The Making of the Tanum Rock Carvings - A Geological Perspective

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Degree of Bachelor of Science
with a major in Earth Sciences
15 hec

Department of Earth Sciences
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2023 B-1244

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ISSN 1400-3821

B1244
Bachelor of Science thesis
Göteborg 2023

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Abstract

The Bronze Age rock carvings in Tanum, Bohuslän, are made in glacially polished granite, a hard crystalline rock that is difficult to engrave. This raises the question: How did the Bronze Age carvers make them, and which techniques and tools were used? In this report, the purpose is to offer a geological perspective on these questions, through an investigation into one such engraved rock panel, Tanum 28 on Aspberget. The relationship between carvings and the properties and features of the rock was studied through close observation with hand lens, and it was found that most carvings on the panel were engraved in homogenous granite, but a few of them intersected local geological features such as mineral orientation, a pegmatite dike, and a fracture. Additionally, some speculative aspects on the making of rock carvings in general are discussed, such as the value and use of rock flour produced from rock carvings, and the presence of water flows on engraved panels, which could be useful when engraving rock.

Further, seismic p-wave velocity was measured inside and outside the rock carvings with a Pundit 200. This was done to measure the microfracture density of the rock, and test if p-wave velocity can be correlated to a typological age chronology of ship carvings. The results indicate that such a correlation is present, which supports the idea that rock carvings may be dateable by p-wave analysis. However, the small sample size, the uncertainty of typologically dating rock carvings, and local variations in p-wave velocity, call for caution in interpreting the results. Finally, an unexpected discovery was that some rock carvings had a higher p-wave velocity inside the carving than outside.

1. Introduction

1.1 Background

The rock carvings of Tanum in Bohuslän, Sweden, are traditionally dated to the Nordic Bronze Age, stretching roughly from 1700 BC to 550 BC. (Horn et al., 2021). They are engraved in monzogranitic Bohus granite, a hard crystalline rock which is difficult to scratch or break by other materials. This difficulty raises the question of how they were made. The carving method, as the term rock carving suggests, has been used to create art in softer rocks. In granite on the other hand, carving is ineffective, and the primary method for making the rock art of Bohuslän was most likely by a percussive technique (Hygen & Bengtsson, 1999). However, the details on how the rock carvings in Tanum was made remains unknown.

For example, if stones were used, is the main method a direct pounding with one rock, or indirect pecking using two rocks as chisel and hammer (Bednarik, 1998)? Could other materials have been utilized? Considering that no iron tools were available in the Bronze Age, this metal is an unlikely candidate. Bronze was available, but it is a soft metal with a Mohs hardness of 3, which should be compared to 7 for quartz, and 6-6.5 for k-feldspar and plagioclase, the main constituents of granite. Therefore, bronze is also an unlikely alternative to rock tools, but not impossible. Further, could other elements have been used to aid in the production of a rock carving, such as heat, or water?

In this report I will provide a geological investigation of the rock art panel Tanum 28 on Aspberget, as well as a discussion on the engraving technique with relation to the geology. On the same panel I will also attempt to correlate the comparative chronology of ship carvings with their seismic p-wave velocity, to test the potential of p-wave analysis for dating rock carvings.

1.2 The Bronze Age coastal landscape

Due to the isostatic rebound of southern Sweden from the last glaciation, the land has risen, and the sea regressed from the Bohuslän coast. The sea would have been roughly 17 m above the current sea level at the start of the Nordic Bronze Age, and around 10 m above at its end (Ling, 2008). The map of Figure 1 illustrates the marine landscape in Bronze Age Tanum. With 17 meters higher sea level, Aspberget is part of a peninsula and is located on the western side of a bay within the archipelago, and Vitlycke Museum is located at the edge of the same bay. The Tanum 28 panel would not have been farther from the bay's edge than 100 meters at the start of the Bronze Age.

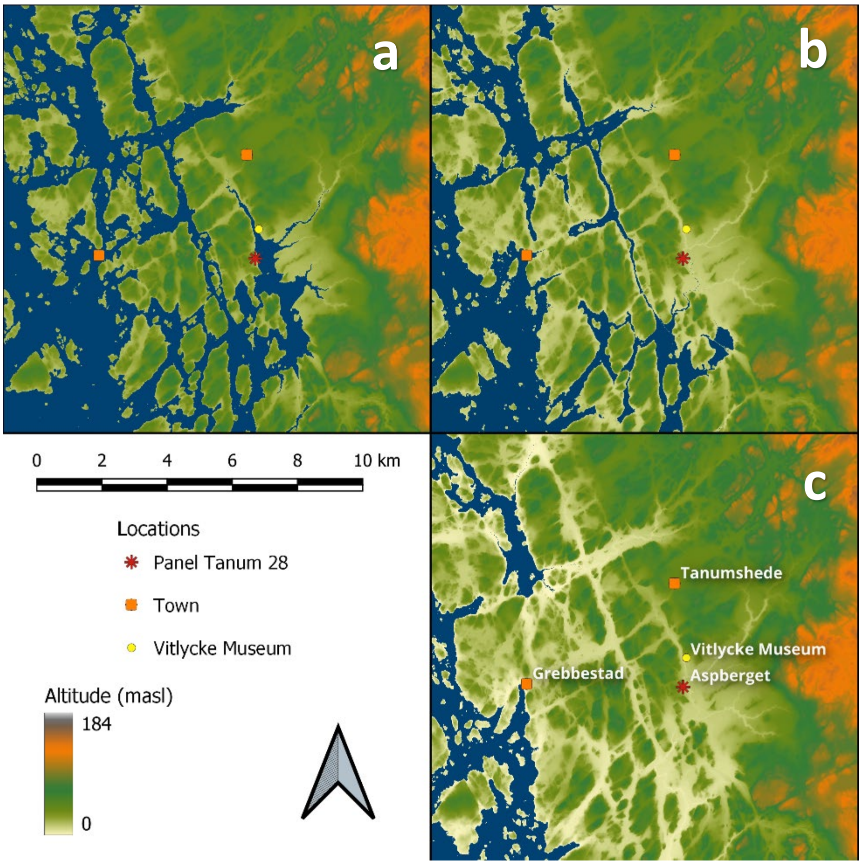

Figure 1. a) Coastline in Tanum 17 m above the current sea level. This simulates the beginning of the Nordic Bronze Age. b) Coastline in Tanum 10 meters above the current sea level. This simulates the end of the Nordic Bronze Age. c) The coastline at present. The map was made using altitude data from Lantmäteriet.

1.3 Shore displacement and comparative chronology

Dating rock carvings is difficult, since they are a reductive artform of removed material from natural rock surfaces, and thus leave no dateable traces. Absolute dating of a rock carving is currently not possible; however, it is possible to typologically discern relative ages. It is assumed that some carvings were made right next to the sea during the Bronze Age, so new rock surfaces would have slowly become available as the sea level sank. Further, certain styles of boats and other images were used after others, in a way that can be correlated with the sea level (Ling, 2008). This comparative chronology from shore displacement is currently the best method of deducing the age of rock carvings: If a carving is found on a low altitude rock, it must have been made after the sea sank below that altitude. From that assumption, Ling (2008) could by using GIS altitude data and GPS positioning assign certain stylistic traits of ship carvings to the various periods of the Bronze Age. A description of this evolution of styles during the Bronze Age follows. For reference, Figure 2 illustrates ship carving terminology, and examples from Ling are shown in Figure 3.

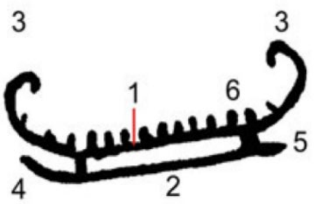

Figure 2. "Late Bronze Age boat (Period V: 950–720 BC) and structural elements of boats: 1) gunwale; 2) Keelline, 3) stem, 4) keel extension/ prow, 5) stern, 6) crewstrokes." From Horn et al., (2021).

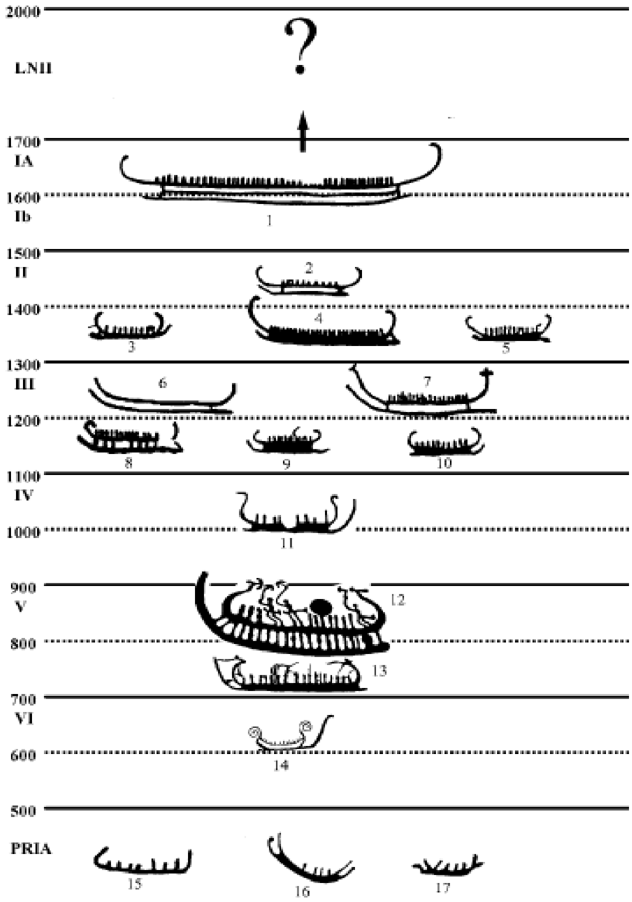

Figure 3. "The tentative ship chronology of the landscape. In accordance with the outcome of this study this figure is then an agreement between the altitude of the ship carvings in relation to shore displacement and comparative chronology." Numbers to the left show years BC. From Ling, (2008).

The Bronze Age Period I ships sometimes have a central line between the keelline and gunwale, and they show none or small keel extensions. In Period II the central line disappears, and the keel extensions become more pronounced and horizontal or slightly bent upward. From Period III, the keel extensions become upturned and the first animal heads on the stems appear. Some stems can be outward turned. In Period IV, outward turned stems are common and often end in animal heads. The keel extensions become very pronounced and turn almost vertically upright. Period V shows vertical or almost vertical keel extensions and inward or outward-turned stems. The ships can be elaborate with animal heads, crew depictions, and other details. In Period VI, the stems are continuously elaborate with spirals, S-curves, and animal heads, and the keel extensions can be very long. Finally, in the Pre-Roman Iron Age, ship carvings are small and symmetrical; some have bifurcate stems in the fore and the aft.

It should be noted that it is common among the rock carvings of Bohuslän to have been updated over time (Horn and Potter, 2018), for example such that the inward turned stems of an Early Bronze Age ship might have been reworked in the Late Bronze Age to have outward turned stems with animal heads. Thus, a ship image that looks like it is from the LBA could have a core made in the EBA.

1.4 Weathering, microfractures and p-wave analysis

Weathering has been an ongoing process on the granite of Tanum since it was polished and later uncovered by the Weichselian glaciers. This weathering occurs from several processes, both mechanical and chemical. Mechanically, unloading of the weight from the ice sheet causes minerals to slowly expand as an elastic response to the change of stress (Marshak, 2019). This stress from glacial unloading is thought to create microfractures in the surface layer of the rock (Horn et al., 2021). Further, the minerals of granite have different thermal properties and expand by different lengths under heating and cooling. Cycles of thermal expansion and contraction from day to night and summer to winter may cause these fractures to grow and multiply over time (Anders et al., 2014), and crystallization of salt in microfractures may also contribute to the weakening of the rock structure (Horn et al., 2021).

Chemically, the various minerals of granite have a wide range of resistance to weathering. Quartz is one of the most chemically stable minerals, while feldspars are prone to weathering by hydrolysis from acid rain, and biotite is prone to oxidation weathering which happens at contact with oxygen in the atmosphere (Marshak, 2019). The chemical weathering therefore only affects the millimetre to centimetre of the rock closest to the surface, which is in contact with air or acid water. Cracks of various sizes and pore spaces from earlier weathering may extend this zone further by allowing paths for air and water to penetrate the rock. Fungal hyphae, from lichen for example, can penetrate microfractures and dissolve minerals by secreting acids, and thereby contribute both to mechanical and chemical weathering (Hygen & Bengtsson, 1999).

It is assumed for this investigation that the process of making the rock carvings of Tanum produced additional microfractures, and those fractures may have grown due to continued weathering in the centuries that followed, such that the rock in carvings made earlier have a higher fracture density than ones made later. A higher fracture density should cause the rock to have a slower velocity for seismic waves. This difference could be detected by measuring the seismic p-wave velocity inside and outside the rock carvings. If the whole set of fractures and pore spaces in the rock surface grows proportional to time, then rock carvings might be dateable by the density of microfractures inside the carved rock.

1.5 Water and fracturing

Water is a common element on the engraved panels in the Tanum area, and rock carvings are often found in or next to where water naturally flows across the panels (Horn et al., 2022). This relationship is true in other parts of Scandinavia as well, for example adjacent to streams and rapids (Nimura, 2016). Could the water be of use when making a rock carving? Hygen & Bengtsson (1999) mention an experiment where the time for making a cup mark was reduced from 45 to 20 minutes when the knocking was conducted with running water on the rock, compared to when dry, but no further details or sources of that experiment are presented. Further, Waza et al. (1980) found that crack propagation velocity in an andesite or a basalt increased by 2-3 orders of magnitude when the rock samples were water saturated compared to when dry. What is the mechanism behind this apparent increase of fracturing when water is present?

I was unable to find literature discussing the phenomenon in crystalline silicate rocks. There is, however, a range of research on the fracturing of non-crystalline glass. Freiman (2012) offers a summary of brittle fracturing in silicate glasses, where the chemical activity of water is emphasized as an agent for greatly increasing fracture growth and lowering the threshold stress required for brittle failure in the glass. Figure 4 is an illustration from Michalske & Freiman (1982) showing the hypothesized mechanism, where a water molecule reacts through electron sharing and proton transfer with an Si-O-Si bond in silicate glass under tension, breaking the bond and creating one hydroxyl group on either side. Del Bene et al. (2003) modelled the reaction and found that two water molecules reacting with and breaking a Si-O bond is more effective than only one.

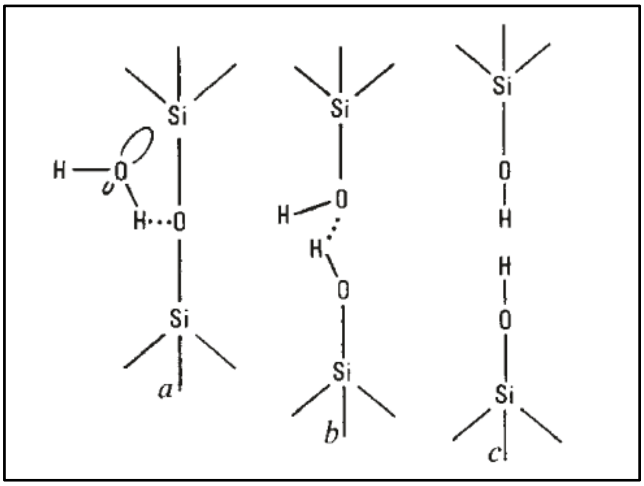

Figure 4. "Representation of the proposed reaction between water and a strained Si-0-Si bond at the crack tip. Reaction steps involve; (a) adsorption of water to Si-0 bond, (b) concerted reaction involving simultaneous proton and electron transfer, and (c) formation of surface hydroxyls." From Michalske & Freiman, (1982).

Glass and granite are compositionally similar. The difference is more related to the molecular structure, where glass is non-ordered silica tetrahedra chained in rings while granite is made up of ordered, discrete crystalline minerals of different composition and orientation. Could the mechanism of water-facilitated fracturing of glass be applicable to crystalline rock like granite as well? That would be a reasonable assumption, even though the form of fracturing may vary because of the structural differences.

1.6 Description of the investigated panel

The investigated panel is Tanum 28 on Aspberget, part of the UNESCO World Heritage of the Rock Carvings in Tanum, and it can be seen in Figure 5. It is a surface of glacially polished granite with shallowly engraved rock art, and the visible part uncovered by moss and lichen has an area of roughly 20 m^2. The panel is located 27 meters above the current sea level and its surface has a very slight undulation, but it can be approximated as flat and dipping about 10° to East-Southeast. The panel contains fractures, pegmatites, and mingled magmas, but is mostly homogenous fine-grained granite. A more in-depth geological description is presented in Results.

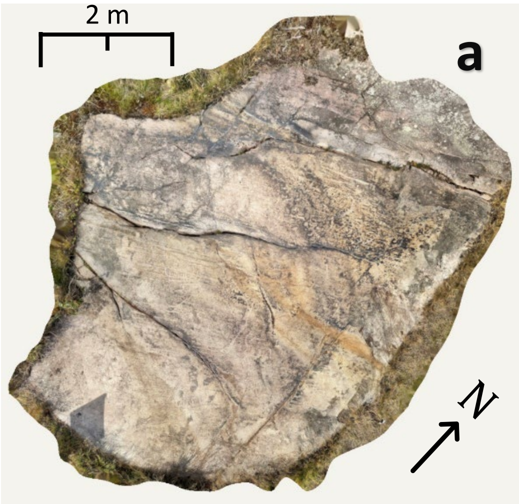

Figure 5. a) 3D scan of the Tanum 28 panel. Image credit: Carina Liebl. b) The Tanum 28 panel as seen from the visitor path. The yellow notebook is 20 cm wide.

A rubbing of the Tanum 28 panel is shown in Figure 6 with rock carvings, pegmatite dikes, and fractures highlighted. Since ship carvings are possible to assign to a comparative chronology, they were the focus of this investigation, and each has been assigned a number from 1 to 15 for easy reference. Other than the 15 ship-like carvings, there are a couple of small boats, a few humanoid figures, one or two animals, and some other features that elude my categorization. Interestingly, the otherwise common motif of the cup mark, a circular depression with a polished surface inside, is almost absent from this panel. Only a single cup mark was found, and it is located below Ship 3.

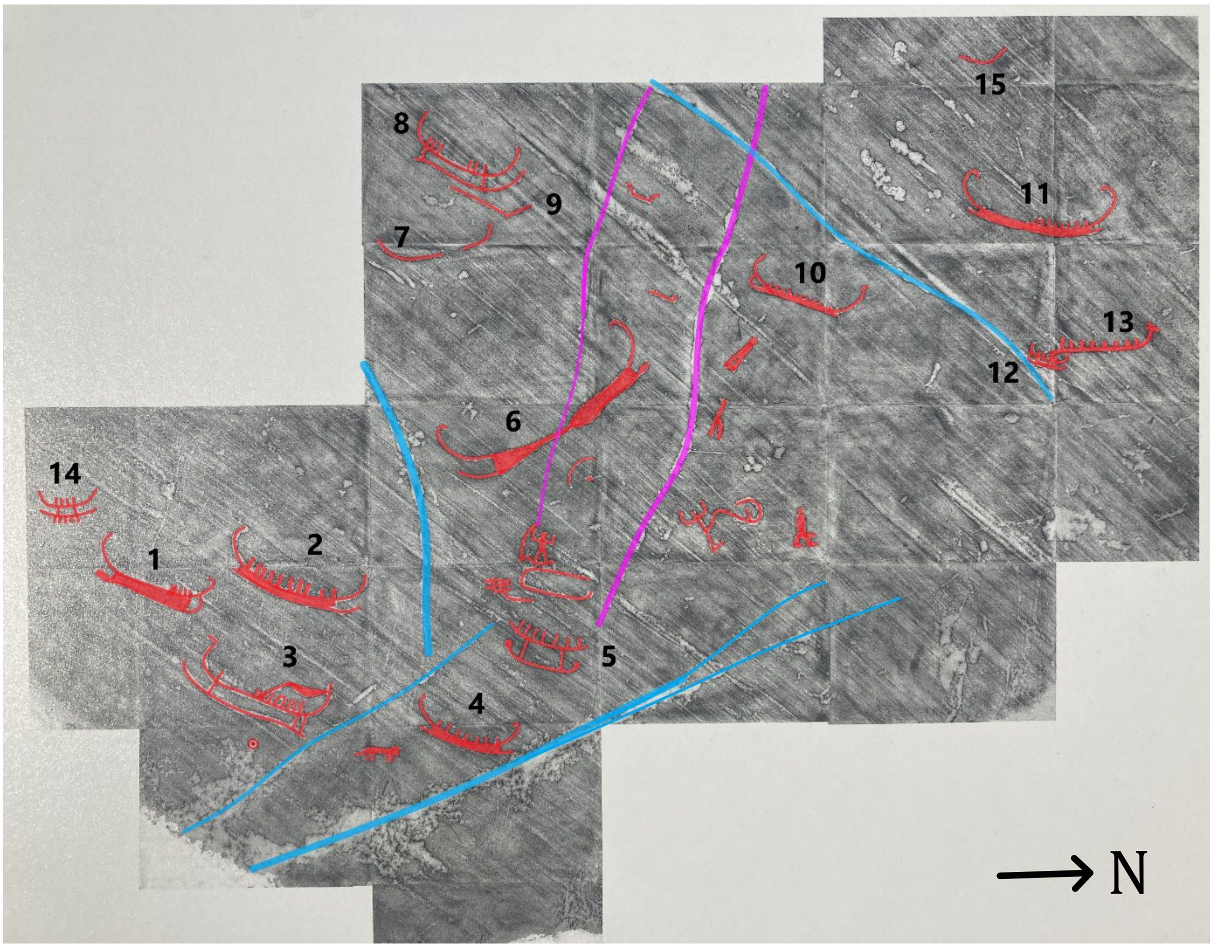

Figure 6. A rubbing of the Tanum 28 panel, showing rock carvings, fractures, and glacial striations. Red: rock carvings, Purple: pegmatite dikes, Cyan: fractures. Image credit: Tanums Hällristningsmuseum, (2015). Colour highlighting and numbering was made by the author.

2. Method

The field study consisted of two parts: The first part was an investigation of the petrology and structural geology of the panel, and the second was p-wave measurements of ship carvings. When describing structures, all directional values of planar and linear features will be written in Clar notation.

2.1 Field observations

The panel Tanum 28 on Aspberget was investigated using a hand lens in and around the rock carvings, as well as on the non-anthropogenic indentations of the rock. The latter could, for example, be glacial striations or weathered surfaces. The rock carvings were observed closely for any patterns or markings within them or on their edges, and the various geological and archaeological elements of the panel were mapped and sketched by hand, as viewed from the visitor's path. Linear elements were measured for their plunge and plunge direction, both the anthropogenic, such as the direction of the ships, measured at the centre point of their keels, and the non-anthropogenic, such as glacial striations and the intersection of granitic dikes with the surface. An attempt was also made at typologically assigning the ship carvings to Ling's (2008) chronology.

2.2 P-wave velocity measurements

2.2.1 Equipment description

The tool Pundit 200 by Proceq (Figure 7) was used to measure the p-wave velocity. This portable computer device can be connected by cable to two ultrasonic transducers, one of which acts as transmitter and the other as receiver. The transmitter produces short clicking pulses, and the receiver records them as seismic waves. From this wave, the p-wave arrival time can be determined, and the seismic velocity of the material calculated. The transducers were attached to an aluminium rod with a separation of 7.0 cm between transmitter and receiver, the shortest separation possible as a whole integer in centimetres. The frames which connect the modules to the aluminium rod are not rigid and allow for slight movements, to ensure that the seismic signal will propagate through the measured medium and not the rod.

Figure 7. The Pundit 200 setup.

2.2.2 Environmental conditions

Environmental conditions affect the Pundit measurements. Temperature differences can thermally contract or expand the measured material by slight amounts which might yield variations in seismic velocity, and it might also thermally alter the equipment. Therefore, it is important for comparison to measure during similar temperatures and calibrate the Pundit before it is used. Also, if the fractures inside the rock are filled with water or ice, this changes the p-wave velocity, since the seismic waves no longer travel around microfractures, but can instead bridge them through the water or ice. Therefore, only rock surface that was thoroughly dry was measured. Since water from snowmelt and earlier precipitation was continuously running through the large cracks in the panel and across ships 1, 10 and 13 during the fieldwork period, these carvings were not measured.

Field measurements with the Pundit were taken in two separate excursions. The first was from the 27th to the 28th of March 2023, and the second on the 5th of April the same year. During the March excursion, there was a large variation in weather conditions with alternating direct sunlight, wind, and snowfall. The panel was also covered by ice that never completely melted during the day. During the excursion in April, the weather was more stable and warmer, allowing Pundit measurements of all dry ship carvings to be conducted within two hours in the afternoon, when the sun was shining on the panel but setting. The temperature of both the air and rock was stable around 7-9 °C during this time, all ice that had been covering the panel in the morning had melted, and the Pundit was calibrated to the ambient temperature before measurements started. I consider the measurements conducted in April to be more comparable, and therefore they are the measurements that were used for analysis.

2.2.3 Measuring method

Measurements were taken by placing the rod with the two transducers on the rock surface, across the 7 cm line to be measured, as can be seen in Figure 7. The transducers were placed steadily onto the measuring spot, not pressed down nor held too lightly, but allowed to rest in place by its own weight. Around 10 measurements were taken at each spot, with the tool moved around within a 5 mm wide circle. This was done to get a good statistical representation, unaffected by local variations such as the distribution of mineral grains or small fractures which might disturb the signal. I took care not to scratch the surface of the panel with the measuring equipment or anything hard of metal or rock, to not damage the panel.

All the ship carvings were measured in at least one spot inside the carved track and another just outside on the closest polished rock surface (Figure 8). For each rock carving, these inside and outside measurements were taken as close to each other as possible, and in the same direction, to avoid sampling anomalies made by local differences in mineral composition or anisotropy. Every spot measured with the Pundit was documented by photographing the surface and adding a coloured line in the image where the measurements were made.

Figure 8. The red lines are 7 cm long and show where measurements were made on Ship 8. Arrows point to possible unfinished crewstrokes.

2.2.4 Data processing and statistics

To determine the p-wave velocity from a measurement, the time delay to the first arrival of the wave is needed. The pundit automatically sets a time for the p-wave arrival at each measurement, but this is often not accurate and therefore many measurements were adjusted manually. It was not always clear what constitutes background noise and what constitutes the beginning of the p-wave. I decided on the method of following the envelope lines of the wave and place the P-wave where they begin to diverge noticeably. An example of a measured wave is shown in Figure 9, and all measuring sites can be found in Appendix 1.

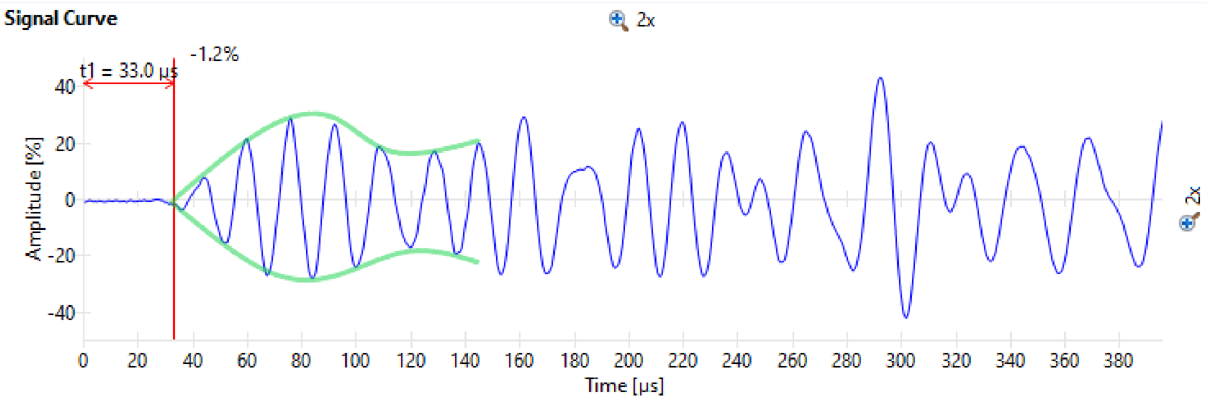

Figure 9. A Pundit 200 measurement outside Ship 8. t1 is the p-wave arrival time. The green envelope lines are added by image editing for illustration.

For statistics, every measuring spot with about 10 measurements was assigned an average, median, standard deviation, and upper and lower quartile. Data points with a p-wave velocity below 1500 m/s are considered to have measured the air without connection to the rock and have been omitted from the calculation. Thereafter, the difference between the inside minus the outside median velocity of each carving were calculated to allow comparison between carved and uncarved rock, and the upper and lower quartiles were used as margins of error for this comparison. This difference between inner and outer p-wave velocities will be referred to as Δv.

The reason for the choice of using the median and upper and lower quartiles, instead of average and standard deviation, is that the distribution of the p-wave velocities for each measurement spot were not symmetrically distributed, and some measurement spots had outliers that changed the average values excessively. These outliers might not be the result of actual measured differences but could originate in that I manually set the p-wave arrival time for each measurement, which is not an error-free process. The upper and lower quartiles are also better at showing an asymmetrical distribution than standard deviations.

3. Results

3.1 Field observations

3.1.1 The geology of the Tanum 28 panel

The rock of Tanum 28 was classified as a monzogranite with a mineral composition of approximately 40% quartz, 30% k-feldspar, 20% plagioclase, and 10% dark minerals, mostly biotite. The granite is homogenous on most of the panel and fine-grained with a grain size of 1-2 mm. Some grains have weathered away even on the most well-preserved polished surface, visible as small holes that are often slit-shaped, which may indicate that the missing minerals are mostly mica. On the south-eastern edge there is highly foliated magma mingling visible. Sometimes with a distinct border to the homogenous granite and sometimes more diffuse. Around the mingling are some pegmatitic areas with especially large k-feldspar crystals of up to 5-10 cm in size, but these areas contain no rock carvings. The homogenous granite has three or four phenocrysts about 2 cm in size on the surface but none of these are connected to a rock carving in an obvious way.

Traces from glacial erosion consist of a well-preserved polished surface, not mirror-like, but smooth and diffusely reflecting the light of the sun. There are glacial striations across the whole surface in the direction of 030/09, of which the widest is 7 cm wide, but most are thinner than 1 cm. Some flakes of the polished surface have fallen off in places, and where this exfoliation occurs it does so mainly along the direction of the striations. The surface is most weathered on the southernmost edge, for about a metre from the moss cover, and the original polished surface is almost gone there. On this part lies ship 14, which is barely visible.

There are four big fractures in the panel. These steer the flow of precipitated water from the top of Aspberget over the panel, and accumulated soil and grass growing in the fractures spill out the water such that the areas around and below ship 1, 10 and 13 were always covered by a thin waterflow or sheet of ice during the investigation Period (Figure 5b). Further, there are two thin pegmatite dikes through the central area of the panel. These contain crystals of k-feldspar, quartz, plagioclase, and biotite that were between 3 to 10 mm in size, and had deeper depressions from weathering, making them more visible with shadows during sunlight. The thinner of the two appear to cut ship 6 in half (Figure 6 and 10b).

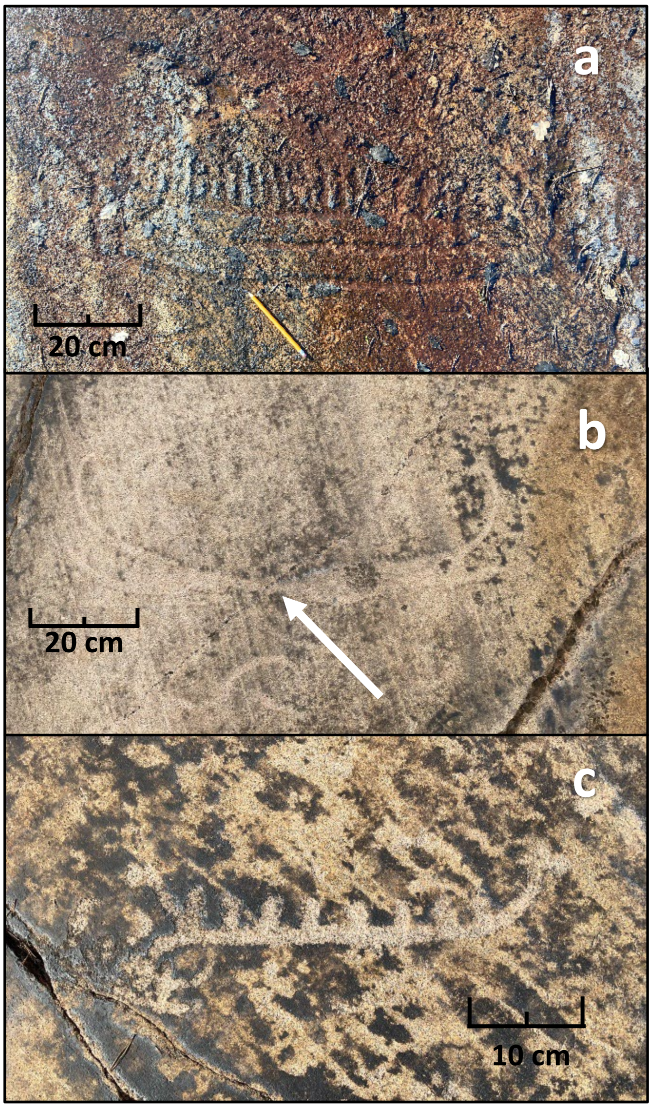

Figure 10. a) A large ship carving on mingled granite with foliation in the direction of the pencil. This ship is located 20 meters north of Tanum 28. b) Ship 6, cut in half by a thin pegmatite dike. The arrow indicates the intersection. c) Ships 12 (left) and 13 (centre), connected to each other. Ship 12 is engraved right above a fracture in the left bottom corner, as if riding on it.

All the rock carvings on Tanum 28 appear to be made exclusively on the homogenous part of the granite. However, this exclusiveness is not a general rule for the rock carvings on Aspberget. 20 meters to the north-east of Tanum 28 is a single large ship engraved into heavily foliated, mingled granite (Figure 10a). Two other examples of overlap between rock carving and non-homogenous geological structures were found on Tanum 28: First, Ship 6 that is divided by a pegmatite dike (Figure 10b), or ship 12 that appear to ride above a water-bearing fracture (Figure 10c). Otherwise, the rock carvings do not intersect pegmatites, phenocrysts, foliated mingling, and large fractures.

A very slight preferred mineral orientation was observed in the central area of the rock where the ships 6, 7, 8 and 9 are located. This orientation had a linear intersection with the surface in the direction of 104/05, and it was visible as small holes from weathered minerals being elongated in this direction. It also affected the shape of the border between carving and the polished rock surface: Where the border was parallel to the orientation it was smooth, where it was perpendicular the border was rough, and where it intersected diagonally a staircase shape was found, with the edge of the stairs aligned with the mineral orientation (Figure 11a). The slanting sunlight also showed small crescent-shaped shadows inside the carvings that were aligned with the mineral orientation (Figure 11b). Ship 8 is the only ship carving in this part of the panel that has crewstrokes, and these are aligned with the mineral orientation. This alignment makes them smoother and more defined between one another. The mineral orientation is also aligned with the dominant foliation direction of the mingled magma on the eastern side of the panel.

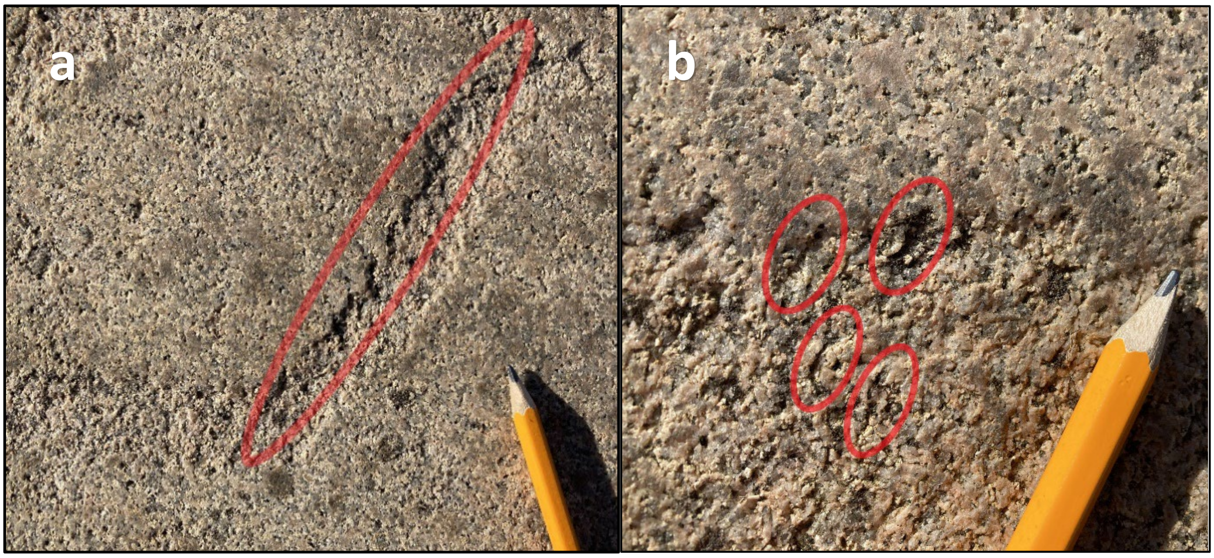

Figure 11. a) The front stem or keel extension of the unfinished ship 9, with shadows showing a staircase pattern on its upper edge. The pattern is aligned with the slight local mineral orientation in up-down direction in this image. b) Crescent shaped shadows in ship 6 aligning with the mineral orientation in the direction of the pencil.

3.1.2 Direction of the ship carvings

The linear direction of ships 1-13, as measured along the centre of their keels, is presented in Table 1. Most of these ships are oriented along the NNE-SSW direction. Deviations are ships 7, 13, and most noticeably ship 6, who are aligned roughly in the NW-SE direction. The plunge value is low for all ships, at most 5°. This should be compared to the dip of the panel's surface at 10°. The ships with a plunge of 0° are perfectly horizontal on the panel and align with the strike of it. Ships 14 and 15 were found after the directional measurements were made and are therefore not included in the table.

Table 1. Keel direction of the ship carvings.

SHIP:	1	2	3	4	5	6	7	8	9	10	11	12	13
PLUNGE DIRECTION:	017	015	006	011	010	137	168	016	016	005	004	018	000
PLUNGE:	03	00	02	00	01	02	01	04	05	00	00	01	00

3.2 Ship carving chronology

Of the ship images 1-15, nr 1, 10, and 13 were not measured, due to them being covered by running water during the fieldwork. Ships 7, 9 and 15 were measured but are not complete ship images and do not show enough features to allow a guess of age in Ling's (2008) chronology. Ship 14 is not visible enough to assign to the chronology. Also, Ship 5 has a unique symmetrical shape with no stems and a keel far below the deck, connected by two lines. These features differ from the common ship motifs, and this may indicate that it does not depict a standard ship, but perhaps a catamaran or an ice sled. Nevertheless, the carving is not suitable to assign to the chronology either.

The ship carvings that were assigned to the chronology are nr 1, 2, 3, 4, 6, 8, 10, 11, 12 and 13. These all seem to correspond to the Bronze Age Periods II, III and IV, and they were categorized into these periods as shown in Table 2. Most of them does not conform well to the traits specific to each period, and there is an uncertainty in this temporal classification. For example, ship 12 (Figure 10c) is difficult to date. It is small, somewhat weathered and located adjacent to a fracture. Its basic hull features look like a Period II ship, but it has a lure blower on one crewstroke, and another crewstroke continues to the keel of ship 13, which has animal heads on its stems. Both the lure and the animal heads are characteristic of Periods III and IV. My evaluation is that ship 12 was made in Period II and the connected ship 13 was a later addition.

Table 2. The chronology of the ship carvings, classified into bronze age periods II-IV. Non-measured ships are red. X's mark the most likely age for each ship. Question marks indicate the uncertainty of the dating. Ships with dashes were not possible to date by their stylistic traits.

Period:	**Ship:**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
II		X	X		X	-	?	-		-	?	X	X		-	-
III			?	X		-	X	-	?	-	X		?	?	-	-
IV				?		-		-	X	-	?			X	-	-

3.3 P-wave velocities

The measurements of p-wave velocities are presented, inside the rock carvings (Figure 12a) and outside them (Figure 12b). The rock in and around ship 2 has the lowest velocities, while that of ship 9 has the highest, and this is true both inside and outside. The total span of p-wave velocities ranges from roughly 1900 m/s to 2300 m/s. Ships 7, 8 and 9 stand out as having the highest p-wave velocities inside the carvings. The complete data set of all measurements can be found in Appendix 2.

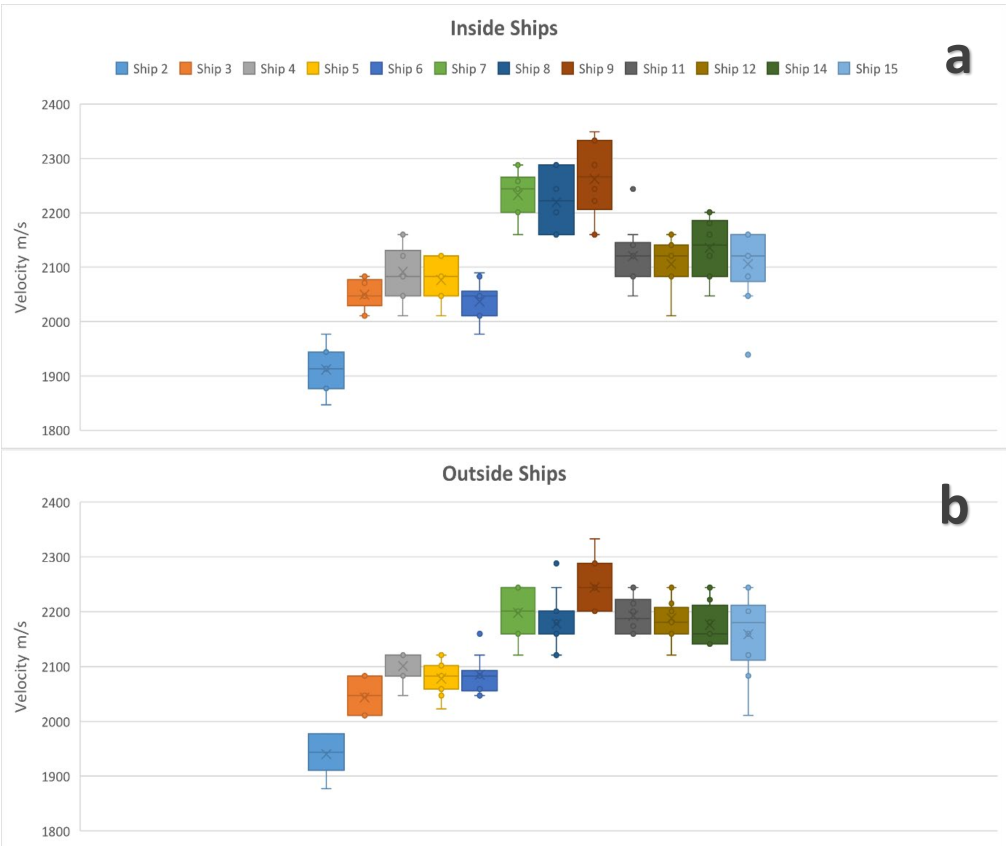

Figure 12. Distribution of P-wave velocities for each measured ship. a) Inside carving. b) Outside carving. The (x) marks the average value of each spot, and the line dividing the boxes marks the median.

Extra measurement spots were chosen on ship 6 and 7, due to them having interesting features in their engravings. Ship 6 (Figure 13a and b) has had its inside between gunwale and keelline engraved, and the inner surface texture differs slightly from that of the edges. More specifically, the glacially polished surface layer does not appear to have been fully removed in the central part, as it has in the edges. Ship 6 was accordingly measured in three spots: One in the centre, one in the keelline, and one outside it. The results show that the centre and edge measurements have the same median of 2047 m/s, but slightly different means and distributions, with the edge measurements being the slower of the two. The distribution of the outside values overlaps the inside ones, but the median is higher at 2083 m/s.

Regarding Ship 7 (Figure 13c and d), it only consists of a gunwale with simple upturned stems, and there is a gap in the centre of the gunwale which has not been engraved. This gap was also measured inside and outside it. The velocities in the gap and in the carving are almost identical, with medians around 2242 m/s, even though material is removed from one but not the other. Note also that the outside measurements are very different from each other despite their proximity: Outside the gap, the median velocity is 2310 m/s and faster than the inside measurements, while outside the carving it is 2201 m/s and slower than the inside measurements.

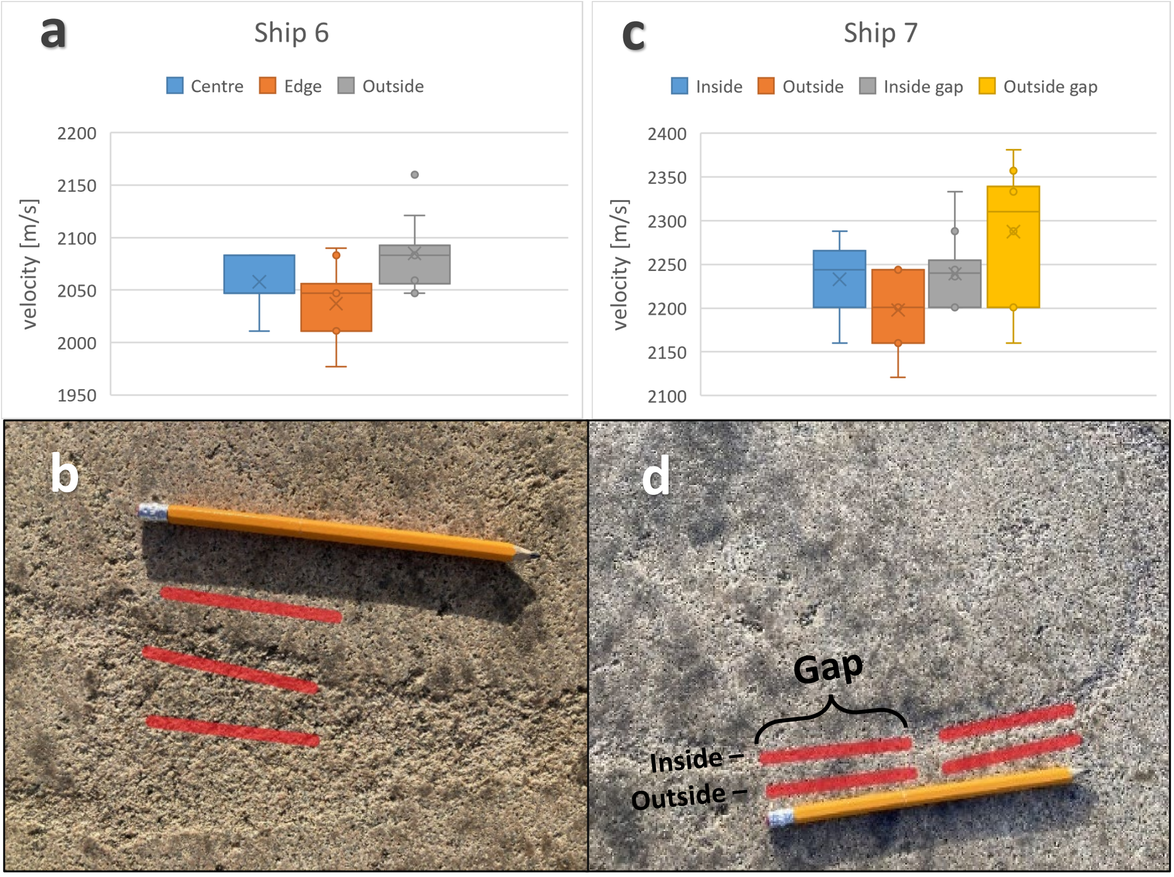

Figure 13. P-wave velocities for different elements of ships 6 and 7.

Figure 14 shows the inside median p-wave velocity for each carving minus the outside median velocity (Δv), in ascending order. For ship 11, 12, 15, 4, 6, 2, and 14, Δv is negative, meaning that the p-wave velocity was slower inside the rock carvings than outside, and the opposite was true for ship 8, 7, and 9 with positive Δv. Ships 3 and 5 had equal medians inside and outside, and the differences for ships 9 and 14 were not outside the error margin. The roman number of the Bronze Age period is shown above the ships that could be assigned to the chronology. As can be seen, the chronology roughly follows the ascending order of Δv. Most notably, ship 8 which is the only Period IV carving, has the highest Δv value and the latest assigned age, while the four ships assigned to Period II are on the lower half of the graph. However, the uncertainty of the chronology should be kept in mind, and that only half of the ship carvings were possible to both date and measure for p-wave velocity.

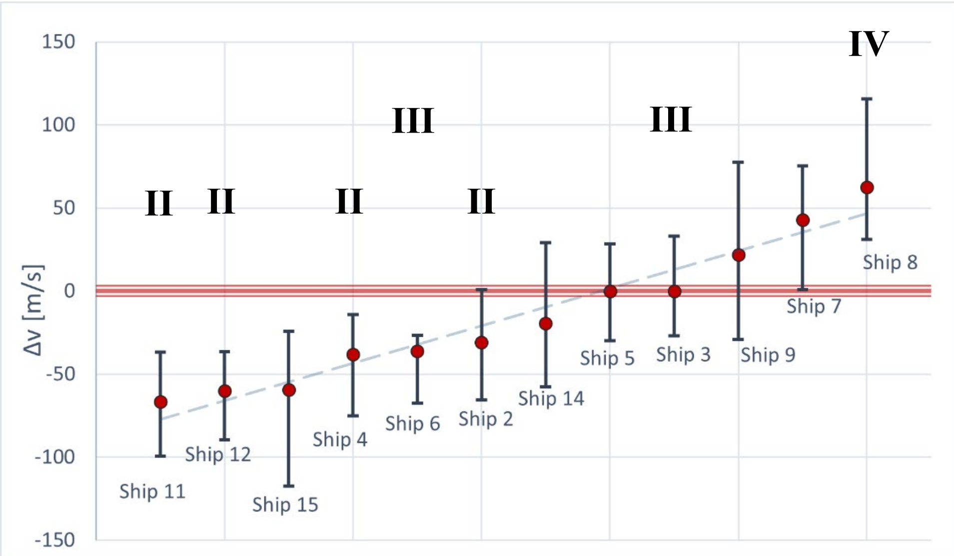

Figure 14. Inside minus outside median p-wave velocity for each ship carving, arranged in ascending order. Red dots show the difference of the medians for all ship measurements and error bars are the upper and lower quartile. Assigned Bronze Age Period are shown above each categorized boat as a roman numeral.

4. Discussion

4.1 A geological perspective

4.1.1 Choice of canvas rock

All carvings of Tanum 28 are made in homogenous, fine-grained granite. I would assume that the main reason for this exclusivity is the homogenous granite's usefulness as a blank canvas, with similar properties over the whole surface. A pegmatite would be more challenging to create artwork on, with large crystals of quartz, feldspar, and mica, that have different properties of elasticity and cleaving. Likewise, a foliated rock might break in the direction of the foliation, and not in the direction that the carver anticipates. However, as the ship carving on foliated rock in Figure 10a shows, it is not an exclusive rule in Tanum to only make art on homogenous granite.

4.1.2 Aesthetic geological features

There do appear to be some aesthetic interactions between carvings and geological features on the panel. First: The big fractures (Figures 5 and 6) seem to frame the rock carvings to some extent, in a way that could possibly have been utilized to divide the panel into different sections for narrative purposes. They also carry water that spills out on the rock carvings, which gives an aesthetically pleasing glitter to them when viewed in sunlight (Figure 15). For another example, Ship 12, which is connected by a crewstroke to ship 13, appears to ride on top of a water-bearing fracture (Figure 10c).

Second: The thin pegmatite dike that intersect the middle of ship 6 looks like a lightning strike (Figures 6 and 10b). Ship 6 has no crewstrokes, and its central hull looks broken or unfinished. Consider also that it is the most directionally misaligned ship on the panel (Table 1). These elements together give the impression of a ship struck by lightning, sinking. The pegmatite dike is thin, and its lowest part appear to end just at the tip of the human figure's staff, below ship 6, as if emanating from the staff.

Third: The mineral orientation observed around ships 6, 7, 8, and 9, affects the texture of their borders, making it smoother in some directions and rougher in others. It is not evident that the carvers took this phenomenon into consideration when engraving the ships, but it does nonetheless make the crewstrokes of Ship 8 more defined between one another with smooth edges. This can be seen in Figure 8.

Figure 15. Ship 10 covered by a thin sheet of slowly running water, making it glitter when reflecting the sun. Pencil for scale.

4.1.2 On the absence of toolmarks

I could not find anything in the rock carvings of Tanum 28 that could be described as toolmarks. The aligned shadows in the ship carvings 6 through 9 (Figure 11) appeared like tool marks, as if a sharp chisel had made them, but since they were all aligned in the same direction and visible even outside the rock carvings as thin holes in the granite, I concluded that they were the result of a slight mineral orientation and not made by humans.

Otherwise, the inside of the rock carvings is grainy and rough, dominated by the relief of mineral grains, and to my eyes show little difference from areas where flakes have exfoliated by non-anthropogenic causes from the granite. Perhaps a more trained eye could detect a difference in texture between rock carvings and from exfoliated flakes, or maybe the millennia of weathering in the carvings have given them the same texture as naturally weathered surfaces. Nevertheless, there are no clearly visible traces of tool use in the carvings of this panel, which could be the result of post-engraving weathering or that the tools used were too blunt to leave marks.

4.2 P-wave analysis

4.2.1 Dating carvings by p-wave velocity

As shown in Figure 14, the chronology of the dated ship carvings roughly follows the curve of the Δv of each carving. The apparent deviations from the trend will be addressed first. Ships 2 and 6 might appear to deviate by being in the wrong order when assigned respectively to periods II and III, but they have very similar Δv values, and as Table 2 shows, their spans of uncertainty are the same, across both periods. Therefore, they are placed roughly as would be expected if there was a correlation between Δv and age of carving. Another observation of note is that ships 6 and 3 are both assigned to period III, but have a significant difference in Δv from -36 to 0 m/s. This need not be a deviation from the trend however, because the outward turned stems of ship 3 point toward it being closer to period IV than ship 6, and therefore the difference conforms to the trend better than what Figure 14 illustrates.

4.2.2 Local differences in p-wave velocity

Ships 7, 8, and 9 showed higher median p-wave velocities inside the carvings than outside, which was not expected. Ships 7 and 9, who show the highest median velocities inside, appear unfinished. Ship 7 only has a single gunwale and stems, with an unengraved gap in its centre, and what constitutes ship 9 is merely two straight lines in an angle. Perhaps this area of the panel was uncommonly difficult to work with, and the carvers gave up before the images were finished? However, ship 8 also occupies the same surface, and it is complete, although it looks like three more crewstrokes could comfortably have been made between the ones already there. When looking closer, some disturbances in the otherwise smooth polished texture indicate that it was attempted to engrave those crewstrokes as well (Figure 8, upper right corner). A plausible cause for the unexpected high inside velocities in ships 7, 8, and 9 might be that the granite at this location has experienced very little weathering, and that the rock just below the outermost layer of mineral grains has been almost completely protected from it. Then, perhaps, the carvers only engraved what was possible to dislodge, and encountered solid unworkable rock just below.

The following question also arises from the results: If the difference between inside and outside p-wave velocities is correlated with the age of the carving, why would ships made 3,000 years ago, in Period IV, have a positive value; while ships made 3,500 years ago, in Period II, have a negative? The difference in age is not very big compared to the millennia that passed afterwards, and it would be surprising if that difference was enough to change the sign of the result.

4.2.3 Extra measurements for ships 6 and 7

If there is a correlation between age and Δv, that means that the extra measurements made for ship 6 (Figure 13a) could be interpreted as follows: The centre part and the keelline were engraved roughly at the same time, since they have the same median velocity inside. The textural differences seen in the field indicate that the centre was engraved after the edges, but possibly in the same session. The findings for ship 7 (Figure 13c) on the other hand, are more difficult to interpret regarding age, since the two outside measurements are so different with almost 100 m/s between the medians. The best explanation may be that the rock right at the gap is very solid without any microfractures, and that the maker of this carving attempted to break the rock in the gap but was not able to dislodge it. The lower velocity inside the gap points toward that it at least is weaker than outside. Perhaps it was weakened by the engraving attempt?

4.3 Speculation on water and rock flour

While not part of the investigation on Tanum 28, the following thoughts are presented as speculation. Creating rock carvings necessarily produces a rest product of the removed material, in the form of rock fragments and rock flour. Perhaps this was not viewed as a rest product at all, but one of the reasons for making a rock carving in the first place? Perhaps the rock flour was collected and used to enrich soil with minerals, making it more fertile? If this was the case, then water would have been useful in keeping the rock flour in place and not blowing away in the wind. As is discussed in chapter 1.5, making a rock carving that is thinly covered by water could facilitate the engraving process through chemical reactions between water and Si-O-Si bonds.

I hypothesize that a mix of water and rock flour is even more useful in creating a rock carving, through two different mechanisms. First, as an abrasive, producing the effect of sandpaper, which could have been used to polish the inside of cup marks for example. Second, to utilize pore water pressure: A semi-permeable, finely ground rock flour mixed in the right ratio with water, could become a silty paste that keep water below the paste trapped. If such a paste is struck with a stone it might experience an increase in the pore water pressure, which could infiltrate into microfractures in the rock and expand them, cracking the outer rock layer further and producing more removable material. The hypothesis that wet rock flour aid in the making of a rock carving in granite with microfractures, could be tested experimentally.

4.4 The rock panel as cocreator of art

On a final note, I would like to raise the idea that the makers of the rock carvings probably had a culture that to some extent was animistic, and that the carvers did not necessarily view the rocks on which they engraved their images, or the water that flowed over them, as inanimate and dead matter. As this research shows, two rock surfaces that to vision and touch appear the same, can have different degrees of weathering, and therefore vary in their allowing of rock art. One solid surface might not become scratched at all, with an intact crystalline matrix that reacts elastically and bounces back any blows struck upon it, while another surface might be full of microfractures that collapses the structure when struck, breaking, and pulverizing it. Such information could only be acquired by conversating with the rock, such as by knocking on it lightly with a stone and listen to the sound that produces. A rock carver would have to closely understand the rock that they wish to engrave, to such an extent that that the rock could be viewed not as an inanimate mass to be shaped by an artist, but rather as a cocreator of the art. Both by directing the human carver to engrave some areas but not others, and by presenting beautiful geological features to be interwoven by human imagery.

5. Conclusion and further research

The data set used for this investigation is small and local, and the observed correlation is dependent on the author's interpretation of the p-wave arrival times and best guess at the ship carving chronology. Therefore, the results should be interpreted with caution. Nevertheless, they hint at a possibility to date rock carvings by using p-wave measurements, and they indicate that further explorations of this method may be fruitful.

The observation of the differences in p-wave velocities inside rock carvings, which could both be significantly higher or lower than the polished rock just outside, was not expected and is difficult to explain. These differences could be the result of age, or it could be variations in the density of pore spaces and microfractures, and thereby the degree of weathering. A higher microfracture density in the surface granite might be what allows rock carvings to be made there, by reducing the ability of the rock to react elastically to blows and causing it instead to crack further by brittle deformation. The depth of weathering would in that case determine the engravable depth for rock carvings on a panel.

Additionally, the presence of running water on the panel is noted as a possible practical aid in both the making of rock carvings by infiltrating microfractures, and in collecting the rock flour that is generated when a rock carving is engraved. The report also raises the possibility that rock flour, produced from the making of cup marks and other rock carvings, could have been a valuable and sacred soil fertilizer in the Neolithic and Bronze Age.

For further explorations on the making of rock carvings in granite, these investigations would benefit from attempts of making modern rock art with tools available in the Bronze Age. To any such endeavour, attention should be given to many elements of the process. Both the measurable, such as times for engraving, p-wave velocities, and amount of rock flour produced; as well as the experiential and qualitative aspects, such as how the artist feels during the process, how the rock reacts to light knocks and hard blows, and what tools and techniques are the most preferable to use.

Acknowledgements

I first wish to thank Carina Liebl for great guidance throughout the work for this report, as well as many interesting discussions on rock art, and Mark Peternell for providing the opportunity to work with a subject in geoarchaeology. Also, many thanks to all family members and friends who have exchanged ideas and kept me nourished throughout the process. Finally, I wish to acknowledge the Earth, for allowing her crust to be used as a canvas for these enigmatic and wonderous images.

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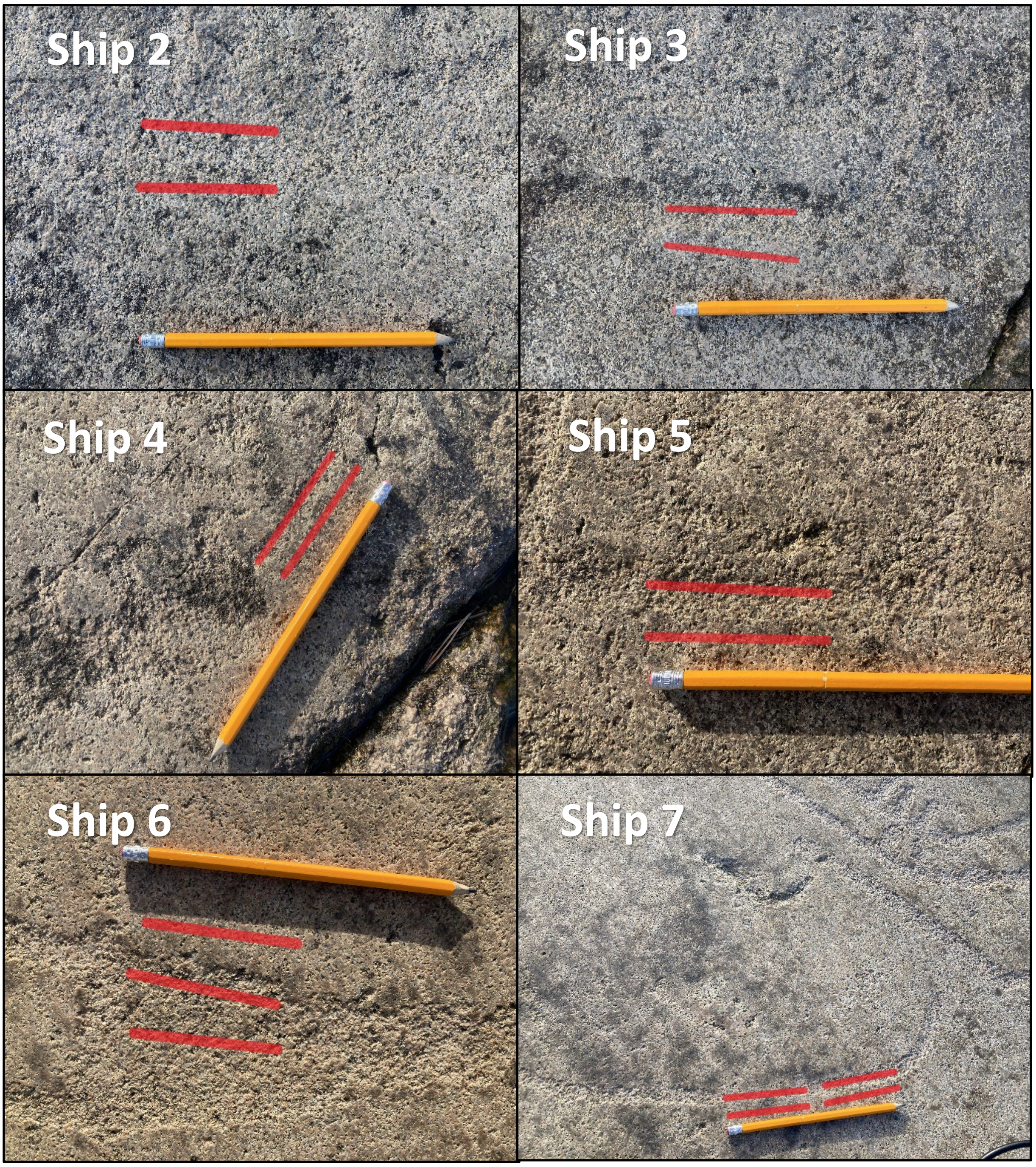
Appendix

Appendix 1. Measurement sites for all ship carvings measured in the field on the 5th of April 2023.



Appendix 2. All p-wave measurements on ship carvings collected in the field on the 5th of April 2023. Red measurements are taken inside carvings and blue measurements are taken outside them.

Ship 2	Time	t_0 [s]	p-wave velocity [m/s]	Ship 8	Time	t_0 [s]	p-wave velocity [m/s]
inside_001	2023-04-05 16:38	35,4	1977	In_001	2023-04-05 17:05	30,6	2288
inside_002	2023-04-05 16:38	36,6	1913	In_002	2023-04-05 17:05	32,4	2160
inside_003	2023-04-05 16:38	36	1944	In_003	2023-04-05 17:05	31,8	2201

inside_004	2023-04-05 16:38	36,6	1913	In_004	2023-04-05 17:05	32,4	2160
inside_005	2023-04-05 16:38	37,3	1877	In_005	2023-04-05 17:05	32,4	2160
inside_006	2023-04-05 16:38	37,9	1847	In_006	2023-04-05 17:05	31,2	2244
inside_007	2023-04-05 16:39	36	1944	In_007	2023-04-05 17:05	32,4	2160
inside_008	2023-04-05 16:39	36	1944	In_008	2023-04-05 17:05	30,6	2288
inside_009	2023-04-05 16:39	37,2	1882	In_009	2023-04-05 17:05	31,2	2244
inside_010	2023-04-05 16:39	37,3	1877	In_010	2023-04-05 17:05	30,6	2288
Outside_001	2023-04-05 16:40	36	1944	Out_002	2023-04-05 17:06	32,4	2160
Outside_002	2023-04-05 16:41	37,3	1877	Out_003	2023-04-05 17:06	33	2121
Outside_003	2023-04-05 16:41	36	1944	Out_004	2023-04-05 17:06	32,4	2160
Outside_004	2023-04-05 16:41	36	1944	Out_005	2023-04-05 17:06	32,4	2160
Outside_005	2023-04-05 16:41	37,3	1877	Out_006	2023-04-05 17:06	31,8	2201
Outside_006	2023-04-05 16:41	35,4	1977	Out_007	2023-04-05 17:06	32,1	2181
Outside_007	2023-04-05 16:41	35,4	1977	Out_008	2023-04-05 17:06	33	2121
Outside_008	2023-04-05 16:41	36	1944	Out_009	2023-04-05 17:06	32,4	2160
Outside_009	2023-04-05 16:41	35,4	1977	Out_010	2023-04-05 17:06	30,6	2288
Ship 3				Out_011	2023-04-05 17:06	32,4	2160
Inside_001	2023-04-05 16:43	33,6	2083	Out_012	2023-04-05 17:06	32,4	2160
Inside_002	2023-04-05 16:43	33,6	2083	Out_013	2023-04-05 17:06	31,8	2201
Inside_003	2023-04-05 16:43	34,2	2047	Out_014	2023-04-05 17:06	31,2	2244
Inside_004	2023-04-05 16:43	34,2	2047	Ship 9			
Inside_005	2023-04-05 16:43	34,2	2047	In_001	2023-04-05 17:29	32,4	2160
Inside_006	2023-04-05 16:43	34,2	2047	In_002	2023-04-05 17:29	30	2333
Inside_007	2023-04-05 16:43	33,8	2071	In_003	2023-04-05 17:29	30	2333
Inside_008	2023-04-05 16:43	34,8	2011	In_004	2023-04-05 17:29	31,2	2244

Inside_009	2023-04-05 16:43	34,8	2011
Outside_001	2023-04-05 16:44	34,8	2011
Outside_002	2023-04-05 16:44	33,6	2083
Outside_003	2023-04-05 16:44	34,8	2011
Outside_004	2023-04-05 16:44	33,6	2083
Outside_005	2023-04-05 16:44	34,8	2011
Outside_006	2023-04-05 16:44	34,8	2011
Outside_007	2023-04-05 16:44	34,2	2047
Outside_008	2023-04-05 16:44	34,2	2047
Outside_009	2023-04-05 16:44	34,2	2047
Outside_010	2023-04-05 16:44	33,6	2083
Ship 4			
Inside_001	2023-04-05 16:47	32,4	2160
Inside_002	2023-04-05 16:47	34,2	2047
Inside_003	2023-04-05 16:47	34,2	2047
Inside_004	2023-04-05 16:47	33,6	2083
Inside_005	2023-04-05 16:47	33,6	2083
Inside_006	2023-04-05 16:47	33	2121
Inside_007	2023-04-05 16:47	34,8	2011
Inside_008	2023-04-05 16:48	33	2121
Inside_009	2023-04-05 16:48	32,4	2160
Inside_010	2023-04-05 16:48	33,6	2083
Outside_001	2023-04-05 16:48	34,2	2047
Outside_002	2023-04-05 16:48	33	2121
Outside_003	2023-04-05 16:48	33,5	2090

In_005	2023-04-05 17:29	30,6	2288
In_006	2023-04-05 17:29	32,4	2160
In_007	2023-04-05 17:29	31,2	2244
In_008	2023-04-05 17:29	31,5	2222
In_009	2023-04-05 17:29	30,6	2288
In_010	2023-04-05 17:29	29,8	2349
Out_002	2023-04-05 17:29	31,8	2201
Out_003	2023-04-05 17:29	30,6	2288
Out_004	2023-04-05 17:30	31,2	2244
Out_005	2023-04-05 17:30	31,8	2201
Out_006	2023-04-05 17:30	30,6	2288
Out_007	2023-04-05 17:30	31,2	2244
Out_008	2023-04-05 17:30	31,2	2244
Out_009	2023-04-05 17:30	30	2333
Out_010	2023-04-05 17:30	31,8	2201
Out_011	2023-04-05 17:30	31,8	2201
Ship 11			
In_001	2023-04-05 17:21	33	2121
In_002	2023-04-05 17:21	32,4	2160
In_003	2023-04-05 17:21	33,6	2083
In_004	2023-04-05 17:21	33,6	2083
In_005	2023-04-05 17:21	34,2	2047
In_006	2023-04-05 17:21	32,7	2141
In_007	2023-04-05 17:21	33,6	2083
In_008	2023-04-05 17:21	33	2121

Outside_004	2023-04-05 16:48	33	2121
Outside_005	2023-04-05 16:48	33,6	2083
Outside_006	2023-04-05 16:48	33	2121
Outside_007	2023-04-05 16:48	33	2121
Outside_008	2023-04-05 16:48	33,6	2083
Outside_010	2023-04-05 16:49	33	2121
Ship 5			
In_001	2023-04-05 16:50	33	2121
In_002	2023-04-05 16:50	33,6	2083
In_003	2023-04-05 16:50	34,8	2011
In_004	2023-04-05 16:50	33	2121
In_005	2023-04-05 16:51	33,6	2083
In_006	2023-04-05 16:51	34,2	2047
In_007	2023-04-05 16:51	34,2	2047
In_008	2023-04-05 16:51	33	2121
In_009	2023-04-05 16:51	33,6	2083
In_010	2023-04-05 16:51	34,2	2047
Out_001	2023-04-05 16:52	33,3	2102
Out_002	2023-04-05 16:52	34	2059
Out_003	2023-04-05 16:52	33,6	2083
Out_004	2023-04-05 16:52	34,6	2023
Out_005	2023-04-05 16:52	34	2059
Out_006	2023-04-05 16:52	33,3	2102
Out_007	2023-04-05 16:52	33,6	2083
Out_008	2023-04-05 16:52	34,2	2047
In_009	2023-04-05 17:21	31,2	2244
In_010	2023-04-05 17:21	33	2121
Out_001	2023-04-05 17:22	32,3	2167
Out_002	2023-04-05 17:22	32,4	2160
Out_003	2023-04-05 17:22	32,2	2174
Out_004	2023-04-05 17:22	31,2	2244
Out_005	2023-04-05 17:22	32,4	2160
Out_006	2023-04-05 17:22	31,8	2201
Out_007	2023-04-05 17:22	31,8	2201
Out_008	2023-04-05 17:22	31,6	2215
Out_009	2023-04-05 17:22	31,2	2244
Out_010	2023-04-05 17:22	32,4	2160
Ship 12			
In_001	2023-04-05 17:24	34,8	2011
In_002	2023-04-05 17:24	33	2121
In_003	2023-04-05 17:24	33,6	2083
In_004	2023-04-05 17:24	33,6	2083
In_005	2023-04-05 17:24	33	2121
In_006	2023-04-05 17:25	33,6	2083
In_007	2023-04-05 17:25	33,6	2083
In_008	2023-04-05 17:25	33	2121
In_009	2023-04-05 17:25	32,4	2160
In_010	2023-04-05 17:25	32,4	2160
In_011	2023-04-05 17:25	32,7	2141
Out_001	2023-04-05 17:25	31,6	2215

Out_009	2023-04-05 16:52	33	2121
Out_010	2023-04-05 16:52	34	2059
Out_011	2023-04-05 16:52	33	2121
Ship 6			
InDeep_001	2023-04-05 16:54	34,2	2047
InDeep_002	2023-04-05 16:54	33,6	2083
InDeep_003	2023-04-05 16:54	34,8	2011
InDeep_004	2023-04-05 16:54	33,6	2083
InDeep_005	2023-04-05 16:54	34,2	2047
InDeep_006	2023-04-05 16:54	34,2	2047
InDeep_007	2023-04-05 16:54	34,2	2047
InDeep_008	2023-04-05 16:54	33,6	2083
InDeep_009	2023-04-05 16:55	34,2	2047
InDeep_010	2023-04-05 16:55	33,6	2083
In_001	2023-04-05 16:55	34,2	2047
In_002	2023-04-05 16:55	34,8	2011
In_003	2023-04-05 16:55	34,8	2011
In_004	2023-04-05 16:55	34,2	2047
In_005	2023-04-05 16:55	34,8	2011
In_006	2023-04-05 16:55	33,5	2090
In_007	2023-04-05 16:55	33,6	2083
In_008	2023-04-05 16:55	34,2	2047
In_009	2023-04-05 16:55	34,2	2047
In_010	2023-04-05 16:55	35,4	1977
Out_001	2023-04-05 16:56	33,6	2083
Out_002	2023-04-05 17:25	31,2	2244
Out_003	2023-04-05 17:25	32,4	2160
Out_004	2023-04-05 17:25	31,8	2201
Out_005	2023-04-05 17:25	32,4	2160
Out_006	2023-04-05 17:25	31,8	2201
Out_007	2023-04-05 17:25	31,8	2201
Out_008	2023-04-05 17:25	31,2	2244
Out_009	2023-04-05 17:25	33	2121
Out_010	2023-04-05 17:26	32,1	2181
Out_011	2023-04-05 17:26	32,1	2181
Out_012	2023-04-05 17:26	32,1	2181
Out_013	2023-04-05 17:26	32,4	2160
Ship 14			
Inside_001	2023-04-05 16:32	31,8	2201
Inside_002	2023-04-05 16:32	33	2121
Inside_003	2023-04-05 16:32	33,6	2083
Inside_004	2023-04-05 16:32	33,6	2083
Inside_005	2023-04-05 16:32	32,4	2160
Inside_006	2023-04-05 16:32	33	2121
Inside_007	2023-04-05 16:32	32,1	2181
Inside_008	2023-04-05 16:32	34,2	2047
Inside_009	2023-04-05 16:32	31,8	2201
Inside_010	2023-04-05 16:32	32,4	2160
Outside_001	2023-04-05 16:33	32,4	2160
Outside_002	2023-04-05 16:33	31,2	2244

Out_002	2023-04-05 16:56	34,2	2047	Outside_003	2023-04-05 16:33	32,7	2141
Out_003	2023-04-05 16:56	34,2	2047	Outside_004	2023-04-05 16:33	31,5	2222
Out_004	2023-04-05 16:56	33,6	2083	Outside_005	2023-04-05 16:33	32,1	2181
Out_005	2023-04-05 16:56	34	2059	Outside_006	2023-04-05 16:33	32,4	2160
Out_006	2023-04-05 16:56	33,6	2083	Outside_007	2023-04-05 16:33	32,1	2181
Out_007	2023-04-05 16:56	32,4	2160	Outside_008	2023-04-05 16:33	32,7	2141
Out_008	2023-04-05 16:56	33	2121	Outside_009	2023-04-05 16:33	32,7	2141
Out_009	2023-04-05 16:56	33,6	2083	Outside_010	2023-04-05 16:33	32,4	2160
Out_010	2023-04-05 16:56	33,6	2083	Outside_011	2023-04-05 16:33	31,2	2244
Ship 7				Outside_012	2023-04-05 16:33	32,7	2141
In_001	2023-04-05 16:58	31,2	2244	Ship 15			
In_002	2023-04-05 16:58	30,6	2288	In_001	2023-04-05 17:13	34,2	2047
In_003	2023-04-05 16:59	31	2258	In_002	2023-04-05 17:13	36,1	1939
In_004	2023-04-05 16:59	31,8	2201	In_003	2023-04-05 17:13	33	2121
In_005	2023-04-05 16:59	32,4	2160	In_004	2023-04-05 17:14	34,2	2047
In_006	2023-04-05 16:59	31,8	2201	In_005	2023-04-05 17:14	32,4	2160
In_007	2023-04-05 16:59	31,2	2244	In_006	2023-04-05 17:14	32,4	2160
In_008	2023-04-05 16:59	31,2	2244	In_007	2023-04-05 17:14	32,4	2160
In_009	2023-04-05 16:59	30,6	2288	In_008	2023-04-05 17:14	33,6	2083
In_010	2023-04-05 16:59	31,8	2201	In_009	2023-04-05 17:14	33	2121
Out_001	2023-04-05 16:59	32,4	2160	In_010	2023-04-05 17:14	33,6	2083
Out_002	2023-04-05 16:59	33	2121	In_011	2023-04-05 17:14	33	2121
Out_003	2023-04-05 16:59	32,4	2160	In_012	2023-04-05 17:14	32,4	2160
Out_004	2023-04-05 16:59	31,2	2244	In_013	2023-04-05 17:14	32,4	2160
Out_005	2023-04-05 16:59	31,2	2244	In_014	2023-04-05 17:14	33	2121

Out_006	2023-04-05 16:59	31,8	2201
Out_007	2023-04-05 16:59	31,8	2201
Out_008	2023-04-05 16:59	31,2	2244
Out_009	2023-04-05 16:59	31,2	2244
Out_010	2023-04-05 17:00	32,4	2160
InGap_001	2023-04-05 17:01	31,3	2236
InGap_002	2023-04-05 17:01	31,2	2244
InGap_003	2023-04-05 17:01	30,6	2288
InGap_004	2023-04-05 17:01	30	2333
InGap_005	2023-04-05 17:01	31,2	2244
InGap_006	2023-04-05 17:01	31,8	2201
InGap_007	2023-04-05 17:01	31,2	2244
InGap_008	2023-04-05 17:01	31,8	2201
InGap_009	2023-04-05 17:01	31,8	2201
InGap_010	2023-04-05 17:01	31,8	2201
OutGap_001	2023-04-05 17:02	32,4	2160
OutGap_002	2023-04-05 17:02	30,6	2288
OutGap_003	2023-04-05 17:02	29,7	2357
OutGap_004	2023-04-05 17:02	30	2333
OutGap_005	2023-04-05 17:02	30	2333
OutGap_006	2023-04-05 17:02	29,4	2381
OutGap_007	2023-04-05 17:02	30	2333
OutGap_008	2023-04-05 17:02	31,8	2201
OutGap_009	2023-04-05 17:02	31,8	2201
OutGap_010	2023-04-05 17:02	30,6	2288

Out_001	2023-04-05 17:15	33,6	2083
Out_002	2023-04-05 17:15	31,8	2201
Out_003	2023-04-05 17:15	31,8	2201
Out_004	2023-04-05 17:15	31,2	2244
Out_005	2023-04-05 17:15	33	2121
Out_006	2023-04-05 17:15	31,8	2201
Out_007	2023-04-05 17:15	31,2	2244
Out_008	2023-04-05 17:15	34,8	2011
Out_009	2023-04-05 17:15	33	2121
Out_010	2023-04-05 17:15	32,4	2160