Report of the expedition to 10 Norse archaeological sites on the western settlement between the 10th and the 29th of July of 2017

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Description of the expedition

Itinerary

Between the 13th and 28th of July we visited 10 Norse farms in the area of Kapisillit (Table 1, Fig. 1). At each site and following the instruction of all the required permits, we found what we thought could be ancient hayfields (Fig. 2) and nearby reference undisturbed sites. Both at hayfield and undisturbed sites we collected samples of plant roots and insects at four plots per location (Fig. 3 and 4). At each plot, we recorded all plant species and took a vertical picture.

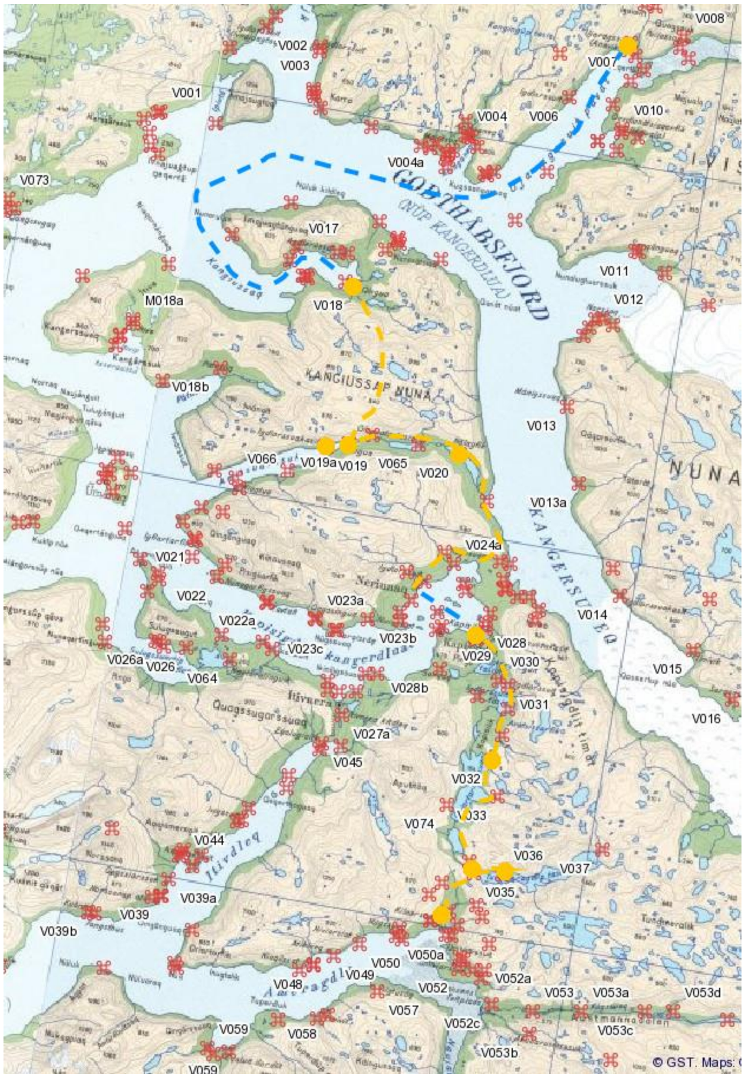

Figure 1. Expedition itinerary. Yellow dots are sampled locations, yellow dashed lines indicate hiking routes and blue dashed lines indicate boat rides.

At each hayfield and beyond the 20-m distance from the ruins, we dug a 30x30 cm^2 soil profile (Fig. 3, Annex 1) and collected one soil sample at 10 cm deep for nitrogen and phosphorus analysis. At each profile, we also aimed to find a fringe of darker soil that could potentially correspond to the period of use of the hayfield created as a consequence of the frequent burnings that Norse used to do according to previous studies (Fig. 5). If the fringe was apparent, we collected soil from the bottom and top of the fringe and additional charcoal samples also at the top and bottom if they were available. Soil and charcoal samples were stored in plastic bags. We dug another profile at reference sites located nearby (<50 m) and outside the hayfield. Reference sites were free of dark layers in the first 30 cm.

Table 1. Chronology of the expedition.

Farm	Dates
V51	13th to 16th
V36	16th to 17th
V35	17th
V32	18th to 19th
V28b	19th
V20	21st to 22nd
V19a	22nd to 23rd
V19	23rd
V18	25th to 26th
V07	26th to 27th

Each soil profile was refilled with the same material extracted and in the same order of extraction. In most cases, a compact piece of soil and roots allowed the perfect preservation of the soil reducing the impact to the minimum (Fig. 3).

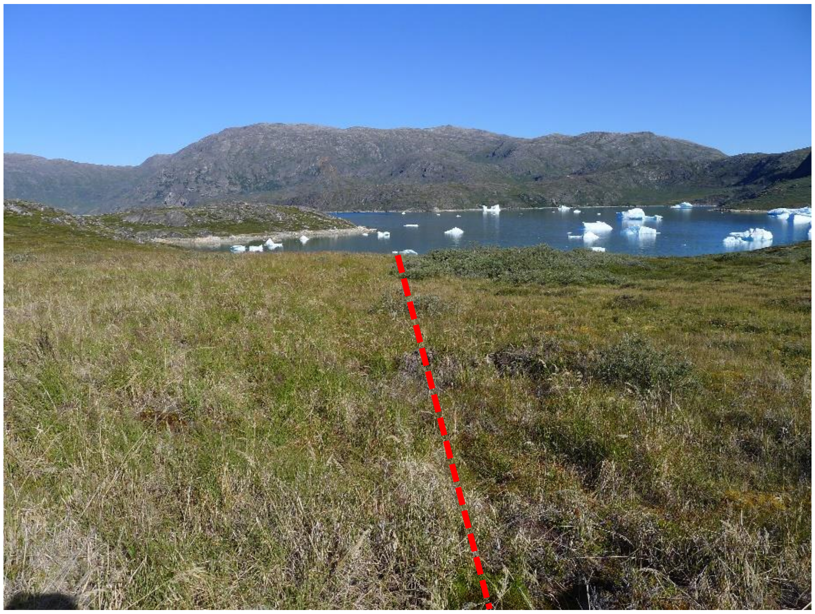

Figure 2. Limit of hayfield in farm V18. Former hayfield to the left of the red dashed line covered with grassland vegetation and woody vegetation and moss to the right

Team

Other than the expedition leader: Asuncion Rodríguez (BC3), Pierre Blevin (CNRS, France), and Sergio Couto (Volunteer, Spain)

Figure 3. Sampling plots at the reference undisturbed site in V51 (left) and digging the soil profile in a former hayfield at V35 (right).

Sample analysis

Plot vertical pictures were digitized using QGIS and their relative cover per species estimated. We used dissimilarity analysis (Horn-Morisita distance) to detect differences between plant community composition at hayfields and undisturbed sites. Plant root samples were submitted to a metagenomics facility to characterize the community of mycorrhizal fungi. Soil samples were analyzed using liquid chromatography and mass spectrometry to quantify the concentration of total nitrogen and phosphorus. Soil samples at the top and bottom were analyzed using accelerator mass spectrometry to detect the concentration of ^{14}C and estimate the age of the charcoal pieces or of the organic carbon.


Figure 4. Plant sampling plots at V51. The left plot was on the disturbed area (hayfield) and the right plot on the reference area.

Figure 5. Soil profile. Two charcoal layers can be visually detected at the bottom of the profile at V32. Measuring tape in centimeters.

Results from the preliminary analysis

The results from the ^{14}C dating are based on the humin fraction extracted from the soil samples (Table 2, Annex 2). Overall, results match the known occupation period in the Western settlement except for one sample at V32 that is much more modern. We found that V35 and V36 show too early starting dates and V7 and V51 show slightly late abandonment periods. However, the small excess of the former is captured by the 1σ error, indicating that these farm may have resisted till the end of the occupation period. It is confusing the fact that in the two sites where we dated humin and charcoal samples at the same depth the results from both carbon sources differ by *c*. 400 years. This result questions the validity of dating the humin fraction of the soil. For unknown reasons, only at these two sites there was almost no difference between the dates at the two depths sampled.

The plant community composition was different between the hayfields and reference sites (Fig. 6). Although the amount of species was almost identical (35 and 34 respectively at hayfields and reference sites), the species and their abundances were significantly different. In particular, it seems that disturbed sites are dominated by annual grasses and forbs and reference sites by woody species (Fig. 4). Nitrogen and phosphorus contents in soil were significantly higher (Mann-Whitney test; $p<0.01$) in farmed sites [median (75% confidence interval); 0.85% N (0.55-1.13) and 46 ppm P (37-146)] than in reference sites [0.18%N (0.132-0.59) and 20 ppm P (12-23)]. The mycorrhizal study has not provided relevant results yet.

This suggests that the legacy of ancient agricultural practices (manuring and irrigation) still persists after 600 to 1,000 years of abandonment. This effect can be partially explained by the higher concentration of N (five times higher) and P (two times higher) in the soil of hayfields.

Table 2. Results from the ^{14}C sol dating. Sample ID coding refers to farm code, first three digits (e.g. V20), and sampling depth in centimeters. pMC – percent modern carbon, RCYBP – radio carbon years before present. Standard results were calibrated using OxCal v4.2.4 using the IntCal13 atmospheric curve. Red text highlights results not matching known occupation periods. Dark yellow text indicates periods slightly outside the known occupation periods but whose error is within known occupation periods. The raw results including the calibration tables are included in Annex 2.

Sample Id	Depth (cm)	Sample type	pMC	1 σ	RCYBP	1 σ	AD year	Time since abandonment	Occupation period
V20	8	charcoal	91.91	0.27	678	24	1338	678	411
V20	8	humin	87.71	0.44	1053	40	963		
V20	18	humin	87.32	0.4	1089	37	927	1089	
V19a	14	charcoal	91.43	0.26	720	23	1296	720	419
V19a	14	humin	86.67	0.42	1149	39	867		
V19a	30	humin	86.78	0.54	1139	50	877		
V18	4	humin	107.28	0.41	Modern				
V28b	9	humin	88.18	0.46	1010	42	1006	1010	
V35	7	humin	92.27	0.5	646	44	1370	646	466
V35	11	humin	87.07	0.68	1112	63	904		
V36	13	humin	91.97	0.33	672	29	1344	672	495
V36	29	humin	86.48	0.48	1167	45	849		
V51	7	humin	93.26	0.31	561	27	1455	561	327
V51	16	humin	89.53	0.44	888	39	1128		
V7	4	humin	93.38	0.26	550	22	1466	550	410
V7-	20	humin	88.74	0.31	960	28	1056		
V32	13	humin	91.62	0.32	703	28	1313	703	838
V32	21	humin	82.54	0.24	1541	23	475		

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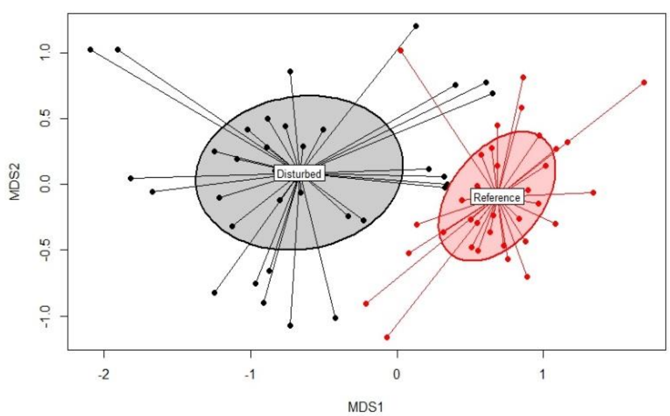

Figure 6. Plant community dissimilarity between reference and disturbed plots. Each dot represents a plot. Non-metric multidimensional scaling (NMDS) based on Horn-Morisita distance. Stress=0.17. Ellipses indicate standard deviation of the average located in the centroid. Dispersion grouped based on the categories "Reference" and "Disturbed" (ANOVA F=13.5, p<0.001).

Annex1. Sampling points per location

Location	Latitude	Longitude	Elevation (m)
V07-dis	64.82222	-50.147	48.3
V07-ref	64.82204	-50.1529	59.8
V18-dis	64.64039	-50.4874	0.0
V18-ref	64.63829	-50.4913	2.9
V19a-dis	64.53994	-50.4532	4.8
V19a-ref	64.54007	-50.4535	2.4
V19-ref	64.53652	-50.4764	0.0
V20-dis	64.54757	-50.2911	53.6
V20-ref	64.54825	-50.2934	63.5
V28b-dis1	64.41439	-50.2581	37.3
V28b-dis2	64.41398	-50.2582	38.3
V28b-ref	64.41133	-50.2379	54.2
V32-dis	64.36026	-50.1627	160.1
V32-dis	64.36025	-50.1625	164.0
V32-ref	64.35956	-50.1622	162.4
V35-ref	64.2875	-50.115	232.1
V36-dis	64.28652	-50.1529	227.9
V36-dis	64.28673	-50.1519	235.5
V36-ref	64.28745	-50.1531	245.1
V51-ref	64.24309	-50.1799	0

The table includes all the profiles excavated, but not all of them were finally used in the study. There are two locations V35-dis and V51-dis that were lost or never recorded. Latitude and longitude are expressed in radians. Elevation is approximate with an error of about 25 m. GPS resolution is approximately 15 m. dis – disturbed, ref – reference.

Annex 2. Radiocarbon dating results

Radiocarbon dating data are property of the author of this report and cannot be used without his explicit permission.

Report: **BC3-03** 13 October 2016

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Samples submitted for radiocarbon dating have been processed and measured by AMS. The following results were obtained:

DirectAMS code	Submitter ID	Sample type	Fraction of modern		Radiocarbon age	
			pMC	1σ error	BP	1σ error
D-AMS 018778	V32DIS-20	charcoal				
D-AMS 018779	V51REF-17	humin	95.74	0.29	350	24
D-AMS 018780	V51DIS-16	humin	89.53	0.44	888	39
D-AMS 018781	V51DIS-7	humin	93.26	0.31	561	27
D-AMS 018782	V7REF-8	humin	94.95	0.24	416	20
D-AMS 018783	V7DIS-4	humin	93.38	0.26	550	22
D-AMS 018784	V7DIS-20	humin	88.74	0.31	960	28
D-AMS 018785	V32REF-9	humin	90.22	0.33	827	29
D-AMS 018786	V32DIS-13	humin	91.62	0.32	703	28
D-AMS 018787	V32DIS-21	humin	82.54	0.24	1541	23

Results are presented in units of percent modern carbon (pMC) and the uncalibrated radiocarbon age before present (BP). All results have been corrected for isotopic fractionation with an unreported $\delta^{13}C$ value measured on the prepared carbon by the accelerator. The pMC reported requires no further correction for fractionation.

Standard results were calibrated using OxCal v4.2.4 (Bronk Ramsey 2013) using the IntCal13 atmospheric curve (Reimer et al 2013). Modern results were calibrated from the fraction modern (pMC) and associated error using the same program but calibrated along the Bomb13 atmospheric curve for the Northern Hemisphere, zone 1 (Hua et al 2013).

Table 2. DirectAMS Results, RCYBP and Calibrated Yr BC/AD

D-AMS ID	RCYBP or *pMC*	Error	1 sigma 68.2%, cal yr	2 sigma 95.4%, cal yr
D-AMS 018778				
D-AMS 018779	350	24	(29.7%) AD 1483 - 1522 (38.5%) AD 1574 - 1628	(41.8%) AD 1458 - 1530 (53.6%) AD 1540 - 1635
D-AMS 018780	888	39	(22.2%) AD 1049 - 1084 (6.5%) AD 1124 - 1136 (39.5%) AD 1150 - 1210	AD 1035 - 1220
D-AMS 018781	561	27	(33.6%) AD 1323 - 1346 (34.6%) AD 1392 - 1414	(50.1%) AD 1310 – 1360 (45.3%) AD 1386 - 1425
D-AMS 018782	416	20	AD 1442 - 1467	(93.7%) AD 1436 - 1490 (1.7%) AD 1603 - 1608
D-AMS 018783	550	22	(19.5%) AD 1328 - 1341 (48.7%) AD 1396 - 1418	(34.5%) AD 1318 - 1352 (60.9%) AD 1390 - 1428
D-AMS 018784	960	28	(23.4%) AD 1024 - 1048 (34.5%) AD 1086 - 1124 (10.4%) AD 1137 - 1150	AD 1020 - 1154
D-AMS 018785	827	29	AD 1190 - 1254	AD 1164 - 1262
D-AMS 018786	703	28	AD 1270 - 1296	(82.0%) AD 1260 - 1306 (13.4%) AD 1362 - 1385
D-AMS 018787	1541	23	(43.7%) AD 432 - 489 (24.5%) AD 532 - 560	AD 427 - 574

References

Bronk Ramsey, C., Scott, M., & van der Plicht, H. (2013). Calibration for Archaeological and Environmental Terrestrial Samples in the Time Range 26-50 ka cal BP. *Radiocarbon*, 55(4), 2021-2027.

Bronk Ramsey, C., & Lee, S. (2013). Recent and Planned Developments of the Program OxCal. *Radiocarbon*, 55(2-3), 720-730.

Hua, Q., Barbetti, M., & Rakowski, A. J. (2013). Atmospheric Radiocarbon for the Period 1950-2010. *Radiocarbon*, 55(4).

Reimer, P. J., Bard, E., Bayliss, A., Beck, J. W., Blackwell, P. G., Bronk Ramsey, C., Grootes, P. M., Guilderson, T. P., Haflidason, H., Hajdas, I., Hatt, C., Heaton, T. J., Hoffmann, D. L., Hogg, A. G., Hughen, K. A., Kaiser, K. F., Kromer, B., Manning, S. W., Niu, M., Reimer, R. W., Richards, D. A., Scott, E. M., Southon, J. R., Staff, R. A., Turney, C. S. M., & van der Plicht, J. (2013). IntCal13 and Marine13 Radiocarbon Age Calibration Curves 0-50,000 Years cal BP. *Radiocarbon*, 55(4).

Report: **1611-019286-019297** 2 December 2016

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Samples submitted for radiocarbon dating have been processed and measured by AMS. The following results were obtained:

DirectAMS code	Submitter ID	Sample type	Fraction of modern		Radiocarbon age	
			pMC	1σ error	BP	1σ error
D-AMS 019286	V20DIS-8 (char)	charcoal	91.91	0.27	678	24
D-AMS 019287	V19ADIS-14 (char)	charcoal	91.43	0.26	720	23
D-AMS 019288	V20DIS-8 (sed)	humin	87.71	0.44	1053	40
D-AMS 019289	V20DIS-18	humin	87.32	0.4	1089	37
D-AMS 019290	V19ADIS-14 (sed)	humin	86.67	0.42	1149	39
D-AMS 019291	V19ADIS-30	humin	86.78	0.54	1139	50
D-AMS 019292	V18DIS-4	humin	107.28	0.41	Modern	
D-AMS 019293	V28BDIS-9	humin	88.18	0.46	1010	42
D-AMS 019294	V35DIS-7	humin	92.27	0.5	646	44
D-AMS 019295	V35DIS-11	humin	87.07	0.68	1112	63
D-AMS 019296	V36DIS-13	humin	91.97	0.33	672	29
D-AMS 019297	V36DIS-29	humin	86.48	0.48	1167	45

Results are presented in units of percent modern carbon (pMC) and the uncalibrated radiocarbon age before present (BP). All results have been corrected for isotopic fractionation with an unreported $\delta^{13}C$ value measured on the prepared carbon by the accelerator. The pMC reported requires no further correction for fractionation.

Standard results were calibrated using OxCal v4.2.4 (Bronk Ramsey 2013) using the IntCal13 atmospheric curve (Reimer et al 2013). Modern results were calibrated from the fraction modern (pMC) and associated error using the same program but calibrated along the Bomb13 atmospheric curve for the Northern Hemisphere, zone 1 (Hua et al 2013).

Table 2. DirectAMS Results, RCYBP and Calibrated Yr BC/AD

D-AMS ID	RCYBP or *pMC*	Error	1 sigma 68.2%, cal yr	2 sigma 95.4%, cal yr
D-AMS 019286	678	24	(48.3%) AD 1280 - 1300 (19.9%) AD 1369 - 1380	(62.0%) AD 1274 – 1310 (33.4%) AD 1360 - 1388
D-AMS 019287	720	23	AD 1270 - 1286	AD 1260 - 1296
D-AMS 019288	1053	40	(6.4%) AD 906 - 916 (61.8%) AD 968 - 1022	AD 892 - 1033
D-AMS 019289	1089	37	(24.7%) AD 897 - 926 (43.5%) AD 943 - 992	AD 885 - 1020
D-AMS 019290	1149	39	(6.4%) AD 778 - 790 (5.8%) AD 826 - 840 (24.6%) AD 864 - 907 (31.4%) AD 914 - 968	AD 774 - 976
D-AMS 019291	1139	50	(5.0%) AD 778 - 790 (3.9%) AD 828 - 838 (59.3%) AD 865 - 978	(94.7%) AD 770 – 998 (0.7%) AD 1005 - 1012
D-AMS 019292	*107.28*	*0.41*	AD 2004.18 - 2006.48	(8.7%) AD 1957.9 - 1958.7 (85.6%) AD 2003.2 - 2007.1 (1.1%) AD 2007.64 - 2007.9
D-AMS 019293	1010	42	(58.9%) AD 982 - 1044 (9.3%) AD 1100 - 1119	(2.2%) AD 902 - 919 (93.2%) AD 965 - 1154
D-AMS 019294	646	44	(30.4%) AD 1286 - 1318 (37.8%) AD 1352 - 1390	AD 1278 - 1400
D-AMS 019295	1112	63	(2.2%) AD 780 - 787 (66.0%) AD 876 - 1014	AD 770 - 1026
D-AMS 019296	672	29	(40.1%) AD 1280 - 1304 (28.1%) AD 1364 - 1384	(54.7%) AD 1273 - 1318 (40.7%) AD 1352 - 1390
D-AMS 019297	1167	45	(61.6%) AD 776 - 896 (6.6%) AD 928 - 941	(2.2%) AD 724 - 739 (93.2%) AD 767 - 981

References

Bronk Ramsey, C., Scott, M., & van der Plicht, H. (2013). Calibration for Archaeological and Environmental Terrestrial Samples in the Time Range 26-50 ka cal BP. *Radiocarbon*, 55(4), 2021-2027.

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