Geoarchaeological investigations at Qassiarsuk (Brattahlíð), Greenland

Ian A. Simpson and W. Paul Adderley

School of Biological and Environmental Sciences, University of Stirling, Stirling FK9 4LA, Scotland, U.K.

Introduction

Qassiarsuk is commonly considered, despite occasional speculation, to be the location of Brattahlíð, the site of Erík Þorvaldsson, the first Norse settlement of Greenland in AD 982 and at the core of the Eastern settlement. The extensive Norse and Inuit ruins at the site have been subject to several archaeological surveys (Bruun, 1895; Guldager et al., 2002; Roussell, 1941) with excavations focussing on the early Norse church structure and churchyard and the nearby Norse dwelling and byre (Krogh, 1982; Meldgaard, 1982; Nørlund and Stenberger, 1934); these have clearly established that this was an important site throughout much of the Norse period in Greenland. The geology of the area is mixed with biotite rich gneiss underlying the north of the site and sandstones underlying the southern portion (Geological Survey of Greenland, 1973). Site topography is characterised by a gently sloping east facing aspect with a terrace, possibly a raised beach, to the west of the present day intensively improved grassland infield areas used to produce winter feed for sheep.

While excavating the 'North farm' at Brattahlíð, Nørlund and Stenberger also excavated a trench in front of the dwelling and reported the occurrence of over 2 m of stratified midden (anthropic) deposits. Our 2005 excavation re-opened this trench so that modern methods excavation and recovery could be applied, including the analyses of soils and sediments (geoarchaeology) in anticipation that these would reflect the cultural and natural environments in which they were formed. In considering soils and sediments in this way they become a record of activity and environmental conditions which can be elucidated by geoarchaeological investigation.

At Brattahlíð our geoarchaeological objectives were threefold. First we sought evidence of and from fossil soils buried beneath the anthropic sediments of the midden that would indicate environmental conditions prior to settlement. Secondly, we sought evidence from the fossil soils of impacts on the landscape associated with settlement and related activities, prior to the deposition of the anthropic midden material. Thirdly, we sought to characterise the anthropic sediments themselves to indicate the nature of activities at the site. For each of these objectives we used thin section micromorphology of undisturbed samples to characterise soils and sediments from the site. This technique allows microscopic identification of features and their relationship to one another from which interpretation of activities and environmental conditions can be made. This is the first time that thin section micromorphology of archaeological soils and sediments in Greenland has been reported. The technique has been successfully used at a number of contrasting archaeological sites in the Norse north Atlantic region (see for example Simpson et al., 1999; 2000; 2003; 2005), giving confidence in its application to Norse Greenland.

Methods

Field sections and sampling

Three sections from the re-excavated midden deposits were examined in detail, from Trenches 1, 4 and 6 (Figures 1, 2 and 3), giving the opportunity to consider variations in deposition processes across the midden. Description of the exposed stratigraphies used Munsell colour notation and standard textural classes allowing soils and sediments on the site to be integrated as stratigraphic contexts and matrices, and which formed the basis for sampling of undisturbed sediments using Kubiëna tins (8x5x5cm). Four samples were collected from each of the three sections. To support the excavation, chronological control of the stratigraphy was achieved through a series of eleven radiocarbon measurements on bone from the midden (ten on cow bone and one on caribou bone; SUERC- 11551-1152, 1556-11562 and 11566).

Thin section sample preparation and description

Thin sections were manufactured from the Kubiëna tin samples using standardised methods (www.stir.ac.uk/thin) based on procedures developed by Murphy (1986). Water was removed from the sediment samples through vapour-phase acetone exchange, confirmed by repeated measurement of the density of the acetone solution. Samples were impregnated under vacuum with polyester resin (Crystic) and peroxide catalyst. The blocks were cured for six to eight weeks with a further period of one week finishing in an oven at 40°C. Sections were then prepared by cutting, bonded onto glass-slides and precision lapped to a consistent 30 μm thickness monitored optically and through direct measurement. After further diamond polishing each section was then cover-slipped.

Micromorphological analyses of the glass mounted thin sections were undertaken using an Olympus BX-50 polarising microscope over a range of magnifications (x 7.5 to x 400). Both transmitted {plain polarized (PPL); between crossed-polars (XPL)} and reflected {oblique incident (OIL)} light sources were used. Descriptions were made following internationally accepted terminology (Bullock et al., 1985; Stoops, 2003) with assessment of the coarse and fine mineral material, organic material and groundmass *b* fabric. A semi-quantitative analysis of features was made and recorded in summary tables; these are given in Tables 1, 2, 3 and 4.

Results and discussion

Field observations and chronologies

Trench 1 in the main excavation area demonstrated that much of the original material had been cut through, with large boulders subsequently re-deposited from earlier possibly numerous and undated earlier excavation activities. Beneath these disturbed materials however, from one section of the trench, there is an intact sequence of deposits ca. 25 cm in thickness (Figure 1). These deposits comprise midden-like black fine sandy silt loams overlying very dark greyish brown gravels and fine sandy silt loams (context 34); these in turn overlie a fossil soil with a black peaty loam upper horizon, micro-laminated with evidence of linear sand lenses (context 26), and underlying greyish brown sandy loam and gravels (context 35). Two radiocarbon measurement from this trench indicate that context 26 can be dated to ca. 1000 AD and the overlying midden deposit to between 1000 AD and 1,100 AD. Four undisturbed samples were collected in Kubiëna tins from the undisturbed deposits, two from the fossil soil and two from the overlying midden material and gravel.

Trench 4 was located beyond the main excavation area (Figure 2). In the south facing section an intact sequence of thick and micro-laminated fine sandy silt loam midden deposits (contexts 10, 8, 11, 13 and 16) containing bone, charcoal and uncarbonised wood fragments overlie a modified fossil soil. The upper horizon of the fossil soil (context 17) is a black organic fine sandy silt loam containing bone fragments and uncarbonised wood fragments. The underlying horizon is a dark greyish brown fine sandy silt loam, but with a thin black horizon 1-2 mm in thickness through it (context 28). As at Trench 1, well sorted gravels lie beneath the fossil soil (context 35). Three radiocarbon measurements from Trench 4 suggest that the fossil soil dates from before 1000 AD with the first midden contexts (context 16 and 13) deposited ca. 1000 AD. This is followed by a hiatus in deposition until ca. 1100 with subsequent continuous deposition through to 1300 AD. Three undisturbed samples were collected from the midden deposits and one from the fossil soil sequence.

Trench 6 was located in the main excavation area and also demonstrates an intact midden sequence overlying a fossil soil (Figure 3). The midden sequence (contexts 5, 6, 15, 21 and 24) is complex with colours including black, very dark grey and dark reddish brown, and textures including gritty sandy loams, sandy silt loams and peaty loams. Occasional charcoals and wood fragments are evident throughout. The underlying fossil soil is characterised by a black peaty loam upper horizon (context 35A) above a thin very dark greyish brown coarse sandy loam horizon (context 35B), beneath which lie the gravel deposits that are evident across the whole site (context 35C). Six radiocarbon measurements suggest anthropic deposition commenced no earlier than 1100 AD, later than that evident in the other trenches, and continued through to ca. 1300 AD. This also implies that the underlying fossil soil was buried later and represents a Norse land surface from settlement though to ca. 1100 AD. Three undisturbed samples were collected from the midden deposits and one from the fossil soil sequence.

Summaries of soil and sedimentary features observed in thin section are given in Tables 1 (Trench 1), 2 (Trench 4) and 3 (Trench 6). Variations in micromorphology between fossil soils and overlying anthropic sediments, primarily the absence or presence respectively of anthropic inclusions, enable them to be considered separately, although aspects of the fossil soils are also evident in the anthropic sediments.

Fossil soils and environmental conditions prior to settlement.

The black peaty upper horizon of the fossil soil evident in the field is characterised in thin section by four discrete micro-horizons organised as repeating sequences of accumulation (Figure 4a). These micro-horizons include - i) an organic discontinuous micro-horizon dominated by amorphous reddish brown fine organic material generally no more than 1.5 mm in thickness (Figure 4b); ii) a dark brown intact and dominantly organo-mineral horizon with spongy microstructures, moderately sorted coarse mineral material, and very few coarse and fine organic materials generally up to 8 mm in thickness ; iii) a brown to light brown intact organo-mineral horizon with spongy, channel / chamber and intergrain microaggregate microstructures with moderately sorted coarse mineral material and very few coarse and fine organic materials but which has a considerably greater thickness of up to 22 mm.; and iv) a micro-horizon dominated by a linear and moderately sorted sub-angular coarse mineral fraction with thicknesses of up to 6 mm and average grain sizes of between 100 and 200 μm (Figure 4c). These are observed as discrete micro-horizons in the samples from Trenches 1 (samples 27, 28, 29) and 4 (sample 21), although micro-horizon iii) is missing and there is more stone in sample 21. In sample 34 from Trench 6 attributes of the four micro-horizons are observed but they are patch and mixed. Beneath the complex upper horizon of the fossil soil, and underlying the midden site, compacted coarse mineral material comprising quartz dominated sands and gravels with feldspars and biotites dominate, together with grey fine mineral material overlying brown mineral and organo-mineral fine material.

The shallow sequence of organo-mineral and organic upper horizon, overlying a grey mineral horizon beneath which lies a brown, dominantly mineral, but occasionally organo-mineral, horizon is typical of a A, E (elluvial), B horizon well drained podsol sequence. The consistently compacted, indurated, nature of the B horizon suggests that the profile has been subject to long term freeze-thaw processes even although silt cappings, a feature of B horizon in podsols found elsewhere in the vicinity of Qassiarsuk, are absent from these fossil soils. A distinctive feature of the A horizon are the contrasts in organic, organo-mineral material, and the variances in the organic and mineral components within the organo-mineral material. We interpret this as clear evidence for intermittent and contrasting periods of landscape instability - increase in moderately well sorted and linear organised mineral component - and stability increase in organic component with decomposition and mixing with mineral material as the A horizon developed. The composition of the accumulated mineral material in the A horizon is similar to that in the underlying E and B horizons, although moderately sorted rather than poorly sorted, and indicates periods of degradation and movement in and around the Qassiarsuk area.

Integration of observations and interpretations suggests that the pastorally-based Norse settlers arriving at this locality occupied an area that was comparatively gently sloping and well drained, and compared to other localities in the vicinity it is likely to have been marginally warmer. The soils however were shallow and would have been nutrient poor with limited inherent productivity as well as lacking soil moisture holding capacity. Furthermore, the combination of soil type and climatic conditions meant a susceptibility to localised soil movement. The juxtaposition of organic A horizon features, rather than mineral accumulations from eroded areas, with overlying sediments indicative of cultural activity suggests that the arrival of the Norse at this site coincided with a period of landscape stability in its vicinity.

Fossil soils and evidence of landscape impacts and activities

As well as pre-settlement environmental information, the fossil soils also retain features observable in thin section that can be associated with settlement impacts and activities on the landscape. There is evidence of rubified sand and gravel (up to 9 mm diameter) with very few fine charcoals accumulated between the fossil soil and anthropic deposit in Trench 1 (Figures 5a, 5b and 5c); in the upper (A) horizon of the fossil soil, charcoals, rubified coarse mineral material and fine bone fragments (Figure 5c) are found in Trench 4 (sample 21); and mixing of micro-horizons together with few charcoals is evident in Trench 6 (sample 34).

Charcoals and rubified coarse mineral materials testify to the burning of the landscape as a deliberate *landnám* activity and a means of clearing the landscape for settlement and grazing activity. Furthermore, the rubification of several of the individual grains amongst the sand and gravel accumulations at ca. 1000 AD and the associated charcoal materials link burning of the landscape with significant disturbance of the environment and a level of mineral material movement greater than that found in the fossil soil prior to settlement. Soils within the site were themselves disturbed and mixed, but not at a level to contribute to the movement of mineral material. Despite this, there is only very limited and inconsistent evidence (rare bone fragments) of waste material being used as fertiliser on soils, even in the fossil soil not buried to ca. 1100 AD, repeating the findings of a more extensive exploration of the Brattahlíð home field and others in the surrounding region (Adderley and Simpson, 2006). Norse settlers in the Brattahlíð region of the Eastern settlement preferred to rely on natural soil fertility and productivities rather than try to enhance fertility through land manuring strategies as in other areas of the Norse North Atlantic.

Anthropic sediments and site activities

The earliest phase of accumulation deposited ca. 1000 AD represented by contexts 16 and 13 in Trench 4, the deposits through to ca. 1100 AD represented by context 34A in Trench 1 and material deposited into the 1100 – 1300 AD period represented by contexts 24 and 21, Trench 6 are characterised in thin section by repeated sequences and mixes of a range of feature attributes. Dark brown and brown organo-mineral material with parenchymatic tissue, fungal spores and hyphae, diatoms and phytoliths, and with occasional fractured but sometimes linear, red amorphous and cryptocrystalline pedofeatures (Figure 6a), comprise the bulk of the anthropic sediments. In places the parenchymatic tissue is fragmented and, very rarely, associated with what are almost certainly degraded calcium spherulites. Large (up to 5 mm) wood charcoal fragments are evident, and very few and few bone fragments together with vivianite (Figure 6b), found where bone fragments are absent, are also evident. None-anthropic material is also evident in these midden sequences, particularly in the earliest phases. Organic micro-horizons dominated by spongy amorphous reddish brown fine organic material and similar to micro-horizon i) found in the fossil soil upper horizon is evident in several parts of the stratigraphy. Similarly, a micro-horizon dominated by coarse mineral material that is linear and moderately well sorted and similar to micro-horizon iv) in the fossil soil is also found.

We interpret the bulk of these anthropic sediments as deriving from uncarbonised predominantly podsolised turf material (Adderley et al., 2006) possibly the waste from structure construction activity but more likely used as bedding for domestic livestock given the occurrence of fragmented parenchymatic tissue with possible associated calcium spherulites interpreted as manure materials (Canti, 1997). Embedded within this material are indicators of domestic waste deposition including bone fragments and, in the lower parts of the stratigraphy, phosphorus rich vivianite resulting from the decomposition and re-crystalisation of bone material in wet, reducing conditions. Fuel residues are also evident as wood charcoal and rubified coarse mineral grains indicative of turf combustion (Simpson et al., 2003). This mix of turf, and livestock, fuel and food wastes is typical of occupational debris associated with a functioning Norse domestic settlement in different areas of the north Atlantic region. The organic micro-horizons are interpreted as indicative of short-term standstill phases in anthropic sediment deposition with a vegetation cover forming across at least part of the midden; deposition was intermittent. Although care is needed in interpreting the micro-horizon accumulations of coarse mineral material as some of this may have been introduced with turf material to the site, some of the micro-horizons do reflect the landscape instability evident prior to Norse settlement and indicate that landscape instability continued particularly during the early phases (pre- 1100 AD) of site settlement, after which landscape instability returned to a pre-Norse settlement intensity.

A marked change in sediment characteristics is observed in the later part of the 1100 – 1300 AD phase, and is represented by contexts 15 and 6 in Trench 6 and contexts 11 and 8 in Trench 4. Here substantial reduction in occurrence of the turf and animal manure indicators (described above) is observed, while frequencies of bone and charcoal increases. While these increases may be because of better preservation conditions, the fact that these materials are found throughout the stratigraphy suggests that this is a cultural rather than a taphonomic change. Additionally, orange – red fine mineral material observed under oblique incident light with rubified coarse mineral fraction and often associated with fine charcoals becomes evident (Figure 6c), a feature indicative of combusted organic, peaty, material. The occurrence of coarse mineral material also increases in these sediments, both as part of the matrix and as discrete linear micro-horizon within the stratigraphy, testifying to an increased landscape instability.

Occupation of the site clearly continued until at least the 1300s, but post 1100 AD subsistence strategy began to change. Evidence of consumption is still present in the form of bone fragments and a more diverse set of fuel wastes, but evidence of domestic livestock wastes becomes increasingly lacking. This may simply be the result of a change in manuring strategy with these wastes ending up in the hone field to improve winter fodder production. However despite some evidence of this occurring at a Norse farm in the Qassiarsuk hinterland (Commisso and Nelson, 2007), our own field and micromorphological investigations have failed to find significant traces of home-field manuring at Qassiarsuk itself or at three other Norse farms in the area. While productivity's of some Norse home-fields were clearly improved by irrigation (Adderley and Simpson, 2006), use of manures to increase nutrient status seem lacking. It is thus possible to suggest that the subsistence strategy of the site started to place less reliance on domestic livestock production post 1100 AD, at least in the immediate vicinity of the site. It may be that the occupants of the site sought to exploit and rely more on other types of resource, marine mammals for example, or that the site was provisioned by regulated the livestock production of farms round about them. The micromorphological evidence suggests that increasing and more persistent landscape instability, at least in the immediate vicinity of the settlement, is a partial explanation for this shift in strategy.

Conclusions

Thin section micromorphology of fossil soils and anthropic sediments at Qassiarsuk (Brattahlið) related to excavation matrices and chronologies have enabled fundamental questions of environment and activity associated with the Norse settlement of the locality to be addressed. Norse settlers at what became Brattahlið arrived in a location that had shallow, freely drained nutrient poor podsols. Significantly, the locality was subject to periodic phases of landscape instability prior to settlement. Initial Norse settlement intensified landscape instability and there is evidence of landscape burning and disturbance in the fossil soils; there is however little evidence to support a systematic manuring strategy to enhance soil fertility. The earlier phases of anthropic sediment deposition reflect, as might be expected, a subsistence strategy based on domestic livestock management and the use of wood and turf as fuel resources. There is however a marked change in anthropic sediment characteristics between 1100 and 1300 AD, with a decline in micromorphological indicators associated with domestic livestock but with bone and fuel residue evidence increasing. We suggest that this represents evidence of a change in subsistence strategy at the site, with a possible widening of resource extraction to include sea mammals and control of domestic livestock production at other farms elsewhere in the locality. A partial explanation for this shift in strategy is continuing landscape instability in the vicinity of this settlement.

Acknowledgments

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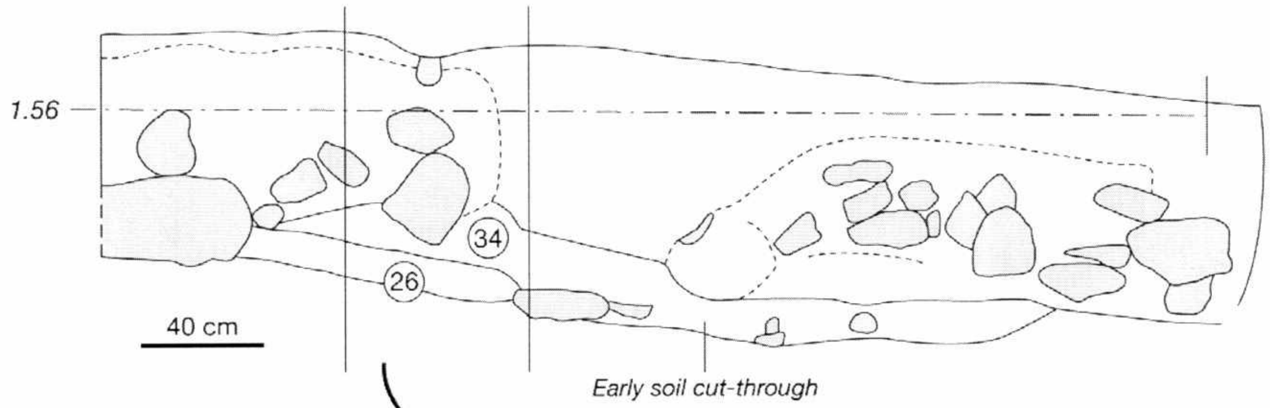
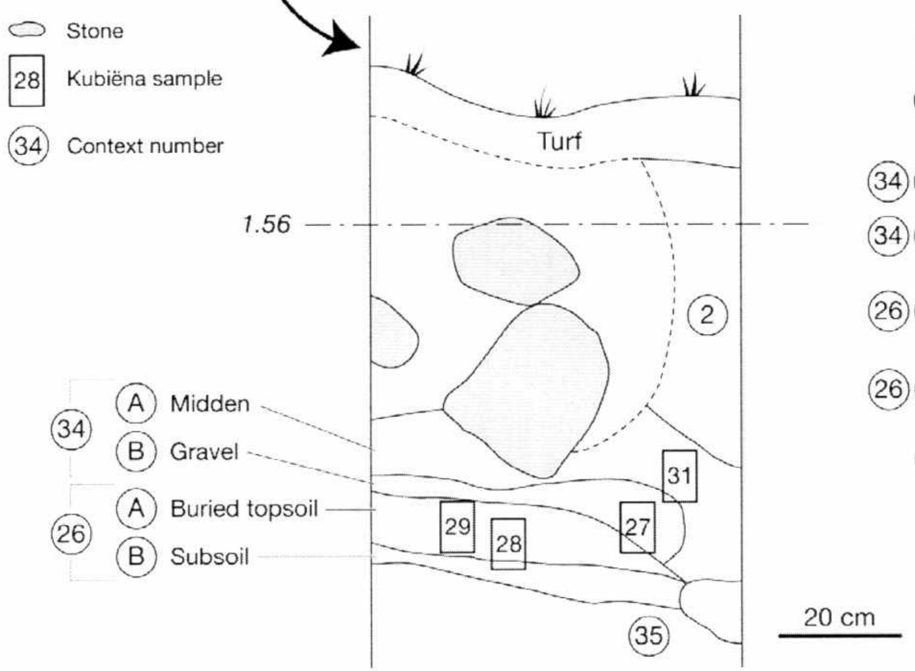
NKA 2629
Trench 1

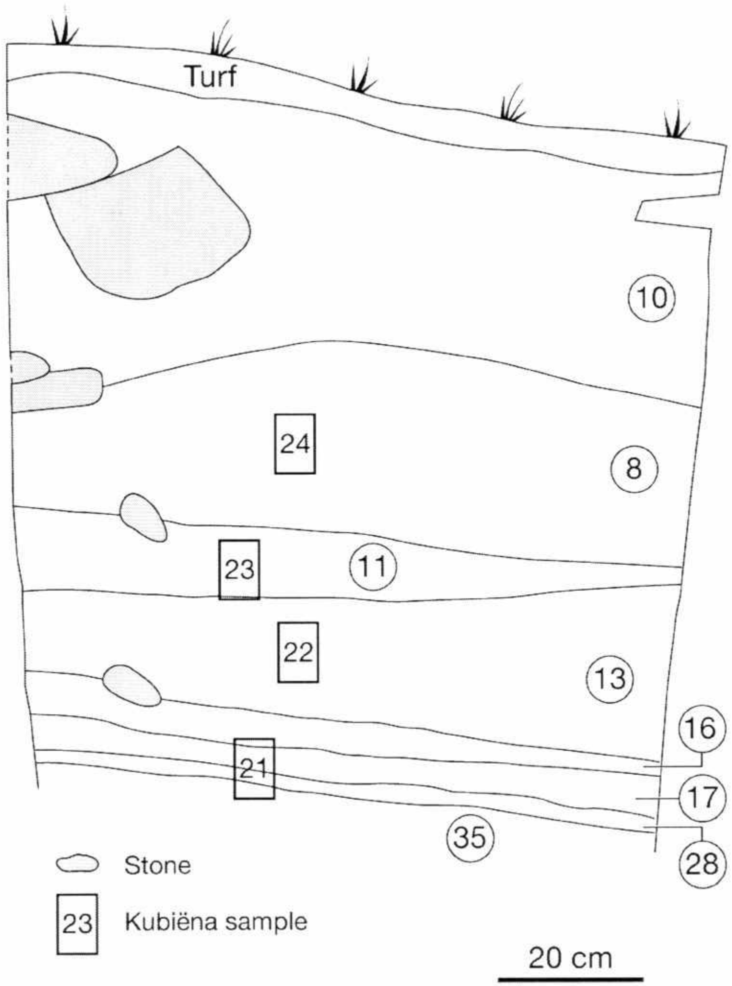




Field description

(2)	Re deposited material 10YR 2/2 very dark brown; sandy silt loam
(34)(A)	7.5YR 2.5/1 black; fine sandy silt loam
(34)(B)	60% gravel 1-2cm sub-angular maximum 5cm; 40% 10YR 3/2 very dark greyish brown; fine sandy silt loam
(26)(A)	10YR 2/1 black; peaty loam micro laminated with evidence of linear sand lenses
(26)(B)	10YR 5/2 greyish brown; sandy loam
(35)	60% gravel 1-2cm sub-angular maximum 5cm; 40% 10YR 3/2 very dark greyish brown; fine sandy silt loam

NKA 2629
Trench 4 South facing section



Field description

Turf 10YR 4/1 dark grey; organic fine sandy silt loam

10 10YR 3/1 very dark grey; fine sandy silt loam; charcoal and bone fragments

8 Micro laminated layer; 10YR 2/1 black; fine sandy silt loam with occasional sand lenses 3-5cm

11 Micro laminated layer; 5YR 3/3 dark reddish brown-dominantly at base of context; 10YR 4/1 dark grey; 10YR 3/2 dark greyish brown; 5YR 3/2 dark reddish brown; fine sandy silt loam

13 Micro laminated layer; 10YR 2/1-2/2 black-very dark brown; 10YR 3/2 very dark greyish brown; fine sandy silt loam; bone, charcoal and uncarbonised wood fragments

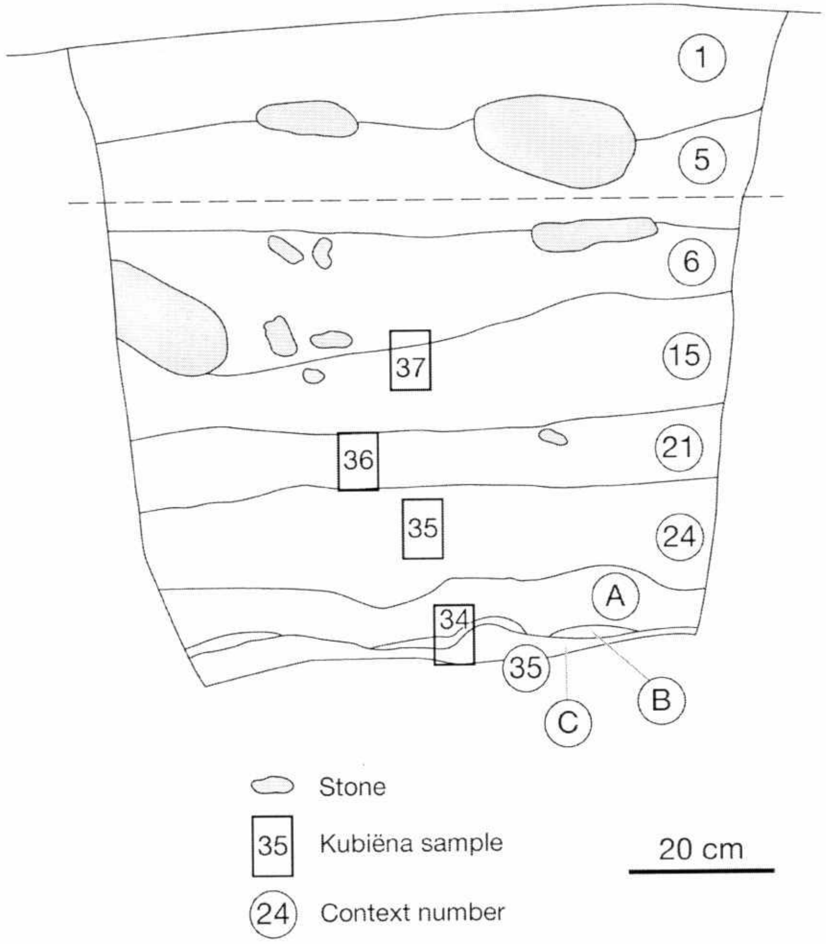
16 Discontinuous layer; 10YR 5/2 greyish brown; 40% gravel 2-3cm sub-angular and angular; gritty sandy silt loam; bone and uncarbonised wood fragments

17 10YR 2/1- black, organic fine sandy silt loam; bone and uncarbonised wood fragments

28 10YR 4/2- dark greyish brown; fine sandy silt loam; thin 10YR 2/1 black band 1-2mm towards base

35 Moderately well sorted gravel 2-3cm maximum 5cm angular and sub-angular

NKA 2629
Trench 6 North facing section



Field description

1	Turf
5	10YR 3/2 greyish brown sandy silt loam; occasional charcoal
6	7.5 YR 3/1 very dark grey gritty sandy loam; occasional stone and bone fragments frequent wood fragments
15	10YR 2/1 black heterogeneous sandy silt loam; occasional charcoal and wood fragments sandy; 2.5YR 5/3 light olive brown
21	7.5YR 3/1 very dark grey gritty sandy loam; occasional charcoal flecks
24	5YR 3/2 dark reddish brown fine 7.5YR 4/3 brown peaty loam; occasional wood fragments
35 A	7.5YR 2.5/1 black peaty loam
35 B	10YR 3/2 very dark greyish brown coarse sandy loam
35 C	Gravel; 60% subangular and subrounded 2-3cm Matrix 40% 10YR 4/2 dark greyish brown gritty sandy loam

Qassiarsuk Trench 1 (Anthropic sediments)

CONTEXT	SAMPLE	COARSE MINERAL MATERIAL >50µm										FINE MINERAL MATERIAL	COARSE ORGANIC MATERIAL				FINE ORGANIC MATERIAL				PEDOFEATURES								MICROSTRUCTURE	COARSE MATERIAL ARRANGEMENT	GROUNDMASS b FABRIC	RELATED DISTRIBUTION
		Quartz	Feldspar	Biotite	Compound quartz grains	Gneiss	Sandstone	Phytoliths	Diatoms	Bone	Rubified mineral		Fungal spores	Lignified tissue	Parenchymatic tissue	Charcoal	Cell residue	Amorphous (black)	Amorphous (red/brown)	Amorphous (yellow/orange)	Clay coatings	Silt infills	Silt coatings	Amorphous crypto - crystaline (reddish brown)	Depletion	Excremental (mamillate)	Excremental (spheroidal)	Calcium spherulites				
34A	31a	•••	•			•		•		•	•	Organo-mineral dark brown •••			•	•		••	•					•					Intergrain microaggregate	Random poorly sorted	Stipple speckled	Porphyric
	31b														••		•		•••					•					Spongy			
	31c	•••	•	•		•		•	•	•	•	Organo-mineral brown •••	•		••	•		•	••					•					Granular spongy	Random poorly sorted	Stipple speckled	Porphyric
	31d	••••	•									Organo-mineral brown •																	Single grain	Random moderately sorted	Stipple speckled	Enaulic
34A	27	•••	•	•		•		•		•	•	Organo-mineral brown •			•	••		••	•										Intergrain microaggregate	Random poorly sorted	Stipple speckled	Porphyric
34B	27	••	•	•		••	••				••	Mineral grey •	•			•		•											Intergrain microaggregate	Random moderately sorted	Stipple speckled	Enaulic

Frequency class refers to the appropriate area of section (Bullock *et al., 1985*) *t* Trace • Very few •• few ••• Frequent/common •••• Dominant/very dominant.
Frequency class for textural pedofeatures (Bullock *et al., 1985*) *t* Trace * Rare ** occasional *** Many

Qassiarsuk Trench 1 (Fossil soils)

		COARSE MINERAL MATERIAL >50µm											COARSE ORGANIC MATERIAL				FINE ORGANIC MATERIAL				PEDOFEATURES											
CONTEXT	SAMPLE	Quartz	Feldspar	Biotite	Compound quartz grains	Gneiss	Sandstone	Phytoliths	Diatoms	Bone	Rubified mineral	FINE MINERAL MATERIAL	Fungal spores	Lignified tissue	Parenchymatic tissue	Charcoal	Cell residue	Amorphous (black)	Amorphous (red/brown)	Amorphous (yellow/orange)	Clay coatings	Silt infills	Silt coatings	Amorphous crypto - crystaline (reddish brown)	Depletion	Excremental (mamillate)	Excremental (spheroidal)	Calcium spherulites	MICROSTRUCTURE	COARSE MATERIAL ARRANGEMENT	GROUNDMASS b FABRIC	RELATED DISTRIBUTION
26A	27i																•		••••										Spongy			
	27ii	••										Organo-mineral dark brown •••			••		•		••										Spongy	Random moderately sorted	Stipple speckled	Porphyric
	27iii	••	•				•					Organo-mineral light brown •••	•		•		•	•	•										Intergrain microaggregate	Random moderately sorted	Stipple speckled	Porphyric
	27iv	••••	•									Organo-mineral brown •						•	•										Intergrain microaggregate	Linear moderately sorted	Stipple speckled	Enaulic
26A	29i																•		••••										Spongy			
	29ii	••										Organo-mineral brown •••			••		•		••										Spongy	Random moderately sorted	Stipple speckled	Porphyric
	29iii	••	•				•					Organo-mineral light brown •••	•		•		•	•	•										Spongy channel & chamber	Random moderately sorted	Stipple speckled	Porphyric
	29iv	••••	•									Organo-mineral brown •						•	•										Intergrain microaggregate	Linear moderately sorted	Stipple speckled	Enaulic
															••		•		•••										Spongy			
26A	28i																•		••••										Spongy			
	28ii	••										Organo-mineral brown •••			••		•		••										Spongy	Random moderately sorted	Stipple speckled	Porphyric
	28iii	••	•				•					Organo-mineral light brown •••	•		•		•	•	••										Crack channel & chamber	Random moderately sorted	Stipple speckled	Porphyric
	28iv	••••	•									Organo-mineral brown •						•	•										Intergrain microaggregate	Linear moderately sorted	Stipple speckled	Enaulic
															••		•		•••										Spongy			
26B	28	••••	•	•								Mineral grey •																	Compact	Random poorly sorted	Stipple speckled	Enaulic

Frequency class refers to the appropriate area of section (Bullock *et al.*, *1985*) *t* Trace • Very few •• few ••• Frequent common •••• Dominant very dominant.
Frequency class for textural pedofeatures (Bullock *et al.*, *1985*) *t* Trace * Rare ** occasional *** Many

Qassiarsuk Trench 4

CONTEXT	SAMPLE	COARSE MINERAL MATERIAL >50µm: Quartz	Feldspar	Biotite	Compound quartz grains	Gneiss	Sandstone	Phytoliths	Diatoms	Bone	Rubified mineral	FINE MINERAL MATERIAL	COARSE ORGANIC MATERIAL: Fungal Hyphae	Fungal spores	Lignified tissue	Parenchymatic tissue	Charcoal	FINE ORGANIC MATERIAL: Cell residue	Amorphous (black)	Amorphous (red/brown)	Amorphous (yellow/orange)	PEDOFEATURES: Clay coatings	Silt infills	Silt coatings	Amorphous crypto-crystalline (reddish brown)	Depletion	Excremental (mamillate)	Excremental (spheroidal)	Calcium spherulite	Vivianite	MICROSTRUCTURE	COARSE MATERIAL ARRANGEMENT	GROUNDMASS b FABRIC	RELATED DISTRIBUTION
8	24a										•	Orange/red (OSL) brown (PPL) organic •		•						••											Spongy			
	24b	••••	•									Grey mineral •																				Random moderately sorted	Stipple speckled	Enaulic
	24c	•••	•	•				•	•	•	•	Brown organo mineral ••	•	•		•	•	•		•					•						Intergrain microaggregate	Linear moderately sorted	Stipple speckled	Porphyric
	24d	•••	•	•		•	•																								Single grain	Linear well sorted		
11	23a	•••	•	•				•		•		Brown organo mineral ••		•			•		•	•											Intergrain microaggregate	Random poorly sorted	Stipple speckled	Porphyric
	23b	••••	•	•								Grey mineral •		•					•												Intergrain microaggregate	Random moderately sorted	Stipple speckled	Enaulic
	23c	••										Yellow brown •••							•						•						Vughy	Random poorly sorted	Stipple speckled	Porphyric
13	22	••	•	•			•			•		Brown organo mineral •••	•				•		•	••					•			•		•	Spongy	Random poorly sorted	Stipple speckled	Porphyric
16	21									•	•						••		•	•••											Spongy			
	i	••										Organo-mineral brown •••			••			•		••											Spongy	Random moderately sorted	Stipple speckled	Porphyric
	ii						••			•		Organo-mineral light brown •••																						
	iv	••••	•								•	Organo-mineral brown •							•	•											Intergrain microaggregate	Linear moderately sorted	Stipple speckled	Enaulic
28	21	••••	•	•		•	•					Grey mineral •																			Intergrain microaggregate	Random moderately sorted	Stipple speckled	Enaulic
35	21	••••	•	•								Brown organo mineral •																			Compact	Random moderately sorted	Stipple speckled	Enaulic

Frequency class refers to the appropriate area of section (Bullock *et al.*, *1985*) *t* Trace • Very few •• few ••• Frequent/common •••• Dominant/very dominant

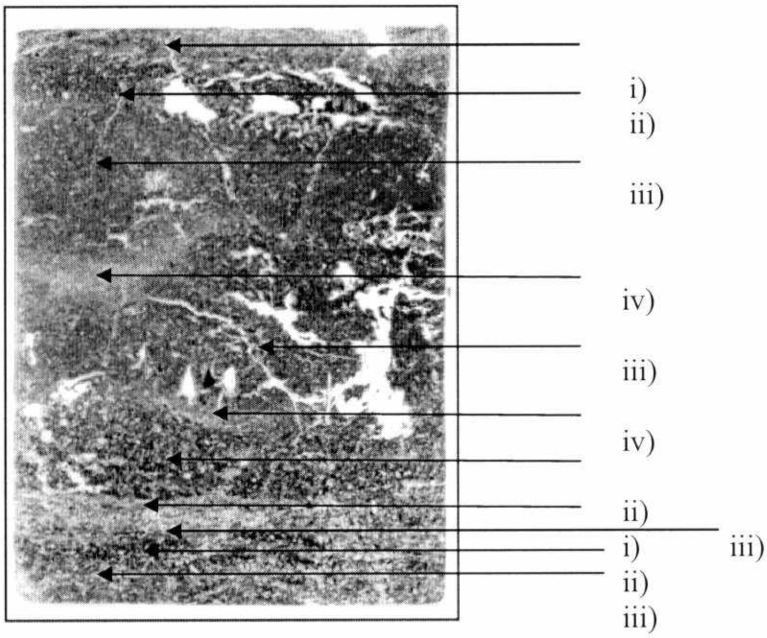
Frequency class for textural pedofeatures (Bullock *et al.*, *1985*) *t* Trace • Rare •• occasional ••• Many

Qassiarsuk Trench 6

CONTEXT	SAMPLE	COARSE MINERAL MATERIAL >50µm: Quartz	Feldspar	Biotite	Compound quartz grains	Gneiss	Sandstone	Phytoliths	Diatoms	Bone	Rubified mineral	FINE MINERAL MATERIAL	COARSE ORGANIC MATERIAL: Fungal spores	Lignified tissue	Parenchymatic tissue	Charcoal	FINE ORGANIC MATERIAL: Cell residue	Amorphous (black)	Amorphous (red/brown)	Amorphous (yellow/orange)	PEDOFEATURES: Clay coatings	Silt infills	Silt coatings	Amorphous crypto - crystalline (reddish brown)	Depletion	Excremental (mamillate)	Excremental (spheroidal)	Calcium spherulite	MICROSTRUCTURE	COARSE MATERIAL ARRANGEMENT	GROUNDMASS b FABRIC	RELATED DISTRIBUTION
6	37	••••	•		•	•		•	•	••	•	Organo-mineral Brown ••			•	••		•	•										Intergrain microaggregate	Random poorly sorted	Stipple speckled	Enaulic
15	37	•••	•			•		•	•	••	••	Organo-mineral dark brown •••			•	••		••	•										Intergrain microaggregate	Random poorly sorted	Stipple speckled	Porphyric
21	36	•••	•					•	•	•	•	Organo-mineral brown •••	•		••	•		•	••									*t*	Spongy	Random poorly sorted	Stipple speckled	Porphyric
24	35	••	•					•	•	•	•	Organo-mineral reddish brown •••	•		••	•		•	••					•				*t*	Spongy	Random poorly sorted	Stipple speckled	Porphyric
35A	34	••	•									Organic and Organo-mineral dark brown •••	•		•	••		•	•••										Spongy Intergrain microaggregate	Random and linear moderately sorted	Stipple speckled	Porphyric
35B	34	•••	•	•								Mineral grey ••																	Compact	Random poorly sorted	Stipple speckled	Enaulic
35C	34	•••	•	•								Mineral brown •												•					Compact	Random poorly sorted	Stipple speckled	Enaulic

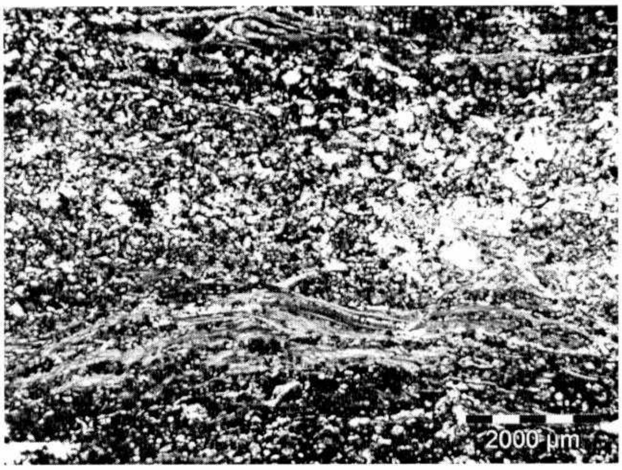
Frequency class refers to the appropriate area of section (Bullock *et al.*, *1985*) *t* Trace • Very few •• few ••• Frequent/common •••• Dominant/very dominant.
Frequency class for textural pedofeatures (Bullock *et al.*, *1985*) *t* Trace * Rare ** occasional *** Many

Figure 4 a-c: Qassiarsuk, Trench 1, Context 26A, Thin Section Sample 29. Fossil soil upper horizon.

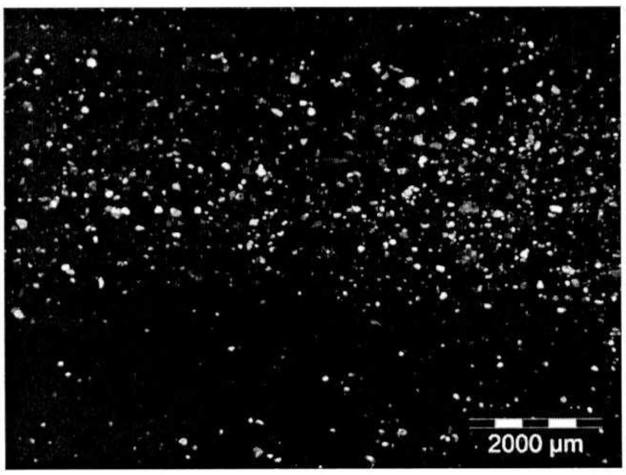


a) Sample 29, Context 26A Micro-horizon sequences in fossil soil upper horizon.

2 cm

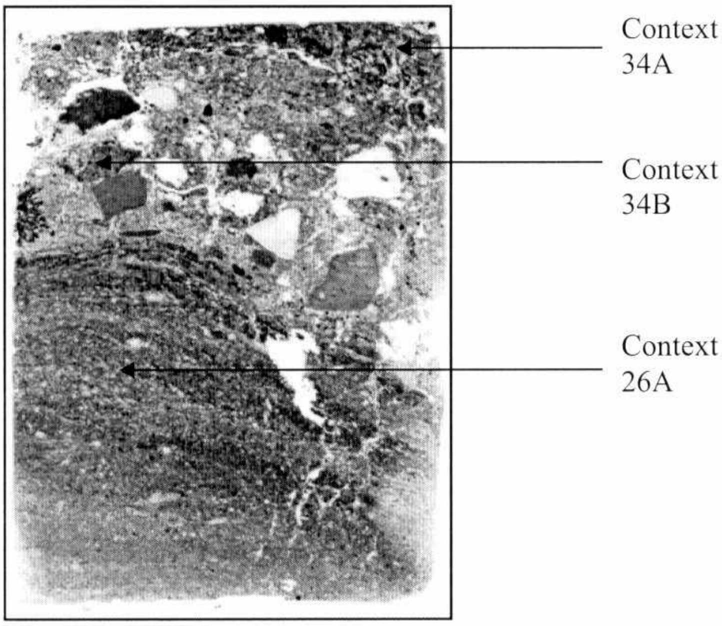


b) Sample 29, showing sequences of micro-horizons i), ii) and iv). Plane polarised light.



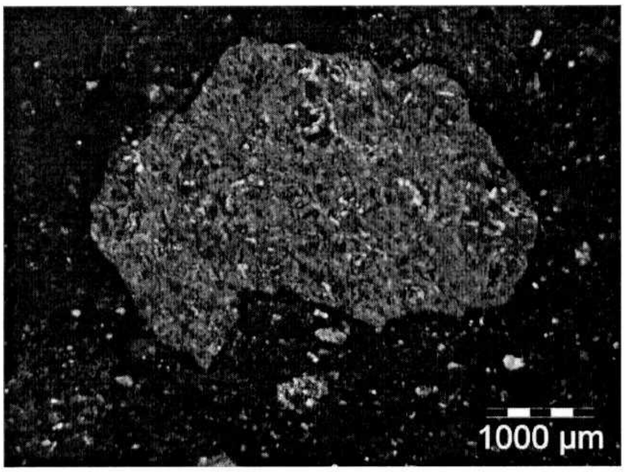
c) Sample 29, the same field of view as b) above, highlighting the mineral component of micro-horizon iv). Cross polars.

Figure 5 a-c: Qassiarsuk, Trench 1, Contexts 34A, 34B and 26A, Thin Section Sample 27.

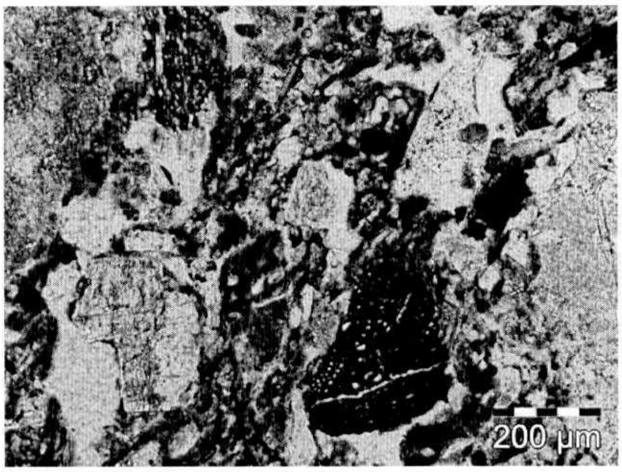


a) Sample 27, Showing overlying anthropic deposit (context 34A, sand and gravel accumulation (context 34B) and fossil soil with micro-horizon sequences (context 26A).

2 cm

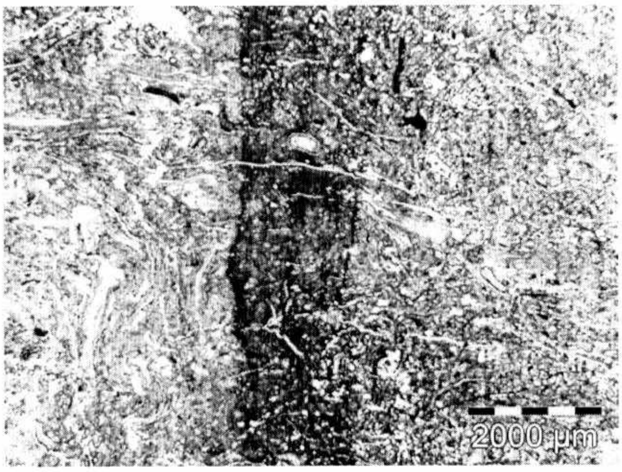


b) Rubified mineral grain, context 34B. Oblique incident light.



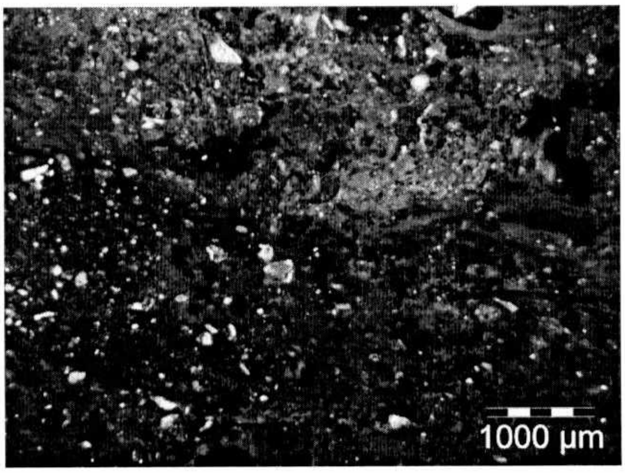
c) Charcoal fragments, context 34B. Plane polarised light.

Figure 6 a-c: Micromorphological features from anthropic sediments, Qassiarsuk.



a) Iron pan in turf debris, the vertical nature indicating anthropic deposition. Context 24, sample 35, Trench 6. Plane polarised light.

b) Vivianite (blue colouring) in thin sections from Context 13, sample 22, Trench 4. Indicative of bone decomposition and recrystalisation in reducing (wet) conditions. Plane polarised light.



c) Rubified organic turf material, contrasting with the darker sediment matrix. Context 8, sample 24, Trench 4. Indicative of combustion. Oblique incident light.