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Kujataa field report 2021-23: Investigations at Ø35, Ø47, and Ø49.

Activating Arctic Heritage, WP2.1 Hidden in the Midden

NKAH numbers 2286, 4335, 2252

WP 2.1 Hidden in the Midden. Report no 20803-6

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Introduction

Activating Arctic Heritage is a research projects coordinated by the two National Museums in Greenland and Denmark, respectively. The present report describes field work carried out by one of the work packages (WP2.1 Hidden in the Midden) in the Kujataa World Heritage area from 2021 to 2023. In 2021 Jørgen Hollesen and colleagues from WP2.2 (Loss of Cultural Heritage) installed monitoring equipment at five sites in the area, some of which are also included in WP2.1. In August 2022 Anne Marie Høier Eriksen, Martin Mortensen and Henning Matthiesen from WP2.1 participated at excavations at Ø47 Igaliku cemetery (with Dorthe Dangvard Petersen and her team) and at Ø35 north of Qassiarsuq (with Peter Steen Henriksen and his team) installing monitoring equipment at the latter site. Furthermore, Peter Steen Henriksens excavation trench from 2021 at Ø49 north of Igaliku was re-opened in 2022 in order to take sterile soil samples. In August 2023 Henning Matthiesen visited all sites to download data and remove all monitoring equipment. The report presents measurements of environmental conditions in the trenches, comprehensive sampling of soil for different analyses and installation of monitoring equipment at Ø35, along with monitoring data from Ø35, Ø47 and Ø49 from the period 2021-2023. Other sites in the Kujataa area (Qassiarsuk, Hvalsey and Kangermiutsiat) are covered by WP2.2. The report should be read in context with the archaeological reports (Henriksen, 2021;Henriksen, 2022;Pedersen et al., 2022) where excavations and find material from the different sites are described in more detail. The report represents a data archive that shall inform discussions of the preservation conditions at the sites and help interpreting site formation process and future preservation.

Background

The environmental measurements and monitoring focuses on a few key parameters that are decisive for the preservation of (most) archaeological materials, that is the pH, temperature, oxygen presence and soil moisture, which is supplemented by a few other parameters (soil porosity, soil components, grain size and conductivity). Details about these parameters are described in e.g. Gregory and Matthiesen (2023), but a very brief description is given here concerning their importance and requirements for monitoring.

pH: Influences the degradation of for instance bone and shell, where a low pH gives increased leaching of their mineral content (Matthiesen et al., 2021). However, the influence goes both ways as a high content of bone or shell in the soil can also buffer soil pH toward the neutral region. pH is a relatively stable parameter (except in the upper most root zone) with limited annual variation and continuous logging is not necessary

Temperature: Influences the degradation of most materials, where increased temperature results in increased decay rates. The transition between frozen/not frozen conditions is especially important, as decay is very slow under frozen conditions (Matthiesen et al., 2014) and as freeze/thaw transitions may physically damage some objects. Spot measurements of temperature in open soil profiles are of little use, instead continued logging is used to map annual variations.

Oxygen presence: Oxygen is a key controlling factor for the degradation of buried archaeological materials, as it is the most reactive and powerful oxidant in the natural environment. Direct measurement of oxygen is possible, but difficult, and in this project its presence or absence is estimated indirectly. Evidence from other sites with organic soils indicate that oxygen is mainly present when the air content of the soil exceeds 10-15% vol (Matthiesen et al., 2015). The air content may be calculated as the porosity minus the water content of the soil.

Water content: Influences the oxygen transport in the midden as the diffusion of oxygen through water is extremely slow, which means that high water contents can decrease oxygen supply and decay rates.

However low water contents can also influence the decay, as the microbial activity may be lowered if the soil becomes sufficiently dry, and very dry conditions can also cause shrinkage and collapse of materials such as wood (Lauridsen et al., 2023). This drying is monitored through soil matrix potential measurements. The water content may be highly variable over time, and spot measurements are supplemented by continuous logging.

Soil porosity and soil components: The soil porosity determines the maximum water content and air content in the soil, which is important in relation to oxygen supply (above). The organic content is important both in relation to the vulnerability towards degradation and for the water retention of the soil, as organic matter has a large water binding capacity.

Grain size and conductivity: The grain size is important in relation to water retention, as for instance fine grained material such as silt will bind water better than sand. Furthermore, grain size may help understand the source of the (inorganic) material, e.g. whether it is fluvial or aeolian. The conductivity may help tracing soil water sources and movement in the soil, where for instance a supply of salt spray from the sea will give a high conductivity.

Measurements of the environmental parameters must be supplemented with an understanding and/or measurements of how the parameters influence the different archaeological materials, but this is not covered in the present report.

Sites

In 2021 WP2.2 (Jørgen Hollesen and his team) installed monitoring equipment at five sites in the Kujataa World Heritage area (Figure 1, all sites except Ø35). In 2022 they visited Hvalsey, Qassiarsuk and Kangermiutsiat to download monitoring data and make drone mapping. The same year WP2.1 carried out field work at three locations: Ø47 (Igaliku cemetery), Ø49 and Ø35, where data was downloaded from Ø47 and Ø49, and monitoring equipment was installed at Ø35. In 2023 monitoring equipment was removed from all sites.

Figure 1: Locations visited in the 2021-23 fieldwork. Map from Google Earth.

Methods

Environmental measurements were made in the trenches and test pits during and immediately after excavation. pH was measured for each 5-10 cm depth using a solid state pH electrode (LanceFET from Sentron) that was pressed directly into the soil profile. Water content and conductivity was measured with a WET-probe (Delta T instruments) for each 5-10 cm depth. Soil ring samples of 100 cm^3 volume were taken at selected depths, for subsequent laboratory measurement of water content (drying at 105 °C), organic content (loss-on-ignition when heated to 450 °C), and inorganic content (weight after ignition). The data were used to calculate the soil porosity and soil air content as described in Matthiesen et al. (2015). Grain size analysis was carried out on soil samples after ignition, i.e. where all organic material had been removed. The grain size was measured by sieving samples in a standard rack of sieves with aperture ranging from 0.0625 mm to 2 mm.

Sterile samples for eDNA studies and lipid analysis was taken at selected profiles and selected graves. All tools for sampling were cleaned in between each use with 15% sodium hypochlorite and rinsed with 96% ethanol. The outer 2-3 cm of the profiles were removed with sterile tools, before the actual sampling took place. Two samples of a few cm^3 volume were taken from each depth, and transferred to sterile bags.

Bulk soil samples (non-sterile) were taken from each archaeological strata. Natural reference soil samples were taken up to a few hundred metres distance from Ø49 and Ø35.

Monitoring equipment for logging of temperature, soil water content and soil matrix potential was installed at several sites (details below). For the water content, ML3 or SM300 sensors (Delta T Instruments) connected to a DL6 or GP2 logger (Delta T) were used, with a logging frequency of 6 hours. For the soil matrix potential EQ3 sensors (Delta T) connected to the DL6 loggers were used. For soil temperature, TinyTag and HOBO sensors were used, with a logging frequency of 1 or 2 hours. All cabling was protected by armoured hose. The loggers were placed in Pelicases with cable glands, and the glands were sealed with silicone in order to make them more water tight.

A rain gauge and air temperature/RH sensor (both from HOBO) was installed in 2021 on a 2 m mast at Ø49. The rain gauge is not equipped with a heating element and will not measure precipitation in the form of snow.

Results and preliminary discussion

The results are presented and discussed separately for each site.

Ø49 / NKAH2252.

The site is located a few km North of Igaliku at the bottom of a small bay and next to a small river (Figure 2). The tidal variation at Igaliku is more than 2 m (Wilken et al., 2019) and parts of the area will be flooded at spring tide, however the site itself is probably lying too high to be directly impacted by sea water. On the other hand, there are some signs of flooding and erosion (Henriksen, 2021) which could be due to meltwater or heavy rain. Sheep are grazing in the area but it is not drained or used for hay.

Figure 2: Location of Ø49. Excavation took place at the yellow marker, and the ruins are visible as an elongated shape next to it.

An area of 1x2 m in the midden was excavated to subsoil by Henriksen and his team in August 2021 (Henriksen, 2021) in an area covered by short grass. They excavated in 5 cm thick horizontal strata and named the layers according to Figure 3 (bottom). Their 0-line was re-established when the pit was re-opened on the 5/8/2022 (Figure 3, top). The position according to handheld GPS is approximately N 61°00.158' W 045°24.586'.

Figure 3: Excavation trench at Ø49 after re-opening in 2022, along with Henriksens drawing and layering number (From Henriksen 2021). Henriksens 0-cm was still present (green line on upper photo)

It was decided to take samples and environmental measurements in the south profile next to the pollen samples from 2021 (Figure 4). Here Henriksens 0-line is 14 cm below the soil surface. In the following all measurements are given relative to the local soil surface, so Henriksen ‘0-5 cm layer’ is equal to 14-19 cm here. Only 3 different strata were identified: Layer 1: 0-5 cm, root felt; Layer 2: 5-70 cm, cultural deposit with dark decomposed midden layers with a few stones and degraded bones; Layer 3: 70-75 cm, sterile fine grained material, beneath this (at 75 cm) stone. The site has probably been inhabited for the whole Norse period (ca 1000-1450 AD), i.e. the material in the midden is approx. 570-1000 years old.

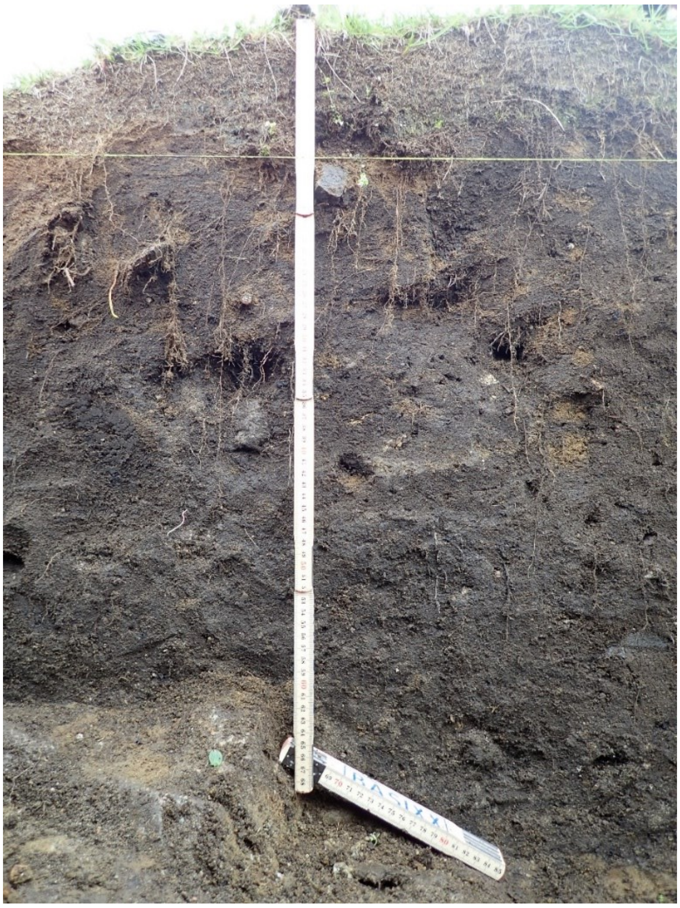


Figure 4. South profile where measurements and samples were taken in 2022

Sterile samples for DNA analysis were taken at 5 cm depth intervals following the stratigraphy from 2021 (i.e. in the top layer at 7 cm below soil surface, and at ca 17, 22, 27, 32, 37, 42, 47, 52, 57, 62, 67 and 72 cm below soil surface). Bulk samples for lipid analysis were taken at 14-17, 30-34 and 66-70 cm below soil surface. Ring samples and bulk samples for reactivity were taken at 10, 30, 50 and 70 cm below soil surface. There were no bones visible in the cleaned profile, but two of the ring samples actually contained bones: a well preserved Bulla in the ring samples from 10 cm, and a degraded bone in the sample from 50 cm. Natural reference soil samples were taken 5-15 cm beneath the soil surface at three points in the vicinity of the midden (ref 1 at N61°00'06.2'' W045°24'34.8'', ref 2 at N61°00'05.5'' W045°24'34.3'' and ref 3 at N61°00'08.4'' W045°24'31.1'')

Results from in situ measurements and ring samples are given in Figure 5.

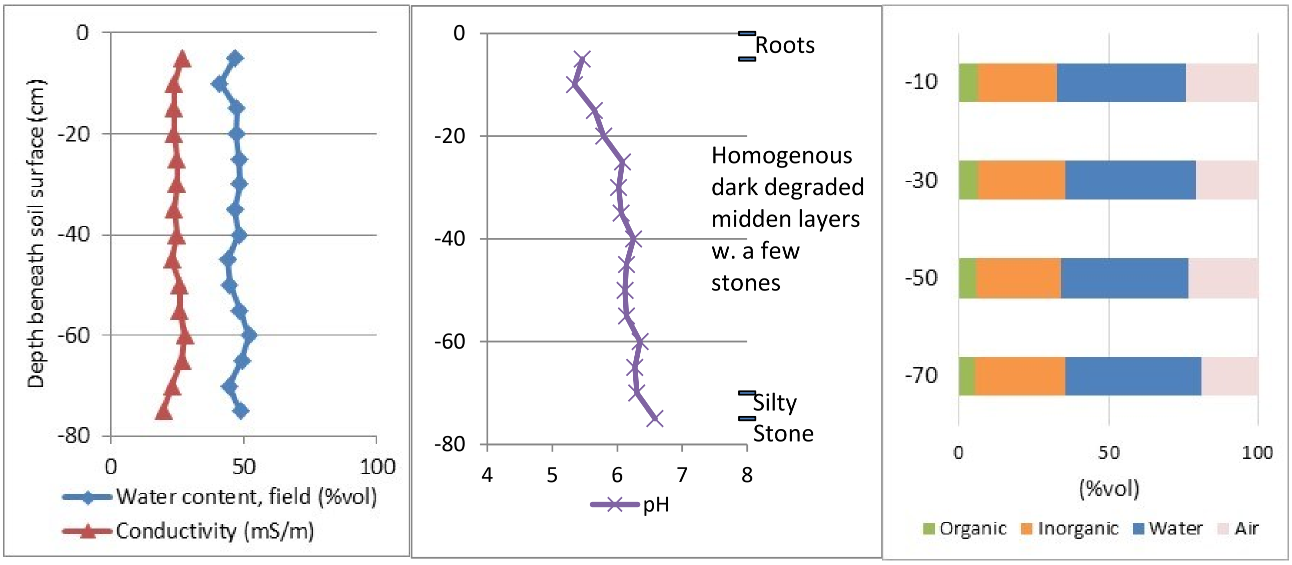


Figure 5: Field measurements and results from ring samples taken in the midden at Ø49 on the 5/8/2022

The results show that the midden deposits are quite homogenous: the soil porosity varies between 64 and 67 %vol, and the air content varied between 19-24 % vol (on the day of sampling 5/8/2022), indicating fully oxygenated conditions. The inorganic content is between 26 and 30 % vol which is at the higher end of all the middens examined in AAH – correspondingly the loss on ignition values of the Ø49 midden is only 9-12 % w/dw. The conductivity values were low (20-28 mS/m) indicating a low influence from sea water or salt spray, and/or a high dilution by fresh water. Regarding pH, the results show a modest increase with depth, from 5.5 in the top layer to 6.3 at the bottom. Grain size analysis of the inorganic part of layer 2 (Figure 6) shows that it mainly consists of poorly sorted sand, including all sizes from fine to coarse. Samples from 30 and 70 cm depth are very similar, verifying that the deposits are quite homogenous. The grain size will influence the water retention in the midden, however, there will also be an effect from the large amounts of organic material in the midden.

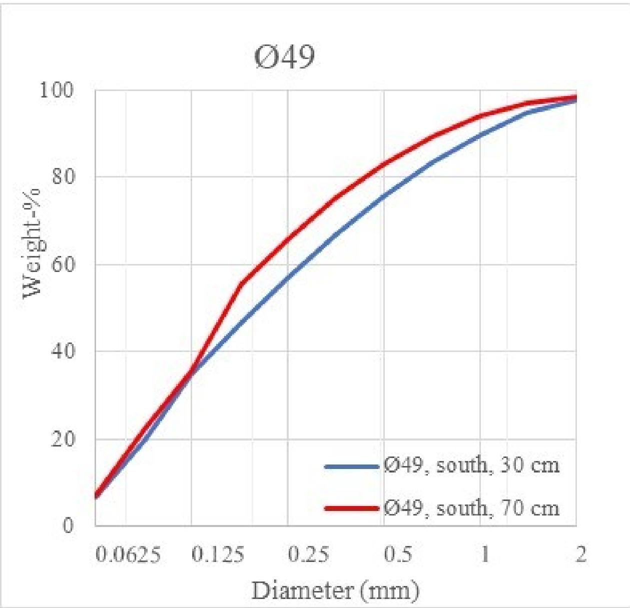


Figure 6: Grain size analysis for samples from Ø49. All organic material was removed by ignition of samples before analysis.

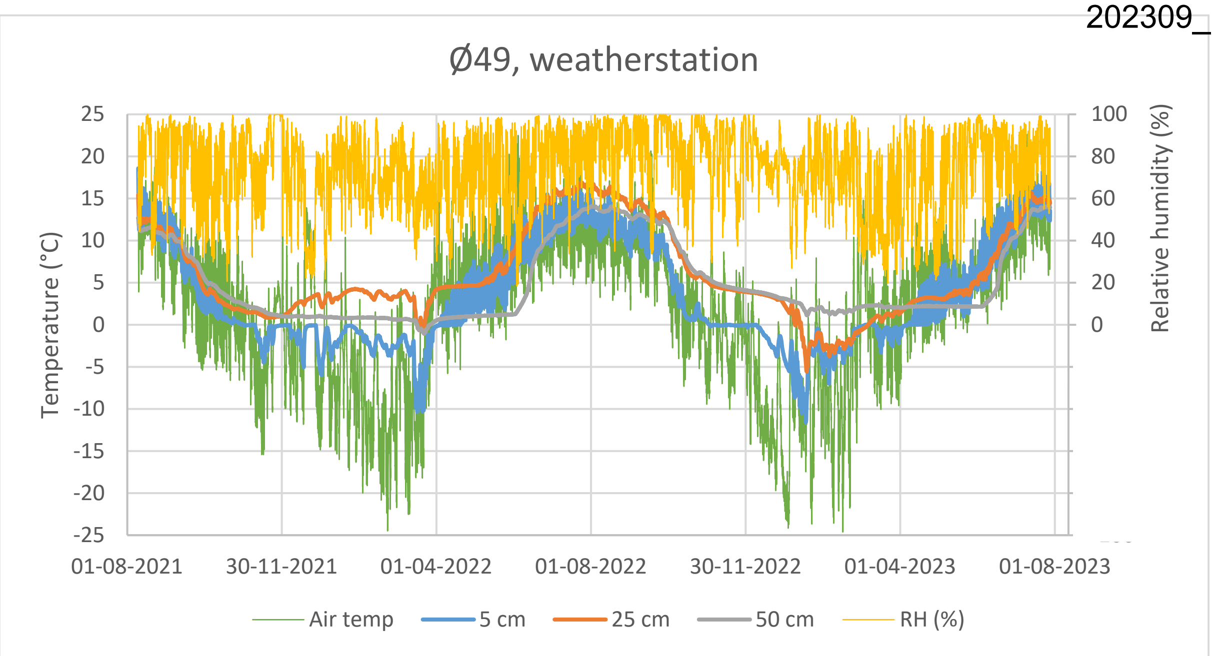
Monitoring data 2021-2023:

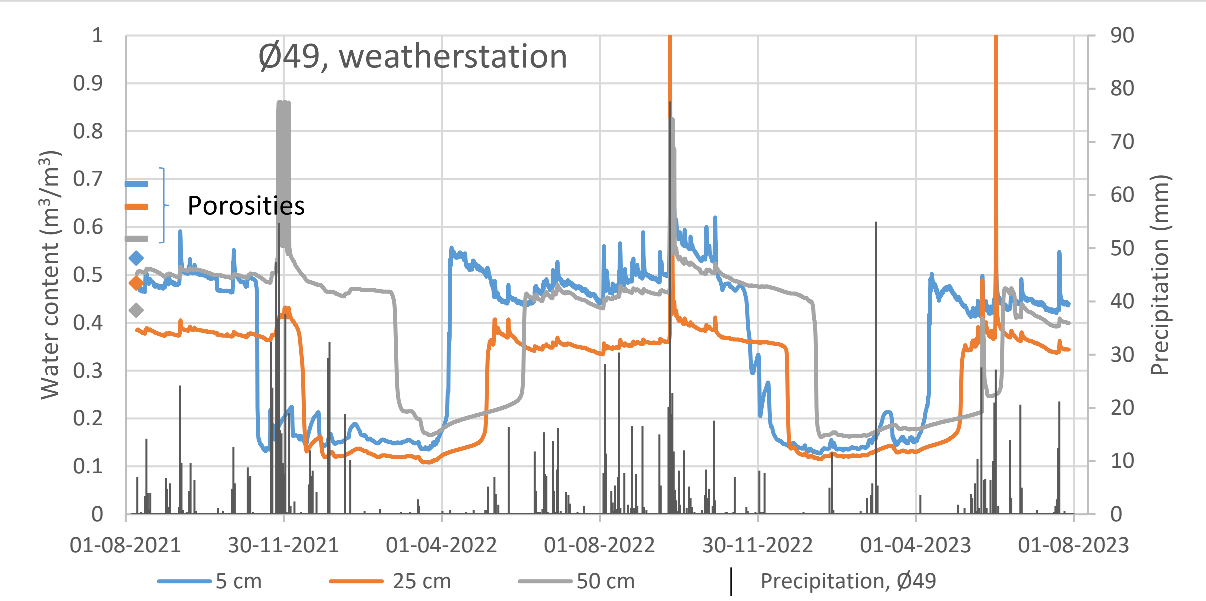
In 2021 a weather station with subsoil sensors was installed by Jørgen Hollesen ca 10 m from the excavation trench. It consisted of a rain gauge, an air temperature/RH sensor, and three soil temperature sensor at 5, 25 and 50 cm depth, all connected to a HOBO logger measuring every hour. Furthermore, three ML3 sensors for water content at 5, 25 and 50 cm depth and a EQ3 sensor for matrix potential at 25 cm depth, all connected to a DL6 logger measuring every 6 h. Ring samples were taken to measure water content and porosity, but no detailed description of the stratigraphy is available. Data from data loggers were downloaded in August 2022 and 2023 after which the sensors, datalogger and weather station were removed.

Figure 7 shows monitoring data from the weather station. First of all, it is noted that the soil stratigraphy at the midden and at the weather station are not necessarily the same as the latter was installed 10 m away from the excavation trench. This means that the data for soil moisture (that are very dependent on the exact soil composition) should be used with some caution, while the soil temperature data are probably similar at the weather station and the excavation trench.

The air temperature varies between +23 and -24 °C from 2021-23, with some remarkably warm periods during winter with positive temperatures in December 2021 and February/March 2023. The soil temperature at 5 cm depth follows the air temperature as expected: the soil freezes at the beginning of November, and is frozen until start of April. There are some periods during winter where it partly thaws (where the soil temperature is 0 °C) but without complete thawing. The sensor at 50 cm depth starts freezing end November and is completely thawed at the beginning of June. Most of the time the temperature is close to 0° C (the so called zero curtain where water freezes or ice melts) and there is only a very short period during March where the temperature drops below 0 °C indicating that all water is frozen. There seems to be some drift of the sensor: in 2021/22 the zero curtain is measured to almost 1 °C and in 2022/23 to 2 °C which is a relatively large offset. The sensor at 25 cm shows peculiar results with positive temperatures during the whole winter and with a spring zero curtain at +5 °C – this shows that the temperature sensor has probably drifted with up to 5 °C and that the absolute values cannot be trusted.

The water content sensors are designed to measure fluid water whereas ice only gives a weak response. This means that the low water contents during winter does not indicate loss of water, but rather that water is frozen to ice. There is a gradual freezing of water in the different layers, as was also indicated by the temperature measurements: at 5 cm depth the soil water freezes November-December, at 25 cm depth it is December, and at 50 cm depth the soil water is not frozen before mid January (2023) or even beginning of March (2022). During summer there is some correlation to the precipitation, and in November 2021 and September 2022 there are periods with a lot of rain that are clearly reflected in the soil water content especially at 50 cm depth where the sensor is probably completely flooded. The water content in these days is measured to be higher than the soil porosity (horizontal line in left side of the water content graph – Figure 7 middle) – this should not be possible but may be due to difficulties in measuring very high water contents. For the soil layers at 5 and 25 cm depth there is typically an air content (i.e. the difference between the measured porosity and monitored water content) of 25% vol or more, indicating oxic conditions. At 50 cm depth the air content is typically 10% or less, which could indicate that there are anoxic conditions in periods, the exception being the very dry year 2023 where the air content is closer to 15 % vol.





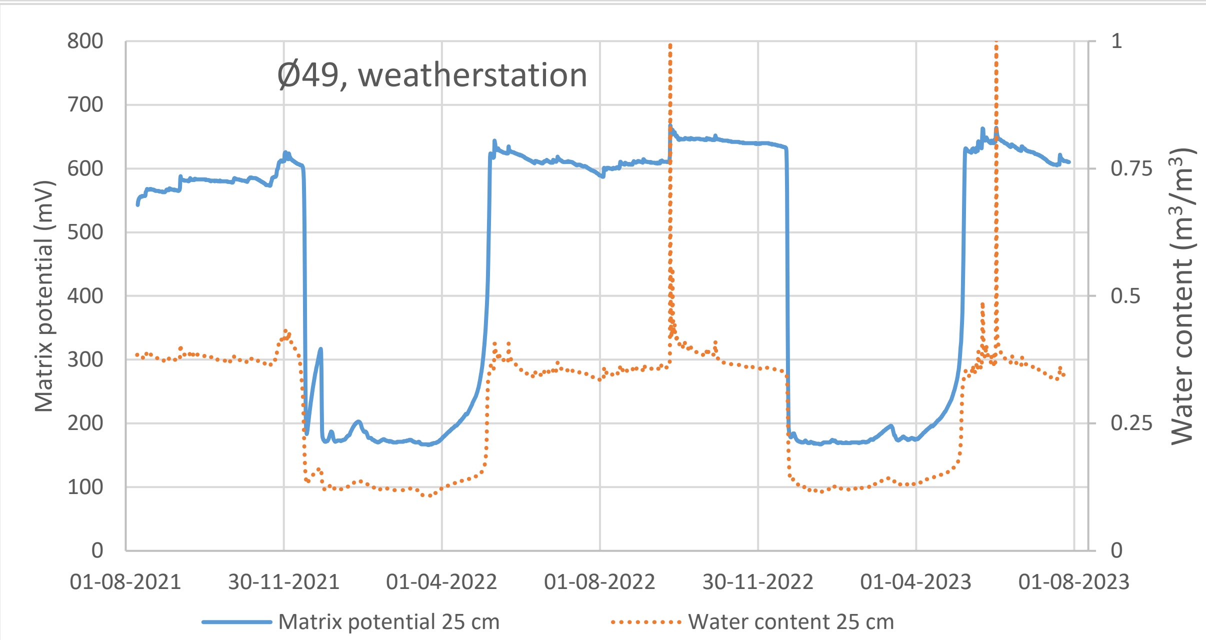


Figure 7: Monitoring data from the weather station installed ca 10 m from the excavation trench at Ø49. Note that the temperature sensor at 25 cm depth probably gives erroneous results (details in text). The precipitation data are only reliable at temperatures above 0 °C, as there is no heating element in the rain gauge.

Concerning the matrix potential that can show if the soil dries up, most of the measurements are above 600 mV – this represents the upper measuring limit for the sensor and indicates wet or moist conditions where free water is present. During winter the signal drops dramatically but this is due to water freezing and cannot be interpreted in terms of matrix potential. Only during first months after installation the potential is lower and within the measuring range – in August and until the 12th of September 2021 it measures 565 mV (corresponding to -12 kPa), from the 12 of September it increases to 580 mV (corresponding to -10 kPa), and around the 20th of November heavy precipitation makes it increase further to 600 mV. Matrix potentials of – 12kPa will only have limited – if any – effect on the degradation.

To summarize, Figure 7 indicates that soil at the weather station is permanently moist with only a short period with very dry conditions (matrix potential of – 12 kPa), and only the deepest deposits experience periods with waterlogged or close to water saturated conditions – thus the degradation is not limited by very wet or very dry conditions. On the other hand, the deposits are frozen for several months every year, where the decay will be limited due to lack of fluid water. However, extrapolation to the deposits in the midden itself should be done with caution.

Ø35 / NKAH2286.

The site is located in the Qorlortup Itinnera valley a few km North of Qassiarsuk in an area dominated by modern sheep farming (Figure 8). There is a brook coming down from the hills with a small water fall next to the site, but there are no signs of erosion from the water.

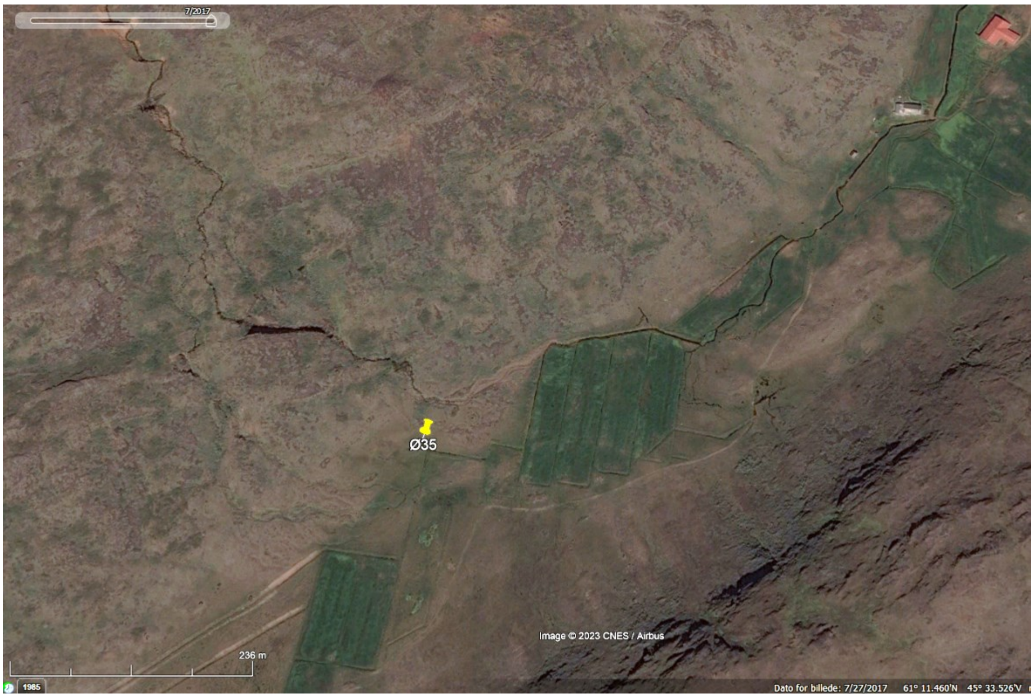


Figure 8: Location of Ø35.

An area of 1x2 m in the midden was excavated to subsoil by Henriksen and his team in August 2022 (Henriksen, 2022) in an area covered by short grass, and only a few meters from a modern drainage ditch that was established in the mid-1980's. They excavated in 5 cm thick horizontal strata and named the layers according to Figure 9 (bottom). The position according to handheld GPS is approx N61° 11.398' W045° 33.739'.

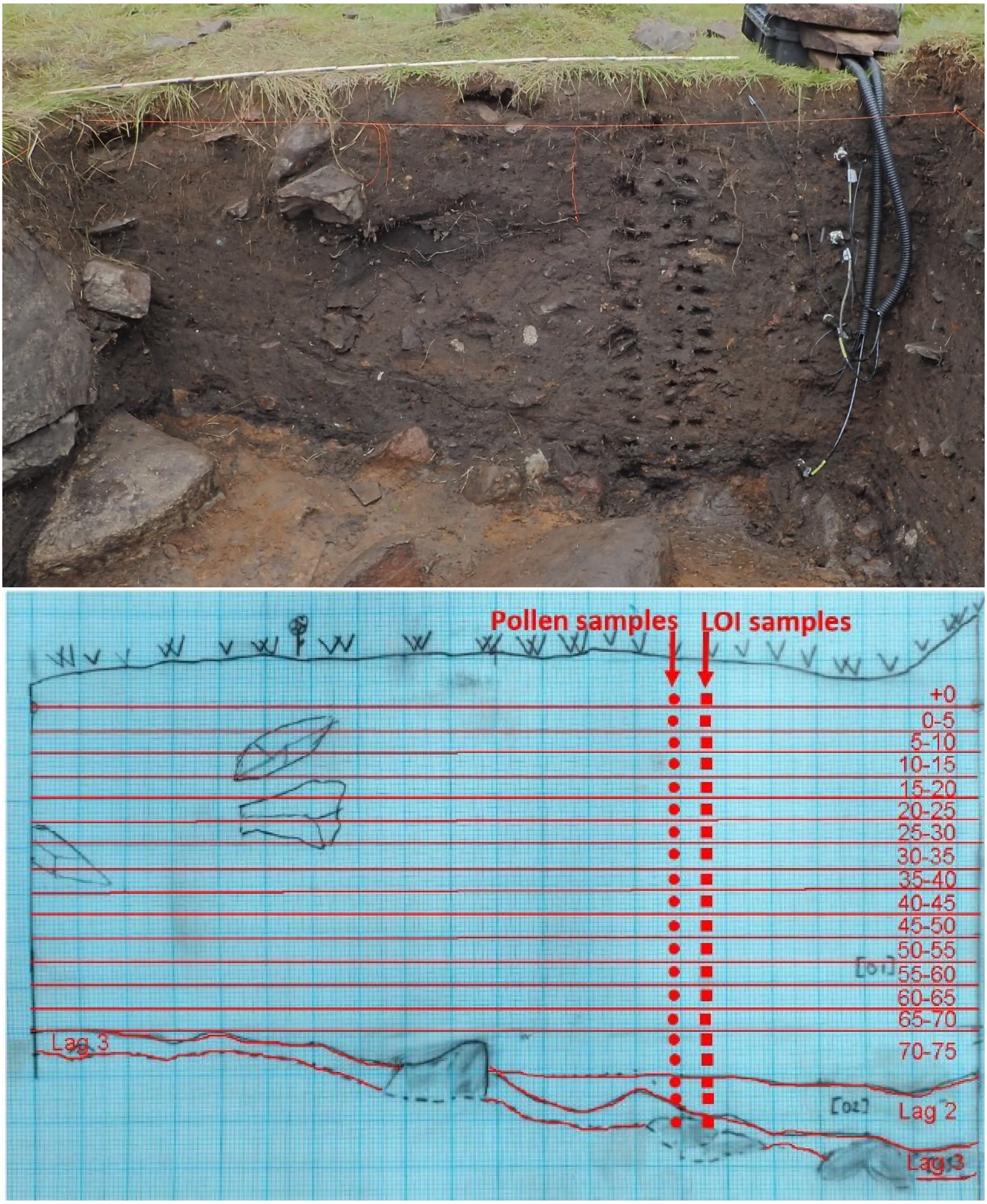


Figure 9: Excavation trench at Ø35, along with Henriksens drawing and layering number (from Henriksen 2022).

Sampling and environmental monitoring focussed on the east profile next to the pollen and LOI samples (Figure 10). Here Henriksens 0-line is 11 cm below the soil surface. In the following all measurements are relative to the local soil surface, so Henriksens 0-5 cm layer is equal to 11-16 cm here. Five different strata were identified: Layer 0: 0-9 cm below soil surface, root felt; Layer 1: 9-88 cm, decomposed midden layer, silty with stones, charcoal and degraded bones; Layer 2: 88-98 cm, compact midden layer; Layer 3: 98-100 cm, layer of charcoal, possibly from landnam; Layer 4: 100- cm: sterile coarse grained material. There were many horsetail rhizomes in the top of the midden, with a few ones at the bottom. The site has probably been inhabited for the whole Norse period (ca 1000-1450 AD), i.e. the material in the midden is approx. 570-1000 years old.

Figure 10. East profile of Ø35 where measurements and samples were taken in 2022.

Sterile samples for DNA analysis were taken at 5 cm depth intervals from 0 to 110 cm depth, in total 21 samples. Bulk samples for lipid analysis were taken at 5-9, 28-32, 65-70 and 98-105 cm below soil surface. Ring samples and bulk samples for reactivity were taken at 20, 40, 60, 80 and 95 cm below soil surface. Natural reference soil samples were taken 5-15 cm beneath the soil surface at three points in the vicinity of the midden (ref 1 at N61° 11.410’ W045° 33.787’, ref 2 at N61° 11.389’ W045° 33.807’and ref 3 at N61° 11.321’ W045° 33.951’)

Results from in situ measurements and ring samples are given in Figure 11.

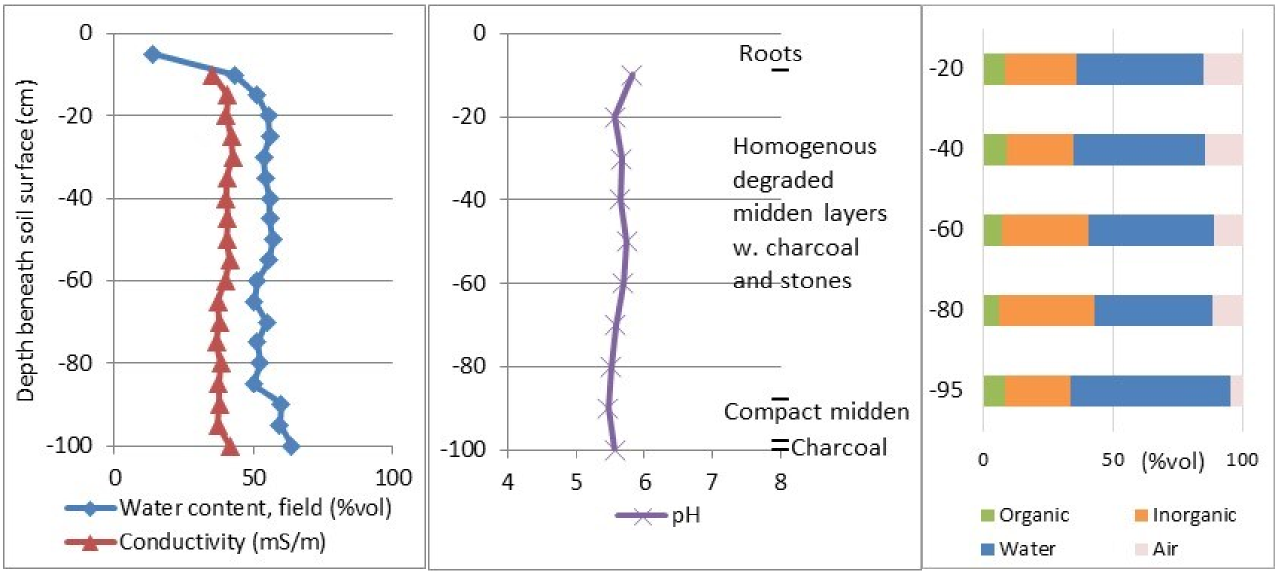


Figure 11: Field measurements and results from ring samples taken in the midden at Ø35

The results show that the midden deposits are very homogenous, apart from the top and bottom layers: the soil porosity varies between 57 and 66 %vol, and the air content (on the day of sampling) decreases for 15 %vol at the top to 5% vol in the deepest, compact layer, indicating that there may be anoxic conditions at the bottom. The inorganic content is between 26 and 37 % vol which is similar to Ø49, but at the higher end of the other middens examined in AAH – thus the loss on ignition values of the Ø35 midden are only 8-16 % w/dw. The conductivity values were quite low (37-43 mS/m) but still higher than at Ø49 – this could indicate more stagnant condition with less dilution by fresh water, but there could also be other explanations. Regarding pH, the results show very little variation with values between 5.5 and 5.8. Grain size analysis of the inorganic part of layer 1 and 2 (Figure 12) shows that the sample at 60 cm (layer 1) mainly consists of poorly sorted, fine to coarse sand with quite a few pebbles larger than 2 mm. The sample from 95 cm (layer 2) has a larger percentage of fine material, and its water retention is probably better than the sample above.

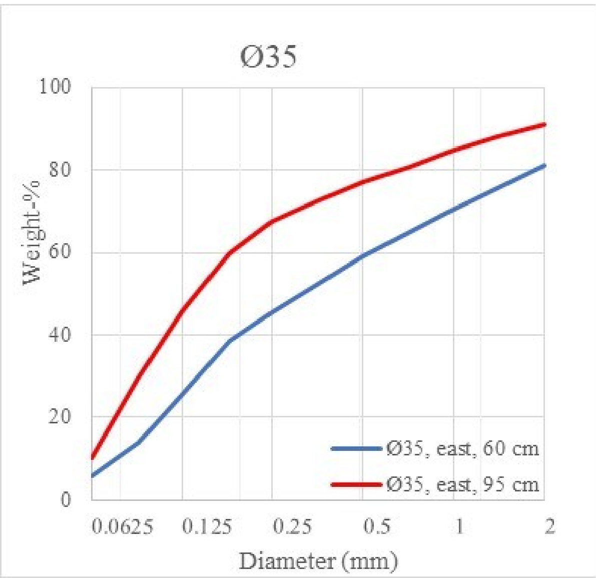


Figure 12: Grain size analysis for samples from Ø35. All organic material was removed by ignition of samples before analysis.

Monitoring data:

In 2022 a GP2 logger was installed with four SM300 sensors at 20, 40, 60 and 95 cm depth logging water content and temperature every 6 hours. Furthermore, a HOBO logger with 5 temperature sensors at the soil surface and at 20, 40, 60 and 95 cm depth were installed logging every 2 hours. Oxygen sensors were temporarily installed at 20, 40, 60 and 95 cm depth during site visit 2/8/2023. Data from the loggers were downloaded and all equipment removed 3/8/2023.

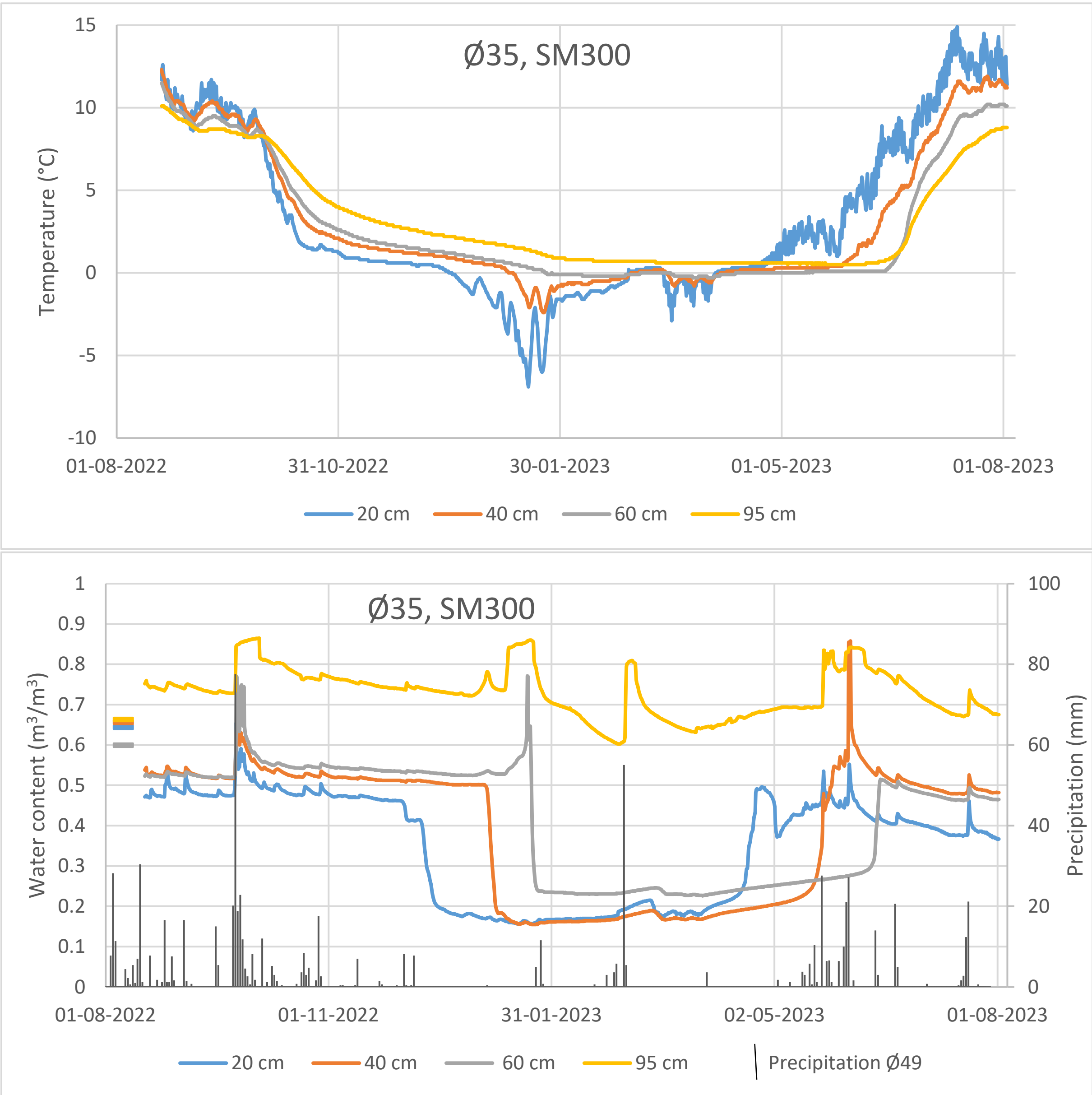


Figure 13: Monitoring data from Ø35. Precipitation data are taken from the weather station at Ø49, approximately 20 km to the south of Ø35.

The air temperature has not been measured at Ø35 but will be similar to measurements from Ø49 (figure 7). There is a remarkably warm period with air temperatures above 10 °C in the beginning of March 2023 which is also reflected in the soil temperatures at Ø35 where the soil temperature at 20, 40 and even 60 cm depth increases up to 0 °C. The soil temperature at 95 cm depth at the bottom of the deposits is slightly above 0 °C for the whole monitoring period.

The water content sensors shows that the deposits at 20 cm depth are completely frozen from December to April, at 40 cm depth from January to May, at 60 cm depth from late January to mid June, while the deepest deposits at 95 cm depth are only partially frozen (as shown by the decreasing water content from January to February). The warm period in March 2023 is reflected in the water contents showing a partial thawing at all depths. A large precipitation event on 2/3/2023 with 55 mm rain in a day probably contributes to the fast distribution of water and heat down into the deposits. In absolute values the water contents are close to or even above the measured porosities most of 2022 while the water contents decrease during the very dry summer of 2023. The absolute values should not be over-interpreted as the SM300 sensors are only calibrated up to 60% vol and may give biased results if the water content increases above this value – thus for instance the deepest sensor at 95 cm reaches a maximum plateau around 85% vol during wet periods that probably indicates waterlogged conditions - here the real water content will be similar to the porosity of the soil, i.e. 66% vol. Despite these uncertainties the monitoring data indicates that there is a low air content and probably anoxic conditions in the deeper deposits for prolonged periods in 2022. For comparison 2023 is very dry and water content measurements show how the soil dries up over the summer allowing more oxygen into the soil. Oxygen measurements directly in the soil on the 3rd of august 2023 showed approx. 75% oxygen saturation at 20 cm depth decreasing to 65% saturation in the deepest deposits – i.e. not full oxygen saturation but still far from anoxic conditions.

To summarize, Figure 13 shows that the midden at Ø35 is permanently moist and that at least the deepest deposits experience periods with (almost) waterlogged conditions during wet seasons, where the air content is below 20% vol and where degradation will be limited due to anoxic conditions. On the other hand during dry seasons the water content is lowered and some oxygen can reach even the deepest deposits. There is only a short period with frozen deposits and the temperatures get relatively high during summer which will enhance degradation.

Ø47 / NKAH4335 – Igaliku cemetery.

The site is located at the northeastern corner of the cemetery surrounding the Norse cathedral at Garðar, in the middle of the small town of Igaliku (Figure 14). The area is fenced, but with a relatively large number of visitors. It is covered with grass that is cut at intervals to keep the ruins visible.

Figure 14: Location of Ø47/Igaliku cemetery. Excavation took place at the yellow marker.

An area of approx. 12 m^2 within the cemetery was excavated by Jette Arneborg and Dorthe Dangvard Petersen and their teams in the period from 2019 to 2022. WP2.1 visited the excavation from 3-8 August 2022 to take samples of soil and skeletons, make some environmental measurements, and download data from a temperature logger installed in 2021. The position according to handheld GPS is approx N60° 59.239’ W045° 25.363’. The measuring system within the excavation is described in Pedersen (2021).

Figure 15: North profile from cemetery excavation. The upper ca 35 cm consist of backfill from 2019 excavation. Environmental measurements were carried out next to the ruler in the north profile (at x 0.0, y 2.5), and in the east profile next to the feet of the skeleton (at x0.7, y 3.0)

Environmental monitoring focussed on the north and east profile, close to the corner on Figure 15, while sampling focused both on the profiles and on the skeletons. In the following all measurements are relative to the local soil surface. The cemetery is highly disturbed due to repeated digging, and there is no overall stratigraphy – this is instead described locally together with the environmental measurements. The skeletons in the cemetery cover the whole Norse period from ca 1000-1450 AD, i.e. the material has been in the ground for approx. 570-1000 years.

Figure 16. North profile at x 0.0/y 2.5 (left) and East profile at x 0.7/y3.0 (right) where measurements and samples were taken. The Tinytag sensor were moved from the North to the East profile to avoid the backfill from 2019.

Ring samples were taken 4/8/2022 in the North profile at 30 and 50cm depth, and in the East profile at 30 and 65 cm depth (Figure 16). Sterile samples for DNA and lipid analysis focused on the skeletons and their signs of tuberculosis. At skeleton APx228 was sampled: soil from the rib area and a very degraded rib. At skeleton AMx218 was sampled: soil from the pelvis area, soil from the rib area, a poorly preserved rib, and a tooth (unclear if it was from AMx218 or AMx231). At skeleton AXx247 was sampled: soil from the rib area, a tooth, and (later) a rib. At ARx246 soil was sampled from the rib area. A natural reference soil sample was taken in an area with no skeletons. Further details are given in field notes from Anne Marie Høier Eriksen and Martin Nordvig Mortensen.

Environmental measurements were carried out in the North profile on the 3/8/2022 and repeated on the 4/8/2022 after a night with heavy rain (Figure 17, top). Measurements in the East profile were carried out the 4/8/2022 (Figure 17, bottom).

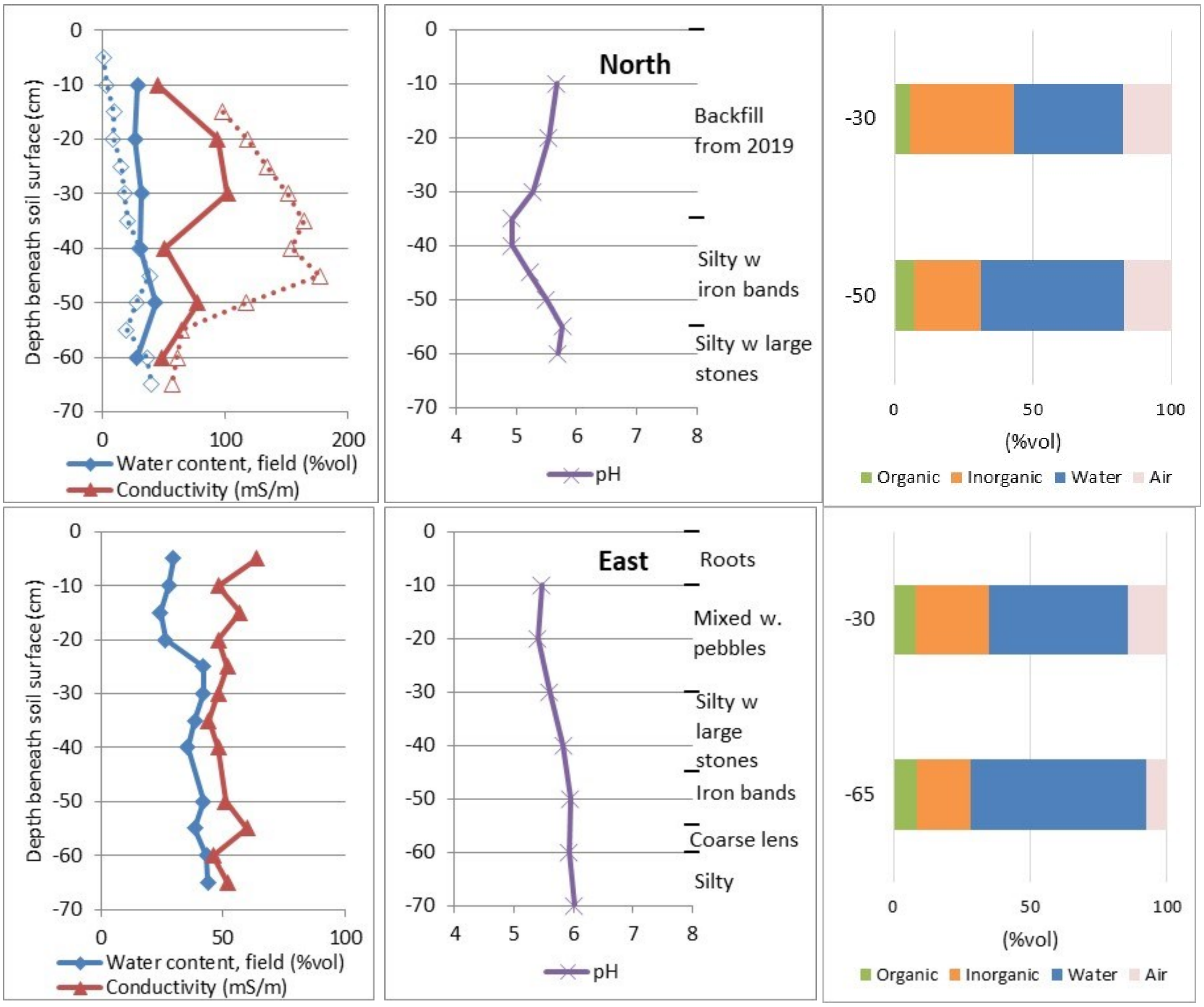


Figure 17: Field measurements and results from ring samples taken at the cemetery. At the North profile (upper row) water content and conductivity was measured twice: before (dashed line) and after (solid line) a heavy rainfall. Measurements in the East profile were carried out after the rainfall. All ring samples were taken after the rainfall.

The results show some general tendencies of the cemetery deposits, despite their apparent heterogeneity: the soil porosity varies between 57 and 72 %vol, and the air content (after rainfall) varies from 18 %vol in the upper deposits and down to 8% vol in the deeper silty layer, indicating that there may be anoxic conditions at the bottom in periods. However, measurements on two sequential days in the North profile also shows how quickly thing may change, as a heavy rainfall led to increased water content and decreased conductivity of the soil layers. The inorganic content is between 20 and 37 % vol which is similar to Ø35 and Ø49. The conductivity values were relatively high (typically 50-100 mS/m – and before the rainfall even up to 180 mS/m). Regarding pH, the results varied between 4.9 and 6.0, where the lower values may result in a poor preservation of the bone material. Grain size analysis of the inorganic part of soil from 30 and 65 cm depth confirms the silty nature of the deposits, especially for the deepest sample (Figure 18). The silt from 65 cm depth had a tendency to clog the sieves, and the analysis may overestimate the real grainsizes. Silt has great impact on the water retention in the midden, indicating that the high water content (and low air content) observed for the deeper layers may be common.

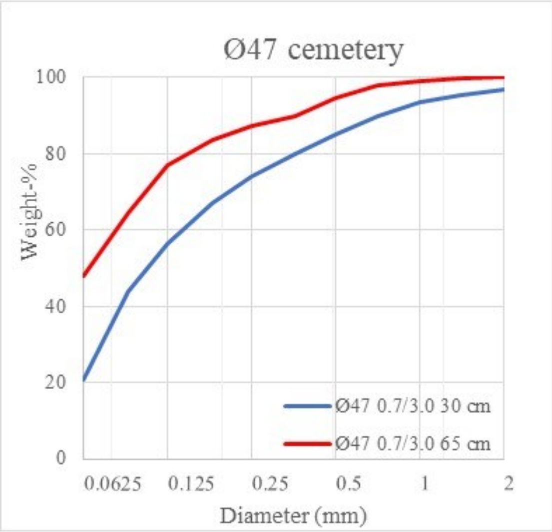


Figure 18: Grain size analysis for samples from the east profile at Ø47. All organic material was removed by ignition of samples before analysis.

Monitoring data 2021-23:

In 2021 a TinyTag logger with two temperature sensors were installed in the north profile of the excavation pit by Jørgen Hollesen (Figure 19). In August 2022 the sensors were moved to the East profile to avoid possible effects from the thick layer of backfill.

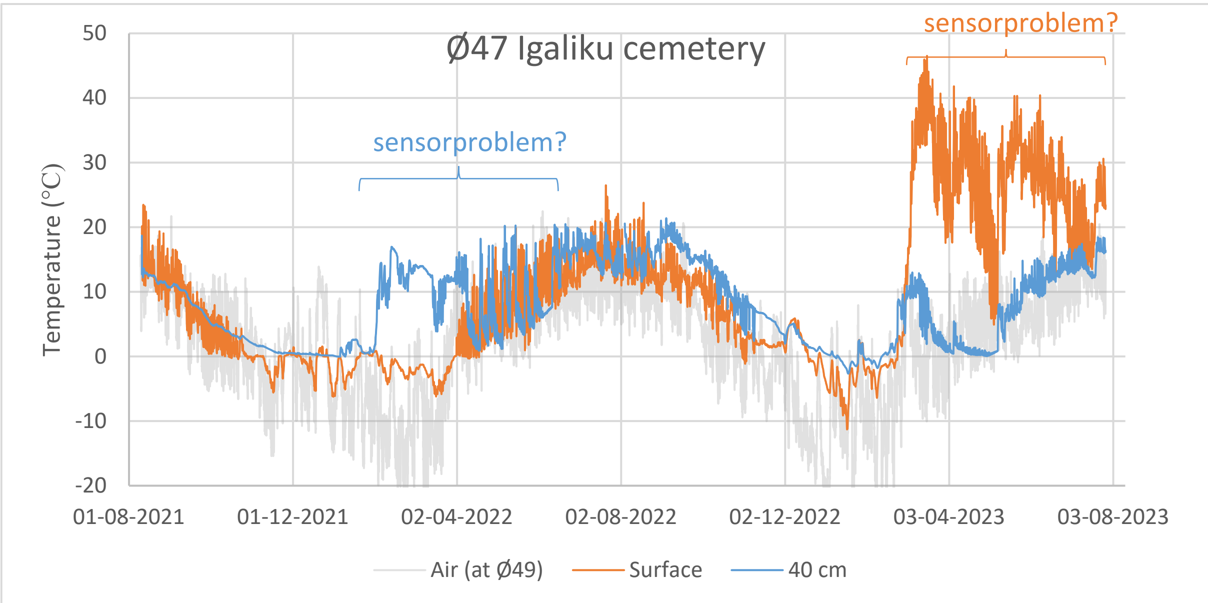


Figure 19: Temperature data from the north profile. Air temperature is taken from Ø49 ca 3 km away

The air temperature varies between +23 and -24 °C, with some remarkably warm periods with positive temperatures in December 2021 and February/March 2023. The soil surface sensor follows the air temperature and shows several freeze/thaw events over the winter. However, in March 2023 the surface sensor suddenly gives unrealistic results with temperatures up to 40 °C. It is unknown what has caused this malfunctioning. Similar with the sensor at 40 cm depth: there is a peculiar rise in temperature in February 2022, where the temperature measurements suddenly increase to +10 °C without any good explanation. A test of the logger and sensors after retrieval show that they both measure correct, so the malfunctioning is only temporary, which makes it difficult to be certain of which measurements are correct and which are biased.

To summarize the preservation conditions for skeletal material are neither very poor nor excellent at Ø47. The soil pH is a bit low and some demineralisation from the bones will probably take place. On the other hand the silty soil has a good water retention capacity so during wet periods it is likely that there are anoxic conditions in the ground were the degradation of organic components in the bone is limited.

Summary

Results of sampling, measuring and monitoring at 2 middens and 1 cemetery excavation in the Kujataa area are described to document what has been carried out during the WP2.1 fieldwork. The present report is only intended to give an overview of the field measurements, and it shall be used in conjunction with studies of the site formation, state of preservation and reactivity of different archaeological materials in order to understand the previous, current and future preservation at these sites.

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