Survey Report of the Vaigat Iceberg-Microbial Oil Degradation and Archaeological Heritage Investigation Project Expedition, July-August 2019

Matthew J. Walsh, Daniel F. Carlson, Pelle Tejsner, with Jens Fog Jensen

The Bear Trap.

Warning! *This report contains photographs of human skeletal remains from archaeological sites. These images are included here to show the type and extent of human remains evident at the archaeological sites described. None of the graves observed during the 2019 survey were handled or altered in any way to obtain these images, and the utmost respect was taken by the survey team in documenting these remains.*

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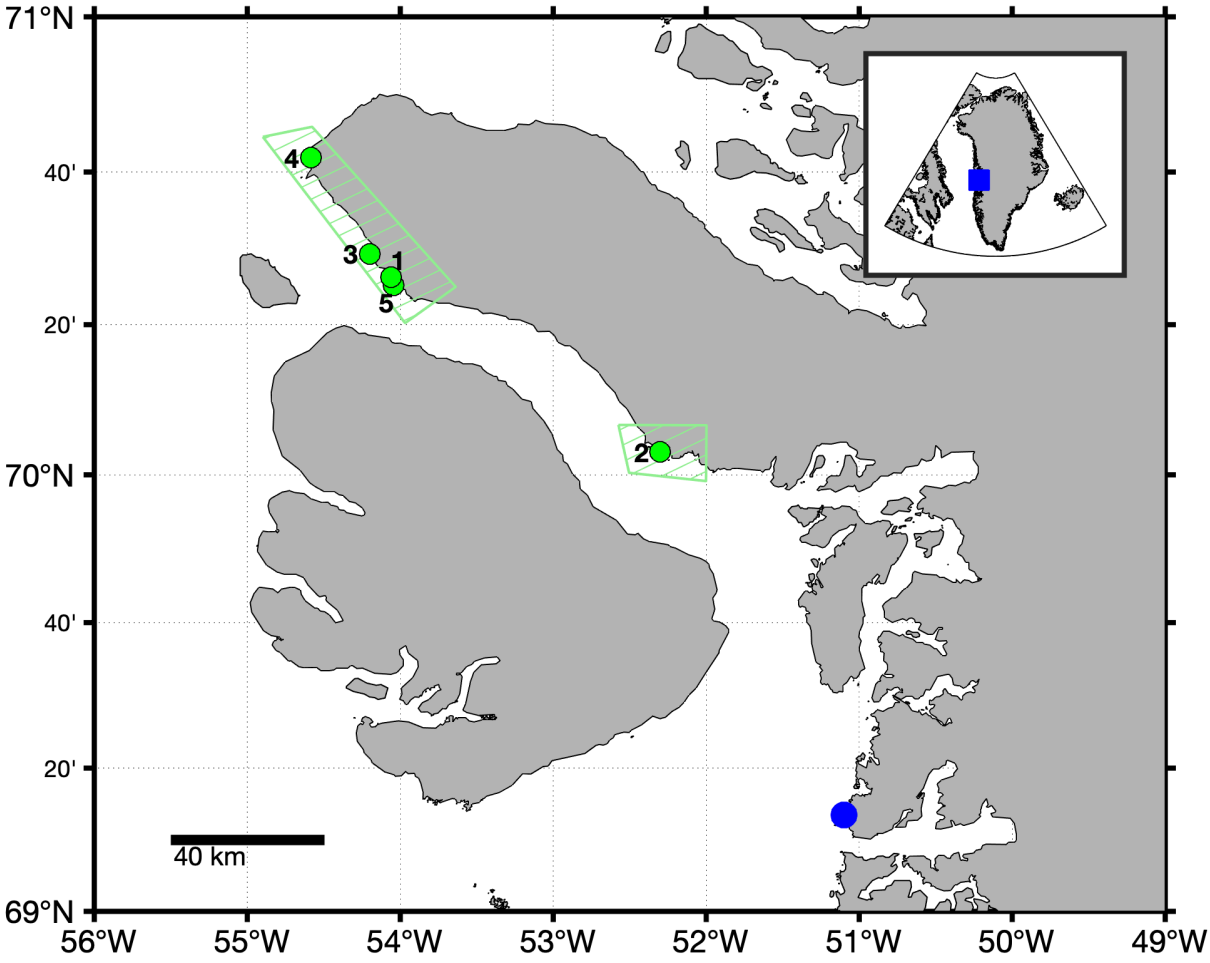
Introduction

The Vaigat Iceberg-Microbial Oil Degradation and Archaeological Heritage Investigation (VIMOA) project surveyed five archaeological sites in the Nuussuaq peninsula of northwest Greenland between July 31 – August 14, 2020. General findings of the major sections of the survey are summarized in Walsh et al. (2020; included as Appendix A). The primary goal of the survey was to re-record sites previously visited by Jensen in 2000 in order to compare coastline and site degradation over the last two decades and to acquire high-resolution photo documentation of at-risk sites in the region.



Map 1. Map of the general areas surveyed during the 2019 VIMOA project. The blue square in the inset map marks the region in Greenland. The blue circle marks the location of Ilulissat. Hashed green polygons demarcate the overall areas surveyed and the numbered green dots indicate the locations of the sites, numbered as they appear in this report. A single ground survey was also conducted roughly between the indicated survey areas, but resulted in just the observation of a single non-diagnostic archaeological feature (tent ring).

Most of the sites visited were previously surveyed in 2000 by Jens Fog Jensen and are described in his report (Jensen 2001). However, the 2019 VIMOA survey also identified additional features at many of the sites. We also provide detailed photographic documentation of numerous major features at each

site, including high-resolution ground and aerial photography. All features were recorded using a handheld Garmin GPS and were recorded in lat/lon wgs84. If you are opening any of the subsequent geotiffs provided in this report in, e.g., QGIS change the projection to UTM zone 21N for accurate locations. The high-resolution orthomosaic images can be accessed and downloaded freely online at the links given in the text and provide exceptional resolution of many of the sites and features described herein. As more images are processed the results will appear in the Greenland Digital Archaeology Community Data Repository on Zenodo: https://zenodo.org/communities/gda

Orthomosaic overview map and elevation models of the Nussaq, Atanikurluk, and Bear Trap sites are also included here as Appendices.

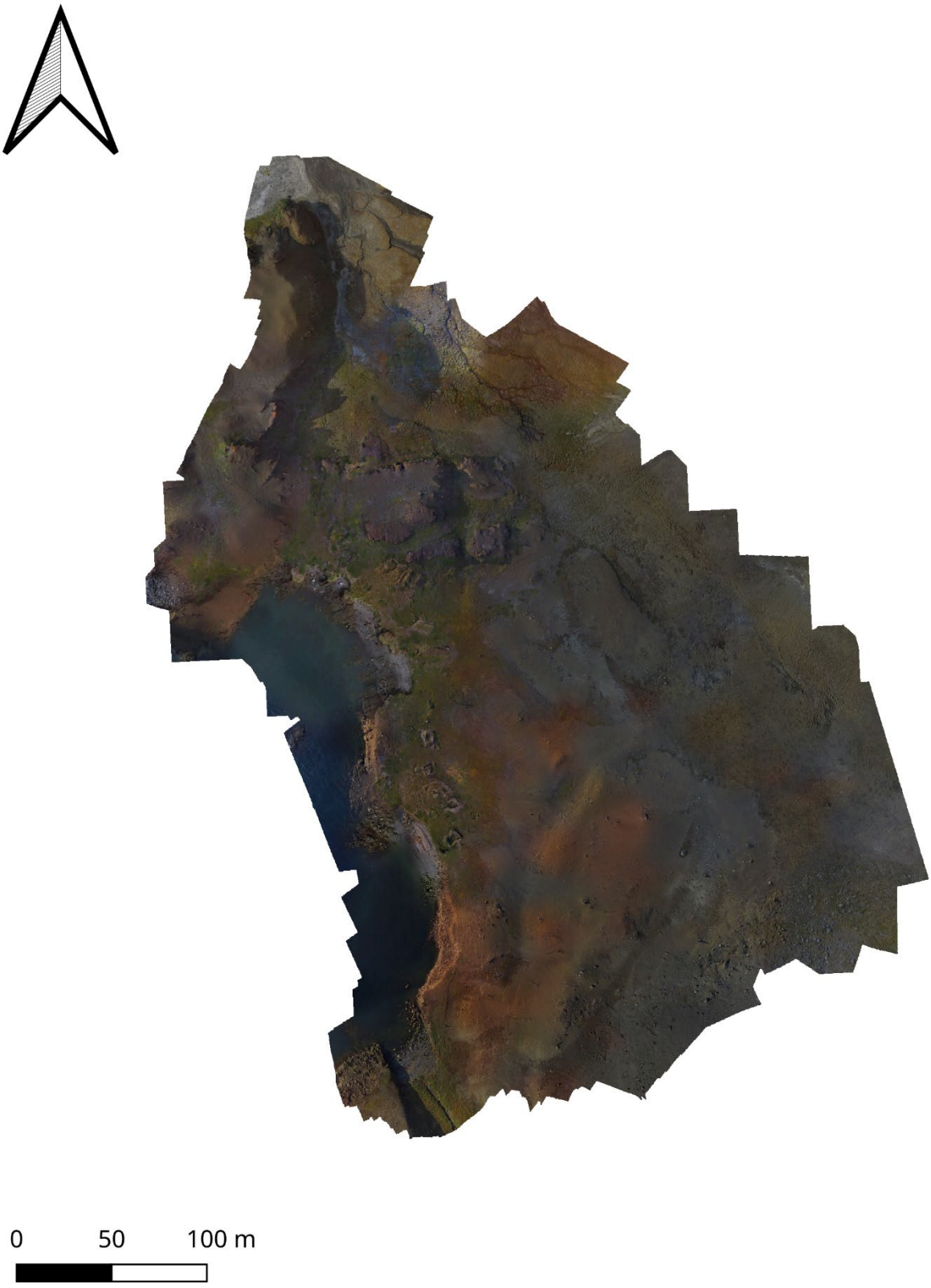
1.Nussaq (Nuusaq; NKAH 3623; Map No. 70V1-III-7)

In his 2001 report, Jens Fog Jensen writes (translated/paraphrased from Danish):

> Nussaq (Palaeo-Eskimo, Thule, Historical). Nussaq is a very large settlement, beautifully situated on a small plain by a west-facing bay. The site contains 9 trapezoidal peat houses, a foundation of peat and a 6 x 3.5 m large house situated in the southeastern part of the settlement. In addition to the south-west gable of the house, facing the beach, there is another 4 x 3.5 m large room. The Christian cemetery is situated high on the hillside south of the latter ruin. A few flakes of killiaq were found in the widespread midden layers eroded along the coastline, but an actual Palaeo-Eskimo horizon could not be recognized.

The 2019 VIMOA survey of the site came across numerous exposed human skeletal remains laying on the ground surface across the site. These had presumably been removed from nearby graves and scattered by scavengers (but not from the Christian cemetery). The Christian cemetery mentioned in Jensen's report comprises roughly 30 quite uniformly elongate ovoid stone heap graves of adults and children, some with exposed coffin-planks. However, these are not the only graves in the vicinity. No less than eleven stone cist and cairn graves were also located behind the site along its east and southeastern margins, along with at least three others along the north edge of the site and two (possibly three) others roughly in the middle of the site, between the north and south clusters of peat houses. Predominantly, these are stone cist graves with over-lain capstones and cairns, many with visible and partly-exposed human skeletal remains, including four graves containing easily visible human crania and two with visible long bones (i.e. femora and humeri), along with many other unidentifiable skeletal elements (see **Map 2.** below).

Three tent rings are also visible in the site vicinity. There is also another tent ring on one of the bluffs roughly 150 meters north-northwest of the village area, overlooking the cove immediately to the north.



Map 2. Aerial orthomosaic map of the Nussaq village site.

Notable features and locations identified at the Nussaq site:

- N 70˚ 26.275; W 54˚ 03.541; human cranium laying exposed in the shadow of a rock outcrop; badly weathered and sun-bleached, frontal section only (Figure 1, below);

Figure 1. Section of human cranium, surface find.

- N 70˚ 26.178; W 54˚ 03.484; human femur, badly weathered and sun-bleached, missing femoral head and most of the proximal end, distal condyles missing, decayed (Figure 2, below);

Figure 2. Human femur laying exposed on ground surface.

- N 70˚ 26.134; W 54˚ 03.439; Grave 3: stone cist grave with scattered cairn, human cranium visible;
- N 70˚ 26.148; W 54˚ 03.472; Grave 5: stone cist grave with scattered cairn, human cranium (just skull cap portion from a sub-adult) as well as two femurs and a tibia visible (from an adult); possible double burial;
- N 70˚ 26.245; W 54˚ 03.776; undetermined stone cairn to the northwest of the main site; possible cache?
- N 70˚ 26.307; W 54˚ 03.866; rectangular tent ring (roughly 57 stones), 3x4 meters, on sheltered uplift south of and overlooking a small cove, up over the rocky bluff that defines the north end of Nussaq site. The tent ring sits just below a high promontory with a relatively flat ground surface of c. 20x20 meters, with a commanding view of the surrounding seascape. No cultural materials evident (Figure 3, below);

Figure 3. Tent ring at the north of the rocky escarpment to the north of Nussaq village site, overlooking a cove.

- N 70˚ 26.203; W 54˚ 03.612; circular tent ring (17 stones, some slightly disturbed/offset) (Figure 4, below; photo view to the north);

Figure 4. Tent ring in southern section of Nussaq village site.

- N 70˚ 26.198; W 54˚ 03.611; Grave 10: stone cist grave with sparse cairn, human cranium visible at southeast end, partly obscured by turf (Figure 5, below; overview photo view looking north);

Figure 5. Overgrown grave cairn (left); close-up between stones reveals visible section of human cranium (right).

- N 70˚ 26.205; W 54˚ 03.594; Grave 11: collapsed stone cist grave with roughly 160x160cm outer margin and inner dimensions of roughly 75x60 cm, collapsed capstone; photo view to the south with other graves in background (note: a worked piece of whale bone [spoon?] visible inside the grave enclosure) (Figure 6, below);

Figure 6. Overgrown grave cairn near eroding edge of beach terrace (left); close-up between stones reveals moss-covered human remains and a worked bone object (right).

- N 70˚ 26.559; W 54˚ 03.623; modern tent ring; stones are loose above the surface, and two large boulders have been incorporated into the ring; c. 3.5x4m semi-ovoid shape; roughly 10m west towards the water is a circular fire pit (N 70˚ 26.555; W 54˚ 03.644); modern debris and

trash scatter throughout the area; a single, non-diagnostic broken chalcedony flake fragment was found among some boulders immediately north (c. 8m) of the campsite;

Graves at Nussaq (apart from the Christian cemetery)

- N 70˚ 26.170; W 54˚ 03.417; Grave 2: stone cist with four intact capstones and scattered cairn stones, with a visible human cranium inside;
- N 70˚ 26.184; W 54˚ 03.421; Grave 1: stone cist with intact large capstones, partially collapsed with scattered cairn stones. No human remains;
- N 70˚ 26.121; W 54˚ 03.373; Grave 4: stone cist with partially collapsed capstones and widely dispersed cairn stones at the base of the slope up to the bluff at the southernmost margin of the site; one human femur visible beneath one of the collapsed capstones;
- N 70˚ 26.148; W 54˚ 03.549; Grave 6: stone cist, partially collapsed, with one intact capstone; human femur, skull cap and single rib visible inside cist;
- N 70˚ 26.118; W 54˚ 03.466; Grave 7: stone cairn; probably a grave, but no visible human remains;
- N 70˚ 26.127; W 54˚ 03.479; Grave 8: stone cairn grave with large collapsed capstone; sub-adult human cranium visible inside;
- N 70˚ 26.220; W 54˚ 03.575; Grave 9: stone cist cairn grave, mostly collapsed with one intact large capstone slab; human femur visible inside enclosure; just west of other graves, built adjacent to the east end of a large, low rock outcrop about c. 10 meters west of a circular double tent ring (Figure 7, below);

Figure 7. Collapsed grave cairn.

- N 70˚ 26.221; W 54˚ 03.553; circular double tent ring; inner ring c. 2.5 meters in diameter, outer ring c. 3.4 meters in diameter; stones are well-set into the ground with considerable lichen coverage. The stones of the outer ring are somewhat displaced. Roughly twenty stones make up the inner ring and between 17-20 for the outer ring but some outliers are difficult to attribute to the outer ring with certainty. Photo view to the east towards shore with Grave 9 at back right (Figure 8, below);

Figure 8. Double tent ring in roughly the center of the Nussaq village site; view looking west-northwest.

Nussaq North:

At the base of the slope at the north end of the Nussaq site, between the bluff and the northernmost turf house, are three (possibly four) stone cist graves which may previously have been mistaken for caches or trap features. Here we have designated them "NG" for "North Graves". NG1 is the farthest inland, NG2 (possibly two side-by-side graves) is roughly between NG1 and NG3, and NG3 is closest to the shoreline, although still c. 35 meters up from the beach.

- N 70˚ 26.269; W 54˚ 03.677; Nussaq North Grave 1 (NG1): stone cist with capstone (no cairn) with human cranium visible beneath capstone (Figure 9, below);

Figure 9. Collapsed stone cist grave in northern section of Nussaq village site; overview (left); close-up between stones reveals human cranium visible beneath the collapsed capstone.

- N 70˚ 26.266; W 54˚ 03.674; Nussaq North Grave 2 (NG2): possible grave (possibly two graves set immediately side by side, delimited by a single line of upright slabs) in close proximity of about two meters just southwest of NG1 where the hillside starts to gently slope down before leveling out roughly 20 meters from where the terrace falls down onto the beach. This feature has a stone slab capstone similar to the other graves at the site, but there are no visible human remains. If a grave, it possibly consists of two sections delimited by upright stones making two rectangular spaces within the overall stone square (Figure 10, below);

Figure 10. Likely overgrown grave in north section of Nussaq village site.

- N 70˚ 26.263; W 54˚ 03.680; Nussaq North Grave 3 (NG3): possible stone cist grave with capstone slab. This feature is in line with NG1 and NG2, but like NG2 showed no empirical evidence of human remains; however, its proximity and similar construction to NG1 suggests that it may possible be a grave (Figure 11, below);

Figure 11. Overgrown grave in north section of Nussaq village site; overview looking northeast with grave in the foreground and beach and bluffs north of the site in the background (left); close-up of collapsed stones (right).

- N 70˚ 26.248; W 54˚ 03.784; double tent ring in depression just northwest of the north end of the terrace, slightly up the northernmost bluff; inner ring c. 4.5 meters in diameter, outer ring c. 6.5 meters in diameter; immediately south of the outer ring (c. one meter) is a circular concentration of stones (cache?) (Figure 12, below);

Figure 12. Double tent ring in deflated terrace just north of the Nussaq village site proper; overview looking southwest (left); close-up (right).

North of Nussaq site along west-facing cove and overlooking upland:

- N 70˚ 26.624; W 54˚ 03.712; modern tent ring, ovoid and 3.5x5m, located on gravelly beach uplift (Figure 13, below);

Figure 13. Modern tent rings up from the beach of the cove north of the Nussaq village site.

- N 70˚ 26.531; W 54˚ 03.601; circular tent ring, c. 4 meters in diameter; stones well-set into the ground with undisturbed lichen. Compare with modern tent ring camp just south (Figure 13, above); both at shady base of ridge slope up from the beach about 50 meters from shore along the long cove north of Nussaq (Figure 14, below);

Figure 14. Well-set tent ring at the base of the slope up from the beach of the cove north of the Nussaq village site; overview looking north up the beach (left); close-up (right).

- N 70˚ 26.696; W 54˚ 03.826; position is at the center of three possible cairns – each likely modern, once possibly even natural – at the northern-most extent of the beach, just south of a small cove down from a rocky, gravelly landform which formed a triangle between two streams. No other archaeological materials in the vicinity. Given the proximity to the modern camp rings, these cairns are probably modern, possibly built for recreation (Figure 15, below).

Figure 15. Small cairn (one of three or four) at north end of the cove north of the Nussaq village site; overview looking south down the beach towards Nussaq (left); close-up (right).

- N 70˚ 26.633; W 54˚ 03.324; Elev. ~83 meters; cairn atop the ridge east of the beach, overlooking the Straight, north of the Nussaq site; another similar cairn(s) is visible c. 100 meters north on an adjacent, slightly lower rocky escarpment;
- N 70˚ 26.669; W 54˚ 03.371; Elev. ~69.1 meters; two stone features, one a cairn and the other a stone box open at one end; the cairn (Figure 16, below, to the left) is a slightly elongated pile of stones (c. 160x125 cm and about 40 cm high) not unlike some of the graves in the valley below, but no remains were observed on close surface examination; the stone box (below, to the right) containing an enclosure of c. 90x30 cm, may be a fox trap or some type of box hearth, but no cultural materials in or nearby and no sign of charcoal, smudging or discoloration;

Figure 16. Stone features at the top of the bluff east overlooking the cove north of the Nussaq village site; collapsed (?) stone cairn (right); stone box (right). The streambed in the background flows into the cove (out of shot and downhill to the left in the photo) from a high inland valley that leads up into the interior of the Nuussuaq peninsula (out of shot to the right in photo). Another relatively small stone cairn is just south of these features on the same flat rocky ground surface at the edge of the ridgeline overlooking the cove (roughly ten meters behind and to the right of the position from which this photo is taken from).

The Nussaq site also contains a midden layer atop the natural bedrock which is elevated in places roughly 3-4 meters above the beach. The midden is relatively thin, c. 30-40 centimeters in thickness. This is actively eroding into the west-facing cove (Figure 17, below).

Figure 17. Top: Coastal bedrock and turf with midden, view looking north at northern end of the rocky beach; Bottom: close-up of the above slumping section of midden, looking south.

2.Atanikerluk (Kangerup nûa, Atanikerluk East & West, Tartunaq Bay; NKAH 1724; Map No. 70V2-III-007)

Jens Fog Jensen's report (2001; translated and paraphrased here) has this to say of the Atanikerluk village site:

> **Lb. No. 15** (Saqqaq, Thule, historical)
> **Atanikerdluk**

Lb. No 15 A (Paleo-Eskimo)
On a 70 m wide rocky beach on the east side of Atanikerdluk, lithic flakes were found among the beach stones. Behind the beach there is a level grass- and willow-covered area surrounded by black-brown basalt cliffs. On this plain were many recent features (tent rings, etc.), and on the rocks in the west side of the bay were found completely fresh pieces of meat and intestines from seals. There is a midden eroding from beneath a grassy overgrown area in the eastern half of the bay, and is roughly two meters thick. The western part of the bay is lower than the eastern and a rocky beach embankment rolls in over crowberry and marsh grass in this half of the bay. The stones on the beach embankment are fist-sized.

Lb. No. 15 B (Saqqaq, Thule, historical)
Site no. 70V2-III-7. In front of the eroded midden edge of the well-known site Atanikerdluk were collected a few lithic flakes as well as a tool of Saqqaq type.

The 2019 VIMOA survey observed that the abandoned village site of Atanikerluk (we have chosen to maintained this spelling variant for the site throughout this report) sits on a low grassy terrace at the southernmost tip of an otherwise high headland tied-island delimited from the mainland by a wide sandy tombolo with broad crescent coves to the south and north. The area itself is roughly 16 kilometers due northwest up the coast from the modern village of Saqqaq and sits at the north end of the broad Tartunaq Bay, one of just a few safe harbors in northwest Nuussuaq. Immediately southeast of the Atanikerluk village site is a small rocky island on which a number of stone cist/cairn graves were observed, although time constraints limited our survey and documentation of them. The style of these graves is similar to those observed in Grave Clusters 2, 3, and 4 located atop the headland just to the north (described below). To wit, north of the village site, scattered across the rocky bluffs that rise up from the surrounding coastline are multiple clusters of graves. Unfortunately, due to time constraints, we were unable to get drone overviews of any of the Grave Clusters, and thus no detailed overview map is available. Like the Nussaq graves already described, most of these are well-built rectangular stone cists, many with capstones and cairns piled atop the stone enclosure. Many have exposed human skeletal remains inside and scattered around. One cluster of graves, the farthest east of the groups, is possibly what remains of a Christian cemetery (Grave Cluster 1), as the graves share characteristics with those from the Christian cemetery at Nussaq, in that the graves are not cists, but elongated ovoid piles of fist- and head-sized stones, rather than the boxy flat stone construction which makes up the other graves in the vicinity. However, this is speculation.

The Atanikerluk village consists of no less than eight square peat house foundations, each roughly 5-6 meters on each side with some variation. With just one outlier at the east margin of the terrace, these are set in two roughly northwest-southeast rows of adjacent houses: a middle row of four houses and a western row of three, all seemingly with entrances uniformly facing due southwest. Tall grass and lumpy terrain made it difficult to determine the exact dimensions of some of the floorplans, and may have obscured other features in the vicinity. A stone cache is built into the bedrock located just northwest of the western row and another two cache-like features – also incorporating the bedrock – are just south of the west row. Near these two is also an upright stone with a cervical vertebra from a whale mounted onto it. In the center of the terrace, prominently set between the house rows, as if marking a courtyard, stands an upright stone of about 1.5 meters in height. Topping this is another rectangular stone, forming a standing “T” monument in the middle of the village (Figure 18, below, left). One cist grave was located not far from the west margin of the village as one moves south and west into the rocky uplands. A single human cranium was lay exposed nearby.

Map 3. Atanikerluk village site and vicinity (blue: village site; orange: Grave Cluster 1; white: Grave Cluster 2; pink: Grave Cluster 3; green: Grave Cluster 4); the long island at bottom right has multiple stone cist graves with exposed human remains of similar fashion to those comprising Grave Clusters 3 and 4. Image taken from Google Earth.

Figure 18. Left: standing stone with perpendicular stone on top, located roughly in the center of the terrace and in the middle of what would have been the village at Atanikerluk; Right: Whale vertebra

set onto a standing stone, surrounded by scattered large stones likely from an adjacent collapsed storage cache. The flat triangular stone at the far center-right appears to have been pecked with cupules.

As mentioned by Jensen, the village site has a thick and rather extensive midden running along the southwest edge of the terrace, which is actively eroding into the strait. The midden is over a meter thick in places and contains both animal bones and lithic flakes (Figures 19 and 20, below).

Figure 19. Drone overview of the midden and bedrock along the southwest edge of the Atanikerluk village site. The stone feature (Figure 18, above) can be seen at top center of the image.

Figure 20. Close-up of the extensive Atanikerluk midden.

Graves and features in the vicinity of the Atanikerluk village site:

- N 70˚ 03.259; W 52˚ 20.145; stone box and two adjacent cairns above cove north of Saqqaq at bay at Tartunaq with good view of the surrounding area; possibly modern and nothing diagnostic (Figure 21, below);

Figure 21. Stone cairns and collapsed box structure overlooking Tartunaq Bay looking generally southeast towards Saqqaq; collapsed small cairn or box structure in foreground with small cairn in center background (left); close-up of another cairn with previous cairn in center background (center); collapsed box structure (right).

- N 70˚ 03.130; W 52˚ 20.190; box cairn; stones with undisturbed lichen; c. 200 cm x 125 cm;
- N 70˚ 03.194; W 52˚ 20.345; Grave Cluster 1 (north on bluffs above Atanikerluk); Inuit/Early Historic; At least nine graves, mostly stone cists with no evidence of additions, but a few with wood plank coffins visible, including at least one child's grave. A few graves have upright stone markers. West of central grave cluster (Grave Cluster 2), overlooking Tartunaq Bay. Most graves are well-covered (i.e. intact) stone cists with cairns over them. The positions of the graves on the rocky landscape follows the trough-like sections in the rocky escarpment, causing the graves to be quite camouflaged against the surrounding bedrock (Figure 22, below);

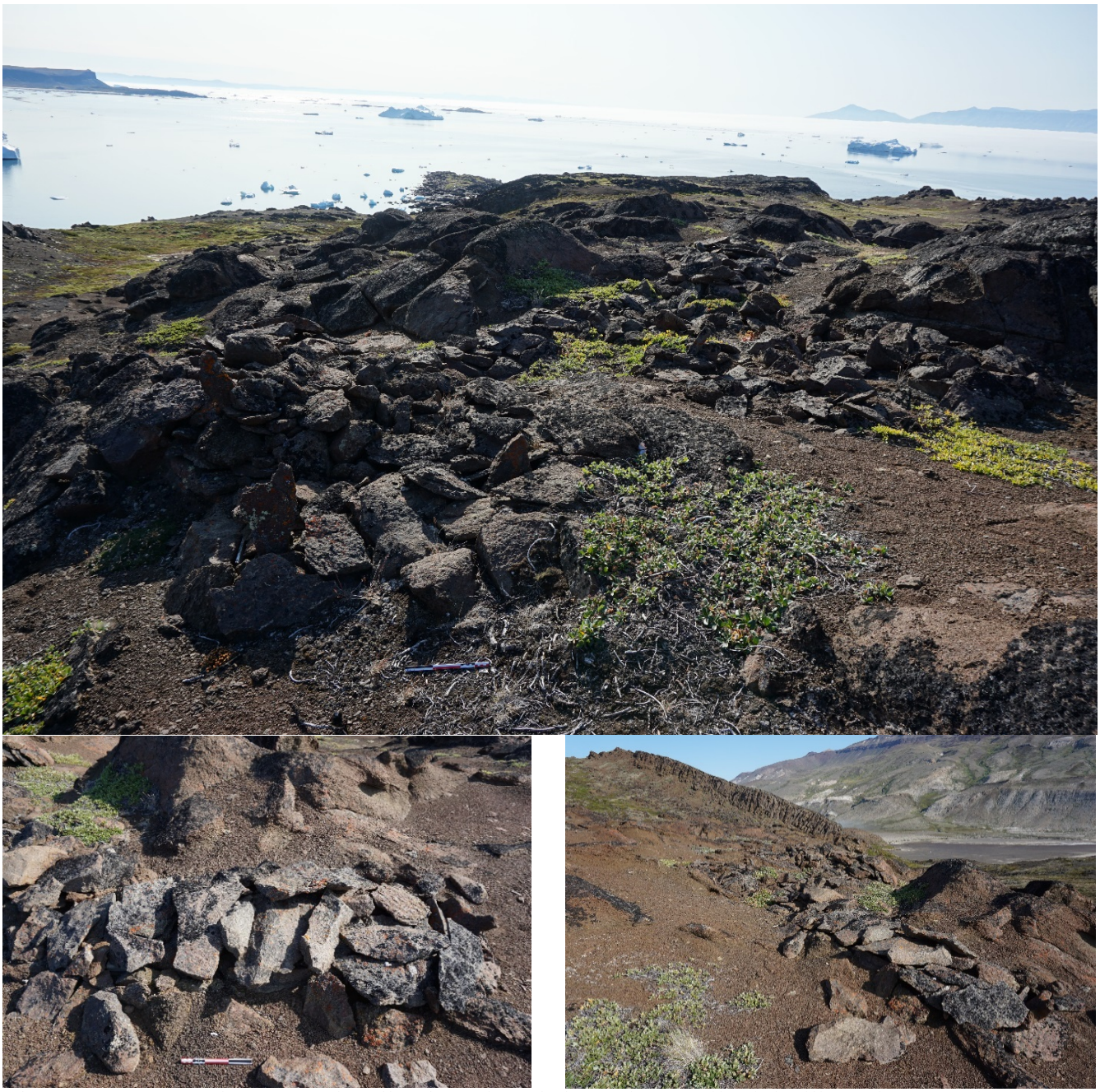


Figure 22. Grave Cluster 1 on headland north and above the Atanikerluk village site; overview looking roughly south with graves in the foreground (top); close-up of well-built intact grave (bottom, left); overview looking inland to the northeast (bottom, right).

- N 70˚ 03.168; W 52˚ 20.421; Elev. ~42.6 m; Grave Cluster 2; Thule/Early Historic (?); graves are partially to mostly covered stone cists with cairns, one at north end with exposed wood coffin (Figure 23, below);

Figure 23. Grave Cluster 2, on the headland north and above the Atanikerluk village site; overview looking west-southwest with Disko Island in the background. Note that one grave closest in the forefront is set somewhat apart from the others, and appears to have once had a wood-plank marker, possibly a cross. A few graves in this cluster have exposed wood planks from coffins. Additionally, rectangular-headed iron nails were observed, indicating that these graves (or at least some of them) date to the Early Inuit/Historic era.

- N 70˚ 03.182; W 52˚ 20.522; Grave Cluster 3 (Figure 24, below). c. 60 meters north of Grave Cluster 2; open grave with exposed cranium. Most graves in this cluster are well-built and structurally intact stone cists with cairns of robust construction, many with relatively large and intact capstones. All graves are intact except the central exposed grave with wood planks and visible human remains, including cranium and mandible;

Figure 24. Overview of Grave Cluster 3, view looking southwest from halfway up an adjacent rock escarpment.

- N 70˚ 03.149; W 52˚ 20.645; Grave Cluster 4 (west); at least eleven cairns, at least two of which (6 and 7) actually contain two or possibly more stone cists; many have exposed or visible human remains (Figure 25, below);
- N 70˚ 03.121; W 52˚ 20.661; Grave 10 of Grave Cluster 4; marked for location because graves 10 and 11 are c. 50m meters due south of the main cluster/line of graves, down a gentle gravel embankment;

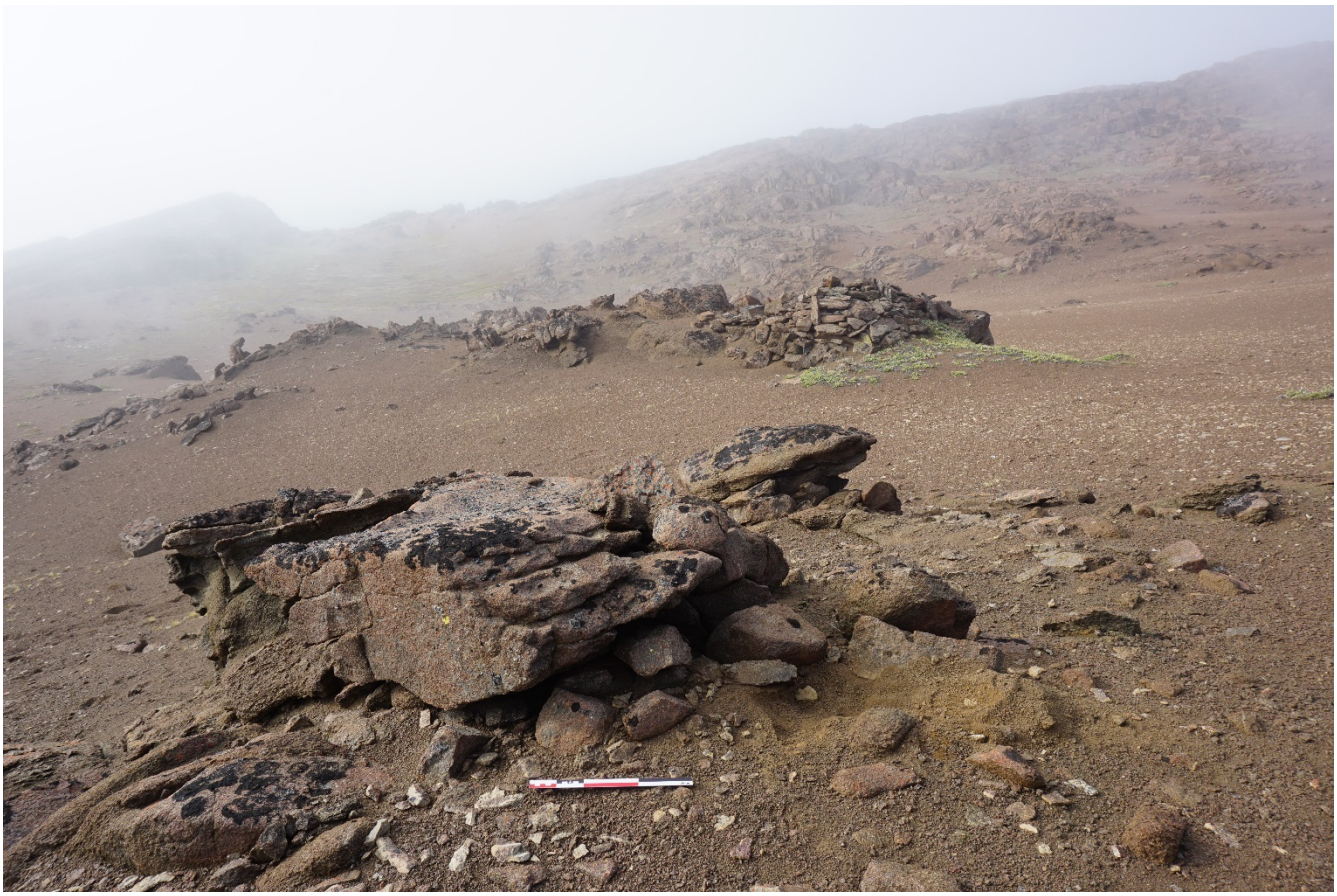


Figure 25. Overview of graves in Grave Cluster 4, view to the west-southwest in thick fog. One grave in foreground with incorporated large boulder, and another cist/cairn grave visible behind at center right.

Other features in the immediate vicinity of the Atanikerluk village site:

- N 70˚ 03.032; W 52˚ 20.642; possible meat cache (?) downslope from Grave Cluster 4 (c. SW); one large cache and one smaller one immediately adjacent among the rocks at the base of the cliff;
- N 70˚ 03.037; W 52˚ 20.313; two empty box-cairns overlooking the cove to the east of the Atanikerluk settlement;
- N 70˚ 03.039; W 52˚ 20.219; stone cist/cairn grave; well-capped cist grave with visible human remains inside, including a cranium at the west end and articulated flexed leg bones at the east end;
- N 70˚ 03.042; W 52˚ 20.634; large, well-built meat cache, half of which is built into the natural bedrock;
- N 70˚ 03.100; W 52˚ 20.456; Grave 12; solitary cist/cairn grave on the ridgeline above the settlement and between the settlement and the main Grave Clusters 1-4, overlooking the cove east of the settlement; human cranium and undeterminable long bone visible, but generally the grave is well-covered and undisturbed;

Figure 26. Example of typical contents of cist/cairn graves in the areas surrounding the Atanikerluk site (interior of a grave from Grave Cluster 4).

Note on Grave Clusters 1-4: For all four grave clusters – besides the graves themselves, visible human remains and occasional wood plank coffins – no other cultural materials were evident. It was not possible to determine if the graves were simply not furnished with grave goods, or whether grave goods had simply not preserved or remained visible, or if they had been removed. However, many of the graves – particularly those not well-camouflaged against the rocky landscape – did appear to have possibly been disturbed.

- N 70˚ 03.262; W 52˚ 20.566; cairn of honeycomb construction at the top of the bluff overlooking the cemetery complex (GC 1-4) and Iluarâ Bay to the north. Views far north along the ridgeline are two side-by-side cairns of similar size and construction (Figure 23, below);
- N 70˚ 03.409; W 52˚ 20.955; Elev. ~84 m.; two cairns at north end of the ridgeline between bays (north of cemetery) (Figure 27, below);

Figure 27. Tall (c. 1-1.5 meters high) cairns at the highest point on the rocky headland above the Atanikerluk site; left with scale, right with view looking southeast towards Saqqaq village.

Note: At the base of the bluff on the beach south of Tartunaq Bay are eleven circular tent rings of basalt rocks. Given the proximity to the community at Saqqaq and the evident foot traffic in the area, these are without question modern in origin and appear to be used often (Figure 28, below);

Figure 28. Examples of modern tent rings on the north beach of the tombolo south of Tartunaq Bay, immediately east of the rocky headland overlooking Atanikerluk village site and the graves described above (view inland roughly southeast).

- N 70˚ 04.443; W 52˚ 22.685; two-room peat house with stone foundation, just above the modern gravel beach. At c. 60 meters north of the peat house is what appears to be the low foundation of another peat house. Modern camps and debris in and around the area; also, possible scattered tent ring, but no diagnostic features or archaeological materials visible in the surrounding area (Figure 29, below). This is the remains of the peat house given as site Qaqait Lb nr. 12 in Jensen's (2001) report;


Figure 29. Two room peat house ('Hunter's Cabin') foundation in center foreground, overgrown with tall grass, with view looking northwest up the beach (left) and west (right). Disko Island can be seen in the background.

- N 70˚ 05.178; W 52˚ 23. 431; Elev. 9.2 m.; circular tent ring with 32 stones and c. 4 meter-diameter; well-set into the ground with undisturbed lichen growth; two more possible stones three meters away down a gentle slope from level ground on the south side of an old slide slump terrace, near fresh water streams to both north and south;
- N 70˚ 05.198; W 52˚ 23.379; Elev. 17.6 m.; circular tent ring with c. 21 stones; three visible inside the ring also, and c. 40 meters upslope;
- N 70˚ 05.178; W 52˚ 23.328; Elev. 21.1 m.; circular tent ring with c. 22 stones (a couple of stones are displaced down slope about one meter out of the main circle and two were visible inside the diameter of the ring);
- N 70˚ 05.918; W 52˚ 24.637; possible tent ring with c. 12 stones; also, one c. 30-meters north of coordinates with 15 stones; hard to tell if this is cultural or a natural distribution of stones as there are no other signs of construction and there are many rocks strewn around the area;
- N 70˚ 05.962; W 52˚ 24.778; tent ring with 15 stones; stones well set-in; entrance space at the north end; c. 4 meters in diameter;
- N 70˚ 06.477; W 52˚ 26.383; ten meters north of this coordinate, up on the terrace above the beach is a stone box of well-set flat stones with consistent lichen growth;
- N 70˚ 06.735; W 52˚ 26.816; disturbed rectangular tent ring of at least twenty stones, with an additional four close-by but displaced; difficult to determine the accurate dimensions of the feature, as the western portion is quite disturbed;
- N 70˚ 06.847; W 52˚ 27.018; large rectangular tent ring of at least forty-four stones; stones to the west displaced, likely due to tidal erosion; c. 5 meters N-S by 4 meters E-W (Figure 30, below);
- N 70˚ 07.031; W 52˚ 27.369; ruin of Historic period wood and stone structure (hunter's cabin on map?);
- N 70˚ 26.531; W 54˚ 03.601; circular tent ring, c. 4 meters in diameter; stones well-set into the ground with undisturbed lichen. Contrast with modern tent ring camp just to the south and described above; both located at shady base of ridge slope up from the beach about 50 meters from shore along the long cove north of Nussaq;

Figure 30. Large tent ring.

North of Tupaussat

The 2019 survey of the coastline north of Tupaussat confirmed the existing evidence which suggests very little archaeology in the area north between Atâ and the Sikillinge settlement site (Lb nr. 21). Our survey of the coastal terraces for a distance of roughly 15 km north from Tupaussat revealed just a single old but unremarkable tent ring.

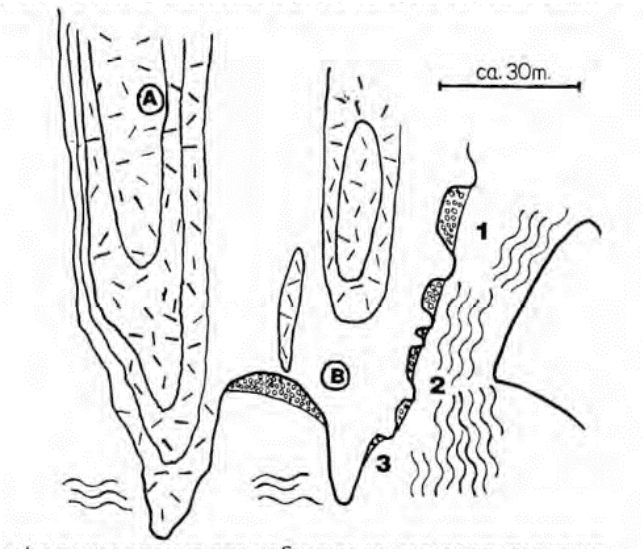
- N 70˚ 21.124; W 52˚ 19.369; Elev. 3.6 m.; rectangular tent ring with c. 39 stones, roughly 2 meters by 2.5 meters; about two meters from the beach erosion cut on a low rocky terrace between two dry streambeds; stones well set-in but not much lichen;

3.Niaqornaarsuk (NKAH 4449; Map No. 70V1-III-011)

The Niaqornaarsuk site sits at the end of a rocky tied-island connected by a broad tombolo of low grassy dunes at the north end of the alluvial fan of the Kûgssuaq River. The outcrop was likely an island of its own just a few thousand years ago. On the southern end, Jensen (2001) and Rosenkrantz (1958) reported a Saqqaq Culture site, which was confirmed by our 2019 survey. In fact, the entire north to south length of the landform should probably be considered a single archaeological site.

Jensen's 2001 survey report has this to say about the site (translated and paraphrased from Danish):

> On the easternmost tip of Niaqornaarsuk there is a Saqqaq settlement, from which Rosenkrantz has collected a considerable material. Findings from the small rocky beaches along the escarpment were collected. The scattered finds on the exposed peat surface were left in situ. There are only a few finds on the surface, and one therefore gets the impression that the area today has been picked almost clean of antiquities (see Ethnographic Collection 423/58). On the peat surface, there were some head-sized large rocks (B in overview sketch map, below), which may be remnants of dwellings, but recognizable features were not observed... On a flat shelf located on the basalt rocks approx. 13 m.h. west-southwest of the Saqqaq area described here is a well-preserved 3-4 m in diam. large circular ring (A). No findings were made in connection with this feature, but in a small meltwater run east of the tent ring, some larger pieces of killiaq were seen.
>
> Findings: Along the river streams, 53 small objects exclusively of killiaq have been collected on the small pebble beaches or more straight stone deposits between protruding rocky sections. There are no chronologically significant types between the collected objects, but the raw material indicates that this is a Saqqaq settlement. At the National Museum there is another large assemblage that was collected by Rosenkrantz.



Map 4. Sketch map of south end of Niaqornaarsuk tied-island, modified from Jensen (2001).

The 2019 VIMOA survey observed, scattered across the southern half of the basalt outcrop which makes up the tied island, a massive quantity of natural chalcedony, as described by Jensen (2001). This material lay about in crumbled fragments, in bubbly formations of tiny shimmering crystals in all shapes and sizes, from fingernail- to fist- to head-sized, as split sheets of stone and bulbous geodes. It litters the ground surface everywhere. Animal bones of all kinds litter the entirety of the area as well, in various states of advanced decay, sun-bleached and disintegrating, however, an extensive coastal midden was not observed as in other areas surveyed; rather a very thin layer can be identified in the eroding coastal escarpments of the south end of the island, but not much more. Fragments from

terrestrial mammals (presumed caribou) are mingled with the smooth, sharp remnants of shattered bird bones, and pinniped and small whale bones lay haphazardly about as if scattered like seed.

Unfortunately, due to time constraints, we were unable to get drone overviews of this site.

Figure 31 (below) provides a panoramic overview looking south of the southernmost cove on the Niaqornaarsuk site. The red arrow is roughly at B on Jensen's sketch map above and shows the general location of the projectile point found on the surface at or near the wash that Jensen describes. The blue arrow is roughly at the location of A in Jensen's sketch map above and shows the general location of one of the tent rings located on the promontory overlooking the cove.

Figure 31. Overview looking south at the south end of the Niaqornaarsuk tied-island, just north of the Kûgssuaq River alluvial fan.

A few flakes of light grey crypto-crystalline slate (i.e. 'killiaq') were observed at the southernmost end of the landform. In the same location, a single microcrystalline slate projectile point was recovered on the surface. This is a small biface with a snapped distal-basal end, probably where a tang had once been (see Figure 32, below). The find confirms the likelihood that the site is of the Saqqaq cultural complex. In the same area at the south end of the landform was also observed a single highly-deteriorated tool fashioned from whalebone, probably an awl or similar implement (not collected).

Figure 32. Projectile point found in alluvial wash on the southern end of the Niaqornaarsuk site. Note, distal end has been snapped off. We attempted to locate the missing fragment but were unsuccessful, probably owing to the fact that the find location was in a washout area the result of water

erosion from a higher point on the landmass, as numerous bone fragments and other materials had also collected in the area, and water erosion from uphill onto the relatively flat rocky surface was evident

A couple of tent rings are located on level ground higher up on the landform, overlooking the southernmost cove, also as observed by Jensen (2001; see comparison photos in Figure 33, below). There is also a tall honeycomb cairn built in recent times, probably by members of one of the geological survey crews that have visited the area with relative regularity over the last few decades. We also observed a couple of red-painted tidal-marker cairns, also of modern construction. Roughly in the middle of the landform, in the general vicinity of the honeycomb cairn is a small stone cairn underneath which is a geological survey marker (DGI marker #52257).

Figure 33. Overview panorama looking northwest of the modern honeycomb cairn in the middle of the tied-island location of Niaqornaarsuk.

Notable features and locations identified at and around the Niaqornaarsuk site:

- N 70˚ 29.305; W 54˚ 11.775; Elev. -4.9 m.; dark grey-black biface (projectile point) on cryptocrystalline basalt (slate/dacite/killiaq); collected. Measurements: length 27 mm, width at base 18 mm, snapped at distal end consistent with oblique impact fracture; the artifact was located on the surface of a flat section of ground at the southeast end of the south cove in an area scattered with natural chalcedony shatter and numerous disintegrating animal bones; water erosion was evident through the middle of the area suggesting that the point originated from higher up the hill slope (Figure 32, above);
  … also just 2.4 meters ESE of the small projectile point was a bone tool (awl) also found on the surface (not collected);
- N 70˚ 29.300; W 54˚ 11.746; Elev. 2.1 m.; grey killiaq flakes at interface between the turf and the cobble stone and rock shore; numerous lithic flakes amid the beach rocks just below the turf edge, including two utilized flakes;
- N 70˚ 29.304; W 54˚ 11.870; severely weathered and smooth-worn cobble of grey killiaq that appears to have been tested as a bi-polar core; most flake scars are weathered to a nearly smooth surface, but both bi-polar platforms are heavily tested and a few small flakes have been removed; located on the surface at the top of the southwest end of the south cove;
  … additional observations: two small marker cairns (quite low) on the west end of southwest end of the south cove near the cliff edge;
- Brass DGI marker #52257 hidden under a small cairn;
- N 70˚ 29.581; W 54˚ 12.271; Elev. 8.9 m.; relatively large basalt (slate/dacite/killiaq) biface pre-form (Figure 29, below, right) found on the surface at the base of a southeast escarpment of a flat section at the north end of the peninsula; three other fragments of the same material

(two of which re-fit; (Figure 34, below, left) found within a one-meter-area, suggesting possible tool manufacture nearby;

Figure 34. Close-up of surface finds of lithic artifacts (fragmented) at north end of the Niaqornaarsuk landform.

- N 70˚ 29.659; W 54˚ 12.274; Elev. 1.5 m.; rectangular tent ring at the end of the central trough/plain that runs nearly the whole length of the northern half of the peninsula; 32 stones with possible inner and outer ring, c. 2.5 meters by 3 meters; stones well set-in, but nothing more diagnostic; overlooked by two modern red-painted tide marker cairns to the north;

Notes on the location in general: Despite chalcedony literally scattered across nearly the entire landform, concentrated most heavily in the southern half of the escarpment, this material does not seem well-suited to tool manufacture due to various characteristics (brittle, thin cortex-to-interior ratio, internal impurities and fissures, etc.). This is true even of the thicker, purer and larger stones that appear to have a relatively smooth microcrystalline structure (i.e. even the good-looking material fractures rather than flakes when struck). The stone tools observed during survey were of a fine almost black metamorphic material that appears to have been brought in. However, most of the flakes observed are of the light grey killiaq described by Jensen (2001; see sample of flakes, Figure 35, below).

Figure 35. Sample of killiaq flakes found eroded onto the beach from the thin midden layer at the south end of Niaqornaarsuk.

- Photo of a tent ring taken at the site by Jens Fog Jensen in 2000 was re-created. These include a close-up of a tent ring at N 70˚ 29.336; W 54˚ 11.893; Elev. 5 m., showing the coastal areas along the southernmost tip of the landform (below, JFJ 2000 photo, left; MJW 2019 photo, right, Figure 36, below).

Figure 36. Overviews of the south end of the Niaqornaarsuk site.

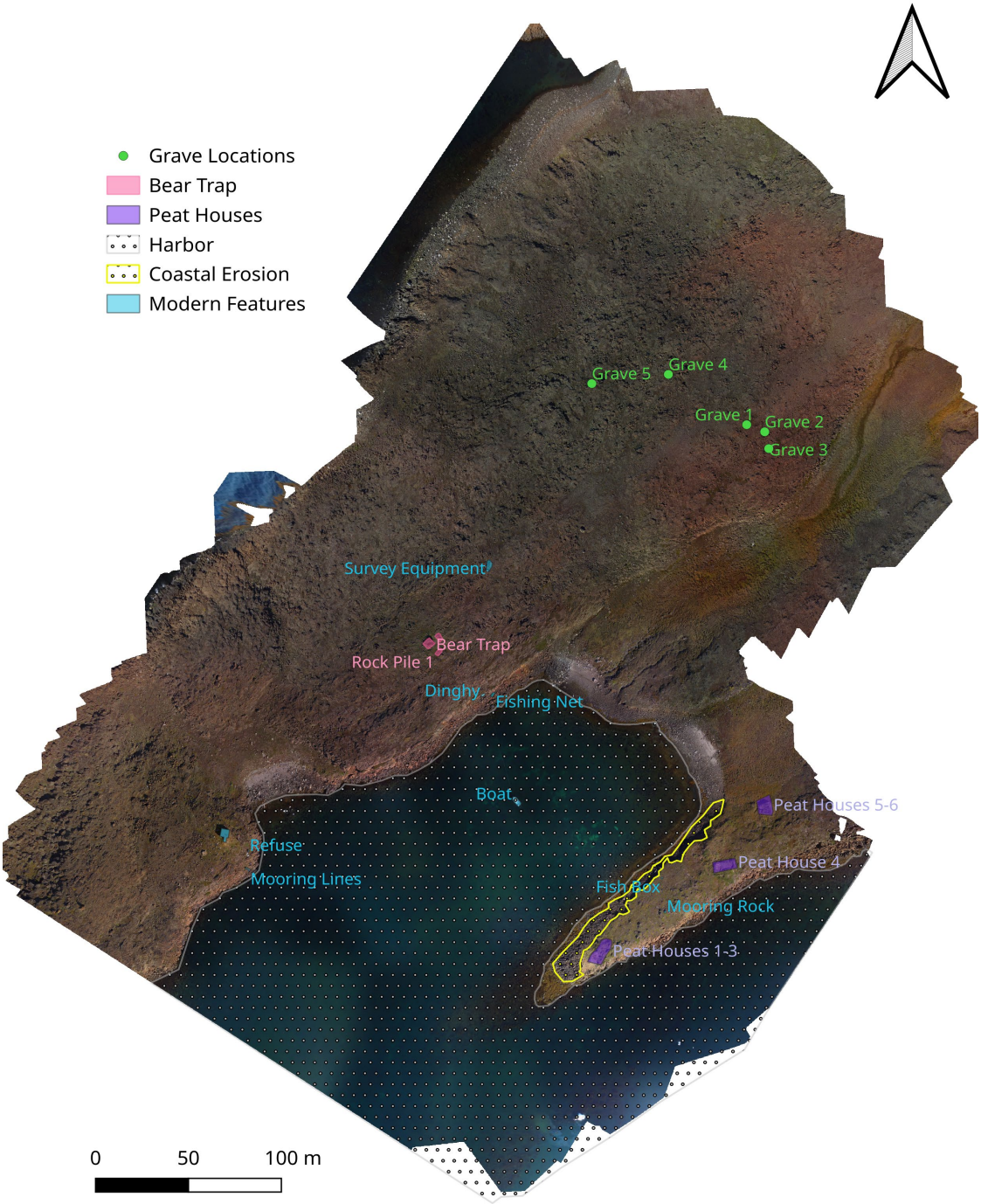
4.The Bear Trap (NKAH 3630; Map No. 70V1-0IV-005)

The 2019 VIMOA survey results reporting on the Bear Trap and surrounding area are provided in Walsh et al. (submitted; manuscript included as Appendix C). The following text and figures are taken directly from that manuscript.

The structure

The Bear Trap's structure forms a squat square of nearly 4.5 m on each side. It was assembled using dry-stone construction primarily from irregularly-sized, but angular, grey-brown basalt stone slabs observed in abundance within the immediate vicinity. It is built directly atop the bedrock basalt of the surrounding landscape. Its foundation stones are quite large and would have required multiple workers and considerable effort to move into position. Its south wall foundation is comprised of four larger blocks, including a large cornerstone on the southwest; the east wall foundation is made up of six slightly smaller, yet still large blocks, including a large cornerstone at the northwest; the outer north wall is dominated by a massive block that takes up much of the east section of the wall but the rest of the north wall foundation is made up of much smaller slabs more consistent with the standard slabs forming the majority of the structure. The outer east wall foundation is also dominated by a massive block and a considerable cornerstone at the northeast, but both blocks actually rest on smaller stones rather than directly on bedrock.

A UAV-derived orthomosaic of the Bear Trap and its surroundings, including the adjacent graves, natural harbor, peat houses, and modern features (Map 5, below):



Map 5. Aerial orthomosaic map of the Bear Trap site and surrounding area.

Figure 37. Top: The Bear Trap; view of easternmost wall and entrance looking southwest. Note, marker cairns visible in the background at far left and center left. A modern hut is also visible in the background. Bottom: An aerial drone image that shows the Bear Trap and the two adjacent rock piles. Photo: DFC.

The structure has a slender entrance and a constricted, rectangular interior space of just 0.9-1.15 m by 2.28 m. In its present state it measures roughly 1.4 m in height at its highest preserved extent, but its original height and roof morphology may only be guessed at. During our 2019 examination of the structure we noted that many of the wall stones facing into the interior are long stones and many appear to have been set so as to jut slightly into the interior by a few centimeters, suggesting to us the possibility that the roof may have been of a gabled construction similar to techniques used in early Medieval dry-stone structures, including in south Greenland, but this suggestion must be taken as conjecture. All four of the walls are consistently over a meter thick. Steenberg (1893: 5-6) gives a quite accurate accounting of the Bear Trap's dimensions. Of the outer walls, the north and west walls measure 4.39 m while the south and east walls measure 4.47 m. The south wall is 1.36 m thick. The north wall is the thickest of the structure, measuring 1.78 m wide on its east end and 1.88 m on its west end. The west wall is roughly 1.44-1.49 m thick. The south wall is the most consistent in width along its length, but is in considerable disrepair on its eastern half. Many of the stone blocks in this section of the structure are loosely scattered along the top of the wall and the wall has begun to slump into the interior at a rather precarious angle. The entrance opening is 0.55 m on the exterior of the east wall and slims faintly to just 0.47 m where it opens into the interior space. The interior space forms a nearly rectangular trapezoid measuring 2.28 m on its north side, 1.17 m on its south, 1.25 m on its east and roughly 1.15 m on its west (see Figure 37, above).

Citing Ingstad (1966: 82), McGovern (1985: 295) provides that the structure "encloses an area of 20-24 m^2". But, this appears to take into account the entirety of the structure rather than reflect the available interior space. We calculate an interior as comprising roughly just 5.7 m^3. This considers that that the original structure had a ceiling of just two meters in height (sans the entry passage). Even if the structure had originally included an interior ceiling of three meters in height, similar to the skemma storehouse at Anavik in southwest Greenland (Roussell 1941: 231), the interior space would actually account for no more than 8.55 m^3. The differences in the widths of the outer walls compared to the interior space between the Bear Trap and the Anavik storehouse (and others in the south Greenlandic Norse settlements) are considerable, with the latter providing significantly more potential interior space.

Outside of the Bear Trap structure, roughly three meters from the northeast wall – just opposite the entrance – and about four meters from the southeast wall lay two rectangular piles of stones of the same type and size of those used for its construction (Figure 2). These may be the remnants of stones which over the years have fallen from the original structure and have – at some point – been collected and assembled into piles, but this is speculation. Another notable difference between the Bear Trap and Norse skemma storehouses is that the Bear Trap rests on a relatively flat expanse of bedrock, albeit in a highly visible location on the landscape of the headland. While this is not unlike the relatively flat surface upon which storehouse No. 5 at Sandnes lies (Roussell 1936: 93), many storehouses were purposefully constructed on prominently raised sections of bedrock or even built atop large boulder erratics. The Bear Trap is not elevated in any way.

The interior floor of the Bear Trap is bare bedrock. The floor comprises a somewhat varied topography, as the section immediately to the north (right upon entering the interior) forms a slightly elevated platform which gives the impression of a raised bed-like surface, measuring 0.78 m wide by 1.88 m long. Along the edge of this, the floor drops into a trough-like channel, sitting at least 10 cm lower (15-20 cm according to Meldegaard 1995: 206) than the platform around which it forms an inverted 'L' shape when viewed from the entrance. Some stones from the inner walls have fallen into the structure,

making the trench difficult to define without moving some materials, which we did not. It is difficult to estimate the exact depth of this depressed space as it was also filled with moss and tuft grass which were not disturbed during our survey as we did not disrupt the surface soil.

Figure 38. The interior of the Bear Trap photographed from the entranceway. On the left edge of the floor the trough can be seen and to the right the raised platform area.

The Cemetery

The 2019 VIMOA expedition (Walsh et al. 2020) observed that much of the headland immediately to the east of the Bear Trap conceals a number of stone cairn graves, well-camouflaged against the natural rock formations of the area. The survey revealed no less than five graves, but given the time constraints imposed during the 2019 visit to the site the survey of the cemetery can only be considered preliminary and more graves could be in the vicinity and may be revealed in a future and more extensive survey. Our review of the extant literature did not discover any previous mention of these graves, thus this information provides novel context for interpreting the Bear Trap's possible original purpose. We identified five grave cairns covering no less than eight observable stone cists, five of which retained identifiable human remains (including at least one double grave). One cairn was extremely large, was covered by massive capstones, and appears to have been erected to cover at least three distinctive cists, and possibly more. Another collapsed and disturbed cairn covered two stone cists, both of which were exposed, as were the human skeletal remains therein. Of note, despite thousands of body-sized cavities created by the natural rock formations across the boulder-strewn

headland, none of those spaces appear to have been used as burial locations. Rather, stone cists and over-built cairns were deliberately constructed on the landscape from loose rocks. While these sometimes incorporate one or more exceptionally large boulders or sections of bedrock for one or more sides, nowhere do the natural rock formations make up the entirety of the containment area.

Interestingly, this holds true even in places in which the landform and rocks could have easily furnished naturally secluded spaces in the local terrain suitable for interring a body. This contrasts sharply with the method that seems to have dominated in the construction of meat caches, in which natural troughs and fissures in the bedrock seem to have been ubiquitously incorporated to some degree into the design of the storage area. In many cases massive boulders or bedrock make up three or all four sides of caches in the area. These natural and semi-natural enclosures would be covered by numerous large and usually long stones placed width-wise atop the storage area. Also of note in this regard, the capstones covering the grave cists often differ markedly from those of caches. Here, grave capstones were often made up of large, flat, oblong stones, sometimes multiples overlapping and frequently of a different rock type and color (mostly white granitic material) from the surrounding material and/or that used to construct the associated cist and cairn. In our observations, cache cover stones more often appear to have been made up of long, relatively flat stones placed perpendicular to the overall length of the cache space, perhaps making it easier for one or two people to open just a section of the cache by lifting a single or a couple of heavy – but not too difficult to lift – stones.

The graves are concentrated into an area of c. 400 m by 150 m running northeast-southwest following the landform of the promontory up to where the headland slopes up into the interior. The nearest grave is located roughly 100 m distance from the Bear Trap.

Figure 39. Grave cairn (“Grave Cairn 4” in notes). Left: overview of the large, partially-open cairn with overlapping white capstones and exposed opening with displaced capstone to the right. Right: the interior of one of at least three separate cists beneath the Grave 4 cairn. View to the west.

Stone features and graves observed east of the Bear Trap:

Figure 40. N 70˚ 41.943; W 54˚ 34.632; Elev. 15.6 m.; well-sealed box cairn (possibly a fox trap) with nothing visibly inside, but well-constructed and seemingly not prominent or high enough to be a place-marker. However, the inclusion of a single white-stone capstone is consistent with the conventional construction of graves in the region. Not within the domain covered by the UAV orthomosaic. 3D model available for download at: https://zenodo.org/record/4011977#.X3jASNMzbUo

Figure 41. N 70˚ 41.917; W 54˚ 34.679; Elev. 22.2 m.; Grave 1; stone cist and cairn with capstones missing; visible human remains include two human crania and some additional undetermined skeletal elements. 3D model available for download at https://zenodo.org/record/3984864#.X0jmJ9MzbUo

Figure 42. N 70˚ 41.911; W 54˚ 34.666; Elev. 21.2 m.; Grave 2; stone cist with cairn stones disturbed and distributed around; no visible human remains.

Figure 43. N 70˚ 41.906; W 54˚ 34.666; Elev. 24.4 m.; Grave 3; collapsed cairn over stone cist with visible human skeletal remains.

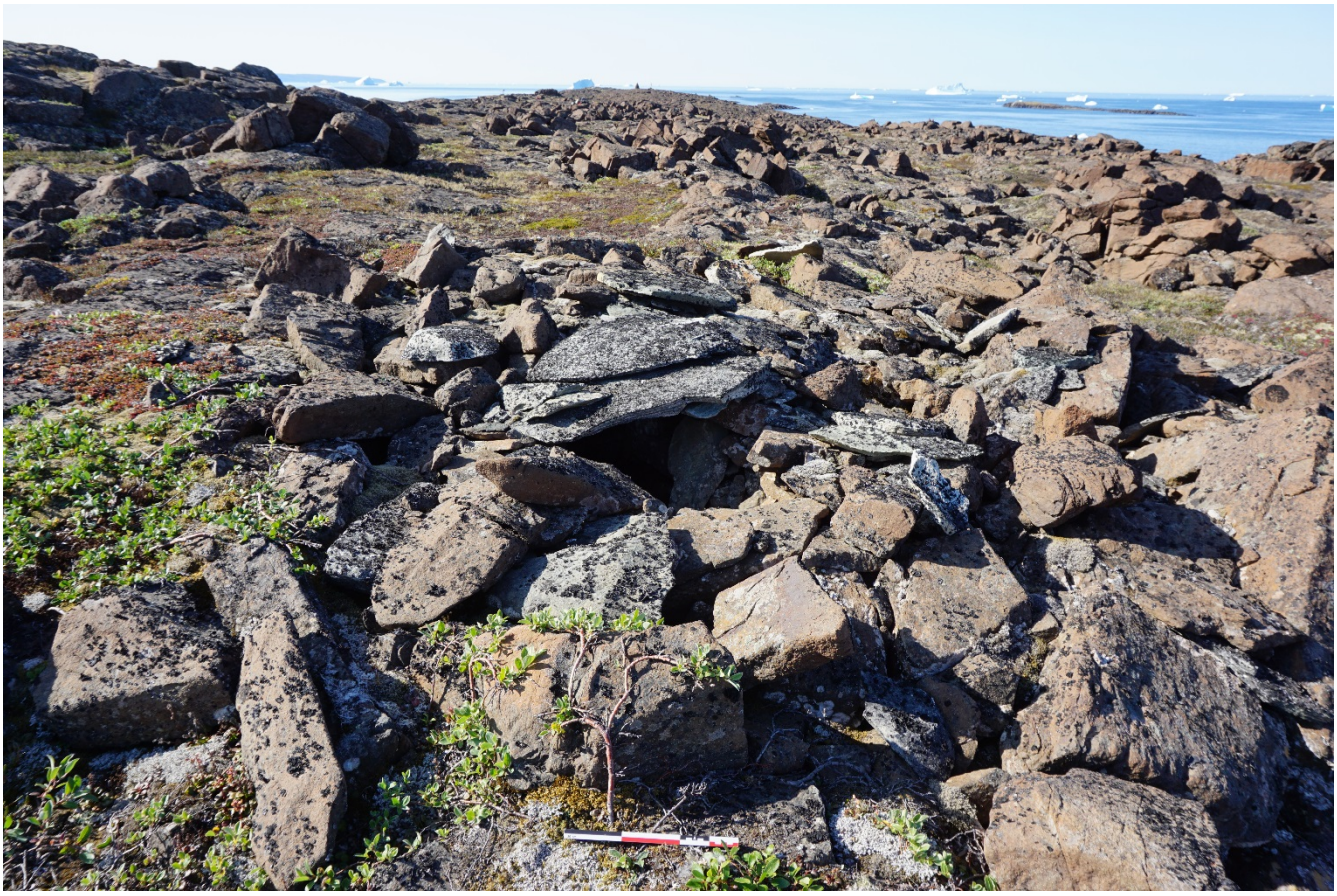


Figure 44. N 70˚ 41.931; W 54˚ 34.741; Elev. 17.3 m.; Grave 4; exposed cist/cairn with large capstones and at least three separate cists beneath the large cairn; but it is difficult to differentiate the exact dimensions and extents of each cist as they remain partially beneath intact sections of the overlapping cairn.

Figure 45. N 70˚ 41.928; W 54˚ 34.818; Elev. 15.7 m.; Grave 5; long, collapsed and exposed stone cist with cairn stones scattered around the immediate area; two cists exposed under one cairn, with visible human remains.

Two hundred meters southeast of the headland on which the Bear Trap marks the midpoint stands the ruins of a small unnamed settlement (NKAH Site 5085; Map no: 70V1-0IV-012). According to the NKAH records, this settlement is of the Thule/Neo-Inuit period. It comprises no less than six oval-rectangular semi-subterranean winter houses of peat and stone, including one rather long rectangular foundation of c. 4 m x 9.5 m. A number of these structures, including one along the west edge of the adjacent cove and the one farthest out on the promontory have begun actively eroding into the sea, along with considerable midden deposits along the inside (i.e. northwest) margins of the adjacent cove. Two whale bone artifacts (a drilled/beveled socket fragments and another drilled fragment) were observed eroding from a midden strata onto the beach of the cove immediately northwest of the settlement at N 70˚ 41.792; W 54˚ 34.737 (see below).

Datasets from the Bear Trap and vicinity:

Project photos of the Bear Trap and some of the nearby features, including one small cairn and one grave, were processed to create orthomosaics and 3D models of the structures. After processing in PhotoScan, 3D models of the Bear Trap, rock piles, and graves were exported as .obj files, for viewing in free software like MeshLab (*https://www.meshlab.net/*). The DEM and orthomosaic produced from the UAV imagery were exported as geotiffs. All raw images and processed datasets were uploaded to Zenodo and links to each dataset and are listed in Table 1.

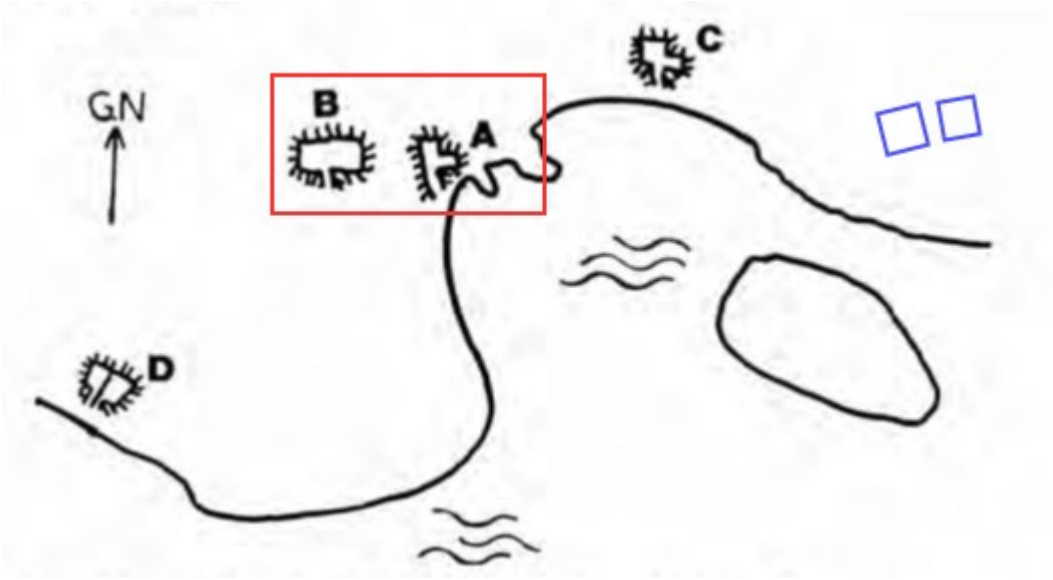
Table 1. Features at the Bear Trap that have had 3D models generated.

Name	DOI	Link	3D Model (.obj/.pdf)	DEM (.tif)	Orthomosaic (.tif)
The Bear Trap	10.5281/zenodo.3980540	https://zenodo.org/record/4075144#.X4MclMzbUo	X		
Box Cairn	10.5281/zenodo.4011977	https://zenodo.org/record/4011977#.X3jASNMzbUo	X		
Grave no. 1	10.5281/zenodo.3984864	https://zenodo.org/record/3984864#.X3i6z9MzbUo	X		
Bear Trap and surrounding area	10.5281/zenodo.4013258	https://zenodo.org/record/4013258#.X3i6bdMzbUo		X	X

5.Niaqornaq (NKAH 3662; Map No. 70V1-III-006)

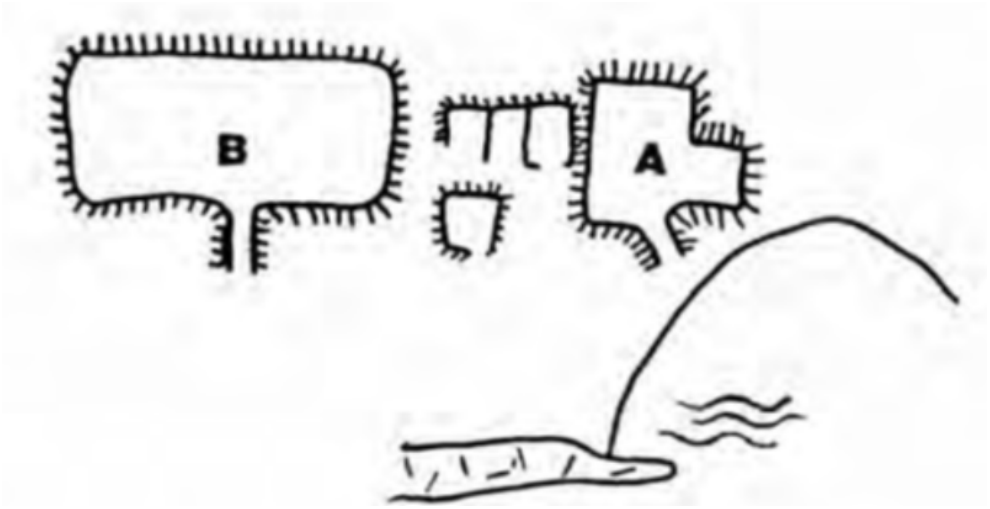
Jens Fog Jensen (2001) surveyed the Niaqornaq village site, noting the remains of multiple peat houses at both the north end of the cove and the eastern terrace. He describes that:

> **Lb. nr. 22 (Palaeoeskimo, Thule)**
> **Niaqornaq**
>
> In a smaller east-facing bay with an island there are several ruins and thick layers of midden. Archaeological site No. 70V1-III-6.



Overview of the location of the individual plots on Lb. No. 22

Lb. No. 22 A (Paleo-Eskimo, Thule)
At a small rocky outcrop in the center of the rocky beach is a well-preserved peat house with a characteristic "side chamber" (see detail sketch, below). The main room measures 6 x 4 m, and that somewhat smaller space on the east side of the house measures approx. 2 x 2 m. In the midden layers in front of the house a micro-flake of milky chalcedony and a flake of gray killiaq were observed.



Detailed sketch of the peat houses A and B on Lb. No. 22 (close-up of the section in red above).

The 2019 VIMOA survey confirmed Jensen's findings and also identified two additional peat houses and the dump area (locations added in blue and orange, respectively, to JFJ's original sketch map, above) and an adjacent area roughly 20 meters to the south of those that appears to have been used as

a trash dump spot of some sort with various historical era debris, all at the south end of the site (Figures 47 and 48, below). We also documented a large number of stone cist and cairn graves which are dotted across the hillsides above the village (inland to the east-northeast east), and a few stone cist graves at the northwestern end of the site as well. Overall we identified eight graves photographically, but there are more scattered across the hillsides that we did not have time to document. Like other graves observed in the region during the 2019 survey, these are of similar size and design as others documented in this report, and we surmise there may be a good many graves as yet unidentified at this site. Many contain visible human skeletal remains and numerous skeletal elements were also encountered laying exposed on the ground surface in numerous places, including human long bones and at least two crania. It appears that many of the graves have been disturbed, whether by nature, scavengers or intentionally, and at least some remains have moved downhill with erosional wash events. Unfortunately, due to time constraints, we were unable to get drone overviews of this site.

Figure 46. View of the Niaqornaq site looking west-southwest from the hillside above the site. At left can be seen the cove and tidal island and visible connecting tombolo.

The northernmost peat house imprint measures roughly 5. X 6 meters square with entrance opening out to the west-southwest, facing the Viagat with a view towards the southern tip of the small nearby island. This interior may have been divided into two separate rooms. The remaining walls are of stone and peat and are roughly 0.75 meters in height. The southernmost house imprint is roughly 6 x 7.5 meters square with an entrance looking west-southwest, and also facing the Viagat with similar view. The walls remain perhaps a meter high and like those of its adjacent neighbor are comprised of stone and turf. Both houses are thick-walled and there are a series of small square pits between them, presumably storage caches. To the south of these houses, roughly 50 meters away is a flat section of bare rock which appears to have been used as a refuse dump during the Historical/Colonial period.

In the blackened section of flat rock were observed many discolored and fragmented mammal bones, one rim sherd from a stoneware bowl, a bone tool with two small holes drilled in it, each with a tiny bone peg still in place, three small sherds which appeared to come from a porcelain saucer or small dish, and two fragmentary glass beads: one – a white-grey cylindrical bead with three blue spiral lines, and the other a smaller, plain, dark blue bead. About five meters upslope from this area, a small, thin whale bone toggle with two holes drilled in it was recovered (Figure 48, below).

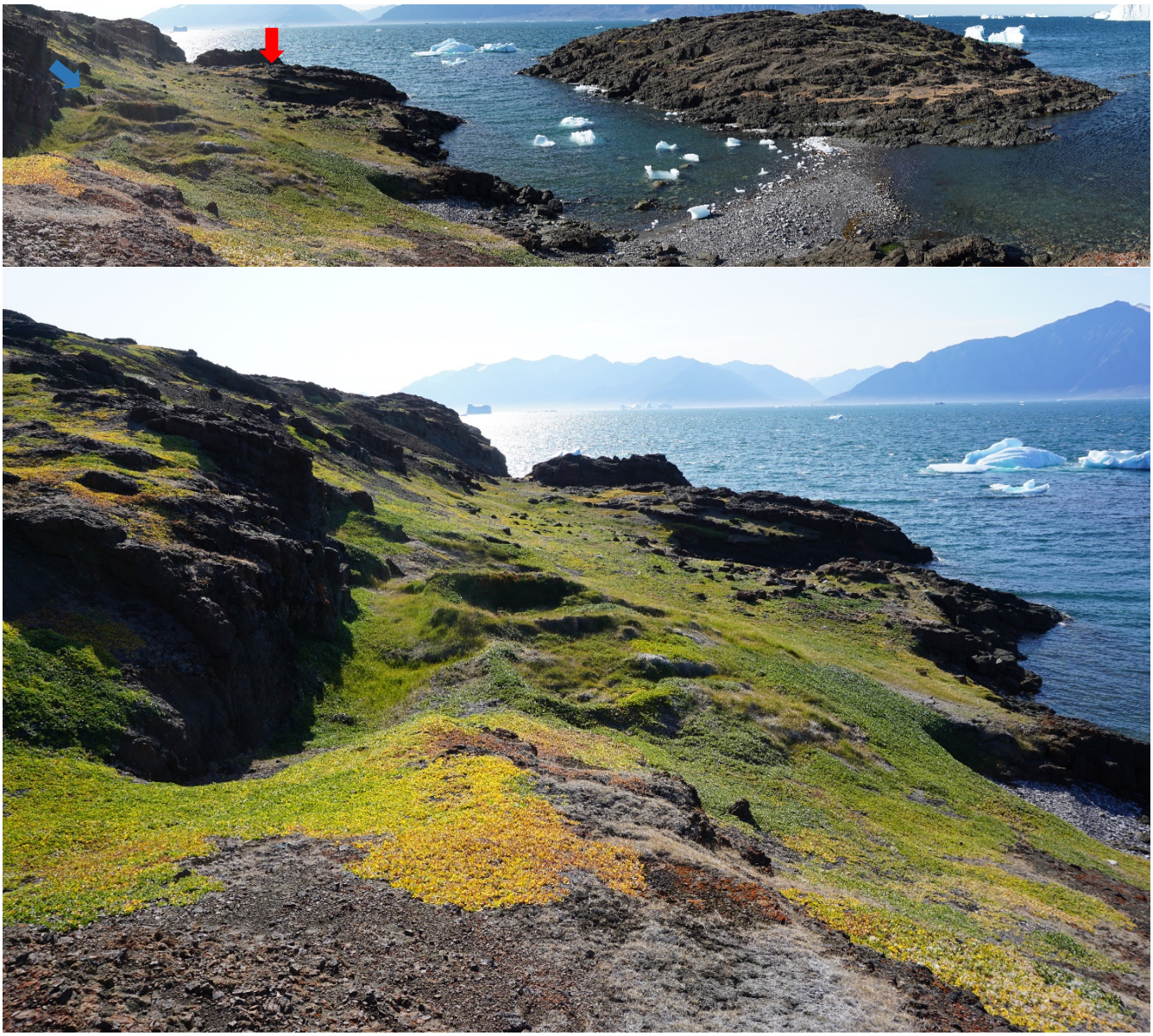


Figure 47. Top: view looking southwest at the south end of the Niaqornaq site showing the tied island. The blue arrow points to the two newly documented peat houses. The red arrow points to the location of the trash dump area. Bottom: close-up of the two peat houses, view looking south.

Figure 48. Above, left: bone toggle from the south end of the Niaqornaq village site close to two peat houses and the debris area south of the small tied-island; Above, right: two bead fragments recovered from the debris scatter at the south end of the site; Below: Close-up of the burnt dump area.

Graves on the slopes above Niaqornaq:

- N 70˚ 25.175; W 54˚ 02.616; Elev. 36 m.; Grave 1; stone cist with large cairn and three large white stone capstones partially displaced; two human crania and a femur visible in the main cist and four human crania placed in a long, connected second compartment at the south end of the cairn (Figure 49, below);

Figure 49. Cist grave covered by a cairn with the skeletal remains of multiple individuals inside.

- N 70˚ 25.169; W 54˚ 02.618; Grave 2; human cranium and indeterminable long bone and two femurs, completely exposed and disintegrating, just c. 2 meters to the south of G1 (above); cairn stones that probably covered the remains appear scattered immediately downslope of the exposed remains;
- N 70˚ 25.170; W 54˚ 02.624; Grave 3; cist and cairn just c. 3.5 meters southwest of G1, along cliff edge with a view overlooking the bay and cove below and to the west (Figure 50, below);

Figure 50. Overview looking roughly west-southwest of cairn 'Grave 3' overlooking the bay; the tied-island can be seen at back left.

- N 70˚ 25.162; W 54˚ 02.620; Grave 4; fairly intact cist and cairn c. 22 meters south downslope of G1; visible human remains as well as a visible bone artifact (knife?) inside cist;
- N 70˚ 25.150; W 54˚ 02.642; Grave 5; well-sealed cist and cairn with visible human remains;
- N 70˚ 25.145; W 54˚ 02.646; Grave 6; cist and cairn with large capstone removed; partially exposed human remains visible;
- N 70˚ 25.135; W 54˚ 02.639; Grave 7; large cist and cairn with capstone caved in; visible human remains;
- N 70˚ 25.077; W 54˚ 02.582; Grave 8; large, well-built stone cist with large capstones seemingly removed and set aside; fully-exposed human remains visible, including four human crania and numerous long bones (Figure 51, below);

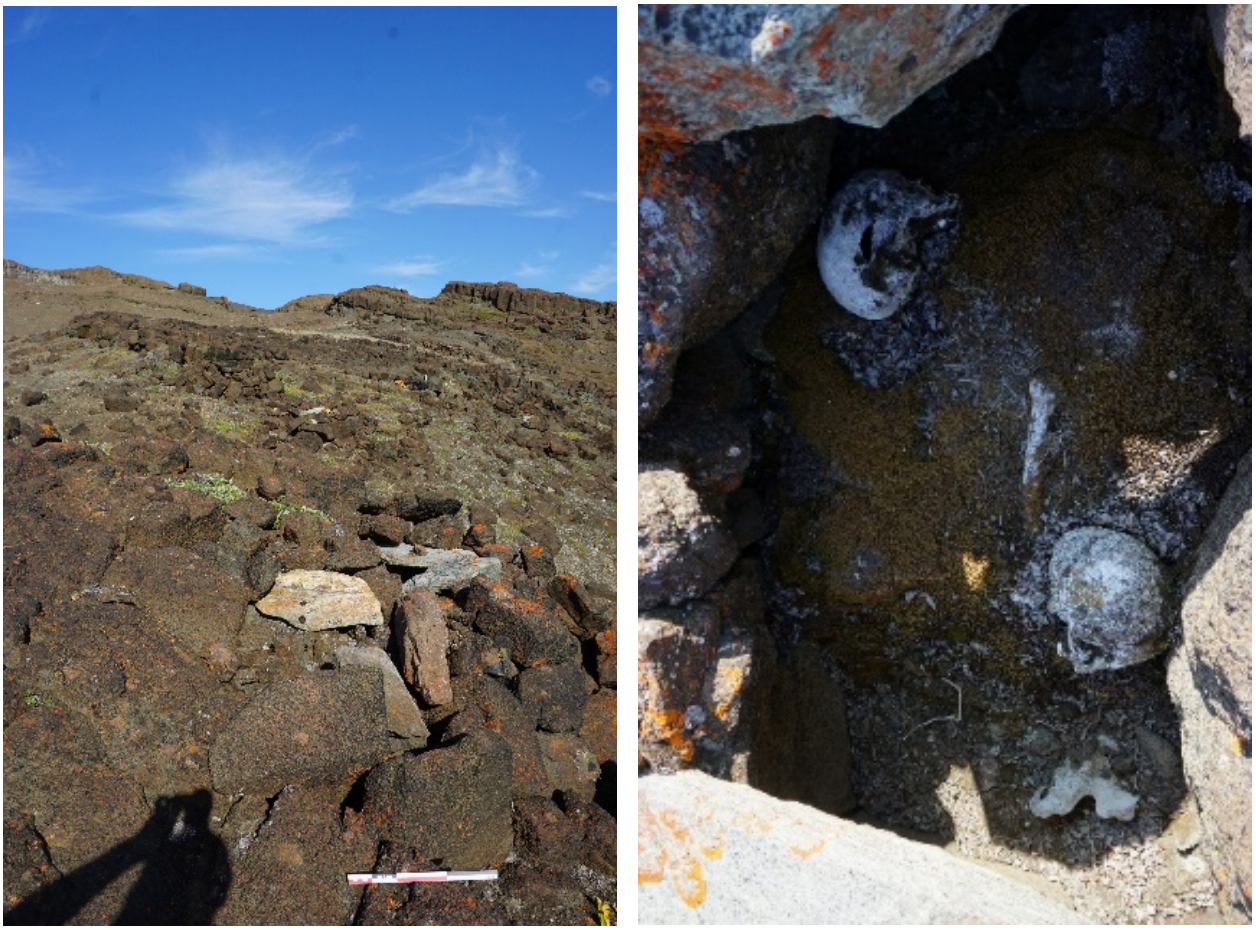


Figure 51. Cist grave (designated 'Grave 8' here) with partially removed capstones and scattered cairn (left); close-up of exposed human skeletal remains in Grave 8 (right).

Human skeletal remains were also observed scattered across the hillside slope, as mentioned previously. Many fragmented remains were observed in erosional wash basins along the hillside (see for example Figure 52, below.

Figure 52. Fragment of human cranium (center) laying in erosional wash area on the hillside above the Niaqornaq village site.

6.Acknowledgements

The VIMOA project was funded by the Danish Center for Marine Research (Project no: 2019-04), was supported by the Arctic Research Centre (ARC) at Aarhus University and is a contribution to the Arctic Science Partnership (ASP). The project researchers would like to thank the captain and crew of the M.S. Tulu out of Nuuk for their excellent support and professionalism during the expedition and Egon Randa Frandsen at ARC for his assistance managing logistics. The authors would also like to thank Jens Fog Jensen, Martin Appelt and Bjarne Grønnow at The National Museum of Denmark for their assistance in accessing records and images in the National Museum's archives and for their expert insights into the region and its archaeology. All necessary permits were obtained for the described study, which complied with all relevant regulations. As such, we are grateful to the Greenland National Museum and Archives in Nuuk for their assistance and permission to work in the area.

Contact:

Matthew J. Walsh, PhD

University of Oslo, The Museum of Cultural History
Department of Ethnography, Numismatics, Classical Archaeology and University History
e-mail: matthew.walsh@khm.uio.no; Matthew.walsh@natmus.dk

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Walsh MJ, Tejsner P, Carlson DF, Vergeynst L, Kjeldsen KU, Gründger F, Dai H, Thomsen S, Laursen E. The VIMOA project and archaeological heritage in the Nuussuaq Peninsula of north-west Greenland. *Antiquity*. 2000; 94(373): e6, 1–7. https://doi.org/10.15184/aqy.2019.230

APPENDIX A

Overview publication

Walsh, Matthew J., Pelle Tejsner, Daniel F. Carlson, Leendert Vergeynst, Kasper U. Kjeldsen, Friederike Gründger, Hanjing Dai, Steffen Thomsen, Erik Laursen

2020 The VIMOA project and archaeological heritage in the Nuussuaq Peninsula of north-west Greenland. *Antiquity* 94(373): e6, 1–7. https://doi.org/10.15184/aqy.2019.230

Antiquity 2020 Vol. 94 (373): e6, 1–7
https://doi.org/10.15184/aqy.2019.230

Project Gallery

The VIMOA project and archaeological heritage in the Nuussuaq Peninsula of north-west Greenland

Matthew J. Walsh[1,2,*], Pelle Tejsner[3], Daniel F. Carlson[3,4], Leendert Vergeynst[3,5], Kasper U. Kjeldsen[6], Friederike Gründger[3,6], Hanjing Dai[7], Steffen Thomsen[5] & Erik Laursen[8]

[1] Museum of Cultural History, University of Oslo, Norway
[2] The National Museum of Denmark, Copenhagen, Denmark
[3] Arctic Research Centre, Aarhus University, Denmark
[4] Department of Earth, Ocean, and Atmospheric Science, Florida State University, USA
[5] School of Engineering, Aarhus University, Denmark
[6] Section for Microbiology and Department of Biosciences, Aarhus University, Denmark
[7] Department of Ocean Sciences, RSMAS, University of Miami, USA
[8] Department of Biology, University of Southern Denmark, Denmark
* Author for correspondence: ✉ matthew.walsh@khm.uio.no

The Vaigat Iceberg-Microbial Oil Degradation and Archaeological Heritage Investigation (VIMOA) project records the results of archaeological survey of five sites in Greenland that are threatened by extreme weather conditions related to climate change. The project demonstrates the advantages of collaboration between archaeologists and natural scientists, and provides a repository of data to help preserve the archaeological record.

Keywords: Greenland, Arctic coastal erosion, photogrammetry, climate change, Palaeo-Eskimo Culture

Introduction

Surveys of archaeological sites conducted in the Nuussuaq region of north-west Greenland during the Vaigat Iceberg-Microbial Oil Degradation and Archaeological Heritage Investigation (VIMOA) research cruise documented five sites affected by exceptional and on-going deterioration of Arctic coastal archaeology. This process is exacerbated by detrimental weather conditions and temperature increases resulting from climate change. In addition to the five sites surveyed, the region hosts numerous other important archaeological sites, including the type-site for the Saqqaq cultural complex, the oldest documented human occupation in west Greenland dating to *c.* 4450–2850 cal BP.

The VIMOA project exemplifies the ways in which archaeologists and natural scientists can work together in a truly multidisciplinary fashion to achieve individual and common goals through holistic research strategies and shared resources. The project had three foci: to investigate microbial degradation of hydrocarbons in Greenlandic coastal seawater; to study the effects of icebergs on the distributions of hydrocarbons, nutrients, microbes and phytoplankton; and to assess the current state of archaeological sites in the Nuussuaq area.

Received: 26 September 2019; Revised: 25 October 2019; Accepted: 12 November 2019

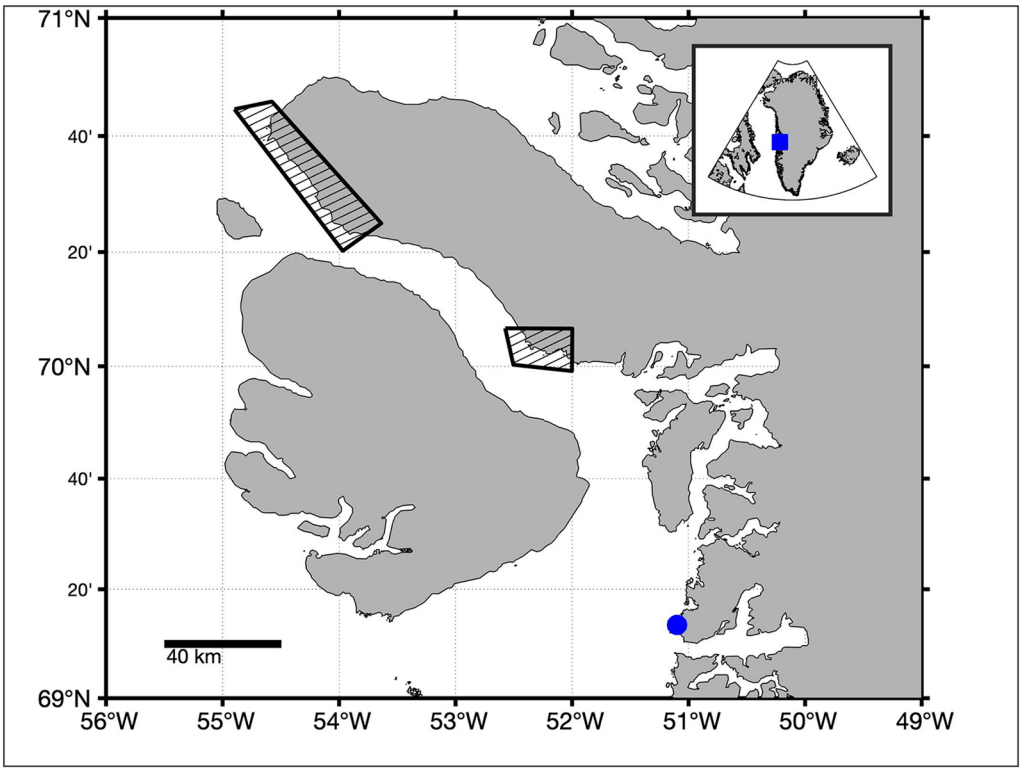

Figure 1. Location map showing the Nuussuaq Peninsula and Qeqertarsuaq Island, West Greenland. Survey areas mentioned in the text are marked out as hashed polygons; the blue circle marks the location of the town of Ilulissat (figure by D.F. Carlson).

The archaeological aspect of the expedition contributes to the regional archaeological record by surveying five coastal sites to document their state of preservation.

The archaeological survey focused primarily on the north-west of the Nuussuaq peninsula, covering the area surrounding the Kuugsuaq River delta and extending around 50km to the north-westernmost tip of the peninsula and the location of 'The Bear Trap' site (Figure 1). Site degradation over a 20-year period was documented by comparing photographs taken during survey in 2000 (Jensen 2001) with photographs taken during the 2019 survey from the same datum and direction (Figure 2). These clearly show the cumulative effects of 20 years of coastal erosion on the site, and its impact on the integrity of Arctic coastal archaeology in general.

Methodology

Extensive aerial (drone) mapping and drone- and ground-based photography of the archaeological sites and features was undertaken during the survey. Agisoft Photoscan Professional version 1.4.5 'structure from motion' photogrammetry software was used to process images

Figure 2. Comparison of the preservation of semi-subterranean peat houses on the terrace at Nussaq: left) photograph taken in 2000 (photograph by J.F. Jensen); right the same shoreline in 2019 (photograph by M.J. Walsh).

acquired by a DJI Phantom 3 Standard quadcopter drone, fitted with a 12 megapixel digital camera. This was augmented by high-resolution ground-level photography using: a 50.6 megapixel Canon 5DSR Mk 3 full-frame DSLR fitted with a 24mm lens; a Sony a6000 APS-C mirrorless camera fitted with a 17mm lens; and a 24.3 megapixel SONY α5100 APS-C mirrorless camera fitted with a 24mm lens. The images were processed in Photoscan to produce high-resolution 3D point clouds, digital elevation models and orthomosaics that were geo-rectified using ground control points surveyed using real-time kinematic GPS (Figure 3).

These digital products provide quantitative representations of overall site characteristics, as well as individual features such as peat houses, caches, cairns and graves. Three-dimensional models preserve these remote and rapidly deteriorating cultural heritage sites in a digital format, facilitating virtual exploration in the future. The imagery is used for documenting the current state of the archaeological sites in the survey areas, but will also be valuable for investigating terrestrial floral ecology and the abundance, and distribution, of nearshore macroalgae, further contributing to a holistic understanding of the ecology of these sites, and the region more generally.

Sites

During the Thule and early historic periods (*c.* AD 1300–1800), the sites of Nussaq, Atanikerluk and Niaqornaq were all moderately sized settlements, by regional standards. Each site has remnants of semi-subterranean houses built from peat and stone, and boasts numerous stone meat stores, several tent-rings and both prehistoric and historic graves (Figure 4). Nussaq is also the site of a large Christian cemetery. The sites all have extensive coastal middens; these are actively being lost to coastal erosion. Structures on each site are also imminently threatened by erosion. The integrity of the graves is being compromised at all of the sites, and all are in various states of deterioration, some with human remains completely exposed.

Niaqornaarsuk is located on a long headland connected to the mainland north of the Kuussuaq River delta by a tombolo forming broad sandy bays to the north and south. Jensen (2009: 191) observed that the rocky formation on which this Saqqaq site is located might have been cut off from the mainland during prehistory. Earlier appraisals of the site identified

Figure 3. Panoramic and aerial view of the Atanikerluk site (panoramic photograph by M.J. Walsh, aerial photograph by D.F. Carlson).

Figure 4. Saqqaq features at the Niaqornaarsuk site, with a Palaeo-Eskimo tent-ring in the foreground: left) photographed in 2000 (photograph by J.F. Jensen); right photographed during the 2019 VIMOA project survey (photograph by M.J. Walsh).

a Palaeo-Eskimo presence—probably Saqqaq—and circular tent-rings and artefacts at both ends of the promontory suggest subsequent occupations (e.g. Jensen 2001). Photographs taken during Jen Fog Jensen's (2001) survey were successfully replicated for comparison (Figure 5).

'The Bear Trap' (Bjørnefælden in Danish), also known as 'The Great Trap' (*Putdlagssuaq* in Kalaallisut), is a unique structure in north-west Greenland (Figure 6). The building is a square, dry-stone built structure with a narrow entrance and an interior space of just 1.15 by 2.28m. It survives to a height of approximately 1.40m, but its original height and roof morphology remain conjectural. All four walls are over 1m wide. First documented in 1736 (Meldegaard 1995: 214), it was later recorded by Steenstrup (1893), who described the structure and recorded its dimensions. Besides its eponymous purpose, The Bear Trap has been hypothesised as having been constructed as a storehouse by the Greenland Norse to store valuable commodities such as polar bear hides and narwhal and walrus tusks (Meldegaard 1995), particularly during large-scale hunting forays into the region (McGovern 1985). While the structure's original purpose is likely to elude positive identification, during our 2019 survey it was observed that The Bear Trap is located at the westernmost periphery of an early cemetery, probably associated with a settlement nearby to the south. Thus, we support the hypothesis proposed by Rosenkrantz (1967), that the structure may actually have been a burial chamber, perhaps for a high-status Norse individual. Whatever the nature of the structure, it is a valuable part of the archaeological heritage of Greenland. A major contribution of the VIMOA project is the creation of a digital record to preserve the data of sites such as these. In this case, a detailed 3D model of The Bear Trap and its surroundings was created from the recorded data (Figure 6).

Future directions

It has been well established that current environmental conditions, driven by climate change, are critically endangering archaeological heritage across the Arctic (Blankholm 2009). One outcome of the VIMOA project has been to provide a digital platform for the preservation of data that will be both technically and analytically valuable to archaeologists, but also

Figure 5. Top) view of Niaqornaq from the north-east; bottom left) northern cove at Niaqornaq showing a large peat house and midden directly on the shoreline erosion scar; bottom right) detail of well-sealed cairn grave with characteristic white stone capstones in place (photographs by M.J. Walsh).

Figure 6. Left) view of 'The Bear Trap' from the south (photograph by M.J. Walsh); right) oblique view of a geo-rectified dense point cloud image of 'The Bear Trap' and immediate surrounding area looking north (image created by D.F. Carlson using drone imagery processed in Agisoft Photoscan).

accessible and of interest to the wider public. We hope that the modelling aspect of the project will help to generate interest in the preservation of archaeological heritage in Greenland, and throughout the Arctic, while also raising awareness of the pressing need to preserve that archaeological heritage before it is lost.

Acknowledgements

The VIMOA project was funded by the Danish Centre for Marine Research (project number 2019-04), supported by the Arctic Research Centre at Aarhus University and it contributes to the Arctic Science Partnership. We thank the captain and crew of the *M.S. Tulu*, Egon Randa Frandsen at ARC, Jens Fog Jensen, Martin Appelt and Bjarne Grønnow at The National Museum of Denmark, and The Greenland National Museum and Archives.

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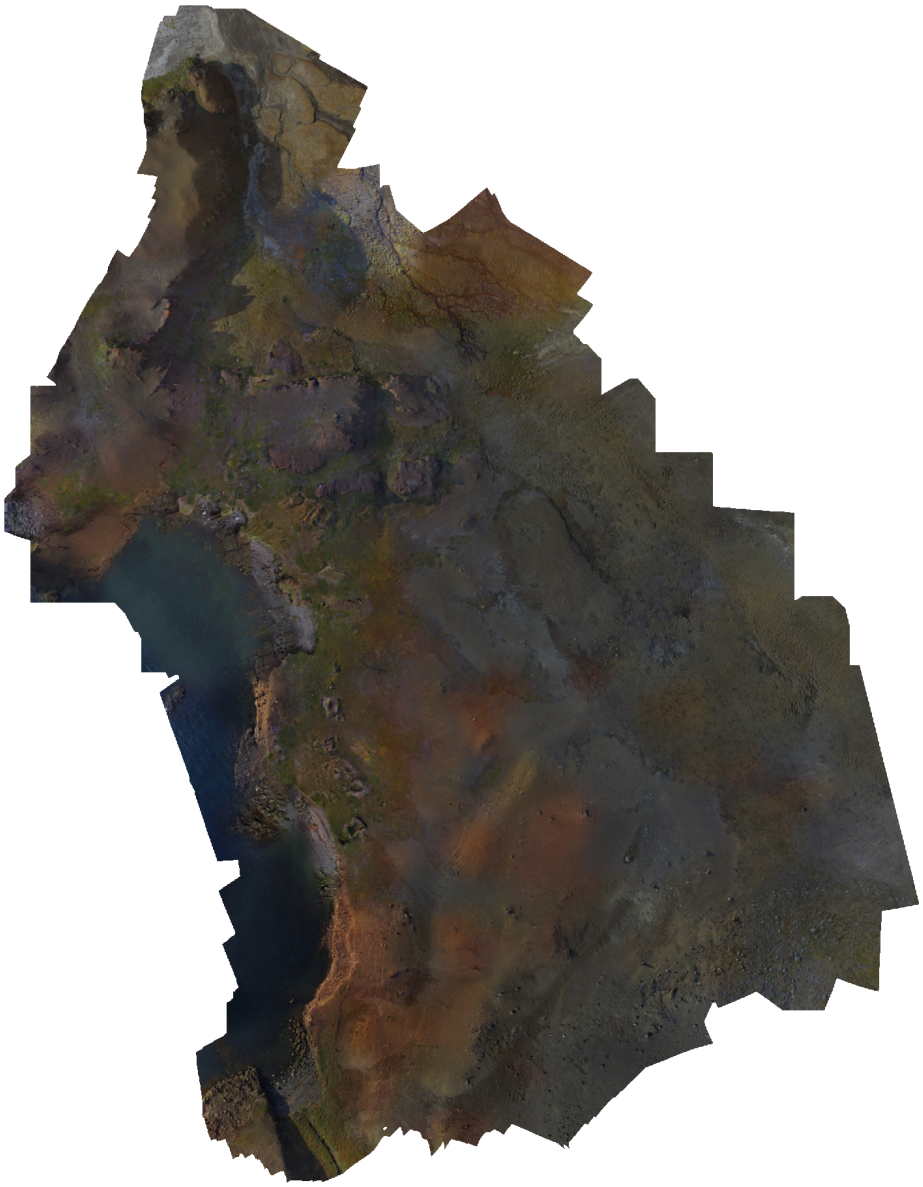
APPENDIX B

Nussaq Digital Imagery Processing Report

20190801 Nuusuaq

Processing Report

21 October 2020



Survey Data

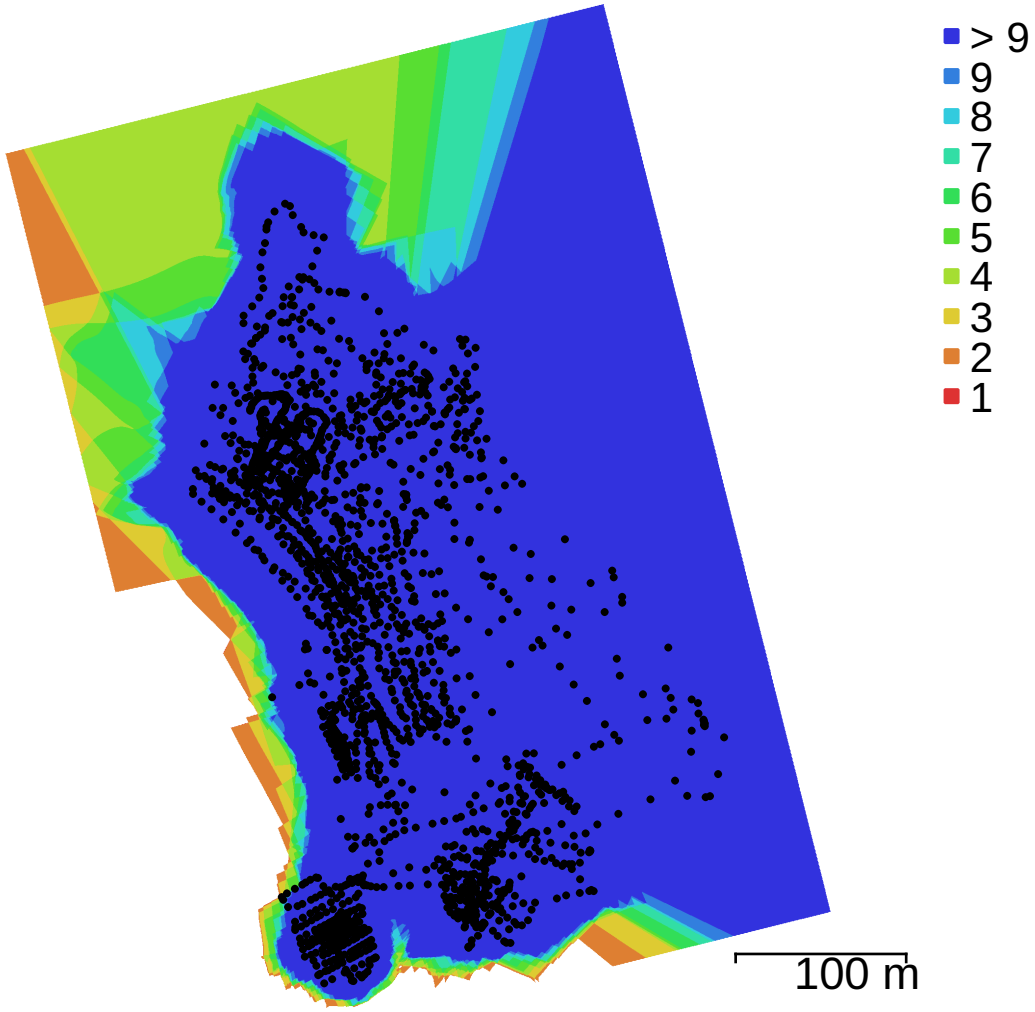


Fig. 1. Camera locations and image overlap.

Number of images:	2,146	Camera stations:	2,144
Flying altitude:	34.6 m	Tie points:	2,627,398
Ground resolution:	1.19 cm/pix	Projections:	6,658,408
Coverage area:	0.181 km²	Reprojection error:	0.34 pix

Camera Model	Resolution	Focal Length	Pixel Size	Precalibrated
FC300C (3.61mm)	4000 x 3000	3.61 mm	1.56 x 1.56 µm	No

Table 1. Cameras.

Camera Calibration

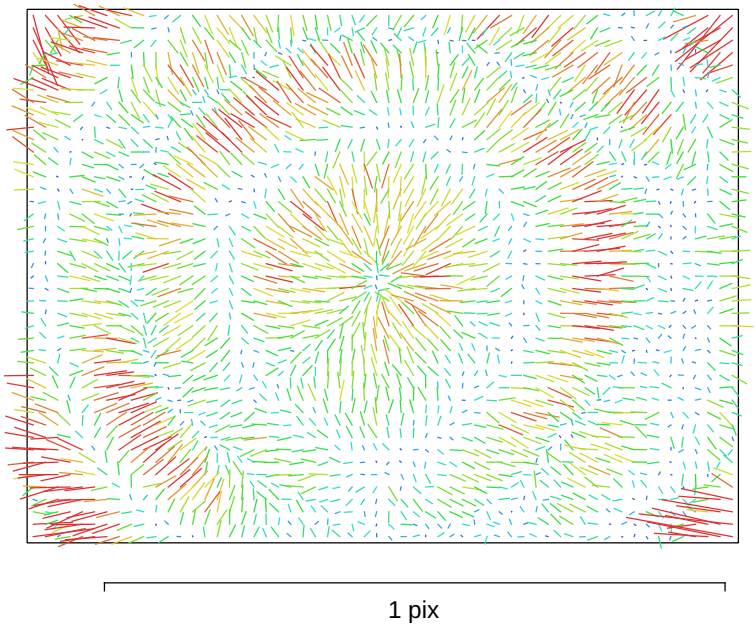


Fig. 2. Image residuals for FC300C (3.61mm).

FC300C (3.61mm)

2146 images

Type	Resolution	Focal Length	Pixel Size
Frame	**4000 x 3000**	**3.61 mm**	**1.56 x 1.56 µm**

	Value	Error	F	Cx	Cy	K1	K2	K3	P1	P2
F	**2715.45**	0.023	1.00	-0.01	-0.72	-0.31	0.29	-0.15	-0.05	0.14
Cx	**20.2336**	0.0059		1.00	-0.00	-0.02	0.02	-0.03	0.59	-0.00
Cy	**12.099**	0.0086			1.00	0.13	-0.14	0.05	0.03	0.17
K1	**-0.139789**	7.5e-06				1.00	-0.94	0.89	0.00	-0.24
K2	**0.128997**	1.8e-05					1.00	-0.97	0.01	0.08
K3	**-0.0280415**	1.4e-05						1.00	-0.01	-0.08
P1	**-0.000123773**	5.4e-07							1.00	-0.03
P2	**0.000440831**	6.3e-07								1.00

Table 2. Calibration coefficients and correlation matrix.

Camera Locations

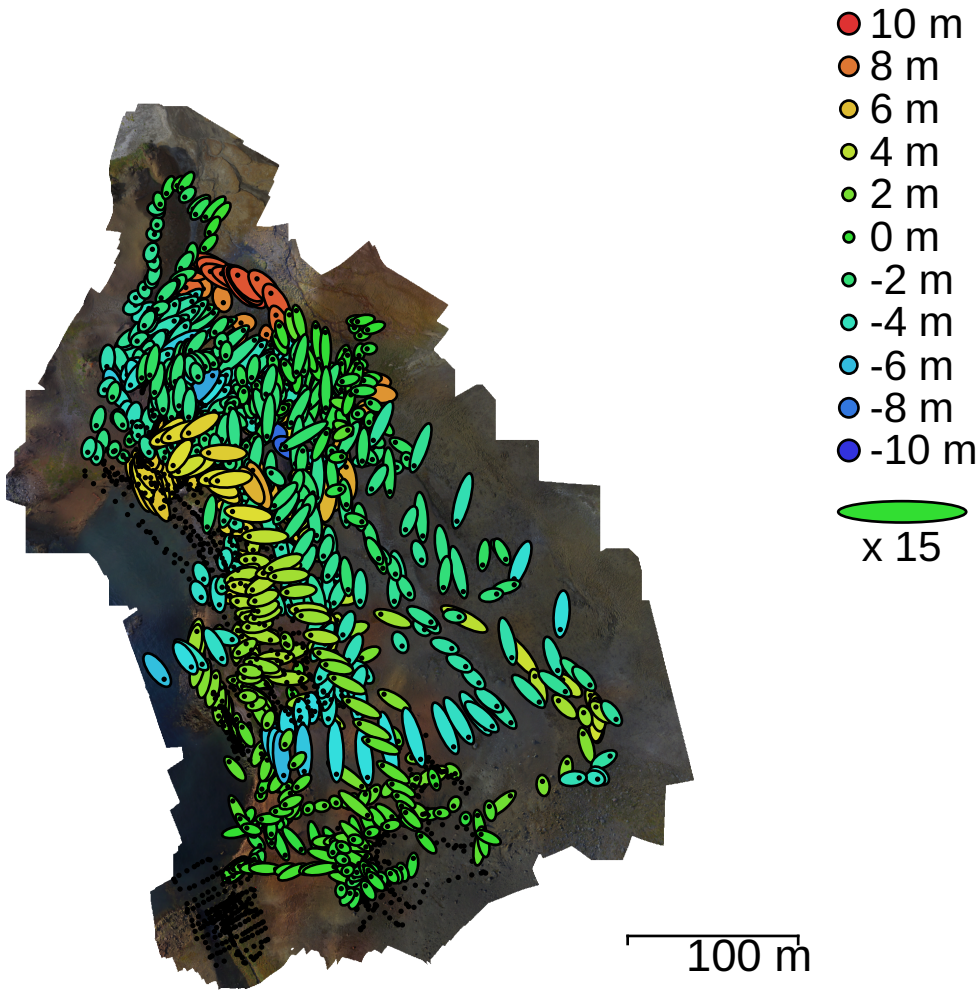


Fig. 3. Camera locations and error estimates.
Z error is represented by ellipse color. X,Y errors are represented by ellipse shape.
Estimated camera locations are marked with a black dot.

X error (m)	Y error (m)	Z error (m)	XY error (m)	Total error (m)
0.519259	0.642056	3.42353	0.825752	3.52171

Table 3. Average camera location error.
X - Longitude, Y - Latitude, Z - Altitude.

Digital Elevation Model

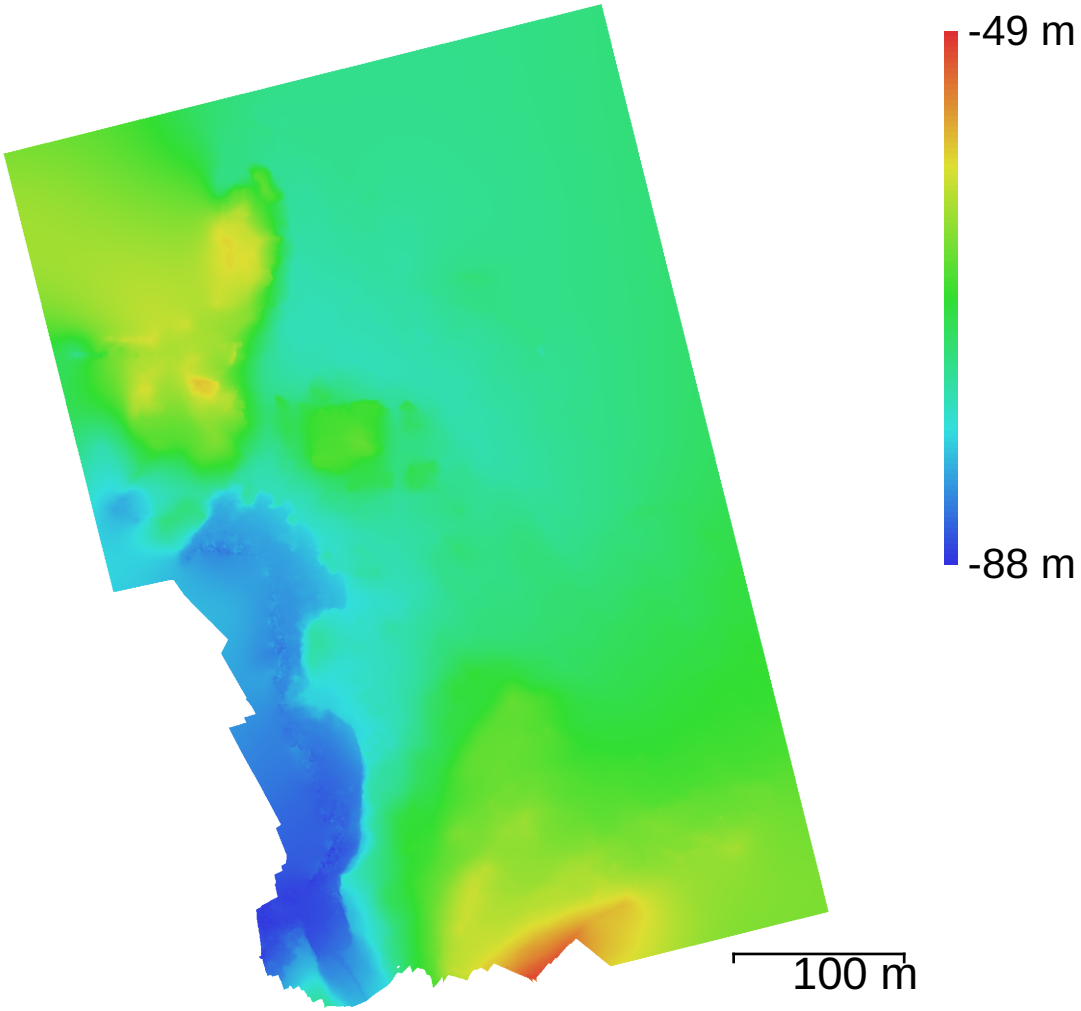


Fig. 4. Reconstructed digital elevation model.

Resolution:	9.51 cm/pix
Point density:	111 points/m²

Processing Parameters

General	
Cameras	2146
Aligned cameras	2144
Coordinate system	WGS 84 (EPSG::4326)
Rotation angles	Yaw, Pitch, Roll
Point Cloud	
Points	2,627,398 of 10,988,153
RMS reprojection error	0.14774 (0.340197 pix)
Max reprojection error	0.3 (3.06682 pix)
Mean key point size	2.27169 pix
Point colors	3 bands, uint8
Key points	Yes
Average tie point multiplicity	4.9623
Alignment parameters	
Accuracy	High
Generic preselection	No
Reference preselection	No
Key point limit	60,000
Tie point limit	0
Adaptive camera model fitting	No
Matching time	5 days 0 hours
Alignment time	3 hours 2 minutes
Optimization parameters	
Parameters	f, cx, cy, k1-k3, p1, p2
Adaptive camera model fitting	No
Optimization time	5 minutes 27 seconds
Dense Point Cloud	
Points	14,075,116
Point colors	3 bands, uint8
Reconstruction parameters	
Quality	Low
Depth filtering	Aggressive
Depth maps generation time	19 minutes 52 seconds
Dense cloud generation time	58 minutes 0 seconds
DEM	
Size	5,083 x 6,514
Coordinate system	WGS 84 (EPSG::4326)
Reconstruction parameters	
Source data	Dense cloud
Interpolation	Enabled
Processing time	27 seconds
Orthomosaic	
Size	40,664 x 49,472
Coordinate system	WGS 84 (EPSG::4326)
Colors	3 bands, uint8
Reconstruction parameters	
Blending mode	Mosaic
Surface	DEM
Enable hole filling	Yes
Processing time	17 minutes 46 seconds
Software	
Version	1.4.4 build 6848
Platform	Linux 64

APPENDIX C

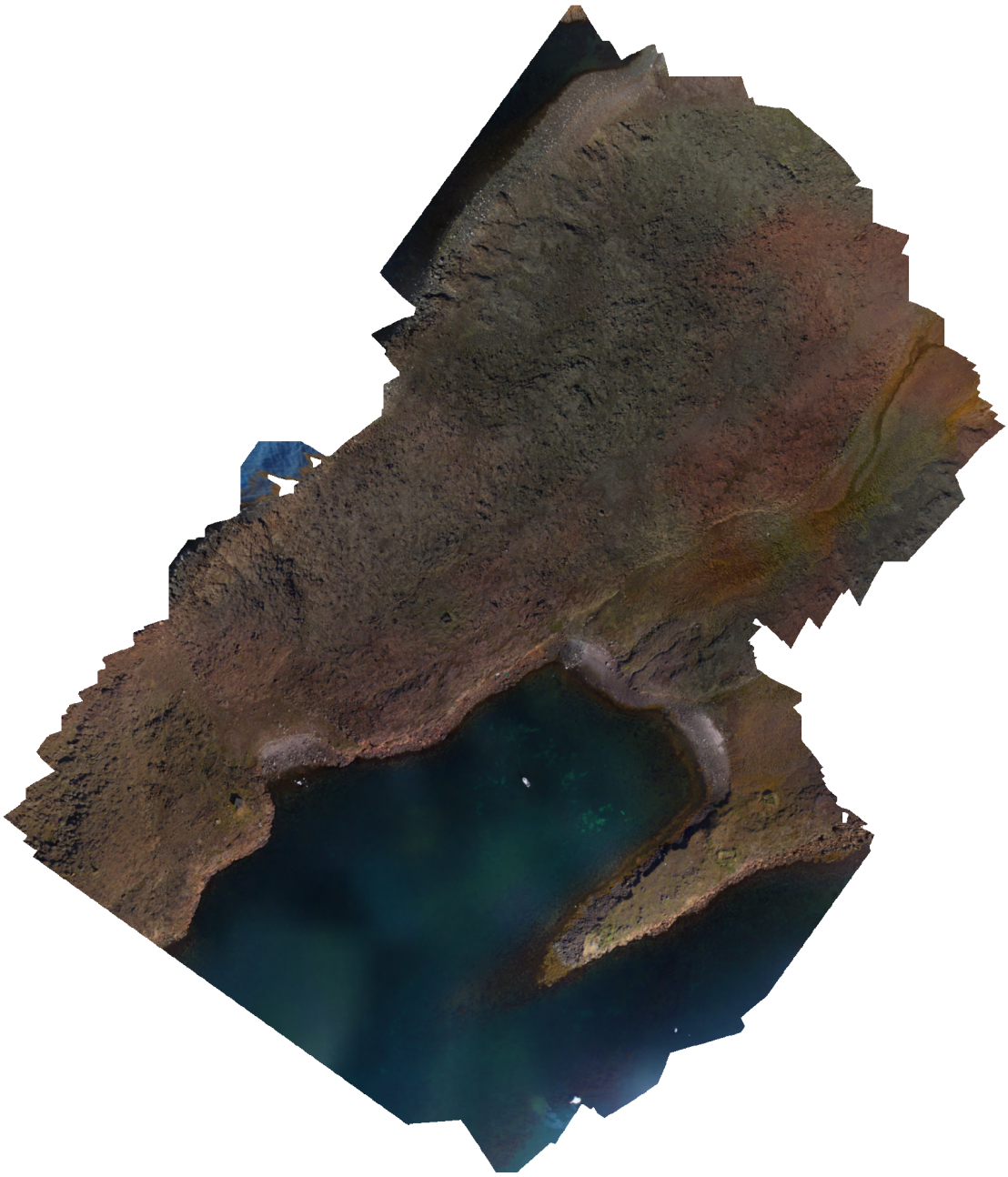
The Bear Trap Digital Imagery Processing Report
&
Manuscript publication:

Walsh, Matthew J., Daniel F. Carlson, Pelle Tejsner and Steffen Thomsen
ND The Bear Trap: Reinvestigation and digital imaging of a unique stone structure on the northwest tip of the Nuussuaq Peninsula, Greenland. *PLOS ONE*. Submitted.

Bear Trap Phantom Survey

Bear Trap Aerial Survey

24 August 2020



Survey Data

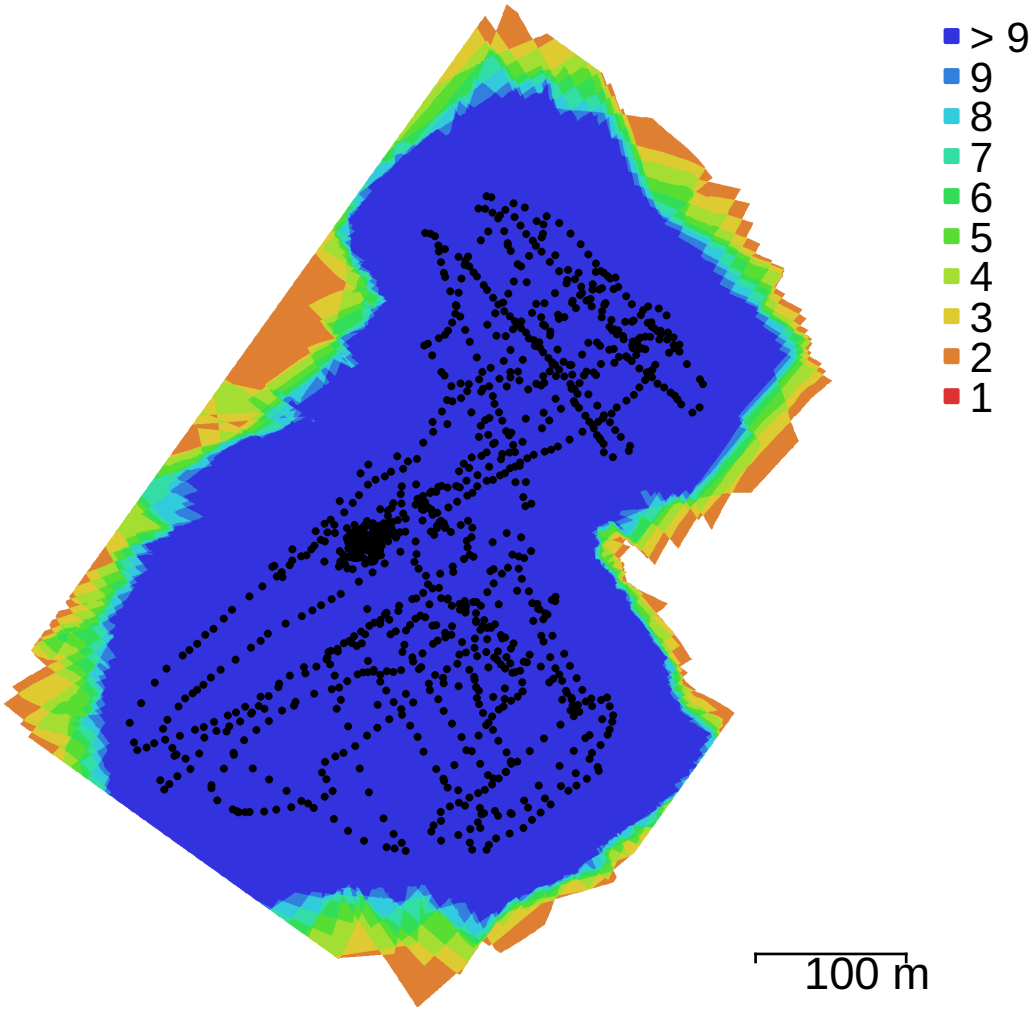


Fig. 1. Camera locations and image overlap.

Number of images:	1,113	Camera stations:	1,113
Flying altitude:	56.8 m	Tie points:	2,270,992
Ground resolution:	1.92 cm/pix	Projections:	8,615,294
Coverage area:	0.197 km²	Reprojection error:	0.688 pix

Camera Model	Resolution	Focal Length	Pixel Size	Precalibrated
FC300C (3.61mm)	4000 x 3000	3.61 mm	1.56 x 1.56 µm	No

Table 1. Cameras.

Camera Calibration

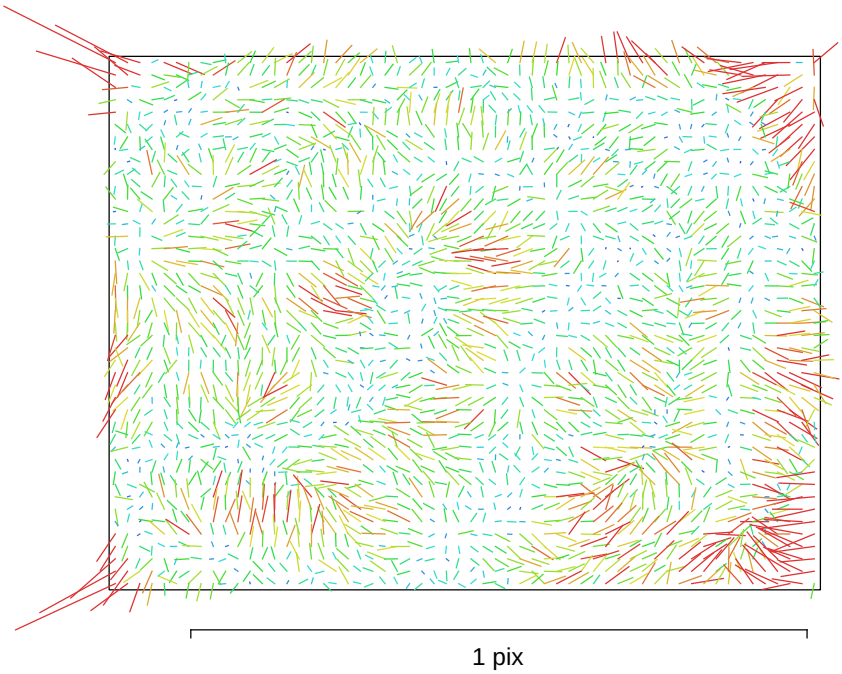


Fig. 2. Image residuals for FC300C (3.61mm).

FC300C (3.61mm)

1113 images

Type	Resolution	Focal Length	Pixel Size
Frame	**4000 x 3000**	**3.61 mm**	**1.56 x 1.56 µm**

	Value	Error	F	Cx	Cy	B1	B2	K1	K2	K3	K4	P1	P2	P3	P4
F	**2708.24**	0.046	1.00	-0.05	-0.92	0.68	-0.18	-0.29	0.20	-0.14	0.12	0.53	0.64	-0.35	-0.41
Cx	**19.4923**	0.011		1.00	0.04	-0.04	0.70	0.02	-0.01	0.00	-0.00	0.29	-0.07	0.02	0.05
Cy	**19.0339**	0.03			1.00	-0.84	0.19	0.19	-0.11	0.06	-0.05	-0.53	-0.64	0.32	0.46
B1	**-3.81599**	0.0062				1.00	-0.18	-0.19	0.07	-0.03	0.02	0.51	0.73	-0.28	-0.52
B2	**-0.658964**	0.0034					1.00	0.05	-0.03	0.01	-0.01	-0.13	-0.20	0.08	0.16
K1	**-0.146176**	2.2e-05						1.00	-0.96	0.90	-0.85	-0.15	-0.22	0.10	0.12
K2	**0.162801**	9.4e-05							1.00	-0.98	0.95	0.09	0.11	-0.09	-0.02
K3	**-0.0889901**	0.00016								1.00	-0.99	-0.06	-0.06	0.07	-0.02
K4	**0.0352943**	9.3e-05									1.00	0.06	0.05	-0.07	0.03
P1	**5.00074e-05**	7.6e-07										1.00	0.71	-0.58	-0.15
P2	**0.000227951**	2.7e-06											1.00	-0.71	-0.23
P3	**-0.393095**	0.022												1.00	-0.47
P4	**1.58398**	0.018													1.00

Table 2. Calibration coefficients and correlation matrix.

Ground Control Points

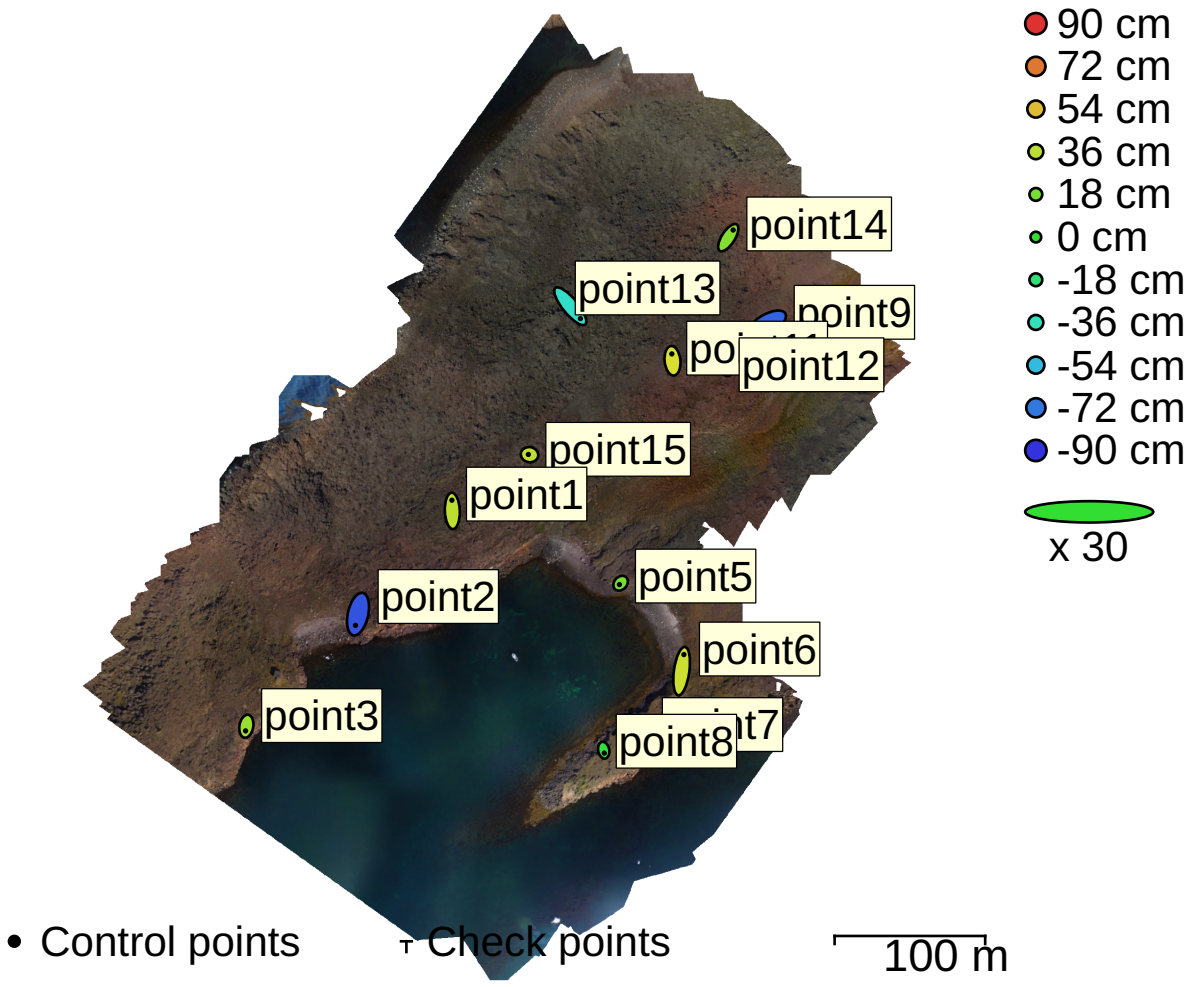


Fig. 3. GCP locations and error estimates.
Z error is represented by ellipse color. X,Y errors are represented by ellipse shape.
Estimated GCP locations are marked with a dot or crossing.

Count	X error (cm)	Y error (cm)	Z error (cm)	XY error (cm)	Total (cm)
13	23.7931	36.5554	42.082	43.6166	60.6078

Table 3. Control points RMSE.
X - Longitude, Y - Latitude, Z - Altitude.

Label	X error (cm)	Y error (cm)	Z error (cm)	Total (cm)	Image (pix)
point2	-11.2609	-49.916	-81.361	96.1146	0.563 (45)
point3	-3.39847	-20.4217	27.1149	34.1147	1.218 (39)
point5	-5.34678	-5.85184	17.9202	19.595	1.852 (46)
point6	10.1222	73.2283	40.0517	84.0772	3.741 (40)
point7	-37.6518	12.3158	-32.8417	51.4579	2.252 (50)
point8	2.53569	-12.8475	-3.69532	13.6068	3.383 (44)
point9	-44.8578	-26.7995	-77.3358	93.3341	1.683 (42)
point11	-3.10971	30.3485	43.4442	53.0858	1.501 (76)
point12	33.9051	-27.2176	9.19135	44.4391	1.167 (49)
point13	44.6244	-54.6456	-38.9418	80.585	1.478 (53)
point14	21.7274	33.7536	21.2963	45.4414	1.895 (24)
point15	-5.28914	0.963474	37.6749	38.0566	1.742 (50)
point1	-1.76483	47.3653	36.1558	59.614	1.143 (68)
Total	**23.7931**	**36.5554**	**42.082**	**60.6078**	**1.936**

Table 4. Control points.

X - Longitude, Y - Latitude, Z - Altitude.

Digital Elevation Model

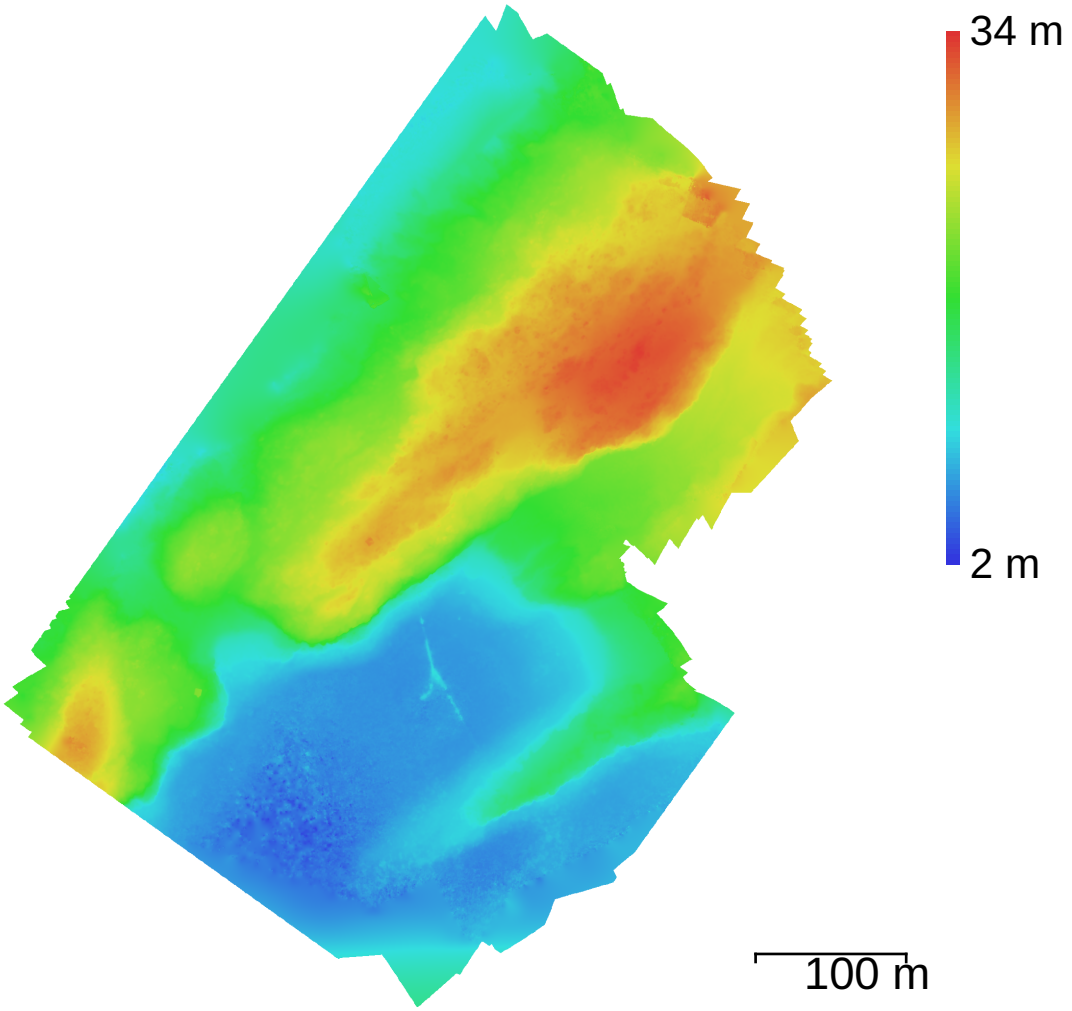


Fig. 4. Reconstructed digital elevation model.

Resolution:	7.66 cm/pix
Point density:	170 points/m²

Processing Parameters

General	
Cameras	1113
Aligned cameras	1113
Markers	13
Coordinate system	WGS 84 (EPSG::4326)
Rotation angles	Yaw, Pitch, Roll
Point Cloud	
Points	2,270,992 of 5,701,868
RMS reprojection error	0.201299 (0.687643 pix)
Max reprojection error	0.499981 (14.2503 pix)
Mean key point size	3.28483 pix
Point colors	3 bands, uint8
Key points	Yes
Average tie point multiplicity	5.43322
Alignment parameters	
Accuracy	High
Generic preselection	Yes
Reference preselection	Yes
Key point limit	60,000
Tie point limit	0
Adaptive camera model fitting	No
Matching time	1 hours 19 minutes
Alignment time	1 hours 20 minutes
Optimization parameters	
Parameters	f, b1, b2, cx, cy, k1-k4, p1-p4
Adaptive camera model fitting	No
Optimization time	27 seconds
Dense Point Cloud	
Points	33,186,283
Point colors	3 bands, uint8
Reconstruction parameters	
Quality	Medium
Depth filtering	Aggressive
Depth maps generation time	1 hours 51 minutes
Dense cloud generation time	5 hours 18 minutes
DEM	
Size	8,705 x 9,228
Coordinate system	WGS 84 (EPSG::4326)
Reconstruction parameters	
Source data	Dense cloud
Interpolation	Enabled
Processing time	39 seconds
Orthomosaic	
Size	28,712 x 34,756
Coordinate system	WGS 84 (EPSG::4326)
Colors	3 bands, uint8
Reconstruction parameters	
Blending mode	Mosaic
Surface	DEM
Enable hole filling	Yes
Processing time	12 minutes 50 seconds
Software	
Version	1.4.4 build 6848
Platform	Linux 64

The Bear Trap: Reinvestigation and digital imaging of a unique stone structure on the northwest tip of the Nuussuaq Peninsula, Greenland

Walsh, Matthew J., Daniel F. Carlson, Pelle Tejsner and Steffen Thomsen

Keywords

Greenland, The Bear Trap, Norse structure, Structure from Motion photogrammetry, Arctic heritage

Abstract

The stone structure known as the 'Bear Trap' or 'Bjørnefælden' in Danish, and 'Putdlagssuaq', 'The Great Trap' in the local Greenlandic Kalaallisut, is a unique and enigmatic feature on the Arctic landscape of northwest Greenland. Here we present new findings on this drystone structure located on the Nuussuaq peninsula. We update the archaeological context of the site and its surroundings, and for the first time provide a detailed 3D model of this structure as well as an orthomosaic and digital elevation model, preserving its details digitally in high-resolution. In addition, investigations of the site and its surroundings during summer 2019, contribute to the ongoing discussion of the structure's original purpose. Based on the discovery of previously undocumented graves in the vicinity, we concede with previous scholarly speculations that the Bear Trap was possibly used as a grave or possible cenotaph, rather than as a *skemma*, the typical stone storage structure of the Greenland Norse.

Introduction

The Bear Trap is a relatively small stone-built structure that was constructed along a rocky promontory at the western end of the Nuussuaq Peninsula, due north of where the Vaigat Strait connects the northern Disko Bay and adjacent fjords to Davis Strait (Figure 1). The structure was first referenced in 1736 and is first described in the literature on the region in 1758 (Meldegaard 1995: 214). K. J. V. Steenstrup (1893) made the earliest detailed description of the structure, providing both a sketch of the monument and measurements of its dimensions. It was mentioned again in 1938 (Meldegaard 1995: 205) and Jørgen Meldegaard of the National Museum of Denmark visited and described the site again in 1953. McGovern (1985: 295) provides an excellent review of the literature relating to the structure and discusses its potential function as part of the Greenlandic Norse's *Nordrsetur* hunting expeditions into the region. Besides its eponymous purpose, the structure has been hypothesized as having been constructed by the Greenland Norse as a storehouse for caching valuable trade commodities such as polar bear hides and narwhal and walrus tusks. Most recently, Madsen (2012: 133) provides a brief summary of the site, and characterizing it as a 'maritime waystation'/storehouse structure (of his Type 3c). Another theory is that it was built by Norwegian whalers, probably for a similar depot purpose, but this conclusion may be reliably dismissed based on Steenstrup's findings in 1878 of a Thule drilled-bone object recovered from an undisclosed location inside the structure (Steenstrup 1893). Despite these interpretations, the structure itself offers little to suggest its original purpose. During an archaeological survey of the area in 2019 (Walsh et al. 2020) it was discovered that the Bear Trap stands at the western periphery of an ancient cemetery, most probably composed of graves from the indigenous Thule Culture. From this context, we provide new data on the Bear Trap and form a discussion around the possibility that the structure was perhaps a Norse grave or monument incorporated into the existing funerary landscape.

Material and Methods

Digital images acquired from unoccupied aerial vehicle (UAV) and ground-level surveys were processed using Structure from Motion Multiview Stereo (SfM-MVS) photogrammetry software to create 3D models, digital elevation models (DEMs), and orthomosaics of the Bear Trap, individual graves, and the surrounding area. Recent advances in consumer camera and UAV technologies and

computer vision algorithms have made SfM-MVS a popular and effective tool in archaeology and natural science (see Sapirstein and Murray 2017 for a detailed review). Briefly, images with a high degree of overlap can be processed using SfM-MVS to identify and match prominent features (key points), that are visible in multiple images (tie points) taken at different locations and from different angles. The software uses the collection of tie points to reconstruct the 3D geometry of the scene. The point cloud can then be used to construct a 3D mesh model, as well as a DEM and an orthomosaic, all of which aid in quantitative analyses of the objects or areas surveyed. The 3D model allows virtual inspection of the structure or landscape, as well as digital preservation of deteriorating features. Here, we briefly summarize the methods used to acquire and process the imagery. Datasets and images can be accessed through the links provided in Table 1.

Ground level photo surveys

In this study, ground level photographs of the Bear Trap, graves, cairns, and rock piles were acquired with mirrorless Sony a5100 and a6000 cameras. Scale markers with known dimensions were placed in each scene and remained stationary throughout the duration of the photo survey.

Aerial photo surveys

Low-altitude aerial images were acquired with a DJI Phantom 3 Standard quadcopter UAV equipped with a 12 megapixel camera. The Phantom 3 was flown manually and still images were acquired at 5 second intervals. A total of five aerial photo surveys were carried out, resulting in 1113 useable images. Thirteen ground control points (GCPs) were distributed throughout the area and their positions were surveyed using two low-cost Emlid Reach (http://emlid.com/reach) global navigation satellite system (GNSS) receivers. One Reach unit operated as a stationary base station and the second rover unit was used to survey each GCP. The data from the Reach units were used in post processed kinematic (PPK) mode as time constraints did not permit the setup of the communications necessary to operate in real time kinematic (RTK) mode. The log files from the base station and rover were processed using the procedure outlined by Emlid and their distribution of the free RTKLib software (https://docs.emlid.com/reach/common/tutorials/gps-post-processing/). Ellipsoidal heights were converted to altitude by subtracting the geoid height, which was determined using the online UNAVCO Geoid Height Calculator (https://www.unavco.org/software/geodetic-utilities/geoid-height-calculator/geoid-height-calculator.html).

SfM-MVS image processing

Images were first manually reviewed to flag and remove low-quality pictures, as blurry and/or over-exposed images reduce the quality and accuracy of the 3D reconstruction. Images were processed using AgiSoft PhotoScan Professional (version 1.4.4; Linux Ubuntu) following the workflow outlined here. PhotoScan's 'High' accuracy setting and key point and tie point limits of 60000 and 0, respectively, were used during the initial alignment, or bundle adjustment, step. To reduce the processing time, generic preselection was enabled for the ground level imagery, and generic and reference preselection were enabled for the UAV imagery. Gradual selection was used to remove tie points that exceeded thresholds for the projection accuracy, reconstruction uncertainty, and reprojection error and the lens parameters were computed. Camera calibrations were performed after each gradual selection criterion was used to select and delete tie points. The sparse point cloud was then scaled either using markers with known dimensions or GCPs that were placed in the scene and that remained stationary for the duration of the photo survey. Dense point clouds were computed

using PhotoScan's 'Medium' quality setting to ensure sufficient memory for the computation. Mesh models were created for the ground level surveys of the Bear Trap and the grave using the 'High' quality setting. The dense cloud computed from the UAV imagery was used to create a DEM and an orthomosaic. The total error of the GCPs is 0.61 m.

Datasets

After processing in PhotoScan, 3D models of the Bear Trap, rock piles, and graves were exported as .obj files, for viewing in free software like MeshLab (*https://www.meshlab.net/)*. The DEM and orthomosaic produced from the UAV imagery were exported as geotiffs. All raw images and processed datasets were uploaded to Zenodo and links to each dataset and are listed in Table 1.

Table 1.

Name	DOI	Link	3D Model (.obj/.pdf)	DEM (.tif)	Orthomosaic (.tif)
The Bear Trap	10.5281/zenodo.3980540	https://zenodo.org/record/4075144#.X4McldMzbUo	X		
Box Cairn	10.5281/zenodo.4011977	https://zenodo.org/record/4011977#.X3jASNMzbUo	X		
Grave no. 1	10.5281/zenodo.3984864	https://zenodo.org/record/3984864#.X3i6z9MzbUo	X		
Bear Trap and surrounding area	10.5281/zenodo.4013258	https://zenodo.org/record/4013258#.X3i6bdMzbUo		X	X

Figure 1. [A] The location of the study site in western Greenland is marked by the magenta square. [B] A topographic map of the western Nuusuaq Peninsula and Disko Island derived from BedMachine v3 (Morlighem et al, 2017). The Vaigat Strait separates Disko Island from the Nuusuaq Peninsula and connects Disko Bay and adjacent fjords to Baffin Bay. The location of the Bear Trap is indicated by the magenta square. [C] The 0.8 m resolution UAV orthomosaic of the Bear Trap and relevant features labeled.

Results

The structure

The Bear Trap's structure forms a squat square of nearly 4.5 m on each side. It was assembled using dry-stone construction primarily from irregularly-sized, but angular, grey-brown basalt stone slabs observed in abundance within the immediate vicinity. It is built directly atop the bedrock basalt of the surrounding landscape. Its foundation stones are quite large and would have required multiple workers and considerable effort to move into position. Its south wall foundation is comprised of four larger blocks, including a large cornerstone on the southwest; the east wall foundation is made up of six slightly smaller, yet still large blocks, including a large cornerstone at the northwest; the outer north wall is dominated by a massive block ~~which~~ that takes up much of the east section of the wall but the rest of the north wall foundation is made up of much smaller slabs more consistent with the standard slabs forming the majority of the structure. The outer east wall foundation is also dominated by a massive block and a considerable cornerstone at the northeast, but both blocks actually rest on smaller stones rather than directly on bedrock.

Figure 2. Top: The Bear Trap; view of easternmost wall and entrance looking southwest. Note, marker cairns visible in the background at far left and center left. A modern hut is also visible in the background. Photo: MJW. Bottom: An aerial drone image that shows the Bear Trap and the two adjacent rock piles. Photo: DFC.

The structure has a slender entrance and a constricted, rectangular interior space of just 0.9-1.15 m by 2.28 m. In its present state it measures roughly 1.4 m in height at its highest preserved extent, but its original height and roof morphology may only be guessed at. During our 2019 examination of the structure we noted that many of the wall stones facing into the interior are long stones and many appear to have been set so as to jut slightly into the interior by a few centimeters, suggesting to us the possibility that the roof may have been of a gabled construciton similar to techniques used in early Medieval dry-stone structures, including in south Greenland, but this suggestion must be taken as conjecture. All four of the walls are consistently over a meter thick. Steenberg (1893: 5-6) gives a quite accurate accounting of the Bear Trap's dimensions. Of the outer walls, the north and west walls measure 4.39 m while the south and east walls measure 4.47 m. The south wall is 1.36 m thick. The north wall is the thickest of the structure, measuring 1.78 m wide on its east end and 1.88 m on its west end. The west wall is roughly 1.44-1.49 m thick. The south wall is the most consistent in width along its length, but is in considerable disrepair on its eastern half. Many of the stone blocks in this section of the structure are loosely scattered along the top of the wall and the wall has begun to slump into the interior at a rather precarious angle. The entrance opening is 0.55 m on the exterior of the east wall and slims faintly to just 0.47 m where it opens into the interior space. The interior space forms a nearly rectangular trapezoid measuring 2.28 m on its north side, 1.17 m on its south, 1.25 m on its east and roughly 1.15 m on its west.

Citing Ingstad (1966: 82), McGovern (1985: 295) provides that the structure "encloses an area of 20-24 m^2". But, this appears to take into account the entirety of the structure rather than reflect the available interior space. We calculate an interior as comprising roughly just 5.7 m^3. This considers that that the original structure had a ceiling of just two meters in height (sans the entry passage). Even if the structure had originally included an interior ceiling of three meters in height, similar to the

skemma storehouse at Anavik in southwest Greenland (Roussell 1941: 231), the interior space would account for no more than 8.55 m^3. The differences in the widths of the outer walls compared to the interior space between the Bear Trap and the Anavik storehouse (and others in the south Greenlandic Norse settlements) are considerable, with the latter providing significantly more potential interior space.

Outside of the Bear Trap structure, roughly three meters from the northeast wall – just opposite the entrance – and about four meters from the southeast wall lay two rectangular piles of stones of the same type and size of the stones used for construction (Figure 2). Presumably, these may be the remnants of stones which over the years have fallen from the original structure and have – at some point – been collected and assembled into piles, but this is speculation. Another notable difference between the Bear Trap and Norse *skemma* storehouses is that the Bear Trap rests on a relatively flat expanse of bedrock, albeit in a highly visible location on the landscape of the headland. While this is not unlike the relatively flat surface upon which storehouse No. 5 at Sandnes lies (Roussell 1936: 93), many storehouses were purposefully constructed on prominently raised sections of bedrock or even built atop large boulder erratics. The Bear Trap is not elevated in any way.

The interior floor of the Bear Trap is bare bedrock. The floor comprises a somewhat varied topography, as the section immediately to the north (right upon entering the interior) forms a slightly elevated platform which gives the impression of a raised bed-like surface, measuring 0.78 m wide by 1.88 m long. Along the edge of this, the floor drops into a trough-like channel, sitting at least 10 cm lower (15-20 cm according to Meldegaard 1995: 206) than the platform around which it forms an inverted 'L' shape when viewed from the entrance. Some stones from the inner walls have fallen into the structure, making the trench difficult to define without moving some materials, which we did not. It is difficult to estimate the exact depth of this depressed space as it was also filled with moss and tuft grass which were not disturbed during our survey as we did not disrupt the surface soil.

Figure 3. The interior of the Bear Trap photographed from the entranceway. On the left edge of the floor the trough can be seen and to the right the raised platform area.

The Cemetery

The 2019 VIMOA expedition (Walsh et al. 2020) observed that much of the headland immediately to the east of the Bear Trap conceals a number of stone cairn graves, well-camouflaged against the natural rock formations of the area. The survey revealed no less than five graves, but given the time constraints imposed during the 2019 visit to the site the survey of the cemetery can only be considered preliminary and more graves could be in the vicinity to be revealed in future and more extensive survey. Our review of the extant literature did not discover any previous mention of these graves, thus this information provides novel context for interpreting the Bear Trap's possible original purpose. We identified five grave cairns covering no less than eight observable stone cists, five of which retained identifiable human remains (including at least one double grave). One cairn was extremely large, was covered by massive capstones, and appears to have been erected to cover at least three distinctive cists, and possibly more (Figure 4). Another collapsed and disturbed cairn covered two stone cists, both of which were exposed, as were the human skeletal remains therein. Of note, despite thousands of body-sized cavities created by the natural rock formations across the boulder-strewn headland, none of

those spaces appear to have been used as burial locations. Rather, stone cists with over-built capstones and cairns were deliberately constructed on the landscape from loose rocks. While these sometimes incorporate one or more exceptionally large boulders or sections of bedrock for one or more sides, nowhere do the natural rock formations make up the entirety of the containment area. This grave construction technique was also observed for other graves in the region during our 2019 survey (elsewhere in northwest Nuussuaq).

Interestingly, this holds true even in places in which the landform and rocks could have easily furnished naturally secluded spaces in the local terrain suitable for interring a body. This contrasts sharply with the method that seems to have dominated in the construction of meat caches, in which natural troughs and fissures in the bedrock seem to have been ubiquitously incorporated to some degree into the design of the storage area. In many cases massive boulders or bedrock make up three or all four sides of caches in the area. These natural and semi-natural enclosures would be covered by numerous large and usually long stones placed width-wise atop the storage area. Also of note in this regard, the capstones covering the grave cists often differ markedly from those of caches. Here, grave capstones were often made up of large, flat, oblong stones, sometimes multiples overlapping and frequently of a different rock type and color (mostly white granitic material) from the surrounding material and/or that used to construct the associated cist and cairn. In our observations, cache cover stones more often appear to have been made up of long, relatively flat stones placed perpendicular to the overall length of the cache space, perhaps making it easier for one or two people to open just a section of the cache by lifting a single or a couple of heavy – but not too difficult to lift – stones.

The graves from the cemetery northeast of the Bear Trap are congruent in construction technique and aesthetic with each other but differ markedly from the construction of the Bear Trap itself. They are concentrated into an area of c. 400 m by 150 m running northeast-southwest following the landform of the promontory up to where the headland slopes up into the interior. The nearest grave is located roughly 100 m distance from the Bear Trap.

Figure 4. Grave cairn 4. Left: overview of the large, partially-open cairn with overlapping white capstones and exposed opening with displaced capstone to the right. Right: the interior of one of at least three separate cists beneath the Grave 4 cairn. View to the west.

Across the cemetery, the majority of the observed human remains were crania, sometimes with larger long bones such as occasional femora, some ribs, and one tibia were observed, along with other deteriorated long bones which could not be easily identified from mere surface observation and without disturbing the graves (which we did not do in any way). The nature of the remains (crania and long bones) and the types of graves (box cists) suggests that this congregation of burials made up a pre-Contact or proto-historic cemetery in which excarnated remains – in some cases of multiple individuals – were deposited as bones rather than articulated inhumations. This is clear from the positions of most of the observable bones, which suggests that for the most part, the remains were not articulated at the time of deposition. This fits with Thule burial traditions in which the deceased may have been first exposed to the elements and scavengers, only to be later collected and deposited (e.g. Walsh and O'Neill 2018). In addition to the grave cairns, a number of smaller, well-sealed, low-built cairns and features resembling box hearths were documented scattered across the landscape. It is

possible that some of these features may have been fox traps or marker cairns respectively, but their semi-intact state makes it impossible to determine their exact purposes without disturbing them. No skeletal remains or materials of any kind were observed in any of these smaller features, with the exception of a single box-shaped cairn feature on a neighboring promontory immediately to the north of the Bear Trap (N 70˚ 42.053; W 54˚ 34.812) which contained a single sherd of undecorated modern ceramic, the presence of which is probably the result of either animal deposition or possibly vandalism by modern tourists.

Stone features and graves observed east of the Bear Trap

Figure 5. Well-sealed box cairn (possibly a fox trap) with nothing visibly inside, but well-constructed and seemingly not prominent or high enough to be a place-marker. However, the inclusion of a single white-stone capstone is consistent with the conventional construction of graves in the region. Not within the domain covered by the UAV orthomosaic. 3D model available for download at: https://zenodo.org/record/4011977#.X3jASNMzbUo

Figure 6. Grave 1; stone cist and cairn with capstones missing; visible human remains include two human crania and some additional undetermined skeletal elements. 3D model available for download at https://zenodo.org/record/3984864#.X0jmJ9MzbUo

Figure 7. Grave 2; stone cist with cairn stones disturbed and distributed around; no visible human remains.

Figure 8. Grave 3; collapsed cairn over stone cist with visible human skeletal remains.

Figure 9. Grave 4; exposed cist/cairn with large capstones and at least three separate cists beneath the large cairn; but it is difficult to differentiate the exact dimensions and extents of each cist as they remain partially beneath intact sections of the overlapping cairn. See also Figure 3.

Figure 10. Grave 5; long, collapsed and exposed stone cist with cairn stones scattered around the immediate area; two cists exposed under one cairn, with visible human remains.

Two hundred meters southeast of the headland on which the Bear Trap marks the midpoint stands the ruins of a small unnamed settlement (NKAH Site 5085; Map no: 70V1-0IV-012). According to the NKAH records, this settlement is of the Thule/Neo-Inuit period. It comprises six oval-rectangular semi-subterranean winter houses of peat and stone, including one rather long rectangular foundation of c. 4 m x 9.5 m. A number of these structures, including one along the west edge of the adjacent cove and the one farthest out on the promontory have begun actively eroding into the sea, along with

considerable midden deposits. During our 2019 survey two whale bone artifacts (a drilled/beveled socket fragments and another drilled fragment) were observed eroding from a midden strata onto the beach of the cove immediately northwest of the settlement, that separates the settlement promontory from that of the Bear Trap and the adjacent cemetery.

Figure 11. A UAV-derived orthomosaic of the Bear Trap and its surroundings, including the adjacent graves, natural harbor, peat houses, and modern features.

Discussion

The case for storage

Meldegaard (1953; 1995) promoted the notion that the Bear Trap was originally constructed by the Greenland Norse possibly for use as a storage depot. Indeed, there is reliable evidence of the region's value to the economies of Northern Europe (e.g. McGovern 1985; Perdikaris and McGovern 2007; Roesdahl 2003, 2005). Ample archaeological and archaeometric-derived evidence suggests that the Nuussuaq area was regularly exploited by the Norse during Nordrsetur hunting expeditions specifically targeting the acquisition of walrus, seals and other valuable wild animal resources such as polar bear, narwhal and possibly white falcons (Arneborg 2003; Frei et al. 2015; Ljungqvist 2005; McGovern 1985; Star et al. 2018; Vebæk 2008; Vésteinsson et al. 2002). The acquisition of some of these animals, particularly walrus and polar bears, would have been a dangerous proposition (see McGovern 1985: 308). As already argued by Rosenkrantz (1967) and reiterated by McGovern (1985: 285), if the purpose of the Nordrsetur expeditions was to acquire "major portions of the goods needed for transatlantic trade" then the Bear Trap's modest dimensions do not seem adequate for or efficient as a storage space for any considerable quantity of such goods as large animal hides, walrus tusks or narwhal horns. For example, the length of the structure's interior space would not well suffice to contain even an average-sized adult narwhal tooth (c. 1½-3 m in length), much less a stockpile of such materials. Arguably, the interior space would barely serve to store a relatively small surplus of stacked animal hides from larger animals. Add to this that, at over a meter thick, the Bear Trap's walls are also far thicker than would be necessitated for the effective temporary storage of such items. Additionally, there should, theoretically, have been little obligation to stockpile or protect such commodities during the relatively short Nordrsetur expeditions. As noted above, comparison to similar drystone storage structures (*skemma;* see e.g. Berglund 1973) elsewhere in Greenland is further weakened by the realization that storage structures for stores such as food perishables (see e.g. Roussell 1941: 231) and surplus goods would not likely have been necessary for the relatively short Nordrsetur expeditions, which would have lasted a maximum around 11 weeks during the height of summer, including about 30 days travel time to and from the Disko region roundtrip (McGovern 1985: 306). Thus, the existing evidence suggests that, unless it was used to store rather compact boat gear and/or hunting supplies during the expeditions (see e.g. Roussell 1941: 231), there seems little logic in considering the Bear Trap as a storage facility.

The case for a grave

There is no direct evidence that the Bear Trap was meant or used as a grave. However, a case can be made via numerous supporting arguments for just such a possibility, especially considering our

findings of graves in the vicinity. If the nearby graves predate the Bear Trap, then as a burial monument, its position at the southwestern margin of the existing cemetery and its central position on the promontory could have been seen by its builders as an appropriate and convenient use of already sacred ground. At the same time, the structure's distinctive and exceptionally robust construction would set it (and thus any occupant) apart from the other graves in the existing 'cemetery', both literally and symbolically. If the Bear Trap predates the other graves, one logical conclusion for the subsequent placement of the other graves is that the promontory was already recognized as sacred ground and as an appropriate location for burials. These arguments, however, remain speculative. As noted above, the interior space inside the Bear Trap would not suffice for any considerable hoard of goods and particularly not large or long ones. However, the interior dimensions are curiously appropriate for a single human interment laid extended on the raised surface to the immediate right of the entrance. Further, a less-prominent location would seem logical should the structure have been intended for safe storage, since its conspicuous location actually serves to draw attention to its presence on the landscape as one approaches the adjacent coves. Not incidentally, the adjacent cove between the Bear Trap's promontory and the settlement ruins is one of the only safe harbors within a 75 km radius of the site (McGovern 1985: 297). Given this suite of information, we support the earlier hypothesis that the structure was probably a (perhaps temporary) burial chamber and subsequent cenotaph built by the Norse for one of their own, likely someone who died during one of the Nordrsetur expeditions.

Conclusion

Today, Arctic landscapes are changing at an unprecedented pace. There is no question that Arctic regions are currently experiencing some of the most dramatic and destructive climate-change-driven effects to coastal ecosystems and topography – which includes putting many Arctic coastal landscapes and their archaeology at high risk for loss over the coming decade(s) (see e.g. Desjardins and Jordan 2019; Fenger-Nielsen et al. 2020; Hollesen et al. 2016; Hollesen et al. 2018; Hollesen et al. 2019; IPCC 2013; Matthiesen et al. 2020; McGovern 2014; 2018). Future archaeological studies in the rapidly changing environs of the Arctic may benefit from the use of digital technologies for documenting at-risk archaeological sites, as we seek to preserve Arctic archaeological heritage for future generations. While we can only guess as to the original purpose for the structure, the locality and the ruins themselves are a valuable part of the archaeological heritage of Greenland. As such, a major contribution of our work is the creation of detailed 3-D models and orthomasaics of the unique and intriguing structure that is the Bear Trap and its surrounding features.

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APPENDIX D

Atanerkuluk Digital Imagery Processing Report

20190814_Atanikerluk

Processing Report

21 October 2020

Survey Data

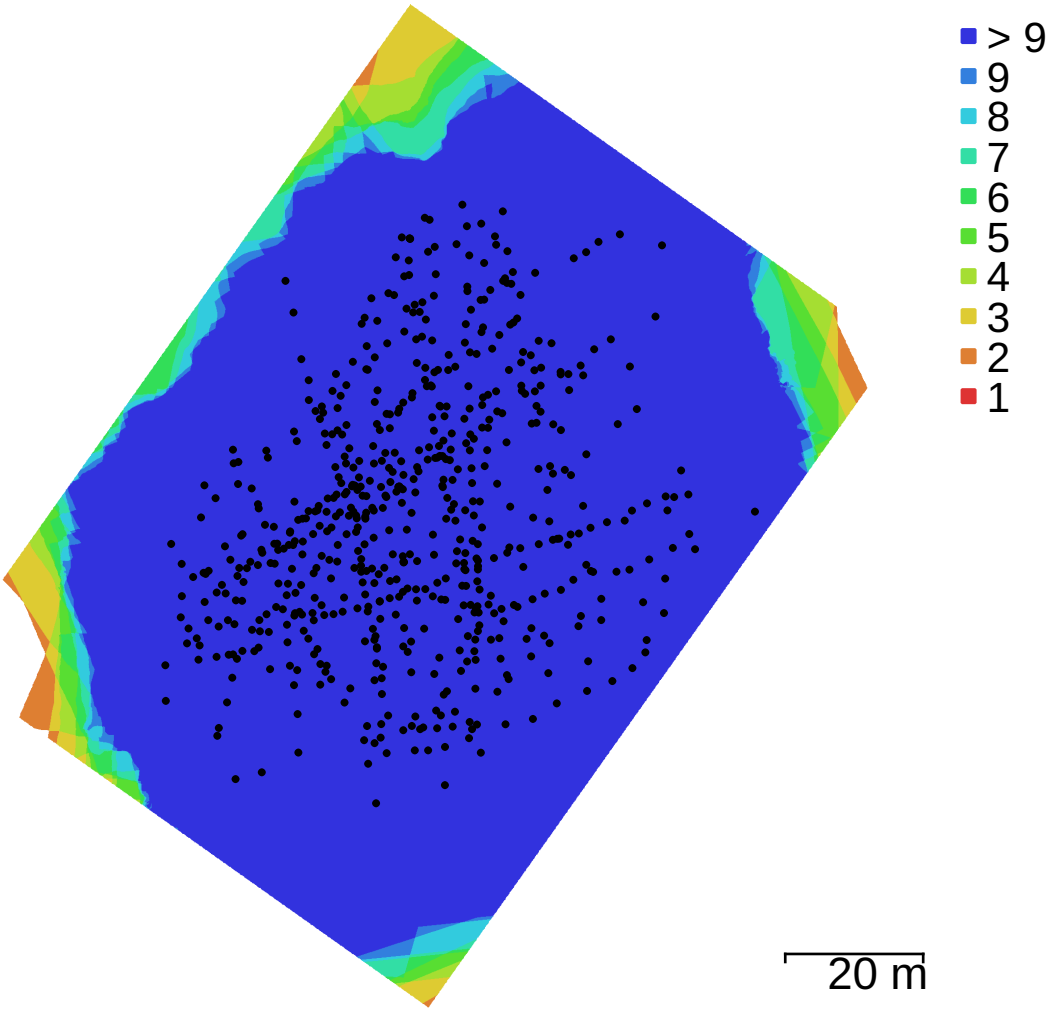

Fig. 1. Camera locations and image overlap.

Number of images:	622	Camera stations:	622
Flying altitude:	23.5 m	Tie points:	1,004,856
Ground resolution:	7.94 mm/pix	Projections:	2,402,831
Coverage area:	9.89e+03 m²	Reprojection error:	0.375 pix

Camera Model	Resolution	Focal Length	Pixel Size	Precalibrated
FC300C (3.61mm)	4000 x 3000	3.61 mm	1.56 x 1.56 µm	No

Table 1. Cameras.

Camera Calibration

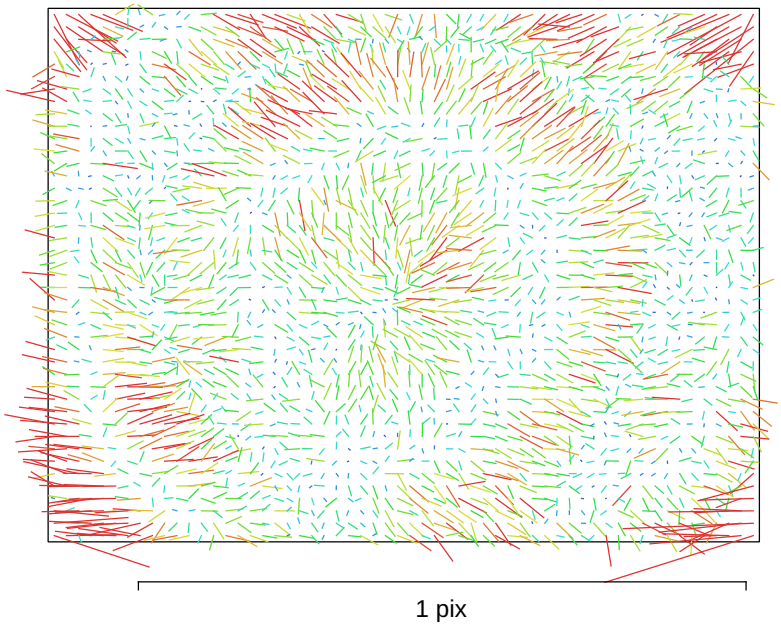

Fig. 2. Image residuals for FC300C (3.61mm).

FC300C (3.61mm)

622 images

Type	Resolution	Focal Length	Pixel Size
Frame	**4000 x 3000**	**3.61 mm**	**1.56 x 1.56 µm**

	Value	Error	F	Cx	Cy	K1	K2	K3	P1	P2
F	**2723.24**	0.035	1.00	-0.05	-0.79	-0.24	0.25	-0.15	-0.01	-0.01
Cx	**20.8135**	0.01		1.00	0.03	0.00	0.01	-0.02	0.73	-0.01
Cy	**6.31648**	0.016			1.00	0.02	-0.11	0.03	0.01	0.38
K1	**-0.141585**	1.6e-05				1.00	-0.95	0.90	-0.01	-0.23
K2	**0.131451**	4e-05					1.00	-0.98	0.01	0.07
K3	**-0.0294111**	3.2e-05						1.00	-0.01	-0.08
P1	**-4.17678e-05**	1e-06							1.00	0.00
P2	**0.000823196**	1.2e-06								1.00

Table 2. Calibration coefficients and correlation matrix.

Camera Locations

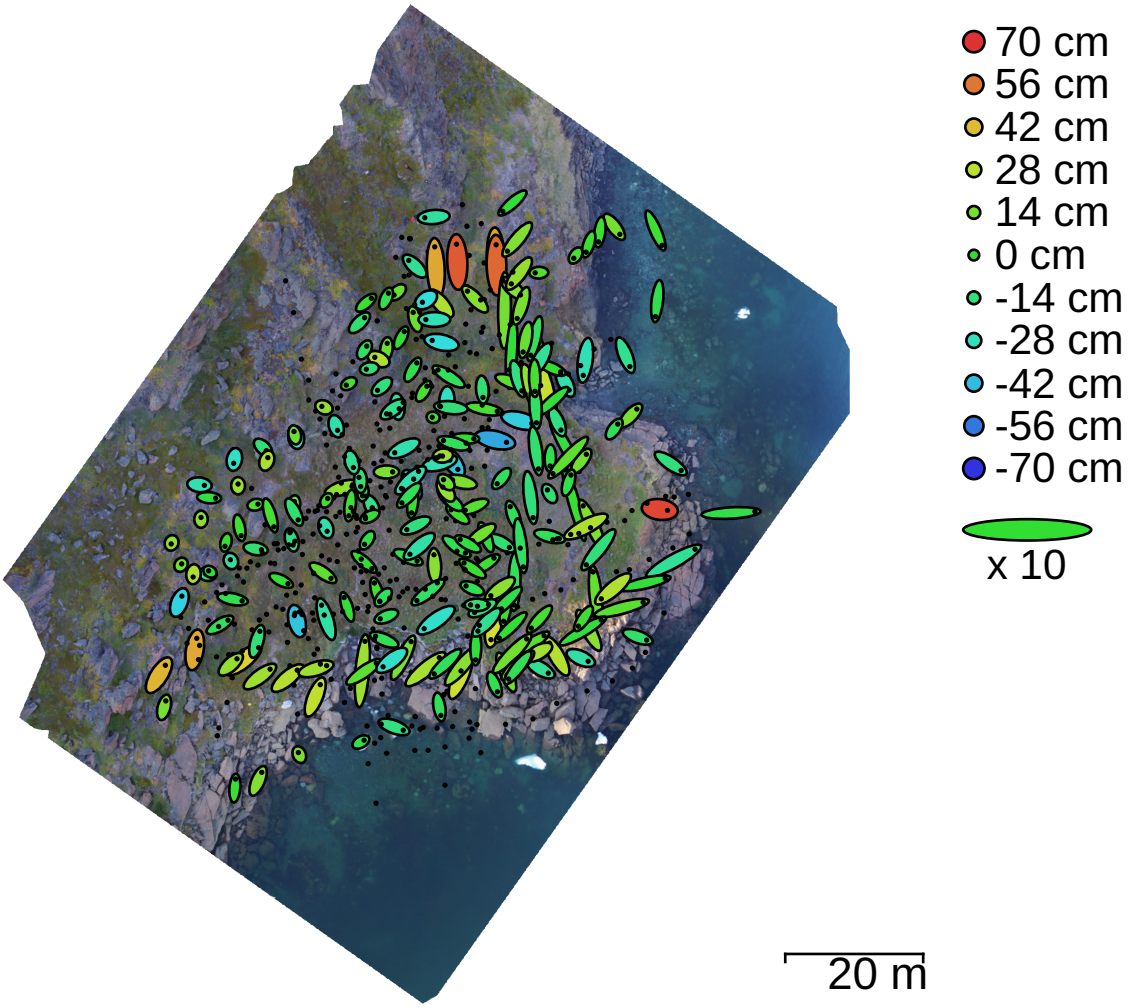

Fig. 3. Camera locations and error estimates.
Z error is represented by ellipse color. X,Y errors are represented by ellipse shape.
Estimated camera locations are marked with a black dot.

X error (cm)	Y error (cm)	Z error (cm)	XY error (cm)	Total error (cm)
21.0836	29.0685	19.1751	35.9096	40.7085

Table 3. Average camera location error.
X - Longitude, Y - Latitude, Z - Altitude.

Digital Elevation Model

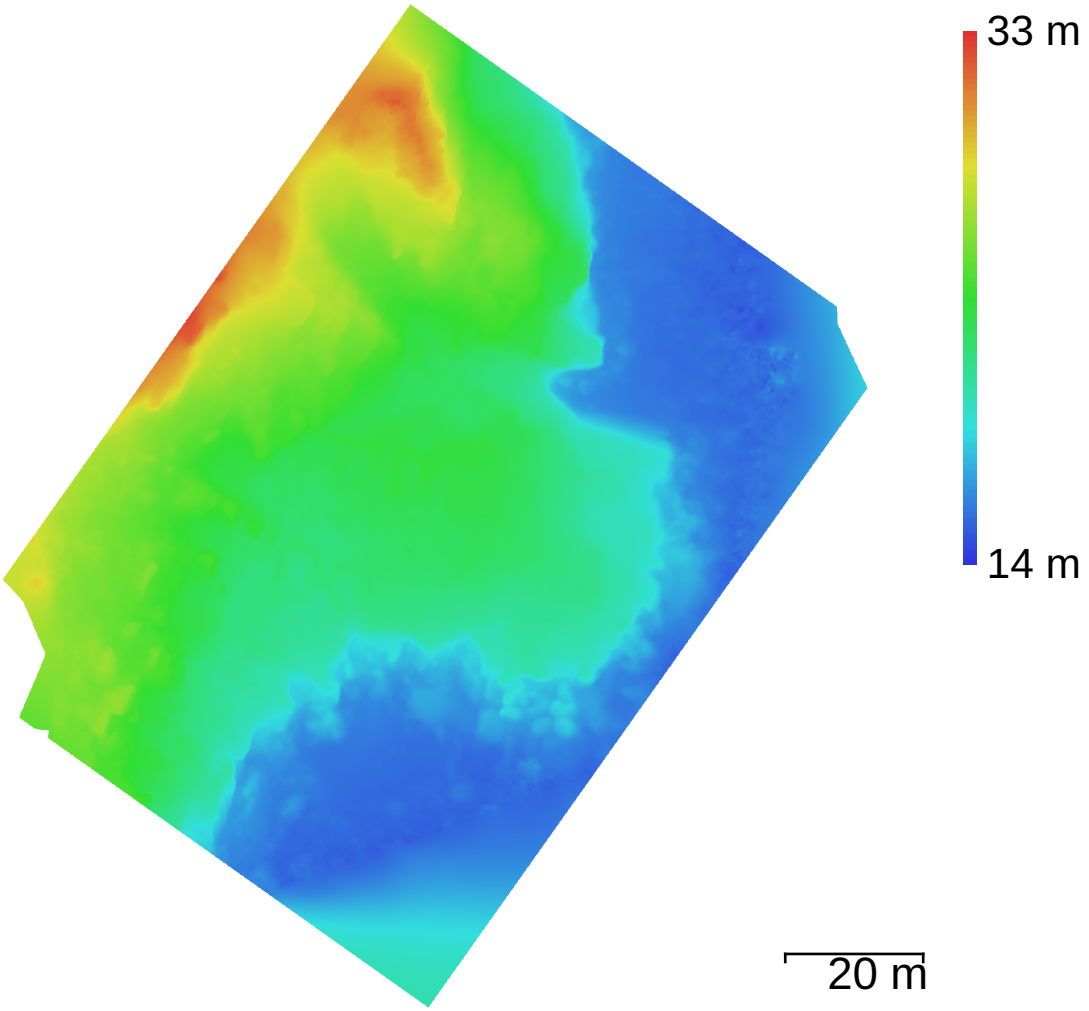

Fig. 4. Reconstructed digital elevation model.

Resolution:	6.35 cm/pix
Point density:	248 points/m²

Processing Parameters

General	
Cameras	622
Aligned cameras	622
Coordinate system	WGS 84 (EPSG::4326)
Rotation angles	Yaw, Pitch, Roll
Point Cloud	
Points	1,004,856 of 2,489,993
RMS reprojection error	0.141232 (0.374887 pix)
Max reprojection error	0.299999 (2.56992 pix)
Mean key point size	2.56291 pix
Point colors	3 bands, uint8
Key points	Yes
Average tie point multiplicity	5.02544
Alignment parameters	
Accuracy	High
Generic preselection	No
Reference preselection	No
Key point limit	60,000
Tie point limit	0
Adaptive camera model fitting	No
Matching time	10 hours 3 minutes
Alignment time	15 minutes 57 seconds
Optimization parameters	
Parameters	f, cx, cy, k1-k3, p1, p2
Adaptive camera model fitting	No
Optimization time	34 seconds
Dense Point Cloud	
Points	3,094,507
Point colors	3 bands, uint8
Reconstruction parameters	
Quality	Low
Depth filtering	Aggressive
Depth maps generation time	6 minutes 45 seconds
Dense cloud generation time	29 minutes 53 seconds
DEM	
Size	2,174 x 2,290
Coordinate system	WGS 84 (EPSG::4326)
Reconstruction parameters	
Source data	Dense cloud
Interpolation	Enabled
Processing time	3 seconds
Orthomosaic	
Size	15,792 x 18,320
Coordinate system	WGS 84 (EPSG::4326)
Colors	3 bands, uint8
Reconstruction parameters	
Blending mode	Mosaic
Surface	DEM
Enable hole filling	Yes
Processing time	5 minutes 6 seconds
Software	
Version	1.4.4 build 6848
Platform	Linux 64