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Tracing the carvers on the rocks

Introduction

Rock Art has been used as evidence to discuss ideas about ideology, religion, long distance trade, warfare, landscapes, and social organization. However, very little focus has been paid to the rock art carvers themselves and the study of rock art has been hampered by the fact that the process of producing the art itself is hardly ever explained. Currently, the knowledge about carving *techniques* is limited. This means, we lack information that could help us to forward theories about the social roles, technical skills and scientific knowledge of carvers in Bronze Age society. Consequently, the main objective with this project (VR 2020-03817) is to enhance our knowledge about the Bronze Age carvers. The project employs a variety of strands and methods, including training AI algorithms to recognize and quantify motifs and style variations, superimpositions, and granite rock and grain structures; however, this study will focus on the techniques and choice of bedrock used to create the rock art in the World Heritage of Tanum. Note that we use the concepts "carve, carving " or "carvers" instead of pecking or peckers, a concept criticised by earlier attempts and scholars (Goldhahn & Ling 2013; Lødøen 2015). However, we hold that this concept is relevant to the observations we have made within this study, and we will discuss this more in depth in the concluding section of this paper.

Regarding the techniques used for making the prehistoric images on the rocks, later experiments favours both direct technique (von Arbin et al. 1995) as well as indirect technique (Lødøen 2015) for the making of prehistoric images. However, questions remain about whether these techniques were the ones that was used on Bohuslän granite in the Bronze Age or if other techniques were utilized. For example, Goldhahn emphasised a link between the metal smith and the "rock smith" (Goldhahn 2014), and the fact that the similarities between the images on the bronzes and the rocks suggested that the same craftsmen were responsible for both types of creation despite the varied mediums. For the Iron Age, Kitzler Åhfeldt (2020, 2019) demonstrated that carvers were sought after specialists with knowledge about mysteries and writing by studying carvings techniques and chronology.

Before we present the results of our study, we will discuss the findings of two before mentioned studies, each of which was significant in its own way. The first study involved the making of Bronze Age carvings on Bohus granite using a direct technique (von Arbin et al. 1995), and the second encompasses an experiment of indirect technique on Devonian sandstone from Vingen, Western Norway, with the use of a replica of a tool found near the rock art in Vingen (Lødøen 2015).

Previous attempts and experiments

Rock art research has suffered from the fact that the act of production of the art itself is seldom discussed. Althin stressed that the act of production may have been more important than the act of consumption but few scholars have elaborated on this idea (Althin 1945; Goldhahn 1999, 2006; Bengtsson 2004). However, throughout the course of the years, some more targeted experimental research has been carried out (von Arbin et al. 1995; Bengtsson 2004; Lødøen 2015).

For instance, a study initiated by Bengtsson and students (von Arbin et al. 1995) at Vitlycke museum in Tanum yielded some interesting insights. An ordinary sized rock art image that involved different chopping techniques was chosen to be copied (von Arbin et al. 1995; Bengtsson 2004; Ling 2014). The decision was made to make a replica of a depicted archer from the Fossum site, which measures 44 centimetres in length, 9 centimetres in width, equipped with a sword and a bow that are each around 17 centimetres in length.

Trials indicated that the most effective stone for working the granite bedrock is amphibolite, this kind of stone has been found adjacent to some rock art sites. These stones are frequently found by the sea-shore and since the sea-shore was in close proximity to the rock in the Bronze Age it is logical to assume that they could have been selected and harvested close to some of the shore connected rock art sites (Bengtsson 2004; Ling 2014). Thus, this observation gives the production process another operational dimension. According to measurements obtained by von Arbin et al. (1995:9), a reproduction of the Fossum archer rock art image was manufactured over the course of a procedure that took roughly 13 hours to complete. Applying this result to the production of larger rock art images, for instance the ship on the Vitlycke panel which is about 360 cm long and 80 cm wide, indicates that this would have taken about 100 effective working hours to complete, which translates into 10–12 days for a single person working 8–10 hours a day. A cooperative approach to the making of large rock art images would have required less time (5 days for two persons, 2–3 days for three persons). Even if the Bronze Age makers of rock art images were probably more adept on account of their experience and/or more rational techniques, the process would nevertheless have represented a large investment in time, skill and ritual practice. The study also resulted in other interesting observations regarding techniques and materials. For instance, direct chopping with a hand-held stone was the most effective method and clearly superior to chopping indirectly by striking a chisel stone with a hammer. Chopping at an angle to the rock was more effective than chopping straight down. Small amounts of water on the surface made chopping easier but too much water was a drawback. Moreover, if the image's contours had been painted or drawn on the rock, as was done in this study, too much water washed them away. There is much in favour of the assumption that some of the most detailed rock art images were first outlined or drawn on the rock (von Arbin et al. 1995). Another observation was that the work readily took on a specific repetitive rhythm. This social observation may throw light on the prehistoric situation for the making of rock art. These technological and material prerequisites for the making of the images also indicate a need for certain skills and knowledge about the nature of the rock, such as its composition, hardness, reaction, and reflection. Moreover, the highly elaborate images called for some kind of artistic knowledge and insight regarding perspectives, conduct, space, form, composition and content (see Bengtsson 2004: 101pp; Coles 2005: 9; Ling 2014: 5). It appears as the making of rock art were governed by some clear norms and codes for which images that could be depicted and combined (Nordbladh 1980; Goldhahn 2006: 82–93). All these requirements suggest that making was confined to a particular agency, individual or group (Bengtsson 2004: 101; Ling and Cornell 2010).

However, there exist a more recent study by Trond Lødøen and Martin Kuchera on this topic that both forwards and challenges the said study (Lødøen 2015). In contrast to the Bronze Age rock art in Bohuslän, this experimental study was made on Devonian sandstone, with the focus on images from hunters' rock art site at Vingen, situated in the municipality of Bremanger in Sogn og Fjordane. It should therefore be noted that both the rock canvas and the images themselves diverge from the above example. Excavations were conducted around rock art panels at Vingen in the 1990s and after 2000 with the aim to forward chronological and socio ritual use of the site. Radiocarbon datings suggest that habitation began about 4900-4200 cal BC, maybe as early as 5400 cal BC (Lødøen 2003, 2014). Whilst the occupation and use of the Vingen site may have lasted 700-1200 years, the rock art production per se may have occurred in a shorter time frame (Lødøen 2013). During the excavation, a pecking tool was found, in a Late Mesolithic culture layer, adjacent to several rock art panels (Lødøen 2003). It was quite clear from the form of the item that it was a pecking instrument used for creating rock art. The wide pecking marks that formed the countless lines that make up the images at the site had the same width as the pointed tip of ´the elongated tool. Later geochemical analysis of the tool indicated that it was composed of diabase and that the material originated from the Mesolithic Rock Quarry at Stakaldeneset near Flora, south of Vingen. The discovery of the pecking hammer inspired Lødøen to research the history of rock art creation. According to Lødøen, the shape and form of the hammer and the pecking marks made it likely that a comparable tool had been used to form the thin lines and many pecking marks in the images with the use of an indirect technique.

The following experiment was carried out in collaboration with Morten Kutschera (Lødøen 2015), one of Scandinavia's most accomplished experimental archaeologists, who also has in-depth familiarity with all the tool-making processes employed throughout the Stone Age in Western Norway as well as extensive experience with various types of raw materials utilised during the same period. In order to perform this experiment, suitable rocks with a flat surface and a similar quality to the stones bearing the images from Vingen were collected. Additionally, it was decided to create the tools from the same diabase that was used to make the object that was found at the site. To discover the approach and manufacturing process, precise duplicates of the initial images were created with different development types and patterns. As a flint artefact manufacturer, creating rock images came natural after hours of precision punching. The biggest challenge was to find the right seated position, which required alternating between kneeling and holding his left elbow on the ground. It would have been simpler to create images on a sloping rock surface, as is the case for most Vingen images. Kutschera identified an effective pecking tempo of four rapid strokes when moving the chisel a few millimetres, followed by another four strokes.

The tool found during investigations in Vingen appears to be thickest in the middle, providing strength and a well-designed tip for the working the rock (Lødøen 2015:69). Thus, all the replicas of the tool that were made were designed after the premise to be thickest around the centre and narrow towards a somewhat rounded point (Lødøen 2015:70-71). The stone tool was subsequently used in combination with a mallet of wood and the results were strikingly like the original image. The results of the studies demonstrated how crucial it was to always keep the tool´s tip sharp because the ability to pierce the rock surface with the same force was lost the moment it became flat. Although pecking markings could still be made, but they were both obscure and superficial (Lødøen 2015). As it was essential to sharpen the edge before the image could be finished, two different chisels were used for the smaller images. Three different chisels were employed to create the slightly more intricate human form.

The experiment showed that continual chisel sharpening resulted in minimal material and tool length loss and the same tool were used to create four smaller images thus the tooled remained in the same state after hours of pecking all the images. Creating the tools was also the most time-consuming process for the experiment (Lødøen 2015:72).

The hook or animal-headed staff hook 45 minutes to make, whereas the smaller one was made in just 27 minutes (Lødøen 2015:72 Figure 9). Pecking a small animal figure took over 50 minutes (52), while a complicated human image took 1 hour and 20 minutes (Lødøen 2015:72 Figure 10). The study indicated that powerful and accurate blows were sufficient for the making of the images, with minimal weight required.

In the following, we will provide an explanation of the results obtained throughout the course of our project in terms of tracing the carving technique used during the Bronze Age on Bohuslän granite.

The Bohus granite

The "Bohus granite" is primarily comprised by granitic rocks with a smaller proportion of intermediate to mafic rocks (figure 1). The granite belongs to the late Sveconorwegian (Grenvillian) intrusive suite. It was formed in a stress regime characterised by extension and was emplaced along a fault zone that dips slightly towards the east (Eliasson et al. 2003). The ages of the emplacements range from around 920 to 890 million years ago. Except for the intermediate to mafic components, the various granites share a comparable monzogranitic composition. The primary mineral phases in these granites are quartz, k-feldspar, plagioclase, and biotite. Most of the medium-grained granites are mostly red to greyish-red in colour, gradually transitioning to a more greyish-white shade towards the northeastern and eastern edges (Eliasson et al. 2003). The mineral composition and the relatively uniform, magmatic structure are the primary factors contributing to the high mechanical strength of the granite (Åkesson et al. 2004).

Weathering in the Bohus granite is postglacial as most of previous surface weathering was eroded during the final period of glaciation. Thus, the current surface topography has primarily been shaped by weathering processes occurring in the Holocene after the Late Weichselian deglaciation, which took place approximately 12,000 years ago (Swantesson 1992). In southern and central Sweden throughout the Holocene, micro weathering has resulted in minimal alterations to the surface topography, with changes measuring only a few centimetres (Swantesson 1985, 1992). Therefore, the surface morphology of the rock panels in the Bohus granite, utilised by the carvers during the Bronze Age, has experienced minimal alterations until today, and even less in areas where the polished surface, obtained from glacial activity, remained intact.

Microcracks that weaken rocks are frequently found in granites and are believed to form because of various pressure reductions. The formation of microcracks in the Bohus granite can be attributed to isobaric cooling during the crystallisation process, lithostatic stress release during uplift and exhumation, and post-ice age rebound caused by the melting ice cover in Scandinavia. Due to weathering, microcracks have undergone widening and deepening since the carvers were working on the panels. However, this mostly results in a clear delineation of the panels' divisions rather than a significant alteration of their overall topography (Horn et al. 2021).

Carving techniques identified in the Bohus granite

Indications from the field

Fieldwork was conducted on rock art sites across the whole area with the Bohus granite (figure 1). Both larger and smaller sites were selected for this purpose. While we can find the structures across most panels, we will show them with examples from Tanum 26, Tanum 28, Tanum 75 and Foss 6 (figure 2). These locations were chosen because of the well preserved glacially polished surface (Tanum 26, Tanum 28, Tanum 75) indicating that the low weathering on the panels has good preservation of original structures from the carving process. The strong foliation in the contact area between Bohus granite and orthogneisses at Foss 6 serve as visual reference frame to identify traces of tool markings crossing in different angles.

A close inspection of the outlines of the carving shows a variation between straight outlines and irregular edges (figure 2A, B). It can be argued if the use of straight and lobated outlines is an artistic feature made on purpose or a necessity forced by different techniques applied. On the irregular outlined edges, we frequently see small scratch lines that come in sets of three (rarely four) as shown in figure 2A-B and D-E. To separate anthropomorphic created

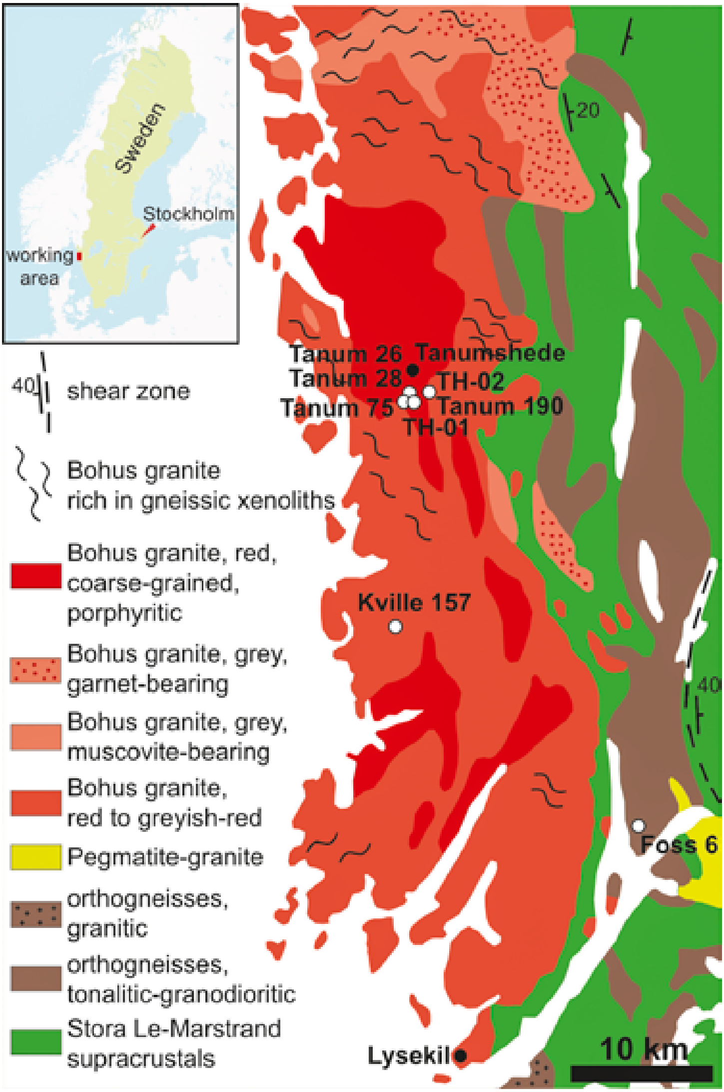

Figure 1. Geological map of main rock types in Bohuslän with case study sites (white circle) indicated. (Modified after Horn et al. 2023)

edges from natural weathering it needs to be carefully examined. Having a cut going through several minerals and not following natural cleavages of the mineral is seen as a decent qualification to be considered part of the original carved edge. We expect to also have anthropogenic edges that follow natural cleavages as it is following the easiest way to break during the carving process. Linear indents have been observed stretching from the boundary inwards. The location of Foss 6 is an excellent example to investigate these structures (figures 1, 2C). Because of the strong foliation visible in the rock, we have an easy to observe reference structure enhancing the contrast for the scratched lines turning with the curve of the boat (figure 2C, red lines).

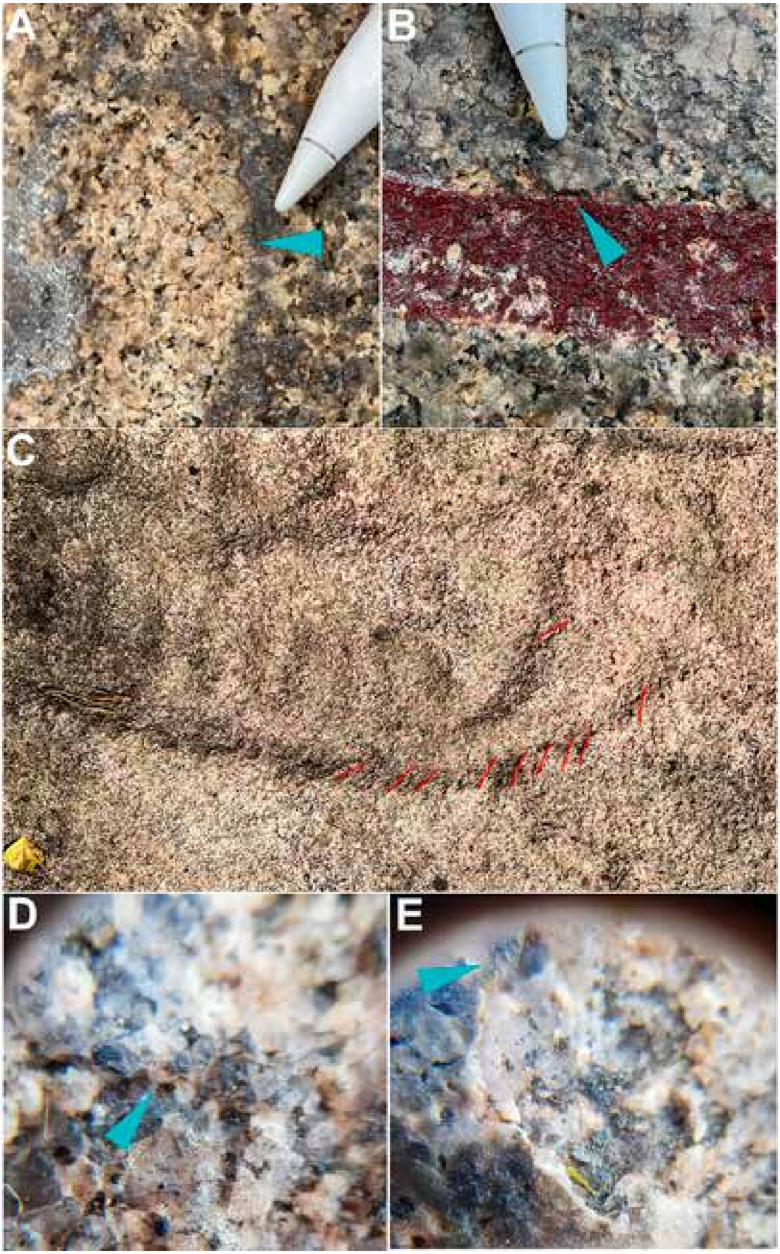

Figure 2. Field photographs from carvings in the Bohus granite with tool marks. (A) Irregular to lobate and (B) straight carving outlines, and toolmarks (blue arrow), Tanum 26 (A) and Tanum 75 (B); (C) Scratched lines (red) inside a carved ship; the orientation of the scratches follows the ship geometry, Foss 6; (D) and (E) highly magnified tool marks at the edge of a carving (blue arrow), Tanum 26. Photos: Carina Liebl

The inner part of the carving has a smooth feel to it. Even compared with very well polished granite surface it feels very smooth. Considering typical weathering in granite some rounding of the mineral grains is expected, but they are to even following a continuous surface. It can be argued if the polishing was created over time by sand and water caught in the indent of the carving. In that case we would expect to have smoother areas in the location sand and water would accumulate first, but we see this feature with no prioritized location in the carving. Thus, we interpret it as anthropogenic and made by the carvers, yet without knowing, which technique was used for the polishing.

The markings shown in figure 2 suggest the use of a sharp or pointy tool. Which makes it impossible for them to be made of wood or bone as they are too soft especially at a small tip. While we consider the possibility to use rocks for a final polishing, the structures in the field show no sign of the typical rounded markings all experiments with rock chisels do (e.g., Lødøen 2015). Thus, the only material that could have been used is metal, either steel or bronze. Following this interpretation, we conducted carving experiments with bronze tools of various sharp and pointy shapes (figure 4B) described in section "Bronze tools" further down.

Indications from experiments

Modern tools

A set of carving test on Bohus granite was done with modern tools. We used an indirect method with a stainless-steel chisel and hammer, and a direct, scratching method with a sharp stainless-steel pen, to test, whether we can recreate the lobate and straight carving boundaries, and the small tool marks (figure 2A-B, D-E). The test involved threes lines on a glacially polished Bohus granite sample (TH-01) taken from the roadside south of Tanumshede (figure 1). Line 1 (figure 3B) was created with an indirect method using hammer and chisel. Within 10min carved a line with a width of 3mm, length of 8.5cm, and depth of approximately 1mm. Here, we were able to produce similar tool marks (three parallel scratches) to the ones observed in the field (figures 2A, D-E, 3B). We can also see the lobated outlines because of the removal of individual grains during the process.

Line 2 (figure 3C) was created with a pointy iron pen by scratching the outline and removing the central part with the before mentioned hammer and chisel method. We were able to create very straight and defined outlines crosscutting through several grains (figure 3C), which are similar to the ones in the field (figure 2B) and conclude that they likely have used a similar technique. The creation of a line with a width of 5mm, length of 9cm and depth of approximately 0.8mm was done in 8min. The experiment in line 3 (figure 3D) will be described and discussed in section "To carve or not to carve? – a good question", further down.

Bronze tools

After identifying an indirect method as the way to go according to the comparison of structures found in the field and from the experiments with modern tools, as the next step experiments with bronze tools were conducted using a variety of bronze tools in combination with a hammerstone. The tools were cast in collaboration with Vitlycke museum. A variety of shapes of chisels were created for testing and an axe head modelled after a Bronze age original (figure 4B). With permission from Länstyrelsen we took a polished granite sample next to Tanum 190 (TH-02, figure 1), which was located approximately 1m next to a Bronze age rock carving (figure 4A). The sample location assures we use material as close as possible to the original in regards of grain structure and composition.

A key element to carve with bronze are sharp tools. The sharpness decreases quickly while working with each hit of the hammerstone, and the tools need to be resharpened. This is possible to do with sand and water by grinding with a low angle on the rock. The sharping of one tool takes approximately 30min and suggests that the carvers have been working in groups

Figure 3. Photographs from carving experiments using modern, steel tools, on polished rock samples of the Bohus granite. (A) Bohus granite sample with polished rock surface; position of experimental carvings (B-D) indicated; (B-D) Three experimental carvings with hammer and stainless steel chisel (B), scratching a straight outline with a stainless steel chisel (C) and (D) unsuccessful experiment, were none of the techniques from (B) and (C) lead to a carved line. Photos: Carina Liebl

Figure 4. Photographs from carving experiments using bronze tools on a polished rock sample of the Bohus granite. (A) Rock sample TH-02 taken at the side of panel Tanum 190 approximately 1m next to carvings (B) Replicated Bronze age axe head and various shapes of chisels made of bronze (C) carving done with bronze tools and hammerstone. Photos: Carina Liebl

where part of them were busy sharpening the tools. For convenience reasons we used a modern grinding tool to resharpen the tools.

The best progress was achieved by having the chisel in a 50-70 degree angle to the surface and reposition after 3-5 hits with the hammerstone. Sharpening of the tool was done when it got harder to carve into the rock. We were able to carve a line with a length of 4 cm, width of 1.5 cm, and depth of 1.2 mm within 15min (figure 4C).

To carve or not to carve? – a good question

Field observations

Most carvings are found on glacial-polished surfaces. While this likely serves as an artistic aspect of creating a great contrast to the

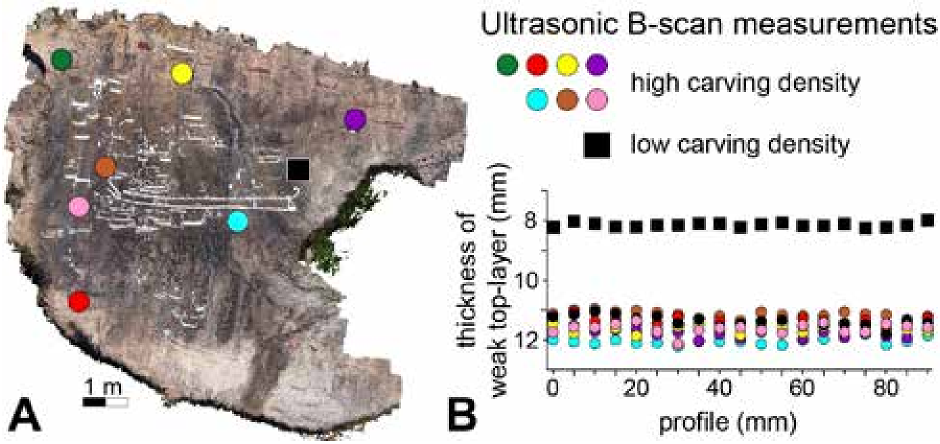

Figure 5. (A) Overview of Kville 157 with locations of B-scan profiles. Circles indicating measurements in areas with high carving density and rectangle with low carving density (image modified after Tanums Hällristningsmuseum Underslös, 2022) (B) plot of depth profile lines for all locations. Colour/shape correlated to location on the panel.

carvings, we believe that it was a necessity to create the carvings.

To support our theory, we have conducted a series of soundwave measurements at eight locations across a ~10 m x 10 m sized panel (Kville 157 (e.g., Nordbladh, 2022), figure 5A, figure 1). The rock is a very homogeneous granite only showing a minor change in grain sizes (5-7mm mean grain size from the upper left to 2-5mm at the lower right) and composition (k-felspar clast of up to 2cm in the lower area). Post glacial surface weathering is weak and has affected the whole rock surface equally. Thus, the rock structural variations and weathering can be largely excluded to influence any variations in the soundwave signals. Following the work by (Saroglou and Kallimogiannis 2017), we therefore interpret changes in the velocity of the soundwave as a function of the density of microfractures per rock volume. We conducted B-scan measurements at eight locations across the panel (figure 5A). By moving the instrument along a line and taking repeated soundwave measurements (10cm line in steps of 0.5cm) this technique creates a profile allowing us to retrieve information about structural changes in depth.

In areas with a relative high density of carvings (figure 5A, circles), 10 cm long sound wave measurement profiles lead to a planar boundary structure at a depth of ~9-12 mm below the surface (figure 5B, circles). We interpret this boundary as a surface-parallel fracture caused by a vertical stress relief during the melting of the ice layer at the end of the last glaciation (Cuzzone et al. 2016). None of the carvings on the panel crosscuts this boundary layer, which indicates that the uppermost ~9-12 mm thick layer was weak enough (weakened rock structure) to be carved. In addition, we can see an area on Kville 157 that has significantly less carvings, only three cup marks and a single line (figure 5A, rectangle). Here, the measured profile clearly show that a surface parallel fracture occurs at already ~8 mm, and therefore, much shallower than on the rest of the panel (figure 5A, rectangle). Comparison of mean s-wave velocity in areas with high carving density (2598m/s) with s-wave velocity in the low carving density area (2769m/s) supports the interpretation that this place has been left out on purpose because the carvers experienced that it is harder to carve there. This is strongly suggesting that the artists behind the carvings had some geological knowledge of the material they worked with.

Observations form experiments

The lines carved during the experiment with modern tools were only 12-14cm apart from each other (Figure 3A). For line 1 and line 2 (Figure 3B, C) it was easy to get into the rock and create an initial line with ~1mm depth. It got harder to carve into the rock with depth of the carving, which was expected as the weakening of the upper layer reduces with depth. The third line (Figure 3D), however, was impossible to carve even when using stainless steel tools. Except for some surface scratches the rock is completely intact.

Conclusions

Whit this study we have been able to forward some open questions related to the people who made the rock art in Bohuslän during the Bronze Age.

1) By comparison of structures from field observations, carving experiments with modern tools and various techniques we were able to identify three carving techniques which, most likely, have been applied by bronze age carvers. An indirect method with hammer and chisel, a more controlled probably scratching, and polishing/grinding of the central area of the carving.

2) A relatively weaker uppermost layer in the granite, caused by post glacial stress relaxation enabled the carvers to create their motifs. While we use modern ultrasonic sensors to identify this features the carvers might have used acoustic properties as well by knocking or tapping on the surface and listening to variations in the sound to decide for the placement. Thus, the placement of carvings on the glacial polished surfaces might not only be an artistic choice but may also reflect a carving necessity. The knowledge about the rock properties indicates a, at least, basic geological knowledge about their canvas, making the bronze age carvers' early "geologists".

3) Modern carving experiment with bronze tools show that they might have been used in the bronze age, even though bronze is a much softer material in comparison to Bohus granite.

The positive outcome of the experiment with bronze tools warrants additional investigations and further experiments must be conducted to confirm or refute this hypothesis. Nevertheless, if we could substantiate that bronze was utilised in the creation of the rock images, it would significantly influence our perspective on the Bronze Age and not least the Bronze Age carvers.

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Kristian Alex Larsen

The Gaze of the Meliks

Tracing connections and patterns in a petroglyph scene in the Eastern Taurus

Abstract

In the Eastern Taurus Mountains of South-Eastern Turkey *are found several petroglyph fields. One of them is in the plain of Tirsin almost 3000 meters above sea-level. Expeditions led by Muvaffak Uyanik in the late sixties disclosed the petroglyphs and they were published a few years later. Since then, no extensive research has been done in the area. The petroglyphs are organised in scenes, and exhibits a variety of animals and anthropomorphic figures. None of them has been successfully dated. One of the petroglyph scenes is analysed by using the approach of agential realism. This approach focuses on the totality of the petroglyph scene and makes productive use of minute details, that might otherwise be deemed insignificant. The analysis reveals a composition of three extraordinary animals gazing at what seems to be a human. Underneath, two ordinary goats are mirroring each other; one ascends and one descends, the latter appears to have killed the human. It is suggested that the scene is about powerful kings or gods confronting a human, who is transgressing the boundaries of a sacred territory. A number of sub-variants of the hypothesis are formulated and offered in order to be used for further research.*

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