REMAINS of Greenland

REsearch and Management of Archaeological sites
IN a changing environment and Society
Field report 2016

Executive Summary

Climate change is leading to the accelerated destruction of archaeological sites in Greenland. In response to this threat, REMAINS of Greenland provides fundamental knowledge to quantify the short and long-term net effects of climate change on the preservation of archaeological record and heritage landscape. REMAINS of Greenland is a multidisciplinary research project administered by the National Museum of Denmark with support from the Center for Permafrost (CENPERM) at the University of Copenhagen and the Greenland National Museum and Archives (NKA). The project group comprises a team of experienced and early career researchers and university students. Research conducted in August of 2016 focused on the Nuuk region in southwest Greenland—an area with a high density and variety of archaeological sites and where the effects of climatic change are already visible. Fieldwork conducted this year expanded on the preliminary work collected in 2012 and 2013 and reported in Knudsen, et al. (2014). Highlights of the 2016 field work include:

- Archaeological survey and sub-surface testing at twelve sites in the Nuuk fjord that included ruin groups found in the Austmannadal Valley, Kilaarsafik, Qoornoq, Iffiartarfik, Nuugaarsuk, Itivi, Ersaa, Kangeq, Qarajat and Tulugartalik.
- Broad spectrum soil and vegetation analysis at Kilaarsafik, Qoornoq, Iffiartarfik, Ersaa and Kangeq. This included targeted sampling of Northern willow (*Salix glauca*) to observe regional changes in the proliferation of this species in Greenland and its relative impact on the integrity of archaeological sites and ruins.
- Installation of environmental monitoring stations in the Austmannadal Valley (V52a and V53d), Kilaarsafik, Qoornoq, Iffiartarfik, Ersaa and Kangeq.
- Decomposition studies on wood and bone at Kilaarsafik, Qoornoq, Iffiartarfik, Ersaa and Kangeq.
- Replication of a number of historic photos throughout the Nuuk fjord to contrast observable changes to the landscape over the past century.
- dGPS and areal UAV survey conducted at Kilaarsafik, Qoornoq, Iffiartarfik, Ersaa, Kangeq, Qarajat, and Tulugartalik.
- Refinement of a comprehensive site valuation protocol, sites visited were described in terms of archaeological significance, state of preservation, and threats against preservation

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Introduction

An urgent need exists to document the effects of modern climate change on archaeological sites in the Arctic. This includes determining where future efforts should be focused to mitigate the impacts of climate change and improve long-term heritage management strategies. The REMAINS of Greenland project explores environmental mechanisms affecting the preservation of archaeological sites in Greenland and provides research based tools that can be used for locating and managing sites at risk.

REMAINS of Greenland is built on the experiences of several previous collaborative projects and employs a team of leading and early career researchers and students. The project's research is currently situated in the Nuuk Fjord in southwest Greenland, a region with a high density and variety of archaeological sites and where the effects of climatic change are extremely visible. The project's first field campaign was conducted from August 4th to 29th, 2016.

This report summarizes the work performed by of the REMAINS research team in August of 2016. Detailed information is provided on the strategies, methods and scale of data collected while in the field. The main objectives of the fieldwork in 2016 were:

- To study site formation processes, recent environmental changes and human impacts based on extant reports of previous archaeological surveys and historical photos

- Perform archaeological surveys and sub-surface testing to evaluate the integrity of the archaeological record at several sites in West Greenland

- Register the distribution, density and root depth of modern floral species found to proliferate at archaeological sites in West Greenland

- Collect data on soil properties and regional vegetation

- Install environmental monitoring equipment for "ground-truthing" and testing of underlying assumptions of the effects of localized climate changes occurring

- Perform detailed mapping and documentation of archaeological site using high precision GPS and low altitude high-resolution aerial photography's through unmanned aerial vehicles (UAV/Drones)

- Test a new protocol for on-site risk assessment, identify immediate and long-term risks and mediate future options for the preservation and protection of Greenland's archaeological heritage

Participants

The group in total consisted of 16 researchers and support staff. Project personnel and their institutional affiliations are listed in Table 1.

Table 1. The 2016 REMAINS personnel and their institutional affiliations.

Name	Affiliation
Jørgen Hollesen (JHO)	Senior Researcher, National Museum of Denmark
Henning Matthiesen (HMA)	Senior Researcher, National Museum of Denmark
Anne Marie Eriksen (AME)	Ph.D. Student, National Museum of Denmark & Centre for Geogenetics, University of Copenhagen
Nanna Bjerregaard Pedersen (NBP)	Post Doc, National Museum of Denmark
Roberto Fortuna (RFO)	Photographer, National Museum of Denmark
Rasmus Fenger-Nielsen (RFN)	Ph.D. Student, National Museum of Denmark & Department of Geosciences and Natural Resource Management, University of Copenhagen
Bo Elberling (BEL)	Professor, Department of Geosciences and Natural Resource Management, University of Copenhagen
Aart Kroon (AKR)	Associated Professor, Department of Geosciences and Natural Resource Management, University of Copenhagen
Andreas Westergaard-Nielsen (AWN)	Post Doc, Department of Geosciences and Natural Resource Management, University of Copenhagen
Emil Alexander Sherman Andersen (ESA)	Student, Department of Biology, University of Copenhagen
Bo Albrechtsen (BOA)	Deputy Director, Greenland National Museum and Archives
Christian Koch Madsen (CKM)	Archaeologist, Greenland National Museum and Archives
Mikkel Myrup (MMY)	UAV/GIS specialist, Greenland National Museum and Archives
Hans H. Harmsen (HHH)	Archaeologist, Greenland National Museum and Archives
Allan Lynge (ALY)	Logistics/Transportation Coordinator, Greenland National Museum and Archives
Randi Sørensen Johansen (RSJ)	Student, Ilisimatusarfik, University of Greenland
Ulunnguaq Nielsen Lyberth (UNL)	Student, Ilisimatusarfik, University of Greenland

Management summary

A brief overview of the day-to-day activities of the field work is provided in Table 2.

Table 2. Summary of the day-to-day activities of the 2016 field season.

Day	Activities
04-08-2016	Packing of equipment
05-08-2016	Packing of equipment & food shopping
06-08-2016	Packing of equipment & food shopping
07-08-2016	Transfer Nuuk – Kilaarsafik of Group 1 (HMA, NBP and HHH); first day of investigation of Austmannadalen
08-08-2016	Transfer Nuuk - Kilaarsafik of Group 2 (JHO, AME, RFO, RFN, ESA, CKM) Day two of ivestigation into Austmannadalen (HMA, NBP and HHH)
09-08-2016	Fieldwork, Kilaarsafik (JHO, AME, RFO, RFN, ESA, CKM) Day three of investigation into Austmannadalen (HMA, NBP and HHH)
10-08-2016	Fieldwork, Kilaarsafik – MMY joins group 2 Day four of investigation into Austmannadalen (HMA, NBP and HHH)
‘11-08-2016	Fieldwork, Kilaarsafik (JHO, AME, RFO, RFN, ESA, CKM, MMY) Day five of investigation into Austmannadalen (HMA, NBP and HHH); team returned to Kilaarsafik in the afternoon
12-08-2016	Transfer Kilaarsafik – Qoornoq (JHO, HMA, NBP, AME, RFO, RFN, ESA, CKM, HHH), two students (RSJ and UNL) joined team in Nuuk
13-08-2016	Fieldwork, Qoornoq (JHO, HMA, NBP, AME, RFO, RFN, ESA, CKM, HHH, RSJ and UNL), BEL, AKR and AWN joined the Group
14-08-2016	Fieldwork, Qoornoq (JHO, NBP, AME, RFN, HHH, UNL, BEL, AWN, AKR) Daytrip to Iffiartarfik (HMA, RFO, ESA, CKM, RSJ)
15-08-2016	Fieldwork, Qoornoq (HMA, RFO, HHH, RSJ) Daytrip to Iffiartarfik (JHO, NBP, AME, RFN, ESA, CKM, UNL, BEL, AWN, AKR)
16-08-2016	Fieldwork, Qoornoq (RFN, ESA, AWN, HHH) Daytrip to Nuugaarsuk and Itivi (JHO, HMA, NBP, AME, RFO, HHH, UNL, RSJ, BEL, AKR)
17-08-2016	Fieldwork Qoornoq (JHO, HMA, NBP, AME, RFO, CKM, MMY, UNL, RSJ, AKR) Transfer 4 persons; Qoornoq – Ersaa (RFN, ESA, HHH, AWN) Transfer 1 person; Qoornoq – Nuuk (BEL) (returned to Denmark 18-08)
18-08-2016	Transfer Qoornoq – Ersaa (JHO, HMA, NBP, AME, RFO, CKM, UNL, RSJ, AKR) Fieldwork, Ersaa (JHO, HMA, NBP, AME, RFO, RFN, ESA, CKM, HHH, UNL, RSJ, AKR, AWN)
19-08-2016	Fieldwork, Ersaa (JHO, HMA, NBP, AME, RFO, RFN, ESA, CKM, HHH, MMY, UNL, RSJ, AKR, AWN) Transfer to Nuuk (JHO, HMA, NBP, AME, RFO, RFN, ESA, CKM, HHH, UNL, RSJ, AKR, AWN)
20-08-2016	Personal day; no fieldwork performed
21-08-2016	Fieldwork, Kangeq (JHO, HMA, NBP, RFO, RFN, ESA, CKM, HHH, UNL, RSJ, AKR) Characterization & selection of samples (e.g. bones and wood) (HMA, NBP, AME)
22-08-2016	Fieldwork, Kangeq (JHO, HMA, NBP, AME, RFO, RFN, ESA, CKM, HHH, UNL, RSJ, AKR, AWN)
23-08-2016	Lab work, Nuuk (JHO, HMA, NBP, AME, RFO, RFN, ESA, AKR)

	AWN returned to Denmark
24-08-2016	Daytrip, Qarajat (JHO, HMA, NBP, AME, RFO, RFN, ESA, CKM, HHH, MM, UNL, RSJ, AKR)
25-08-2016	Daytrip, Tulugartalik (HMA, AME, RFO, ESA, CKM, HHH,MM, UNL, RSJ) Meeting with ASIAQ in Nuuk (AKR, RFN, JHO) End of fieldwork dinner
26-08-2016	Packing of equipment and shipment of samples (JHO, HMA, NBP, AME, RFO, RFN, ESA, AKR)
27-08-2016	Packing of equipment and shipment of samples (HMA, RFO, RFN, ESA) JHO, NBP, AME and AKR return to Denmark
28-08-2016	Packing of equipment and shipment of samples (HMA, RFO, RFN, ESA)
29-08-2016	HMA, RFN and ESA return to Denmark

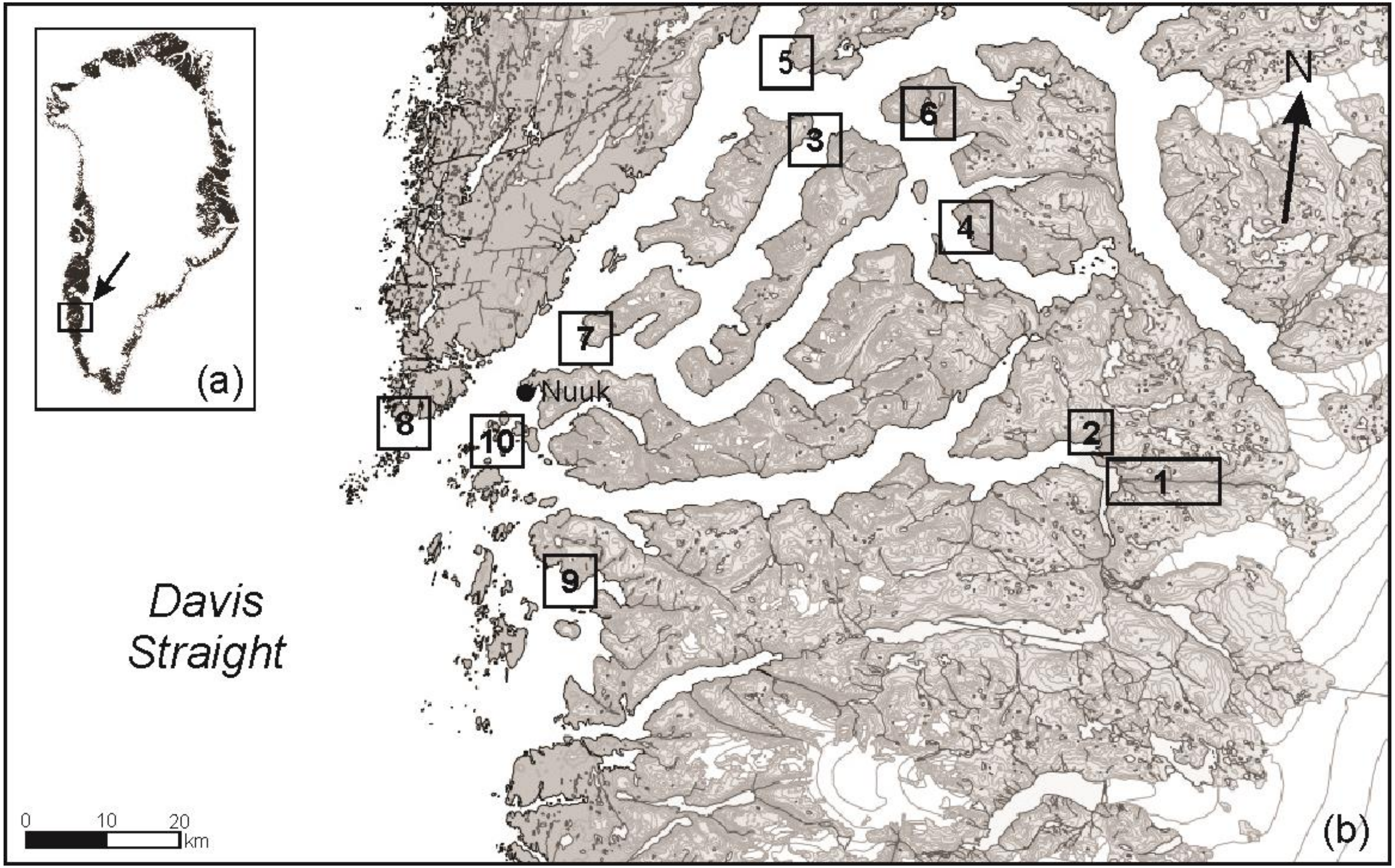

Fig. 1. (a) Nuuk fjord region of southwest Greenland. (b) Locales investigated in 2016: (1) Austmannadal Valley; (2) Kilaarsafik; (3) Qoornoq; (4) Iffiartafik; (5) Nuugaarsuk; (6) Itivi; (7) Ersaa; (8) Kangek; (9) Qajarat; (10) Tulugartalik. Data source: Nunniffiit 1:250,000.

Table 3. Locales investigated by the REMAINS team in 2016.

Map No.	Site	NKAH	Latitude	Longitude	Locality	Cultural phases
1	Austmannadal, V52a	1432	64°13.385' N	50°07.212' W	Inland valley	Norse
1	Austmannadal, V53c	1437	64° 13.155' N	49° 52.307' W	Inland valley	Norse
1	Austmannadal, V53d	1438	64°13.603' N	49° 49.157' W	Inland valley	Norse
2	Kilaarsafik (Sandnæs)	1480	64°14.604' N	50° 10.510' W	Coastal, inland fjord	Saqqaq, Dorset, Norse
3	Qoornoq	577; 1468	64°32.027'	51°05.144' W	Island, inner fjord	Saqqaq (at nearby Tuapagssuit), Norse, Thule, colonial
4	Iffiartarfik	1457; 1202	64°27.567' N	50°38.738' W	Coastal, inner fjord	Norse, Thule, colonial (Hernnhut, Moravian)
5	Nuugaarsuk	1319	64°27.567' N	50°38.738' W	Coastal, inner fjord	Thule, colonial
6	Itivi	570; 1418	64°35.488' N	50°47.945' W	Coastal, inland fjord	Norse, Thule
7	Ersaa	1150	64°14.796' N	51° 36.449' W	Coastal, inner fjord	Thule, colonial
8	Kangeq	1088	64°06.433' N	52° 03.104' W	Island, head of fjord	Saqqaq, Thule, colonial
9	Qarajat	647; 4871	63°57.551' N	51° 30.323' W	Coastal, inland fjord	Thule, colonial (Hernnhut, Moravian)
10	Tulugartalik	1057	64°04.760' N	51° 51.997' W	Island, head of fjord	Thule, colonial

Previous investigations in the Nuuk Fjord

Twelve localities were investigated by the REMAINS team in 2016 (Fig. 1; Table 3). Selection of localities was informed by preliminary work performed in 2012-2013. During these years, investigations were conducted on four Norse sites in the Ameralik Fjord and 14 Thule sites in the Nuuk Fjord. Only two of the Thule sites had been previously investigated by archaeologists; knowledge of the other 12 sites were derived from interviews conducted by Jørgen Meldgaard in 1952 in Qeqertarsuatsiaat and Kangerluarssussuaq (Gulløv 1983:36-38). 2012 project goals included sub-surface testing and development of a regional synthesis of threats posed to archaeological sites. Work performed during these years also included installing environmental monitoring equipment at a few selected sites. Full details of the data collected and preliminary environmental assessments can be found in Knudsen, et al. (2014).

Knowledge of extant historical documentation and previous archaeological research was a prerequisite for all sites investigated in 2016. A history of previous research in the Nuuk fjord can be broadly divided into four periods: (1) early observations from Danish-Norwegian merchants, missionaries and early colonial administrators, ca. 18th-19th century; (2) early systematic archaeological investigations, AD 1830-1940; (3) investigations in the post-war period, AD 1950-1970; and (4) investigations from 1980 to the present.

Early descriptions of sites detailed by European merchants, surveyors and missionaries provides valuable insight into the local histories of archaeologically significant areas in the Nuuk Fjord. For example, information about life in the early settlements provided by Danish and Herrnhut missionaries, such as Thorhallesen (1776) are often embedded with valuable and detailed site descriptions. In the 18th century, several Danish expeditions described and mapped Norse ruins in both the Eastern and the Western Settlement (for example, Bruhn and Arctander of the Royal Greenland Trading Company, 1777-1179). Other valuable contributors include individuals like Sigurdur Breidfjörd (1831-1835), an Icelander working as a cooper in Greenland that made numerous observations about Norse ruins in the Godthaab and Julianehaab Districts.

Early accounts of settlements and ruins groups by the geologist Sir Karl Ludwig Giesecke also provide valuable context. In 1806, Giesecke travelled to Greenland to assess the mineral wealth and trading potential of the country on behalf of the Royal Greenland and Faeroese Trading Company. Giesecke spent seven years travelling throughout southwest Greenland, documenting the minerology of numerous locations while simultaneously making observations about the lives, settlements and traditions of indigenous Greenlanders (Wyse Jackson 1996). His observations often included detailed descriptions of the prevalence and integrity of both Norse and Thule grave sites (for example, Kilaarsafik, Qoornoq, Iffiartafik and others, see Giesecke 1910).

During the 19th century, scientific efforts to record and document the archaeology of Greenland intensified. In 1832, the "Royal Society of Northern Antiquaries" (Det Kongelige Nordiske Oldskriftselskab) was established in Copenhagen and set upon the task of detailing the history of the Norse Greenlanders. Norse settlements were systematically mapped and investigated with results published in a three volume series entitled *Grønlands Historiske Mindesmærker* (Magnússon and Rafn 1838). Early work by H. Rink (ca. 1848-1868) of the Royal Greenland Trading Company and Gustav Holm and K.T.V. Steenstrup (1880) were also responsible for the documentation of numerous Norse ruin groups in the Julianehaab District. Archaeology was continued by Daniel Bruun who worked in the Western Settlement ca. 1903. From 1921 to 1939, archaeologists from the National Museum of Denmark conducted large-scale excavations of numerous Norse farms and settlements throughout the Nuuk Fjord (cf. Roussell and Calvert 1936; Roussell 1941; Knuth 1944).

After the Second World War, new findings along the West coast of Greenland revealed the great time-depth and cultural phasing of Greenland’s Saqqaq and Dorset cultures. Current knowledge of the locations and ruins of Inuit and pre-Inuit peoples in the Nuuk Fjord derives from the extensive survey and testing conducted by Meldgård and Neeleman in the early 1950s. Much of this work was published with complete maps and detailed site plans by Gulløv in his seminal work, *Nuup kommuneam gangarnitsanik eqqaassutit inuit-kulturip nunaqarfii*[1] (1983).

In the early 1980s, scholars expanded their research and began to ask questions related to the intersection of human societies, resource availability and long-term climate trends occurring over the past few millennia in Greenland. In 1981, the Grøndlands Landsmuseum Cooperative Survey initiated a program to systematically assess the threat of ongoing marine erosion and human impacts to archaeological sites and improve understanding of Norse and Inuit land use (McGovern and Jordan 1981; McGovern and Jordan 1982). Data collected during this project heavily informed investigations by the REMAINS at Kilaarsafik and the Austmannadal Valley. Other surveys conducted by the NKA throughout the 1980s to the present have also contributed to much of the current knowledge of the extent and density of archaeologically sensitive areas throughout the Nuuk fjord.

[1] Trans. *Ancient monuments in Nuuk: Inuit culture settlements.*

2016 Investigations

The REMAINS of Greenland project is divided into two Work Packages (WP1 and WP2):

WP1: Studies of site and artefact degradation

WP2: Regional risk assessment

Work performed in WP1 includes: (1) review of previous archaeological surveys, relevant literature, and historic photographs to generalize long-terms patterns of landscape change; (2) perform sub-surface testing to evaluate the present-day integrity of the archaeological record; and (3) collect soil and organic materials to be used in organic decomposition studies. The current state of preservation conditions is evaluated at each site through a protocol work-flow. Subjects explored include coastal processes, erosional forces, vegetation cover, root penetration, annual frost and permafrost, soil water content, soil oxygen content, soil porosity and soil chemistry.

Environmental monitoring stations were established at five sites in 2016 (Kilaarsafik, Qoornoq, Iffiartarfik, Ersaa and Kangeq) and monitoring equipment was refitted with new batteries at two sites in the Austmananadal Valley (V52a, V53d). Data logging at these sites includes detailed information on meteorological conditions, snow cover, vegetation, soil temperatures and water content. These data are used to study inter-site variability and “ground-truth” the rate and severity of degradation occurring to organic materials (e.g. bone and wood) over time. Knowledge derived from these studies is used to develop more nuanced approaches to environmental monitoring in the coming years.

Main objectives in WP1 include:

- Development of a field protocol for site description and risk assessment
- Observation of localized degradation processes at specific sites
- Measurement of the rate of degradation and decomposition of specific organic materials
- Development of interpretative tools for estimating local degradation from regional climate proxies

WP2 addresses the formulation of a regional risk assessment package and development of guidelines for a future heritage management strategy. Assessments of threats to archaeological sites in the Nuuk fjord region are modelled through the integration of multiple data sets and GIS interpolation. GIS models highlight: (1) coastal erosion; (2) fluvial erosion; (3) periglacial processes; (4) vegetation changes, (5) soil temperature; and (6) soil moisture content. GIS models will be incorporated into an updated version of the Greenlandic National Museum’s heritage database (Nunniffiit) to identify archaeologically vulnerable areas. Spatial models will be correlated to broader regional climate change scenarios to be used as a tool for prioritizing future archaeological survey, testing and rescue excavations.

Results of WP2 will be tested/validated using data collected through WP1. The REMAINS project ensures a robust validation process because sites investigated in the Nuuk fjord represent an array of differential ecozones and contrasting environments (e.g. sites with no permafrost vs. perennial frost vs. permafrost or sites with sparse vegetation to high-density growth).

The main objectives of WP2 include:

- Refinement of a field protocol for site characterization and risk assessment
- Study of inter-site variability in decomposition/degradation processes
- Study of specific organic degradation processes in the field
- Development of interpretative tools for estimating local degradation in conjunction with regional climate proxies

To achieve the specific goals outlined in WP1 and WP2, the following sub-sections review the primary methodologies of the field work performed in 2016. A total of 10 general locales were investigated during the 2016 field season (Fig. 1; Table 1). Site selection was based on a predetermined set of empirical questions directed by the research agenda. Criteria used to select specific locales in the research area included:

- Sites located in different environmental/climatic landscape niches (i.e. sites in the inner parts of fjord to the extreme outer coastal region and island groups; sites with a location from just above sea level to sites representing settlement at the highest normal locational altitude)

- Sites known through previous investigations to be rich in organic material—preferably confirmed by the presence of a midden deposit or other archaeological features adjacent to a documented settlement. This ensured a range of case preservation scenarios as well as temporal and situational baselines to measure against new findings

- Sites believed or known to contain the presence of frozen soils/permafrost; i.e. factors observed to reinforce vertical stratigraphy and create optimal preservation scenarios

- Sites that possessed coastal configurations accessible by boat or with terrain conditions providing for the uncomplicated retrieval of data/logging equipment during the project period

- Sites that possessed opportunities for public outreach and dissemination—both in outreach to the local community and in terms of future tourism potential

- High-reward/low-impact localities; i.e. sites where we could expect to retrieve multiple data sets with least impact/disturbance of the ruins and/or archaeological features

- Sites with potential to address complimentary cultural historical, heritage management and environmental research agendas.

In all cases, consistency and replicability of procedures was maintained to provide for the maximum quantity and quality of data collected. Sections that follow summarize the general methods employed in 2016 and provide an overview of the data sets to be integrated into the multi-year study.

 

Fig. 2. Left: Fenger-Nielsen piloting the Tarot 650-aport Quadcopter at Ersaa. Right: Myrup and Fenger-Nielsen programming the flight path of the eBee at Sandnæs (photos: Fortuna 2016, Danish National Museum).

dGPS & UAV surveys

Documenting archaeological sites in Greenland presents considerable challenges. Vector maps (scale of 1:250000) exist but derive from raster maps compiled during post-WWII aerial photography campaigns. To address this discrepancy, fieldwork conducted in 2016 utilized UAVs for the high-precision data capture of areal images of sites and features. On the ground, a Trimble RTK-dGPS was used for: (1) capture the GPS positions of sampling and environmental monitoring sites; (2) anchor ground control points used in terrestrial mapping during drone fly overs; and (3) to waypoint important landscape features and Thule grave features encountered during site walkovers.

Two different UAVs were employed at various times and locations in 2016. The use of two different UAV systems insured a higher success rate for data capture in the event of a technical malfunction. The Tarot 650 and eBee systems employed during the study comprised a suite of pre- and post-flight data processing software (eMotion 2 and Postflight Terra 3D 3) as well as the ready-to-fly hardware capable of autonomous capture of high-resolution aerial photos. Digital photos captured during fly-overs was used for generating detailed orthomosaic maps of the sites. Spatial data attached to each individual photo creates a point cloud of three-dimensional data to create a terrain model consisting of x-, y- and z-points. Software provides the possibility of converting the basic point cloud data into a wide variety of common GIS-formats, such as vectorised shape-files.

Table 4 lists the various systems and the locations employed during fieldwork in 2016. In addition to general mapping UAV flights were carried out as a part of a methodology study at four different altitudes (40m, 60m, 80m and 100m) along a single transect at a number of locations. Three different cameras were used during these test flights: (1) a Sony RX100M3 digital camera (RGB), (2) a Seqoia multi-spectral camera; and (3) a modified Canon NDVI camera. The purpose of this study was to investigate how flight altitude influenced data capture across three different camera types. Detailed Flight information is provided in Appendix A: UAV flight data. Orthomosaic maps of Kilaarsafik, Qoornoq, Iffiartarfik, Ersaa and Kangeq are provided in Appendix B: 2016 UAV Maps.

Table 4. dGPS and UAV systems and locations where they were utilized in 2016.

System	Kilaarsafik	Qoornoq	Iffiartarfik	Ersaa	Kangeq	Qarajat	Tulugartalik
Trimble RTK-dGPS	X	X	X	X	X		X
Quadcopter Tarot 650-sport	X	X	X	X	X		
Ebee fixed-wing UAV	X	X		X	X	X	X

Archaeological survey & testing

Archaeological survey in the form of site walk-overs and visual inspection of archaeological ruins and features was carried out at all locations (Fig. 1) visited in 2016. At Kilaarsafik, Qoornoq, Iffiartarfik, Ersa, Kangeq and Tulugartalik, important archaeological features such as the contours of ruins and features were waypointed and mapped using the Trimble dGPS. At other sites, such as Nuugaarsuk, Itivi, Qarajat and Tulugartalik limited time during site visits necessitated the use of hand-held GPS units for gathering general waypoints supplemented by photo documentation. In all cases efforts were made to correlate, identify and corroborate the presence of documented features and ruin groups (cf. Gulløv 1983).

Sub-surface testing was performed at Kilaarsafik, Qoornoq, Iffiartarfik and Ersaa with locations of test trenches shown in maps provided in Appendix B. Specific locations for testing were chosen in the field after consultation between NKA archaeologists and REMAINS senior field personnel.

Testing was undertaken to: (1) determine the archaeological significance of natural and occupational soil horizons and midden layers; (2) create sample pits to measure localized soil conditions and install environmental sensors and datalogging equipment; and (3) embed modern bone and wood samples into the walls of the profile for decomposition analysis.

Trenches were excavated to a minimum of 20 cm of culturally sterile subsoil where possible. Portions of units that exemplified distinctly different horizons were notated and excavated as separate contexts. Excavated soils were screened through 16 mm^2 mesh screen to capture artifacts and bulk samples (i.e. provenienced wood, charcoal and Blue mussel shell) (Fig. 3). Soils, features and all inclusions observed were described by both color and texture. When possible, excavated soils were matched to Munsell color charts. When color-matching was not possible, best-judgement was used to generalize soil color. A total of 91 artifacts and 75 bulk organic samples (e.g. wood, charcoal, shell) were collected in 2016 with a total aggregate weight of 10.38 kg.

Table 5. Summary of artifacts and samples by location collected in 2016.

Location	Trench	Latitude	Longitude	max. depth below surface (cm)	artifacts collected (*n*)	bulk samples collected (*n*)	total weight (g)
Kilaarsafik	T1	64°14'37.76"N	50°10'33.56"W	60	8	5	362
Qoornoq	T1	64°32'0.91"N	51° 5'13.94"W	~50	40	15	375
Qoornoq	T2	64°31'54.64"N	51° 5'37.09"W	70+	20	34	8631
Iffiartafik	T1	64°27'33.16"N	50°38'43.10"W	50-60	19	16	783
Ersaa	T1	64°14'50.31"N	51°36'31.07"W	50-60	-	5	218
Kangeq	Hole 1	64° 6'26.13"N	52° 3'7.29"W	~60	4	-	11
				Total	**91**	**75**	**10380**

Fig. 3. Madsen and Johansen sorting artifacts at Iffiartafik (photo: Fortuna 2016).

Recovered cultural materials are stored at the Greenland National Museum (NKA). Standard archaeological procedures for cleaning and storage were followed with all provenience information kept with the artifacts at all times. Artifacts and bulk samples were weighed and categorized by a generalized classification scheme of major types. A general summary of artifacts and samples collected in 2016 by type and aggregate weight is provided in Table 6.

Table 6. Artifacts and bulk samples collected in 2014 by type and weight.

Material type	artifacts (n)	organic samples (n)	wt. (g)
ceramic, historic/modern	15	-	14
charcoal	-	13	51
composite tool	1	-	7
faunal, bone	-	30	5465
fur?	-	1	1
glass bead	1	-	2
glass, historic/modern	13	-	36
lithic, calcedony	4	-	11
lithic, other	3	-	16
lithic, sandstone	1	-	10
lithic, slate	6	-	798
lithic, steatite	4	-	92
metal, ferrous	5	-	19
metal, non-ferrous	1	-	1
misc. modern	3	-	1
shell (*Mytilus edulis*)	-	14	3193
slag, ferrous	3	-	7
unidentified	1	-	7
wood	-	17	155
worked bone/antler/tusk	30	-	495
Total	**91**	**75**	**10380**

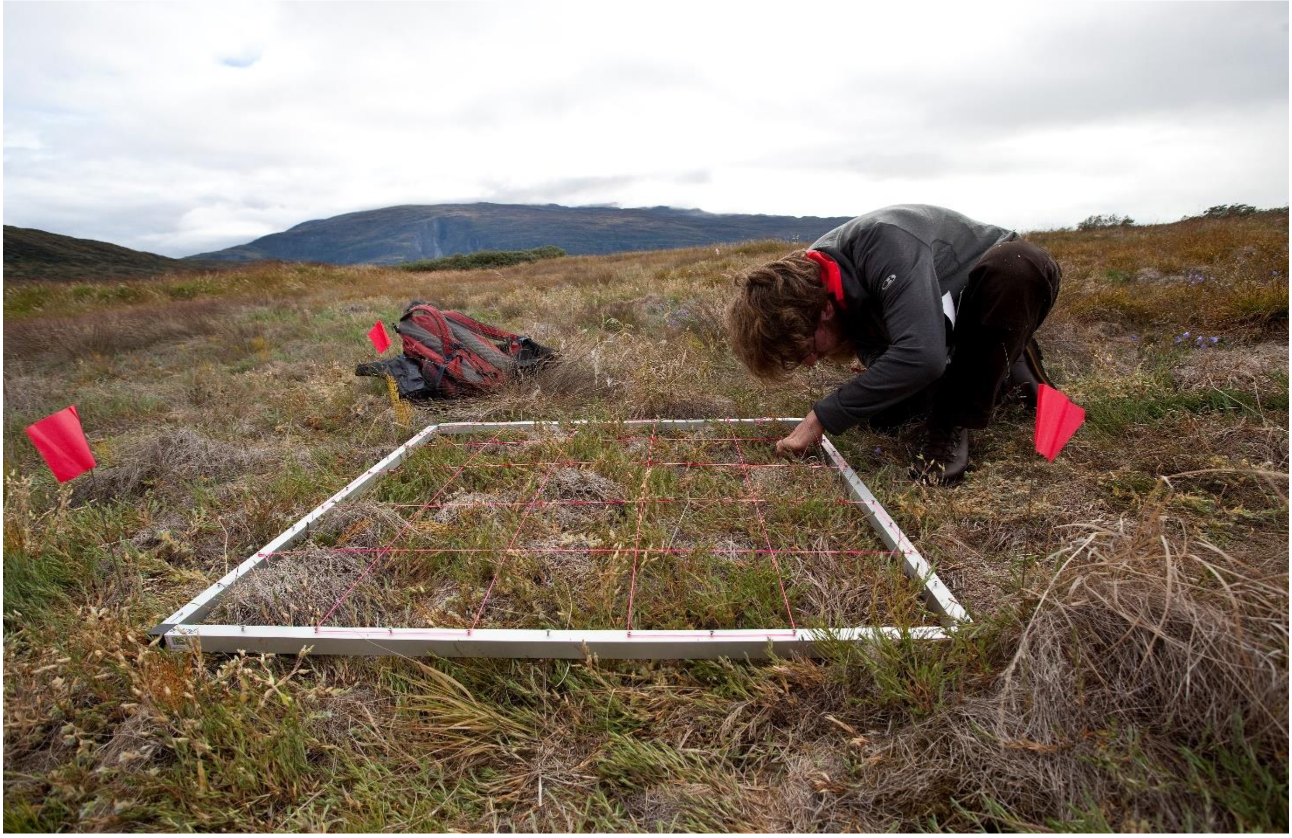

Fig. 4. Fenger-Nielsen sampling vegetation using a 1x1 m grid at Kilaarsafik (photo: Fortuna 2016).

Pedological & vegetation sampling

Broad spectrum vegetation sampling was performed at Kilaarsafik, Qoornoq, Iffiartarfik, Ersaa and Kangeq, Prior to sampling a distinction was made between *natural* and *cultural* soil areas; *cultural soils* would be described as those locations found within ruin groups versus *natural soils* areas found outside or on the periphery of ruin groups. Vegetation cover was quantified using a 1x1 meter frame divided in to 25 sectors by pinpoint analysis (Fig. 4). A 20x20 cm area within each plot was harvested and green biomass collected. Each plot was photographed with a high-resolution camera (Hasselblad) and a multi-spectral camera (Sequia). The normalized difference vegetation index (NDVI) was measured using a Decagon NDVI sensor. The same 20x20 cm area was then removed by shovel to a maximum depth of 30 cm below the surface. Volume specific soil samples ($100cm^3$) were collected from four depths when possible (at 5 cm, 10 cm, 20 cm and 30 cm below the surface respectively). Afterwards the hole was backfilled and turf restored to minimize disturbance to the site and local biota. At each sample location 15-20 leaves were harvested from 1-3 species within or adjacent to each sample plot.

In addition to broad spectrum sampling, detailed vegetation analyses were conducted at numerous locations to study the proliferation of certain creeping grass, sedge and dwarf species such as Northern willow (*Salix glauca*). Due to climate change, some plant species may be expanding their range in the arctic (Epstein, et al. 2012) and this increase may be negatively impacting archaeological sites.

Fig. 5. Eriksen collecting Northern willow (*S. glauca*) columns at Kilaarsafik.

To investigate recent and localized increases in Northern willow (*S. glauca*), 143 dendrochronological samples were collected from ruin groups in the Austmannadal Valley (V52c, V53c, V53d), Kilaarsafik, Qoornoq, Iffiartarfik, Nuugaarsuk, Ersaa, and Kangeq. Sample zones were segregated between the inside (i.e. "cultural") and outside (i.e. "natural") of ruin groups; samples collected from the outside of ruin groups provided local baselines for analysis. When a shrub was identified as suitable for sampling, 10-20 cm of the root column was cleared of soil and debris to provide coverage of approximately 10-20 cm of root stem and 10-20 cm of above ground stem (Fig. 5). Samples were obtained by use of a handsaw and placed into paper bags. 15 leaves from each of the sampled trees were then harvested to conduct C/N + ^{15}N analyses. A total of 131 *S. glauca* samples were collected in 2016, locations and the type of sample collected are detailed in Table 8.

General locations of sampling sites for broad spectrum vegetation and *S. glauca* at Kilaarsafik, Qoornoq, Iffiartarfik, Ersaa and Kangeq are provided in Appendix B.

Table 7. Location and number of broad spectrum vegetation analysis and samples collected in 2016. “Cultural” indicates samples were taken within or in close proximity to an archaeological feature. “Natural” indicates samples were taken outside of a ruin group. All samples are currently stored at the National Museum of Denmark.

Site	”Cultural” sample	”Natural” sample
Kilaarsafik	6	6
Qoornoq, Ruin group 10	6	6
Iffiartafik	6	6
Ersaa	6	6
Kangeq	6	6
Total	**30**	**30**

Table 8. Location and number of wood samples collected in 2016. “Cultural” indicates samples were taken within or in close proximity to an archaeological feature. “Natural” indicates samples were taken outside of a ruin group. All samples are currently stored at the National Museum of Denmark.

Site	”Cultural” sample	”Natural” sample
Austmannadal Valley, 52a	6	6
Austmannadal Valley, 53c	2	-
Austmannadal Valley, 53d	12	12
Qoornoq, Ruin group 13	12	12
Iffiartafik	12	12
Nuugaarsuk	6	6
Ersaa	12	12
Kangeq	12	-
Total	**74**	**57**

Fig. 6. Archaeological testing at Iffiartarfik. After the archaeological testing was complete in T1, data-logging equipment was installed and modern bone and wood samples were embedded in the wall of the trench prior to backfilling.

Environmental monitoring

Climate monitoring stations and dataloggers were installed at Kangeq, Kilaarsafik (V51), site V53d in the Austmannadal Valley in 2012. In 2016, data from these loggers was routinely collected during field work. Data collected from the loggers comprised multiple years of data on air and subsurface temperature, relative humidity, wind speed and direction, snow depth, precipitation, and soil moisture. All batteries were changed out in older equipment and loggers were re-programmed for continuous monitoring until 2018. New stations were installed at Qoornoq, Ersaa and Iffiartarfik.

In conjunction with all sub-surface testing, measurements were taken to collect information on a variety of different soil characteristics that included temperature, pH, moisture and oxygen content. Volume specific soil samples ($100cm^3$) were collected at the same depths as the soil moisture sensors to calibrate the sensors. A list of the locations and the types of data currently being collected are listed in Table 9.
In addition to environmental data, high-resolution automatic cameras were positioned to capture time-lapse sequences of sites every few hours at Kilaarsafik, Qoornoq and Kangeq. The cameras are equipped with 32 GB memory card (SDHC) with space for 2800 pictures (RAW) and will provide a visual record of seasonal changes occurring at the sites.

Table 9. Climate stations and datalogging equipment were installed at numerous locations in the Nuuk fjord region. The table denotes the type of location and type of data recorded at each site

Data logged	**V52a**	**V53c**	**V53d**	**Kilaarsafik**	**Qoornoq**	**Iffiartafik**	**Nuugaarsuk**	**Itivi**	**Ersaa**	**Kangeq**	**Qarajat**	**Tulugartalik**
Air temperature				X	X					X		
Atmospheric humidity				X	X					X		
Wind speed, direction				X								
Snow depth				X						X		
Precipitation				X	X	X				X		
Soil oxygen content				X						X		
Soil temperature	X		X	X	X	X			X	X		
Soil moisture			X	X	X	X			X	X		
Time lapse cameras				X	X					X		

Historic photos

During the investigation efforts were made to replicate historic photos from the past century in the Nuuk fjord. Every effort was made to replicate photos in terms of both perspective and scale to highlight differences in vegetation, topography and to document any evidence of modern human disturbance at the sites. Examples of some of the comparative photo sets are shown in Fig. 7 and Fig. 8.

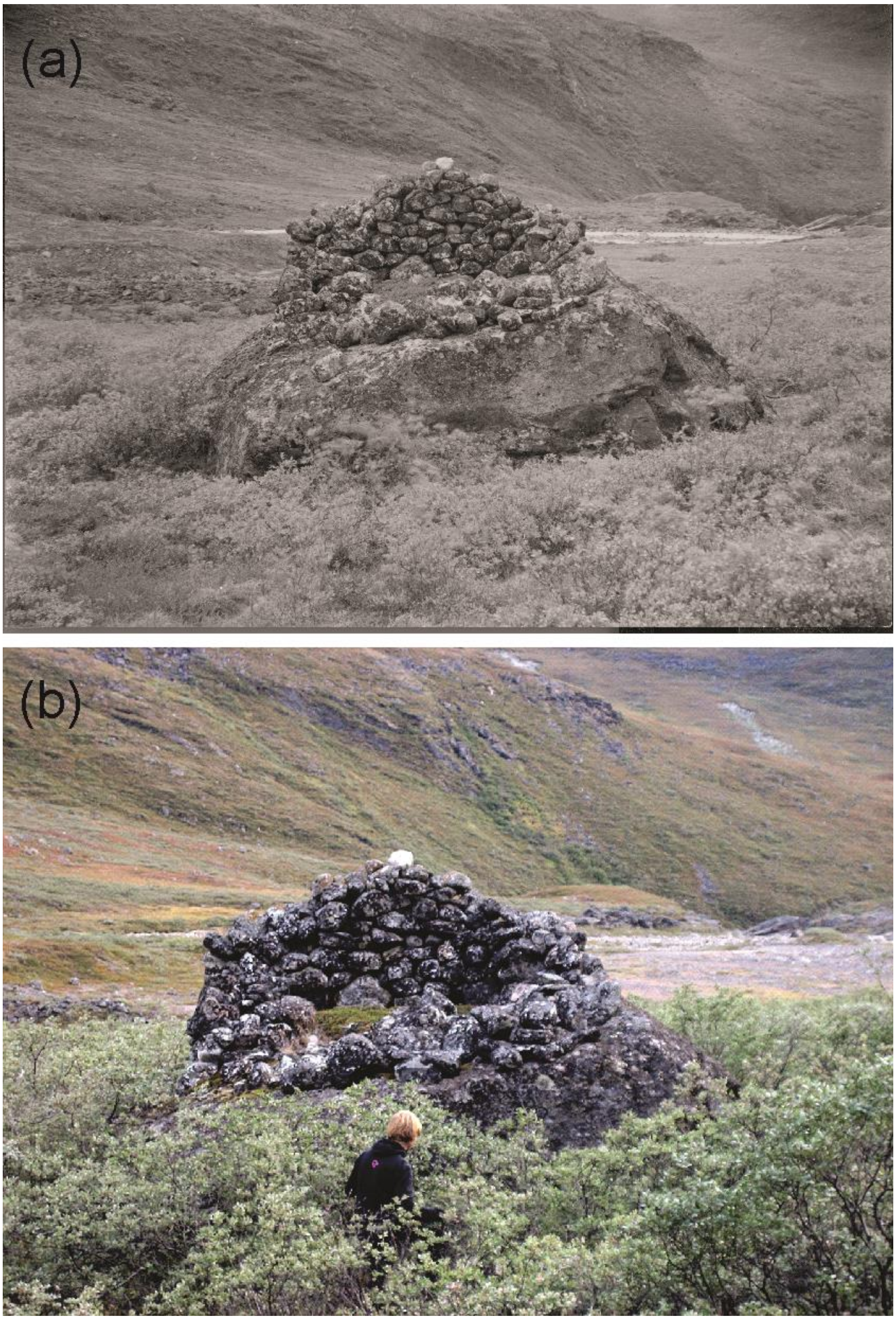

Fig. 7. (a) V53c, facing east. Photo: Roussel 1937. (b) V53c, photo: Matthiesen 2016.

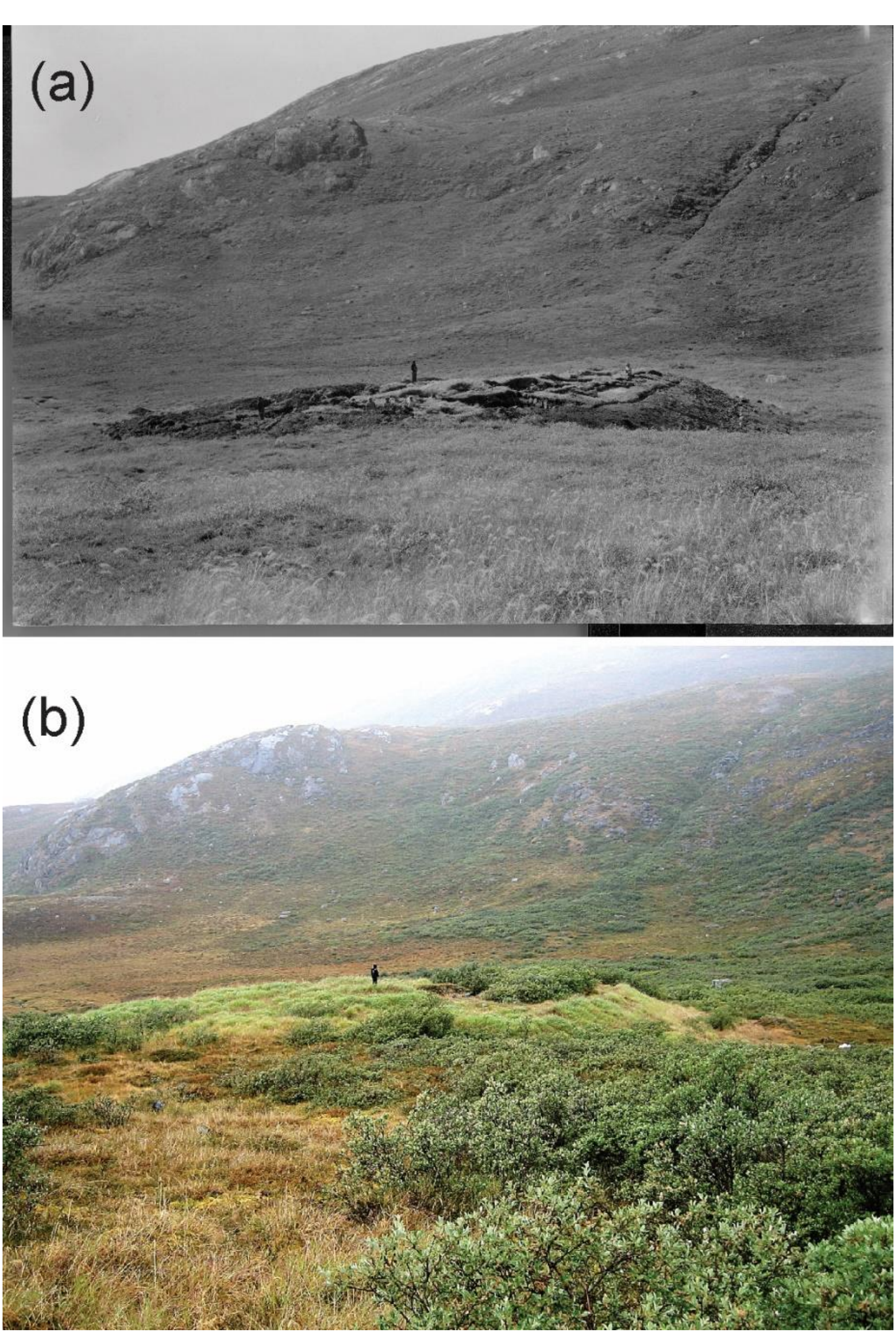

Fig. 8. (a) (a) V53d, facing west. Photo: Roussel 1937. (b) V53d, photo: Matthiesen 2016.

Fig. 9. Prior to installation into the walls of test trenches, bone samples were sewed into fishing net as triplicates or secured with a string attracted to the numbers.

Decomposition studies

A total of 231 bone and 71 wood specimens were collected in situ from trenches and from bulk samples during subsurface archaeological testing in 2016. All specimens obtained in the field for analysis were stored in a freezer in Greenland and transported frozen to Denmark. All the other samples are currently stored at NKA.

In addition to collecting organic specimens, modern bone and wood samples were also installed in the walls of test trenches at Kilaarsafik, Qoornoq, Ersaa and Kangeq. The purpose of installing these samples is to observe the rate and intensity of natural decomposition occurring in midden features at different archaeological sites. These samples provide a necessary baseline for measuring natural and anthropogenic factors that may be accelerating the rate of decomposition occurring in archaeological contexts in the Nuuk fjord region. Bone samples were sewed into fishing nets in groups of three or in some cases (e.g. Ersaa and Kangeq) secured with a string attracted to a label number prior to being embedded in the walls of profiles (Fig. 9).

Fig. 10. Left: Eriksen collecting modern wood and bone samples installed in 2012 in P1 at Kilaarsafik. Right: Profile of trench P1 showing the modern bone and wood samples.

In 2012, modern organic samples of maple (Acer, Danish Ahorn) and pine (Pinus, Danish Fyr) were installed at depths of 20, 40, 60, 80 and 100 cm below the surface (Table 10) in Trench P1 at Kilaarsafik. In 2016, samples were collected for laboratory analyisis. Samples not collected were numbered with new labels attached to pink string and re-installed in the wall of Trench P1.

Table 10. Status of the wood and bone samples installed in Trench PI at Kilaarsafik in 2012 after sampling in 2016. A= Acer, Danish Ahorn, F= Pine, Danish Fir.

Depth (cm)	Wood	Bone	Hair
20	A2,F2 (only chip)	K1,2,3 (1 sample left)	H1
40	A6, F6 (only chip)	K4,5,6 (1 sample left)	H2
60	A4, F4 (only chip)	K7,8,9 (2 samples left)	H3
80	A11, F11 (only chip)	K10,11,12 (1 sample left)	H4 not located - status unknown
100	A14,F14 (both present), A15, F15 (only chip)	K13,14,15 (2 samples left)	H5
120	None	K16,17,18 (2 samples left)	H6

Fig. 11. REMAINS team members discussing the goals of the protocol at Qoornoq near Ruin group 10. From left to right: Madsen, Johansen, Lyberth, Harmsen, Matthiesen and Pedersen.

Site protocol

An evaluation protocol was employed in 2016 to ensure: (1) data retrieved during and after the REMAINS project is consistent, (2) that the data can be summarized in a systematic manner for future integration into the Nunniffiit database, and (3) data retrieved at the site level can be quantified and integrated within a future regional GIS relational infrastructure.

Data recorded in the protocol includes both a quantitative evaluation of a site's relative level of integrity as well as a quantitative observation of a *site's value*. In addition, descriptions of present and future threats are included based on field observations. The protocol is supplemented by supporting material collected during the course of field work (e.g. photos, drawings, spreadsheets and field notes, etc.)

All valuations are ranked accordingly 1 through 5 (1=very poor; 2=poor; 3=medium; 4=good; 5=excellent.) The protocol consists of two tables with different levels of detail:

Table A: This portion of the protocol provides a descriptive summary of the site and synthesizes much of the information notated in *Table B.*

Table B: This table contains detailed valuations specific to the state of preservation of archaeological materials, specific environmental data and subjective archaeological/heritage observations. These types of valuations include documenting and quantifying (1) the beauty/monumentality of the site;

(2) the memory/historic value of the site; (3) physical integrity of the entire site or ruin group; (4) physical preservation at time of visit; (5) the relative rarity and/or representation within a regional context; and (6) the sites information and assemblage value (i.e. what is the sites research potential and could it help to fill any current knowledge-gaps). Lastly, the state of preservation and threats observed are recorded in this table. Observations include notes on the types of threats observed and their severity at the time of visit. The level of detail is adjusted so most the table can be filled out during a short site visit lasting only a few hours.

This protocol follows similar heritage management valuation schemes as offered by (Van De Noort, et al. 2001); Smit, et al. (2006); Marstein, et al. (2007); Dawson (2010); NS9450 (2012); (NS9451 2012); Gregory and Manders (2015). The REMAINS protocol draws upon these previous assessments, but has adapted and included certain features to fit arctic conditions while addressing the underlying goals of WP1 and WP2.

Summary

The 2016 fieldwork sought to collect a diverse assortment of archaeological and environmental data from twelve important locations in the Nuuk Fjord. Even though this area only constitutes a small part of Greenland—climatic conditions vary significantly between areas due to the prevailing microclimates of the fjord system and a strong climatic gradient between the sea in the West and the ice sheet located approx. 100 km inland to the East. Methodologies employed in 2016 provide a robust foundation for the future of the project in years ahead and will significantly contribute to informing other climate risk investigations of cultural heritage in the rest of Greenland and the circumpolar Arctic.

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Appendix A: UAV flight data

Table 11. Detailed information on the flights carried out at the site using a quadcopter UAV (Tarot 650-sport).

Location	Date	Local time	Weather	Survey type	Camera	Altitude	Area (km2)	Photos
Kilaarsaafik	11/8/2016	13:47-13:56	Overcast	Site survey	Sony RX100M3	100 m	0,09	172
Kilaarsaafik	11/8/2016	15:13-15:22	Overcast	Site survey	Sequoia	100 m	0,09	99
Qoornoq	13/08/16	12:37-12:43	Sunny	Site survey	Sony RX100M3	90 m	0,032	108
Qoornoq	13/08/16	19:06-19:10	Sunny	Site survey	Sony RX100M3	90 m	0,032	179
Qoornoq	13/08/16	19:43-19:46	Sunny	Site survey	Sony RX100M3	90 m	0,032	86
Qoornoq	14/08/16	12:44-12:48	Sunny	Transect	Sony RX100M3	40, 60, 80, 100 m		64
Qoornoq	14/08/16	13:02-13:08	Sunny	Transect	Canon	40, 60, 80, 100 m		174
Qoornoq	14/08/16	13:53-13:57	Sunny	Transect	Sequoia	100m		38
Qoornoq	14/08/16	14:54-14:57	Sunny	Transect	Sequoia	60, 80, 100m		48
Iffiartarfik	15/08/16	12:29-12:34	Sun	Site survey	Sony RX100M3	100 m	0.085	133
Iffiartarfik	15/08/16	14:03-14:06	Sun	Transect	Sony RX100M3	40, 60, 80, 100 m		43
Iffiartarfik	15/08/16	14:30-14:39	Sun	Site survey	Sequoia	100 m	0.085	135
Iffiartarfik	15/08/16	15:06-15:18	Sun	Transect	Sequoia	40, 60, 80, 100 m		101
Iffiartarfik	15/08/16	15:45-15:50	Sun	Transect	Canon	40, 60, 80, 100 m		73
Ersaa	17/08/16	14:51-15:03	Overcast	Site survey	Sony RX100M3	60 m	0,03	200
Ersaa	17/08/16	16:07-16:13	Overcast	Site survey	Sequoia	60 m	0,03	118
Ersaa	18/08/16	15:40-15:43	Overcast	Transect	Sony RX100M3	40, 60, 80, 100 m		33
Ersaa	18/08/16	15:48-15:52	Overcast	Transect	Canon	40, 60, 80, 100 m		63
Ersaa	18/08/16	16:11-16:16	Overcast	Transect	Sequoia	40, 60, 80, 100 m		157
Kangeq	21/08/16	12:49-12:55	Overcast	Site survey	Sony RX100M3	80 m	0,062	152
Kangeq	21/08/16	13:25-13:32	Overcast	Site survey	Sequoia	80 m	0,062	103

Appendix B: 2016 UAV maps

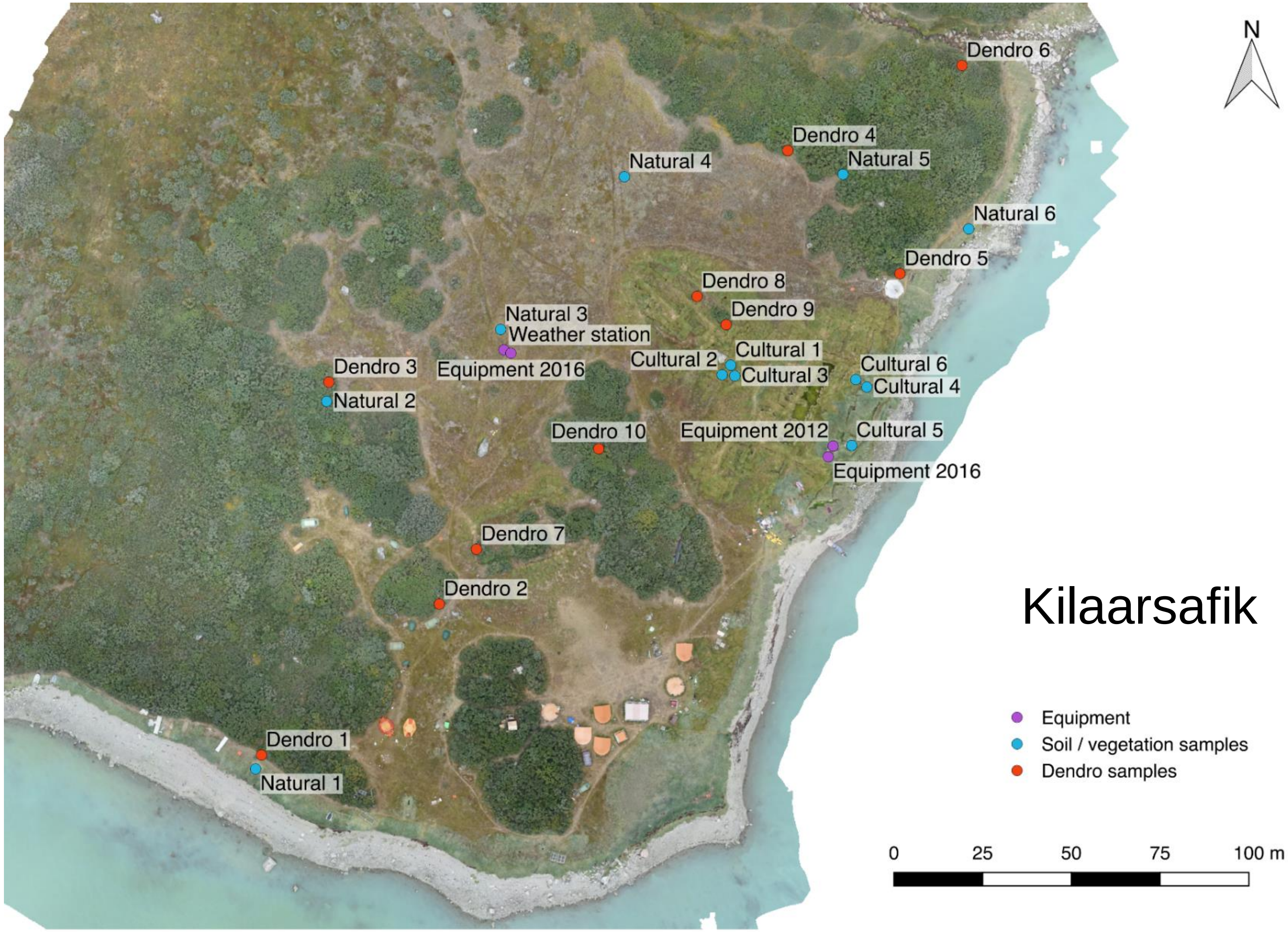

Fig. 12. UAV map of Kilaarsafik showing positions of subsurface monitoring and vegetation sampling.

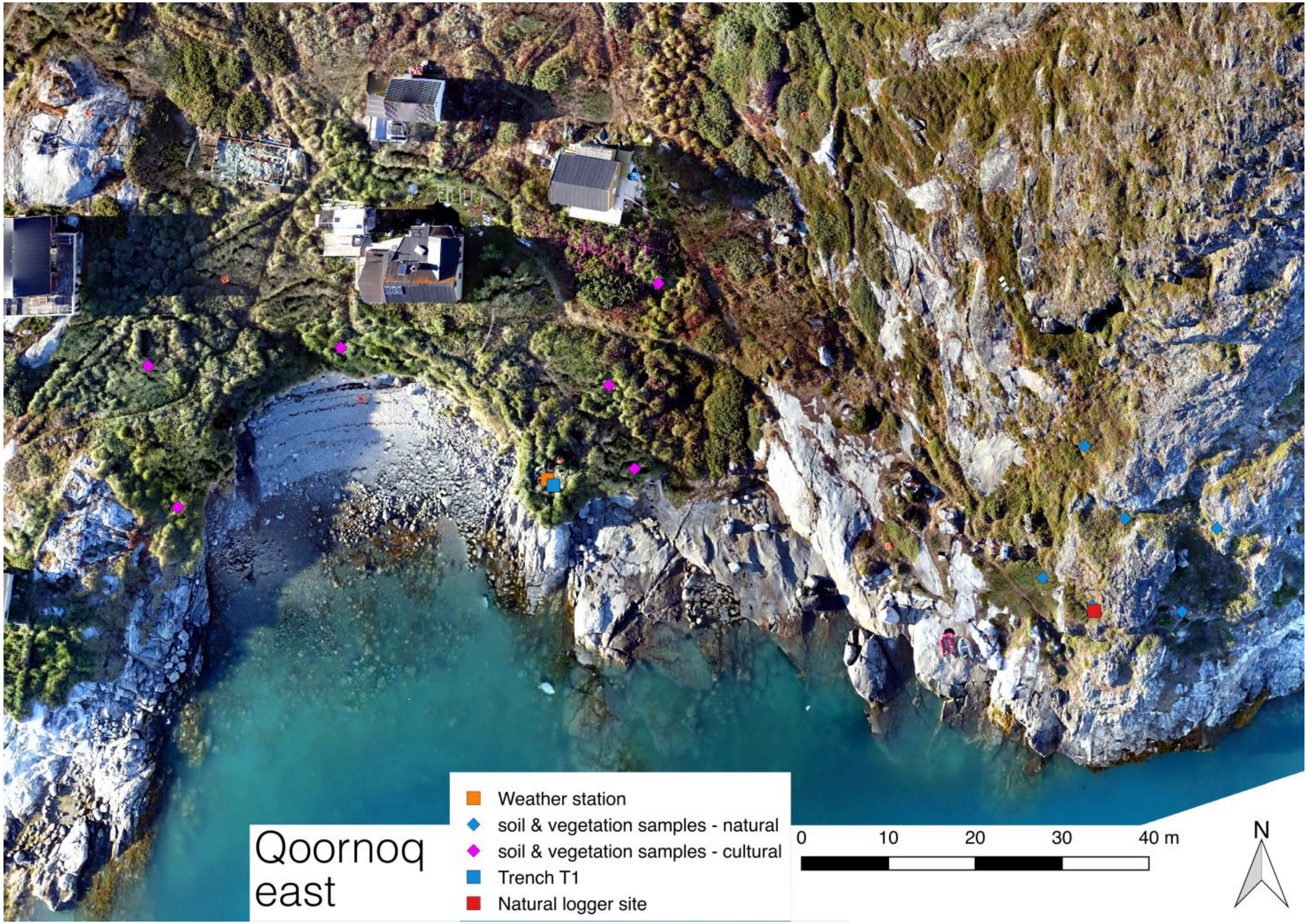

Fig. 13. UAV map of Ruin group 10 at Qoornoq showing the positions of subsurface monitoring and vegetation sampling locations.

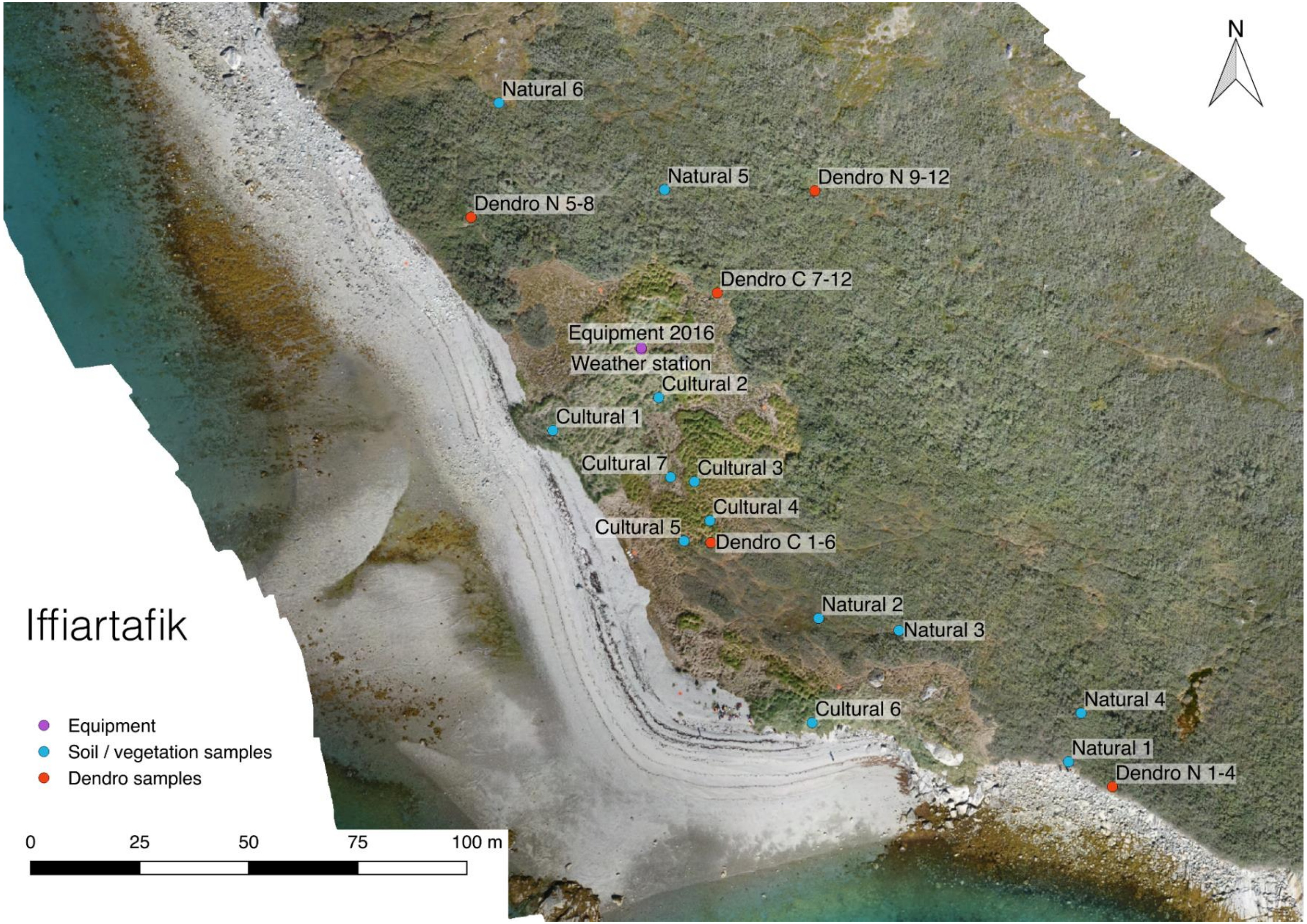

Fig. 14. UAV map of the Ruin group at Iffiartarfik showing the positions of sampling sites and environmental monitoring sites.

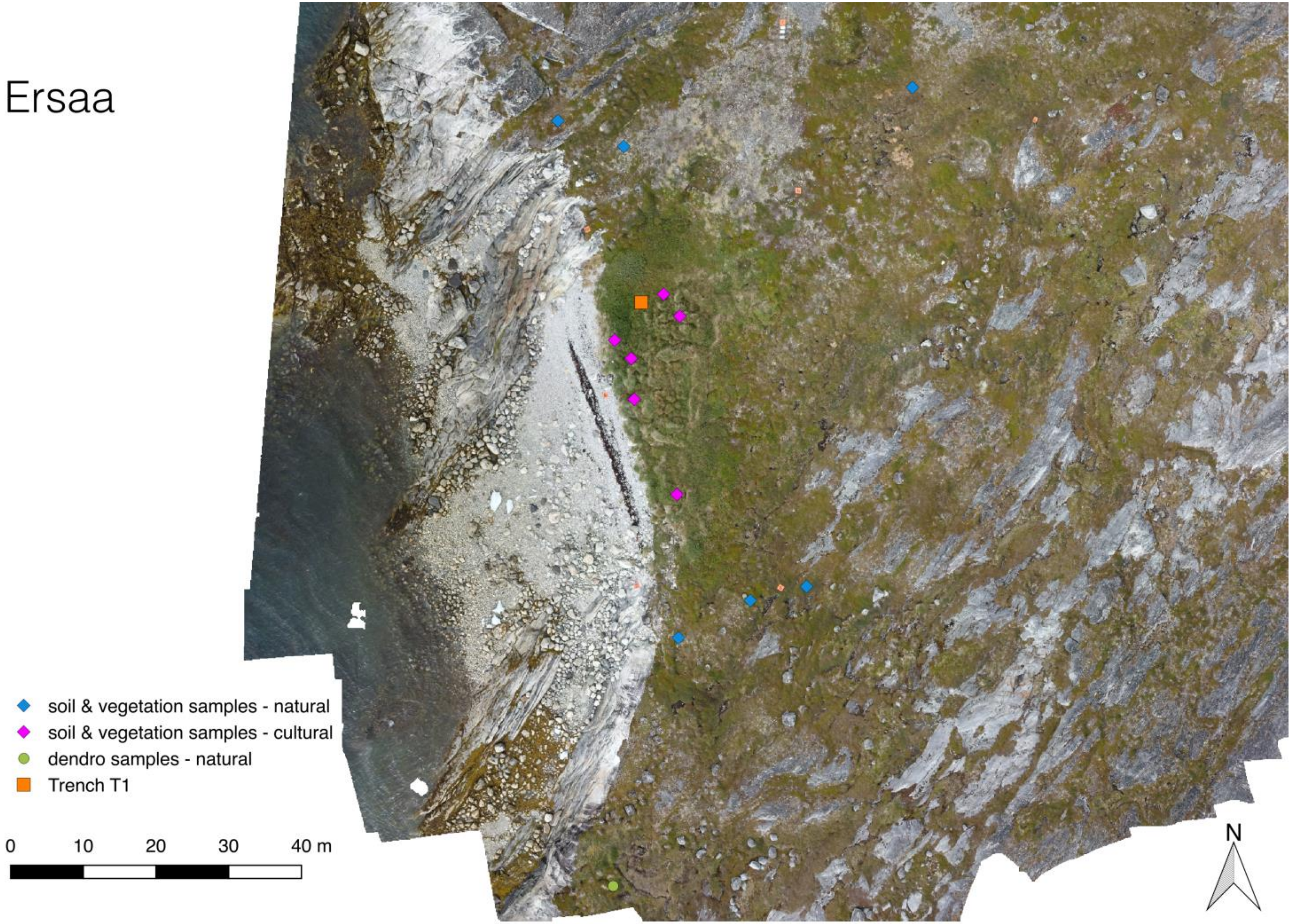

Fig. 15. UAV map of the ruin group at Ersaa and positions of sub-surface monitoring and vegetation sampling sites.

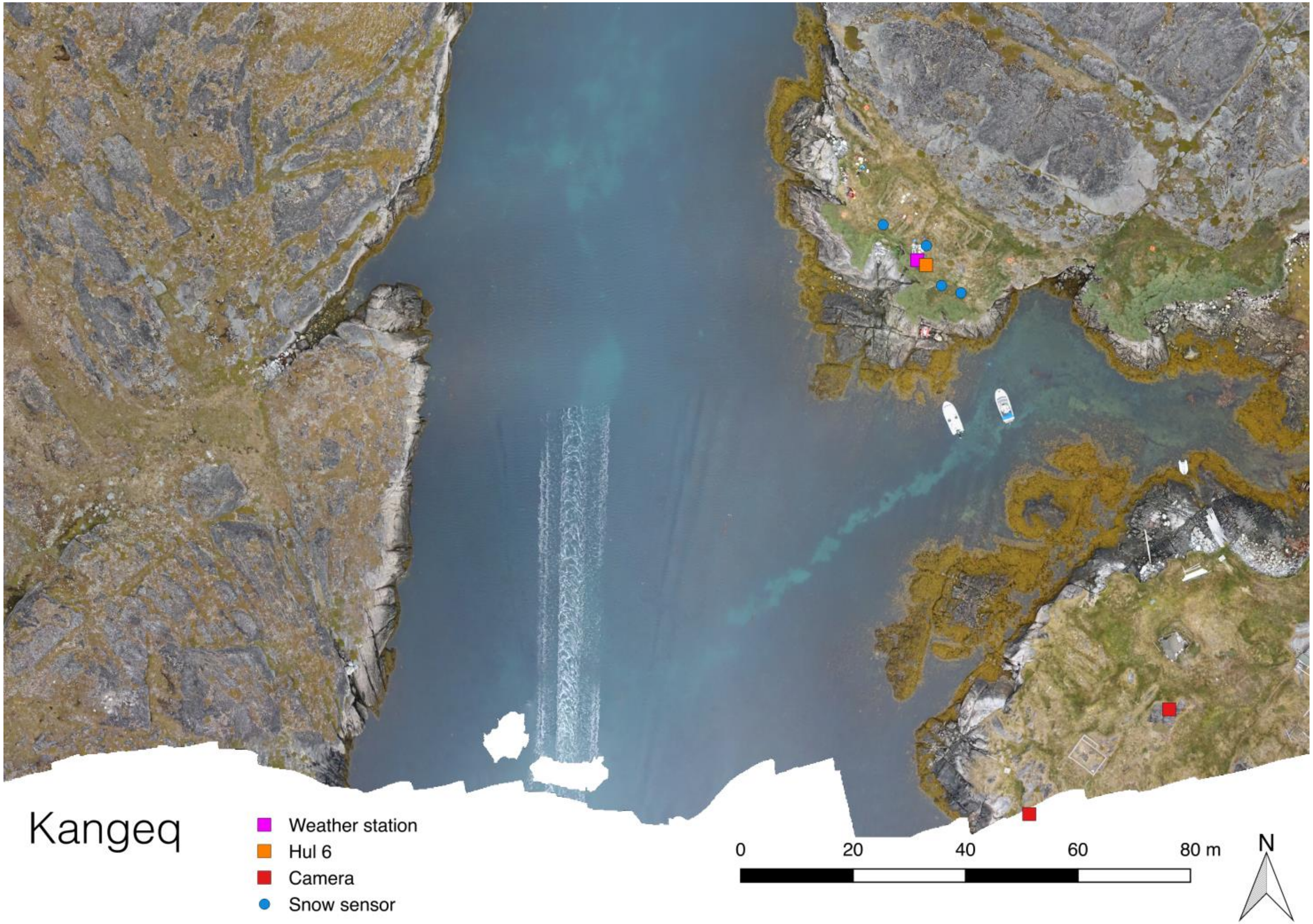

Fig. 16. UAV map of the ruin group at Kangeq and locations of environmental monitoring equipment and time-lapse.