE) rock art research has focused on the pictorial content of the petroglyphs. Rock art was understood as images or symbols reflecting or narrating aspects of cosmology, ideology, and everyday practice (Kaul 1998; Bradley 2009; Skoglund et al 2020). In the later decades, however, the research has also emphasized the potential active aspects, or agency, of imagery (Gell 1998; Morgan 2014; Gosden 2020). In such perspectives, rock art is not merely a passive reflection of ideology and cosmology but a potentially active materiality with physical properties of its own besides the visual element (Jones 2006; Alberti & Fowles 2018; Fahlander 2013, 2019). This perspective has encouraged a greater interest in the material basis of rock art, and its mediality, such as the properties and qualities of the rock and how the petroglyphs interact with water from rain or waves (e.g. Hauptman-Wahlgren 1998; Jones 2006; Gjerde 2010; Fahlander 2019). This emphasis on the imagery as 'composite devices' resonates well with the interest in physical relations in recent ontologically oriented research on rock art (Jones & Cochrane 2018; Alberti & Fowles 2018; Moro Abadiá & Porr 2021). In this research, images are not mere pictures affecting people but also physical enactments, designed and produced to exert influence on the movements and animacies of the world (Ingold 2006; Porr & Bell 2012; Fahlander 2019). Thus, the visual, affective, and physical aspects of rock art are amalgamated into an integrated account of the *ecology of images*, one in which the social, the material, the aesthetics, and other generative forces and agents (human and non-human) are taken into consideration (Morgan 2014; Fahlander ms).

These recent theoretical developments in rock art studies emphasize the importance of the relations and mediality of petroglyphs in different shapes, forms, and sizes. The prime objective is not as much to identify what a motif is or represents, as it is to understand how its physical properties relate to water-sprinkled areas, grooves, cracks and mineral veins in the rock. On a yet larger scale, it is also essential to situate the rock art in the wider landscape and its relations to past sea levels and watercourses (i. e. seascapes). These perspectives and questions pose new demands for the documentation of rock art. Traditionally, the goal of rock art documentation was to capture the imagery by sketching, rubbing, painting or taking photographs (Selinge 1985). To study the relations of petroglyphs and the microtopography of the rock, however, it is necessary to capture a wider picture, that is, preferably the whole topography of the rock outcrop and the environmental setting. This cannot be achieved with traditional methods save for two-dimensional photography. In Sweden, the environmental setting is accessible through nationwide LiDAR scans that provide 3D-views of the topography in high resolution (lantmateriet.se). These are often sufficient to reconstruct land- and seascapes surrounding the

1.

Examples of how rock art motifs relate to the qualities and topography of the rocks. Left: A half-boat motif connected with a vertical quart ore at Slagsta (Botkyrka 279). Right: A series of podomorphs pecked within a meandering band of a different colour (Boglösa 138). Photos by F. Fahlander.

rock art sites but are too coarse to capture the curvature and microtopography of the individual outcrops in sufficient detail. There is also a need to capture colour in order to identify patches, bands and veins of different minerals in the rock (Figure 1). Photographs taken by drones can, through photogrammetrical elaboration, to some extent achieve this at smaller sites, although vegetation, especially trees, tends to prohibit full cover of larger outcrops (Bertilsson 2023). A potentially viable alternative discussed here is to employ affordable stationary scanners such as the newer generation of multi-stations with scanning abilities to create medium resolution 3D-models of the outcrops (with or without colour). By positioning the machine in a national grid, the 3D-models can be aligned with the LiDAR scans of the overall landscape topography.

A matter of size and quality

A problem facing three-dimensional recording of rock art is that the size of the models tends to grow exceedingly large and thus be difficult to handle and store. The high resolution of handheld 3D-scanners generally provides a true and detailed representation of the rock and the petroglyphs, but to scan a whole rock face consistently in high resolution makes the point clouds unreasonably large. Moreover, most handheld scanners lack the ability to scan in colour and require a large number of markers on the rock in order to synchronize the different sweeps. Another drawback is that they generally work at a constant resolution, which makes the size of the models very large and thus less suitable for capturing a whole rock face or the topography of a rock outcrop. From a practical point of view, they also require a very powerful laptop that needs extra battery packs to run throughout a day's work. The scanners and computers are also quite expensive and generally not possible to rent. This said, the development of these products is fast and better and cheaper machines tend to bypass yesterday's top model only a year or two later.

A solution to this problem is to create flexible 3D-models with varying resolutions to keep the size of information down and allow for a swift way of recording. Such a methodology was tested within the frames of a two-year FoU-project, *Digitala bilder för forskning och publik* (eng. Digital images for research and the public), financed by the National Board of Antiques (2020–21). The project aimed to develop a documentation strategy that combines two- and three-dimensional technologies to generate better support for research and to make cultural heritage publicly available. During 2020–21, the project documented 28 outcrops in southwestern Uppland (Sweden) to test and evaluate different documentation methods in three levels of detail (Fahlander 2023). At some sites, an overview 3D-model of the entire outcrop was created with the help of drones or dome scanners. The drones worked well at sites not overshadowed by vegetation, which instead was captured by a series of dome scans. The idea was to use the topographic 3D-models as three-dimensional shells or envelopes to be supplemented with selective smaller areas with petroglyphs in more detail and higher resolution. The panels with rock art were captured in detail by structure from motion (SfM) and stereo-pair-based photogrammetry. The photogrammetric methods are well suitable for fieldwork and deliver very detailed 3D-models without being too large in terms of storage size (Meiljer 2015; Rabitz 2008; Lerma et al 2010; Ortiz Sanz 2012; Alexander, Pinz & Reinbacher 2015; Bertilsson 2018; Kowlessar et al. 2022; Bertilsson & Bertilsson 2023). Since the three-dimensional recording does not include an interpretation of the rock art, ocular and tactile documentation of the motifs was also performed. During the project, however, when post-processing the scanning data, it became clear that both scanners have the capability to record also quite shallow carvings in higher detail than expected. In this text, however, we will focus on the pros and cons of using stationary MultiStations (Leica MS60) and some scanners (Leica RTC360) to capture both rock art and rock outcrop topographies.

Capturing the rock: a case study using Leica MS60 and RTC 360

The FoU-project focused mainly on the rock art of southwest Uppland while this study also includes one locality (Slagsta) in Stockholm County. The rock art of Uppland is quite well studied in previous studies by Kjellén & Hyenstrand

(1977), Coles (2000), Ling (2013), and Fahlander (2018). The rock art motifs mainly comprise boats, anthropomorphs, zoomorphs, podomorphs, circular motifs, and cupmarks in a great variety of designs, shapes and sizes. The documentation of the main sites is good but tends to focus on the imagery with less concern for the rock itself and the local environment. The region is especially suitable for this type of case study because it offers a wide range of different types of localities with varied topography. The outcrops with rock art in this area also comprise many sites where the petroglyphs incorporate the microtopography of the rock such as cracks and veins of differently coloured minerals (Figure 1). The petroglyphs in Uppland also vary in pecking depth which poses a challenge to the documentation techniques.

During the course of the FoU-project, a total of seven localities of different sizes and topographical complexity were scanned with MS60 and RTC360: Boglösa 73, 138, 141, 298, Vårfrukyrka 93, 181, as well as a pilot study at Botkyrka 279 (Figure 2). Boglösa 73 is a medium-sized site, c. 1,5m high, comprising 250 figurative motifs and 74 cupmarks. The rock face extends from higher terrain and has a rather steep curvature. The nearby Boglösa 298 has a relatively flat surface but with a quite steep curvature in the east. It contains only 28 figurative motifs and two cupmarks and is more accessible in comparison to Boglösa 73 with less vegetation.

About 500 meters west of these two sites is Boglösa 138 and 141. They are both quite large sites both in terms of space and number of motifs. Boglösa 138 is a c. 2.5m high outcrop that comprises 214 figurative motifs and 94 cupmarks. The topography is complex with both steep and flat curvatures as well as smaller grooves and bands of differently coloured minerals running over the rock. It is relatively open and accessible although trees partly overshadow the rock in some of the lower areas. The site is also made accessible to the public by a wooden walkway in the western and southern parts. Boglösa 141 is no less complex in terms of topography. It is rather flat, c. 1m high, and is full of grooves and veins of quartz meandering over the rock. The rock art comprises 136 figurative motifs and no less than 401 cupmarks. At present, the outcrop is relatively open but surrounded by trees in the west and south that to varying extents overshadow some of its edges.

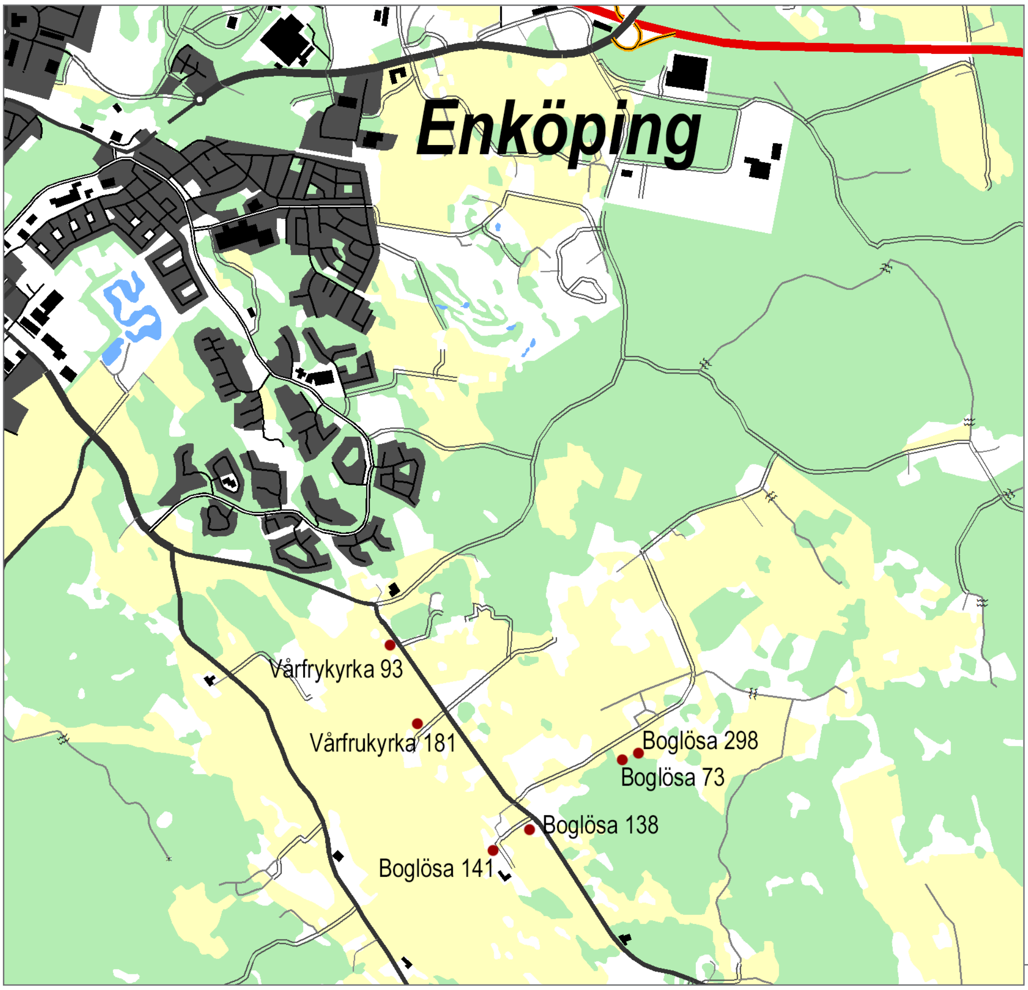
A third couple of sites are situated c. 800 metres northwest of Boglösa 138 and 141. Vårfrukyrka 181 is a relatively small c. 1.5 m high hillock. It is surrounded by a dirt road and arable fields and the carved area is easily accessible. The northern part is, however, covered with shrubbery. The site contains 27 figurative motifs and 30 cupmarks. Vårfrukyrka 93 is also a smaller c. 2 m high hillock. It faces arable land in the south while shrubbery and trees cover the northern part. The carved area is nonetheless quite accessible. The site contains only one 90 cm large and deep-cut anthropomorph, two boat motifs, a few fragments, and twelve cupmarks.

The seventh location, Botkyrka 279, also known as the Slagsta site, is situated c. 56 km southeast of the Enköping area in Stockholm County. It is a c. 2m high

2a.

The location of the studied areas (red) in southern Sweden (black dots are sites with figurative rock art.

hillock with irregular topography characterised by natural striations and quartz veins. Most of the hillock is covered with shrubbery and trees but the rock face with carvings is accessible. On the north-eastern slope within a smooth and dark field of diabase surrounded by a light, coarse-crystalline rock is 25 figurative motifs and more than two hundred cupmarks. Of these sites, Boglösa 73, 138, 298 and Botkyrka 279 were scanned with the Leica MS60 while the RTC360 were used on Boglösa 138, 141, Vårfrukyrka 93, 181 and Botkyrka 279.



2b.

A map of the sites in the Enköping area.

Leica Nova MS60 MultiStation

The Nova MS60 is the latest model of total stations by Leica which is now addressed as a MultiStation because of its scanning abilities. The machine was chosen because it is relatively cheap to rent and has an interface that most field archaeologists are familiar with. The MS60 has two modes: front scan and dome scan. If situated in front of a rock art panel it can scan the whole front or limit the scan to a user-defined polygon area. The model employed in the project scans in variable resolutions down to 1×1 mm (It is possible to define the scanning grid in degrees, which in theory can reach a higher density of 0.5×0.5 mm). This is, however, not the actual resolution of the point cloud but the density of the scan point grid. This means that the distance between the vertical measure points on sloping surfaces will differ slightly during a front scan. It can be compensated to some extent as the MS60 allows for different grid space in the vertical and horizontal axes respectively. In order to save time and the size of the point cloud, it

3.

A front scan of the Slagsta hillock (Botkyrka 279) with a Leica MS60. The top right image shows the boundaries of the scan (in red), the middle image shows the resulting point cloud, and the low image illustrates a small section scanned with the highest resolution (1mm).

may during certain circumstances be useful to define a vertical grid with a greater distance between the points while keeping the horizontal space smaller. For example, a horizontal distance of 5 mm and a vertical of 1 mm. At some sites, this is sufficient when the panel is not on an outcrop but a part of a larger topographical formation. A front scan job can define different fields with diverging resolutions in the same job. This is especially useful as it can scan most of an outcrop in lower resolution and the area with petroglyphs in higher resolution. This was tested at the Slagsta site (Figure 3) where the whole rock face was scanned in a 10×5 mm grid and a smaller area in 1×1 mm. The two rock art boats were captured quite well in the detailed scan area.

The level of resolution and size of the scanned surface is directly related to time. The higher the resolution or the volume of the area, the longer the time it takes to scan. The MS60 have a maximum capability of scanning 30 000 pts/s, which is quite efficient. However, depending on the density of the grid, the software will choose the most suitable number of points emitted from the instrument. For example, in our test of time consumption, different speeds were chosen by the MS60 for the different resolutions (Table 1–3). The actual time for completing a scan does not change if the speed is manually set to a higher value.

Resolution of the grid	Time (no photos)	Time (with colour photos)
1×1 mm	0:35:18	0:36:33
3x3 mm	0:11:52	0:13:07
12×12 mm	0:03:05	0:04:20

Table 1. The amount of time MS60 needs to scan a flat area of 5×2 meters on the ground (hh:mm:ss). Positioned at a height of 1.2 meters and 2 meters from the short side of the rectangle. At this distance, 18 images were required to cover the area. The time for taking the pictures and processing is 2 m 10s. The number of points per second used for the different resolutions was 8000, 4000 and 1000.

Resolution of the grid	Time (no photos) (HH:mm:ss)	Time (with colour photos)
1×1 mm	0:45:14	0:45:51
3×3 mm	0:15:11	0:15:48
12×12 mm	0:03:55	0:04:32

Table 2. The amount of time MS60 needs to scan a vertical area of 4×2 meters (hh:mm:ss). Positioned at a height of 1.6 meters and 6 meters from a wall. At this distance, 6 images were required to cover the area. The time for taking the pictures and processing is 37s. The number of points per second used for the different resolutions was 16000, 4000 and 1000.

Resolution of the grid (dome)	Time (no photos)	Time (with colour photos)
1×1 mm	2:55:24	3:40:24
3×3 mm	0:58:35	1:43:35
12×12 mm	0:14:47	0:59:47

Table 3. The amount of time MS60 needs to scan a full dome in three different resolutions (hh:mm:ss). For the full dome scan, 465 pictures are needed.

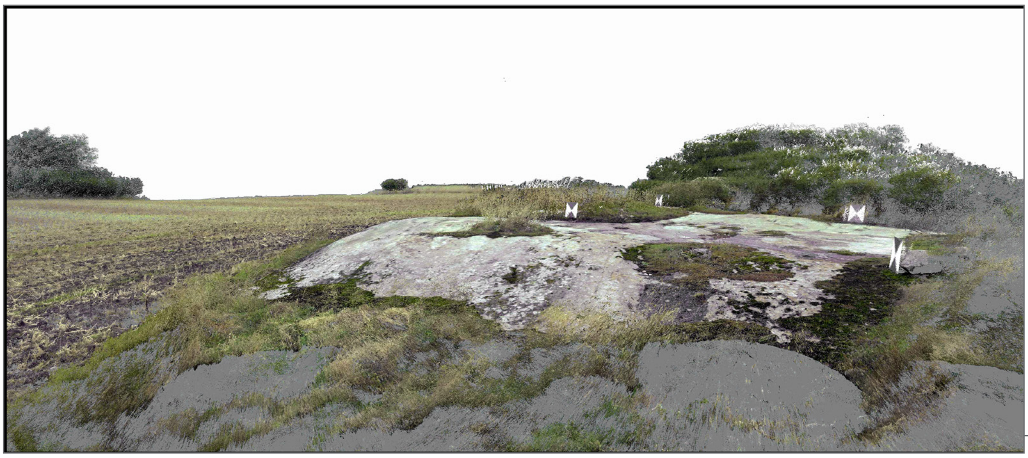
The front scans can be quite time-consuming depending on the size of the area and the level of resolution (Tables 1 and 2). The shape and size of the scanning area, and also how the instrument is positioned in relation to the scanning area, will affect the scanning time. A steep rockface takes approximately 25% longer time to scan than a flat surface (Tables 1 and 2). Considering the small gain in time there is little advantage to using resolutions lower than 5×5 mm. A reasonable compromise for capturing sufficient detail in a realistic amount of time is a grid-distance between 2–4 mm depending on the size of the area. The option to create multiple jobs within the same sequence allows a maximal resolution of smaller areas with rock art motifs and a lower resolution of the rest of the rock. It should be noted, however, that it is rarely possible to cover a whole rock in only one scan, thus extra time needs to be added for additional scans from different positions to fill the gaps.

The MS60 can also scan a full 360° dome around its centre. Under favourable conditions (a small and smooth rock without vegetation) the MS60 can be put on top of the rock to capture the topography in one scan save for a 1.5 m circular area underneath it. The remaining area can be front-scanned separately to complete the whole surface. Another strategy is to combine two dome scans a few meters apart to cover more of the surface. All jobs scanned from the same position are automatically aligned, if the machine is properly situated in the national coordinate system. They can be imported together into one single geographically positioned point cloud. There is thus no need to manually align scans with a different resolution during post-processing of the data.

A main issue of the MS60 is the relatively long time it takes to scan in high resolutions (1×1 mm). The Slagsta example took only one hour, but it would have needed at least one additional scan on the top of the rock as well as a generally higher resolution to capture the striations and grooves in the rock. The dome scans take a substantially longer time because there is no way to limit the scope of the scan. The machine scans everything, including the sky and trees. It is possible to set a distance limit for what is recorded, for instance within 15m, but this will only marginally affect the time because the machine still has to complete the same physical rotations and movements. The MS60 takes almost three hours to perform a dome scan in the highest resolution and is not a realistic option (Table 3). To the numbers in Table 3, it needs to be added additional time to scan the area underneath the machine. In our tests, we also found that several domes often are needed to capture the uneven topography of most rock outcrops. Thus, even a 3 mm grid, which is normally sufficient to capture the important properties of the rock face and some of the rock art may be too time-consuming if two or more domes are needed. In the future, upcoming models (or similar MultiStations of other brands) may prove to be faster and be a viable option for capturing larger areas as well as rock art in sufficient detail, but until then, front-scans remain the realistic option for the MS60.

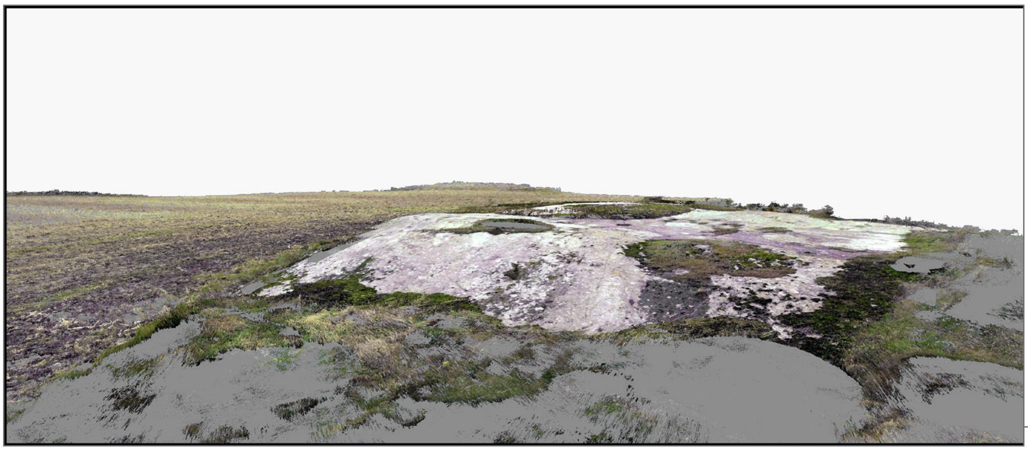
Leica RTC360

Because of the long scan times of the MS60, we evaluated a dedicated dome-scanner, Leica RTC360, as an alternative. Leica offers a series of scanners for different purposes of which the RTC360 is at present the most suitable alternative for this particular assignment. The budget alternative, Leica BLK360, has not performed well in tests, especially considering the amount of noise in the resulting point clouds (Stawe 2018; Hagaeus 2020). The RTC360 has a very simple interface, it can only scan a dome in three different resolutions (3/6/12 mm), with or without colour. Because the angle increases by distance, the resolution is stated at 10 m distance. The resolution will decrease slightly by distance The RTC360 is a very effective machine that takes only 3 minutes, including process time, for a full dome scan in colour in the best resolution (3 mm). This makes it feasible to cover



4.

The point cloud of the Boglösa 181 outcrop. The grey patches are parts of the surroundings not captured by the scanner. View from the southwest.



5.

The point cloud of the Boglösa 181 outcrop where the basic ground level under the current vegetation was revealed in Cyclone 3DR. View from the southwest.

complex rock topography with a series of 5–10 scan points. The different domes are aligned by the software, Cyclone Register 360™, and the point clouds can be imported individually or as one. This results in a model with vegetation still intact (Figure 4). Because the domes include a bit extra of the surrounding landscape, the point clouds are initially quite large. This is easy to edit out in the software, Cyclone Register 360™, in which all points outside a given area outside the outcrop are deleted. To further polish the point cloud and remove the vegetation we used Cyclone 3DR™. After this step, the size of the point cloud was reduced by 50%. The process of removing the vegetation is fairly simple. The quickest way is to let the software identify the ground points and separate them from the rest of the point cloud. This function, however, requires that the average slope of the area is defined. It can take some trial and error in each case before achieving a satisfying result. It is, of course, also possible to remove the vegetation manually, but this can be time consuming when working with multiple sites. In Figures 4 and 5 we present one example of the process, Boglösa 181, where we performed five dome scans with the RTC360. Figure 4 shows the point cloud with the vegetation intact, while Figure 5 shows the same outcrop where the basic ground level under the current vegetation is revealed in Cyclone 3DR.

An interesting and useful bonus of the RTC360 is the *TruView* app that uses the photographs taken from all scan points to generate a seamless VR-view of the outcrop as well as panorama views of the landscape (Figure 6). At present, this is only accessible from the free TruView software but the photographs can be extracted individually and viewed in other software. The VR-view of the sites can be quite useful for orientation when the sites cannot be visited in person.

The RTC360 is in many ways an agile machine for creating great 3D-models of the topography of small to medium sized rock outcrops. It is also surprisingly good at capturing petroglyphs (Figure 7a). The limit of the present model to 3×3 mm resolution captures most petroglyphs, but not always shallow ones (which are difficult to capture by photogrammetrical techniques). If positioned by GPS the scans and TruView-points are positioned in a geographical reference grid and can easily be aligned with GIS-based environmental models. The machine is easy to handle, especially in combination with a tablet, and the process is very fast. The downside of RTC360 is the high rental price (c. 500 EUR/day) and the need for special software (Cyclone Register) to extract the point cloud.

6.

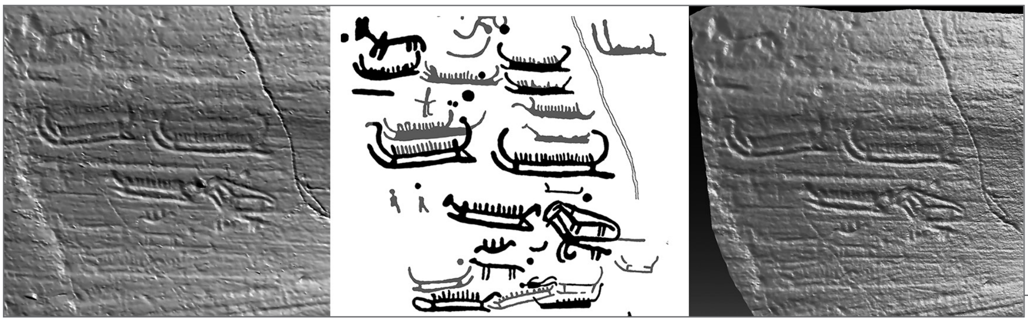
A series of views looking southeast to the northwest over Vårfrukyrka 181 through Leica's TruView app. The small images in the lower right corner show the position and direction from where you are viewing the outcrop and the surrounding landscape.

Discussion and evaluation

The tests performed in the project emphasise different performative and practical aspects of the MS60 and the RTC360. Both have their particular advantages and limits and perform better or worse for different tasks. For practical use, however, the time factor is crucial. The MS60, for example, manages to capture rock art and microtopography of smaller rock faces using the front-scan mode. As our tests have shown a 5x2m area only takes 45 minutes to scan in 1x1mm resolution, including photos for colour texture. The time can be reduced further by using different vertical and horizontal resolutions or by scanning parts without rock art and finer cracks in a lower resolution. However, the present model of MS60 is too slow to record the curvature and topography of a whole outcrop in sufficient detail using the dome scan mode.

The RTC360, on the other hand, manages this task very well. It takes only 3 minutes for each dome, and even a large and complicated site can be fully covered by multiple scans within less than an hour. The present model works surprisingly well for the rock art motifs under optimal circumstances, but may not always record all shallower pecked motifs. A scientific analysis of the exact shape and depth of the motifs, superimpositions etc may, however, need a higher level of detail.

In addition, the resulting 3D-models are also sufficiently detailed for public outreach if the known rock art is emphasised with colour (or if the rock is scanned when the motifs are freshly painted). They should also suffice as a basis for augmented reality applications by which visitors at a site could swipe a mobile phone over the rock and see the motifs appear through the screen (see e.g. Blanco-Pons, Carrión-Ruiz & Lerma 2018). Creating such applications, is, however, quite labor intensive and also needs additional expensive software (Samhell Webbinarium). The TruView VR-app is useful for both public and scientific purposes to explore the present environment of the rock outcrop and how the petroglyphs are distributed on the rock. Although the app is freeware, Cyclone Register is still necessary for importing the data from the scanner.



7.

3D-models of Boglösa 73 created with RTC360 (left) and MS60 (right) with Lattice renderer in Meshlab. The middle figure shows an ocular and tactile interpretation of the same area with shallow motifs in grey (middle). For the RTC360 a resolution of 3x3mm was used and for the MS60 1×1mm.

An economic and practical way of obtaining both a 3D-model of the outcrop and all of the petroglyphs of a site is to combine a series of RTC360 domes with photogrammetric methods on the pecked parts of the rock. Structure from motion can produce very exact 3D-models on par with handheld 3D-scanners. Of course, a handheld 3D-scanner can also be used on the important areas (which does not need to scan in colour as this texture already is available through the dome scans). Because much outdoor rock art tends to be weathered and with coarse microstructure, 3D-documentation will only benefit from a certain level of detail. A very fine resolution would not necessarily contain more information but only result in an unnecessarily large file size. It should, however, be noted that combining two different point clouds (from scanner and photogrammetry) is not without problems. The clouds need to be properly aligned and preferably using a common coordinate system. Depending on the resolution, it can be quite time-consuming. It is much easier to use one and the same method that automatically aligns different scans into one like the Cyclone and Infinity software does.

This brings us to a common issue in using the Leica scanners, which both depend on dedicated software to extract and manage the scanned data. This is a minor problem for MS60 as most archaeological firms and departments already use total stations and have a licence for Infinity™. The cost in Sweden as of 2022 is c. 59k SEK per licence for Infinity Lite™ and c. 25k SEK for Cyclone Register 360™, which are necessary for importing the scan data. A licence for Cyclone 3DR™ amounts to c. 40k SEK, which besides importing scanner data from the RTC360 has other useful functions such as meshing point clouds and the ability to recognise the ground surface under the vegetation. Unfortunately, Infinity does a poor job of meshing point clouds and has very few options to change the parameters. It is not sufficient for the particular task of recording the rock and the petroglyphs. Cyclone 3DR does a better job with meshing, but to get better control of the process it is often better to use a dedicated meshing application such as Agisoft Metashape™ or Meshlab™. The process of meshing point clouds of several million points will take considerable time depending on the size of the object and the specs of the computer. In fact, just importing and processing scan data into Infinity™ or Cyclone 3DR™ can take one or two hours even with a high-end computer. To summarize the discussion, none of the tested machines may individually comprise a complete solution for documenting rock art and the microtopography of the rocks in ways that will satisfy more advanced research questions. Taking the practical issues into concern, the RTC360 is at present the most capable of satisfactorily capturing the shape, curvature and microtopography of whole outcrops. It can also capture most petroglyphs – although not always to the same extent as handheld scanners and high-end photogrammetry. To be a fully-fledged documentation tool it needs to be complemented with other methods that allow for more detail.

Summary

Because many rock art motifs relate to and integrate the microtopography of the rock, 3D-documentation adds a necessary third dimension to our understanding of rock art. They also provide possibilities to enhance the visibility of faint lines by using oblique light from different angles, creating depth maps, or manipulating the data. In addition, accurate 3D-models can measure the rate of wear and degradation of the rock and predict water flows etc. 3D-models of the rocks can also be utilized for various virtual reality and augmented reality applications for both research and public presentation. At present, none of the methods employed (photogrammetry and 3D-scanning) to create 3D-models of both the outcrops and the petroglyphs by themselves offers a complete solution one has to weigh their feasibility in terms of costs, time and quality. Our tests show that the Leica MS60 MultiStation and the RTC360 scanner in different ways are useful in 3D-documentation of rock art. Both machines can record petroglyphs in quite high detail – although not always to the same level as handheld scanners or professional photogrammetry. The MS60 is quite time-consuming to scan larger surfaces in the highest resolution, but the ability to use different resolutions for different areas in the same job can significantly reduce the time for scanning. Because of the long time to conduct dome scans, the MS60 is less suitable to cover larger areas or the whole topography of an outcrop. The RTC360 scanner, on the other hand, does a swift job at this and despite the rather low resolution it still manages to capture both the microtopography of the whole rock outcrop as well as some of the rock art. Finally, it should be noted that none of the 3D-methods includes any interpretation of the rock art motifs. Depending on the accuracy of the model and the pecking depth of the rock art, this often needs ocular and tactile analysis on the rock itself (Meijer 2015:72). If the aim is to understand how rock art relates to water-sprinkled areas, grooves, cracks and mineral veins in the rock, and to situate the rock art in the wider landscape and its relations to past sea levels and watercourses (i.e. seascapes), 3D-scanning is a viable way to go. Both scanners evaluated in this study have the capability to produce data that makes it possible to study the relations of petroglyphs to the microtopography of the rock, the whole topography of the outcrop as well as the environmental setting.

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