Origin of the sandy terraces at Grundset, Elverum, South-Eastern Norway

Evidence from archaeological soil micromorphology

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Sandy terraces developed in poor eolian sands have been discovered in the Glomma river valley, Hedmark, south-eastern Norway, during the last two decades. These are of a specific morphological type which has not been found elsewhere in Norway. Some of them have been excavated and dated, stimulating an intense debate among Norwegian archaeologists as to whether they are of natural or anthropogenic origin, and whether or not they were used for agriculture. One of these sandy terraces was investigated using conventional radiocarbon dating, morphological descriptions, pollen analysis and soil micromorphology in connection with archaeological excavations. The pollen results were rather poor, but the micromorphology analysis, combined with radiocarbon dating, was able to reveal that the terrace had developed under strong anthropogenic impact since c. AD 400–560 (1595±80 BP). The sandy soils had probably been improved and used for cultivation, interrupted by lengthy fallow periods or abandonment. Soil improvement seems to have been intensified from c. AD 1025–1220 (925±75 BP) onwards, possibly for cultivating crops with growth requirements that matched these soil properties.

Keywords: cultivation, terraces, micromorphology, Iron Age, forest, Norway

Introduction

A specific type of sandy terrace was first discovered in Norway in 1994, at Rødsmoen in Åmot, just north of Elverum (Bergstøl 1997:81). These terraces have only been found in the Glomma valley within the Hedmark forest in the interior of eastern Norway (Fig. 1). As they are only found on poor sandy soils, a discussion arose among archaeologists as to whether they were man-made or natural features. Further investigations by Østeraas (1995), Sørensen (1996), and Holm Sørensen (1997) have added weight to the suggestion that they may have been formed in connection with cultivation and possibly soil improvement.

In connection with the extension of a gravel pit, Hedmark County Council implemented an archaeological survey of Grundsetmarka in Elverum in 2003 (Holseng 2003), with excavations carried out by the Museum of Cultural History (KHM), University of Oslo, in April and June 2005 (Holm & Berg-Hansen 2007). The main purpose of this excavation was to find answers to the following questions: Are the terraces of natural or anthropogenic origin? How were they built up? Were they used for agriculture, and if so, what kind of cultivation and which form(s) of management were used? To gain insights into these matters, the archaeological investigations included conventional radiocarbon dating, pollen analyses and micromorphological analysis, and focused on one of the terraces, chosen because of the complex stratigraphy revealed by the archaeological investigation.

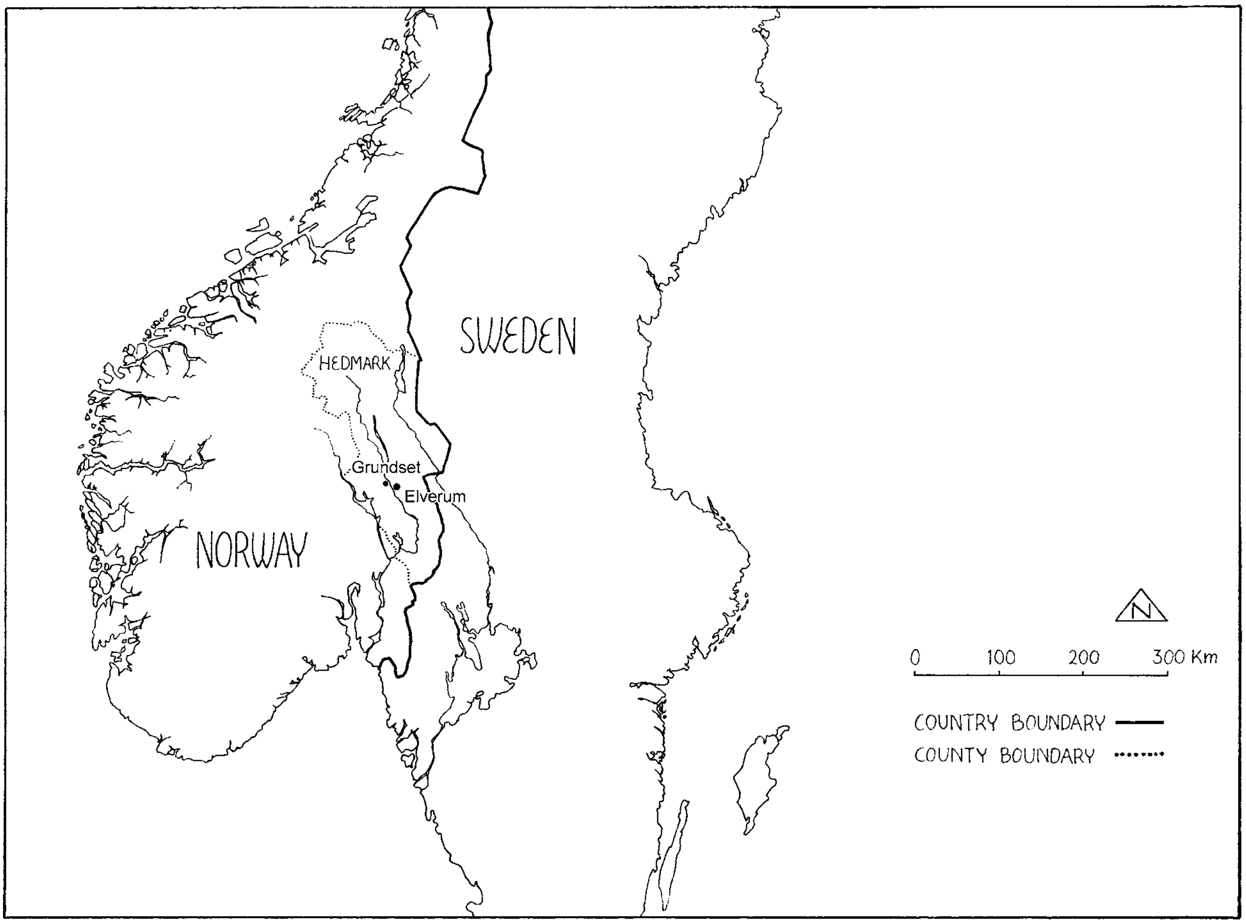

Figure 1. The investigated area, Grundset in Elverum, Hedmark, south-eastern Norway.

The Grundsetmarka area

Grundsetmarka is located just west of the Glomma River in the municipality of Elverum, a district in central Hedmark County (Fig. 1). Elverum is situated above the post-glacial shorelines, and therefore most of the Quaternary deposits in the area consist of till. There are accumulations of fluvial sand along the Glomma River, and also occurrences of eolian sand deposited during a halt in the ice front just north of Elverum. Strong catabatic winds from the glacier separated the upper layer of the barren till outside the ice front, and this resulted in the formation of eolian sand dunes on top of the till (Bargel 1982; Leif Sørbel pers. comm.).

Grundsetmarka is a forested area close to the fields of the Grundset farm, and is located c. 250 m above the present-day fields of the farm. Prior to the excavation, the vegetation cover of the site consisted of pine forest with an understorey of bilberry (*Vaccinium myrtillus* L.) and various species of heather.

The Grundset farm is mentioned in written sources from the Middle Ages, and its name is indicative of an Iron Age origin (www.dokpro.uio.no/perl/middelalder/diplom_vise_tekst.prl?b=17024&s=n&str=; Harsson 2002). There are no known grave mounds close to the farm, but the forest of Grundset, named Grundsetmarka, hosts a very rich variety of prehistoric and Middle Age cultural heritage objects.

Archaeological investigations

The archaeological survey revealed 21 cultural heritage objects, including a pit for catching wolves, a tar kiln (Norwegian: tjæregrøft) and charcoal pits. The most common feature of the area, however, was a type of terrace, presumably used for cultivation. During the excavation, eight terraces, five charcoal pits, the tar kiln and the wolf pit were excavated. Trenches and test pits were dug and samples were collected for conventional radiocarbon dating, pollen analyses and micromorphology.

The charcoal pits are shallow, 2–4 m in diameter and 0.5–0.7 m deep, and were dated to AD 900–1300, which corresponds well with other datings of charcoal pits in Hedmark, though there are few dates prior to AD 1000 (Rundberget 2007). Such pits that were used for burning wood to make charcoal are common in Hed-

Table 1. Field soil description of profile 7.

Horizon	Depth (ca.)	Description
O (A)	0–3 cm	Very dominant organic materials: litter, many roots, loose consistency, high porosity, abrupt boundary.
E	3–5 cm	Fine sand, single grain structure, no stones, slightly hard (dry) consistency, common fine roots, many charcoal fragments, low porosity, Munsell colour (dry): 5 Y 6/1, wavy boundary.
B (1)	4–20 cm	Dominant fine sand, few fine gravel, weak single grain structure, no stones, soft consistency, few fine roots, frequent charcoal fragments, low porosity, Munsell colour (dry): 10 YR 5/6 and 10 YR 7/6, abrupt boundary.
E (B)	20–30 cm	Dominant fine sand, no stones, soft and very slightly hard (dry) consistency, very few fine roots, very common charcoal fragments, low porosity, Munsell colour (dry): 5 Y 6/1 (10 YR 6/ 2,3), abrupt to wavy boundary.
B (2)	30–45 cm	Dominant fine sand and fine gravel, soft and slightly sticky (dry) consistency, frequent charcoal fragments, very low porosity, Munsell colour (dry): 10 YR 5/6, gradual (locally diffuse or abrupt) boundary.
E (B)	45–60 cm	Dominant fine sand, slightly hard consistency, few to common charcoal fragments, very low porosity, Munsell colour (dry): 10 YR 7/1 and 5 YR 5/8, gradual wavy boundary.
BC	60–75 cm	Dominant medium gravel, rounded to angular stones, hard and slightly sticky consistency, low porosity, Munsell colour: 7,5 YR 5/6, diffuse boundary.
C	75–85	Dominant fine to medium gravel, rounded to subrounded and angular stones, hard consistency, very low porosity, Munsell colour: 7,5 YR 3/4, diffuse boundary.

mark and were mainly in use during the late Viking period and the Middle Ages. Charcoal was used both for bloomery iron production and in forges (Rundberget 2007).

The tar kiln found in Grundsetmarka is in the form of a shallow ditch, 10 m long and 0.3 m deep. Tar kilns are found in the forests of Hedmark, but are not as common as charcoal pits. They generally date back to anywhere between prehistoric times and the 20th century (Rolfsen 2002). The tar kiln in question was dated to AD 750–1000, which is relatively early (Rolfsen 2002). There is a risk when dating tar kilns of sampling wood that is too old, e.g. old pine roots which were used in the kilns because of their tar content. As the two samples were dated to the same period, however, it is likely that the tar kiln was in use in the Viking period.

The wolf pit was covered with vegetation, and a piece of meat was placed on top to attract the wolf, which then fell into the pit. Such pits are usually quite large and probably once had a wooden construction inside. No dateable material was found during excavation of the wolf pit.

Methods

Excavations and soil descriptions

Three of the terraces were investigated by opening test pits and five terraces by cutting trenches. The profiles of the open trenches were described thoroughly according to the guidelines for soil description (FAO, ISRIC 1990; Greve et al. 1999) in order to classify the soils and differentiate between layers of cultural origin and those dominated by natural features (Table 1).

Soil micromorphology

Soil micromorphology is the description and interpretation of components, distinctive features and structures of undisturbed samples of soils and related materials based on thin sections made from impregnated soil blocks and viewed under a petrographic microscope (Bullock et al. 1985; Stoops 2003; Goldberg & Macphail 2006). Other detailed descriptions of the method are presented by Courty et al. (1989), Macphail et al. (1990), Sageidet (2000), Simpson & Adderley (2003).

Samples for micromorphology were collected at Grundset in July 2005. Three samples were taken from the cleaned profile 7 of one of the terraces (R7) by help of Kubiena boxes (Fig. 2 and 3). Two of them (Mi-1 and Mi-2) were located one above the other at depths of 20–33 cm and 40–48 cm, respectively (Fig. 2), about 15 cm away from pollen sample series 7B (Høeg 2007), and the third (Mi-3) was from a depth of 25–39 cm at a point about 3 m away from Mi-1 and Mi-2 (Fig. 3). A summary of the contents of the micromorphology samples is presented in Table 2. The thin sections were prepared at the Laboratory for Micromorphology at the University of Ghent, Belgium, based on the procedures described by Murphy (1986).

Figure 2. Profile 7, Kubiena boxes are pressed into the profile to collect the samples Mi-1 (above) and Mi-2 (below).

Figure 3. A Kubiena box is pressed into the profile to collect the sample Mi-3, about 3 m apart from profile 7.

After impregnation with a polyester resin, the samples were cut into microscopically thin layers and mounted on a glass plate. The standard thickness of a thin section is about 20–30 μm and the standard size about 8 x 5 cm. A Nikon petrographic microscope was used with plain polarized light (PPL), between crossed polarizers (XPL), and with oblique incident light (OIL). A microscope with ultraviolet light (UV) at the McBurney Geoarchaeology Laboratory at the University of Cambridge was used to observe possible UV fluorescence from organic materials.

The descriptions of Mi-1 (Table 3), Mi-2 (Table 4) and Mi-3 (Table 5) are presented according to the international guidelines (Bullock et al. 1985, Stoops 2003). The abbreviation "c/f" is used for the relation between coarse and fine materials, with a limit at 10 μm, and "TVS" for the total void space as a percentage of the surface area of the thin section. Each area on a thin section that had a characteristic soil microfabric type (SMT) was described separately. The depths of the areas described are approximate, and if the boundary of an area was not horizontal, its alternative depth is indicated in parentheses. The Latin, English and Norwegian names of the plants mentioned in the text or tables are listed in Table 7.

Radiocarbon dates

A charcoal sample of pine *(Pinus sylvestris)* from about 40 cm below the surface close to micromorphology sample Mi-3 (sample 7.6), was dated to AD 400–560 (1595±80 BP), and another charcoal sample of pine from about 26 cm below the surface close to Mi-2 and Mi-1 (sample 7.4) was dated to AD 1025–1220 (925±75 BP). All the relevant dates obtained from the archaeological investigations are listed in Table 6.

Pollen analysis

Vertical pollen series were sampled at five points in the area investigated, two of them (R7 A and R7 B) being close to the micromorphology samples (Fig. 2). The 64

Table 2. Overview of the three thin sections and their locations.

Sample number	Context	Sample depth	Description
Mi-1	R 7, Profile 7 B	20–33 cm	Table 3
Mi-2	R 7, Profile 7 B	40–48 cm	Table 4
Mi-3	R 7, Profile 7, 3 m apart from B	25–39 cm	Table 5

samples of about 1 cm^3 were taken with small plastic tubes and treated in accordance with Fægri and Iversen (1989). Samples rich in sand were treated with hydrofluoric acid (HF). Pollen was analysed with a microscope magnification of x400–1000 by H. Høeg (Høeg 2007).

Results and discussion

Characterisation of the terraces and soil classification

The terraces at Grundsetmarka were scattered over the surveyed area and were difficult to identify at first glance, so that the terrain had to be surveyed thoroughly in order to recognise them. They were also rather small, from 10 to 20 m long, up to roughly 10 m wide and from 10 to 30 cm higher than the rest of the terrain at the front. They were slightly curved or in some cases lobular in shape, and their surfaces were even, with a slight inclination towards the front of the terrace. The front was quite steep, making this part of the terrace the easiest to recognise in the surveys.

The soil profiles were classified as podsolic (Holm & Berg-Hansen 2007:15f). A description of profile 7 is presented in Table 1. At the top (O (A)) was a thin turf layer with roots and decaying heather vegetation, while below the thin, light grey leached E horizon, there was an orange B horizon characterised by a small addition of scarcely visible charcoal particles, indicating that this layer had been cultivated. Beneath this was a black layer containing significant amounts of charcoal and some humus. It was this that was interpreted as the original surface layer, as it marked the beginning of a second set of layers characteristic of a podsol.

In the front of the terraces were a number of grey and orange layers, together with black layers having a high charcoal content. These were interpreted as the remains of a turf wall put there to keep the sand in place. The sand inside the turf wall was probably moved there with a spade to construct the terrace and make it suitable for cultivation.

Dating of the terraces

The dating of objects connected with agriculture is quite problematic, as they have often been used for a considerable length of time and are seldom the result of one event. The charcoal layers at Grundsetmarka are best preserved in the front parts of the terraces, because this part was intentionally built up, as shown above, whereas the interior parts of the terraces were probably filled in with a spade, which will have physically eroded the charcoal particles. The charcoal samples from the terraces of Grundsetmarka were taken from distinct charcoal layers that had probably resulted from forest fires, i.e. they were likely to have resulted from single events. The wood analyses showed that the charcoal was of pine with small amounts of birch. A pine forest may burn either in a natural forest fire, e.g. one caused by lightning, or as a result of fire clearing for cultivation purposes.

A charcoal layer under terrace no. 10 was dated to the late Bronze Age, 805–540 BC (Table 6) and represents a single *terminus post quem* date for the cultivation of this terrace (i.e. the earliest time at which the event could have taken place). It is impossible to ascertain whether the charcoal layer from which the sample was taken had resulted from a natural forest fire or from clearance for cultivation. It was covered with cultivated soil, but it was not possible to specify the time that might have elapsed between the depositions of the two layers. If the fire had been intended for clearing the forest for farming, the time interval was probably relatively short. On the other hand, this particular charcoal layer could have been considerably older than the terrace, as it was covered with leached soil and a subsequent charcoal layer in some parts of the profile.

This oldest phase of possible cultivation on the terraces may be related to the indications of cultivation shown in a pollen diagram from a bog located c. 2.5 km up the hill from the terraces. These include possible *Cerealia* pollen, an increase in *Cyperaceae* and a reduction in *Pinus* and *Alnus*, all dated to before 440–365 BC (Overland & Hjelle 2007). A field with as many as 315 clearance cairns within an area of 5 hectares has been found close to this bog, and seven of these cairns have been ^{14}C-dated, but none gave a date before the birth of Christ. Since only a small sample of the cairns have been excavated, however, it is still possible that the dates may not cover the whole period for which the field was in use. In another cairn field at Grundsetmarka a stone with cup marks has been found. Cup marks may similarly date back to the Bronze Age,

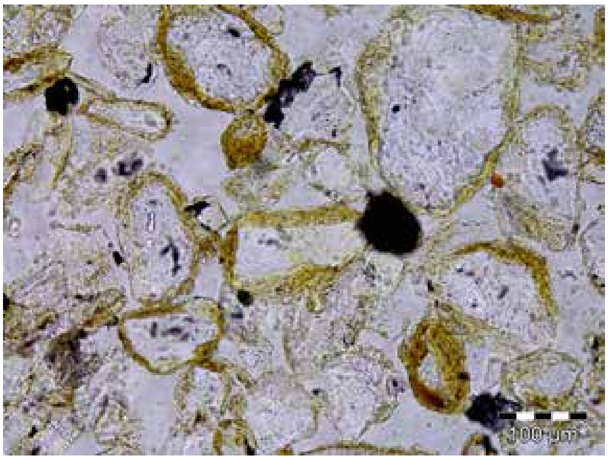

Figure 4. Mi-1, silty coatings around mineral grains, microscope magnification: x100, PPL, depth c. 27 cm

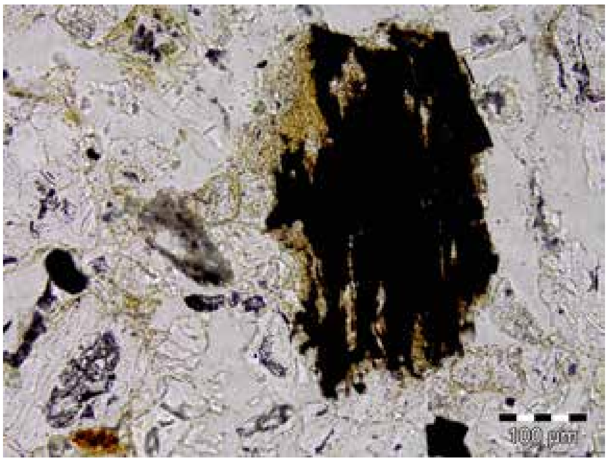

Figure 5. Mi-2, charcoal fragment (450 µm) with silt infillings and presumably phosphate impregnations, microscope magnification: x100, PPL, depth c. 43 cm.

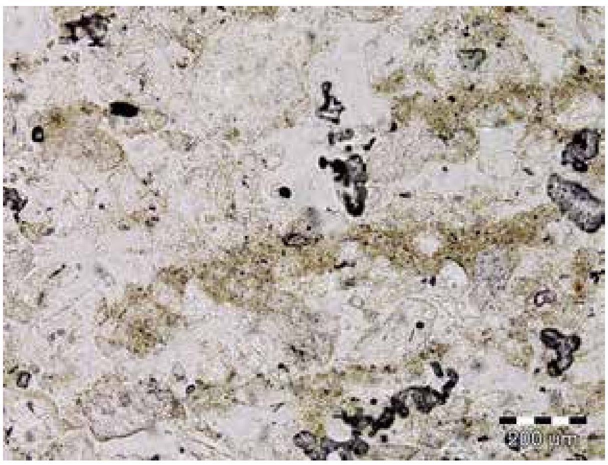

Figure 6. Mi-2, crusts or compaction zones, microscope magnification: x100, PPL, depth c. 46 cm.

but they can also be considerably younger (Innselset 1996). Another find from Grundsetmarka is a stone axe from the late Neolithic to early Bronze Age, and simple stone axes dating from the late Neolithic period or the Bronze Age have been found close to other localities with terraces presumably used for cultivation (Hilde Amundsen pers. comm.). Thus, there are some indications of agricultural activity in the forests of Grundsetmarka in the Bronze Age.

A charcoal layer under terrace no.12 was dated to 195–45 BC (from a sample of pine, cf. Table 6), while another sample from the same charcoal layer was dated to AD 1010–1040 (from birch). This difference of more than 1000 years is inconsistent. One possible explanation is that the first sample may have come from an old pine trunk that burned together with the rest of the forest. In the dry inland climate of Elverum pine trunks may survive as dry wood for a considerable length of time. Another possibility is that the old pine charcoal may be from an earlier fire and had simply been preserved in the more modern layer.

A charcoal layer under terrace no. 9 was dated to AD 215–330, giving a *terminus post quem* date for the terrace itself, and a layer under terrace no. 7 dated to AD 400–560 likewise gives a *terminus post quem* age for that terrace. Another charcoal layer, which was part of a patch of buried turf in terrace no. 7, was dated to AD 1025–1220. This charcoal was certainly the result of a forest fire, but it is uncertain whether the fire was intended to clear the forest for farming. The dated layer is stratigraphically higher in the profile than the older layer and gives a *terminus post quem* age for the youngest cultivation layer in the profile.

The youngest charcoal sample was that taken from terrace no. 5, which was dated to AD 1220–1260. It is not easy to establish a good chronology on the basis of these dates, but they do indicate a period of farming in the early Iron Age and another in the Middle Ages. In the above-mentioned investigation at Rødsmoen, Åmot, the ^{14}C-dates spanned a period from the late Bronze Age to the late Middle Ages (Bergstøl 1997). This corresponds well with the dates for Grundsetmarka, which also start in the late Bronze Age and end in the High Middle Ages, a little earlier than those for Rødsmoen.

Results of the pollen analysis

The pollen content of the samples was low, and mostly only large amounts of charcoal dust were found. Most of the pollen was found in the present-day turf layer, indicating some agricultural activity in the post-me-

Figure 7. Mi-3, plant residues, ca. 1700 µm wide (ca. 1.6 cm long) microscope magnification: x50, PPL, depth c. 28 cm.

Figure 8. Mi-3, leaf section, size 3 mm x 400 µm, microscope magnification: x25, PPL, depth c. 32.5 cm.

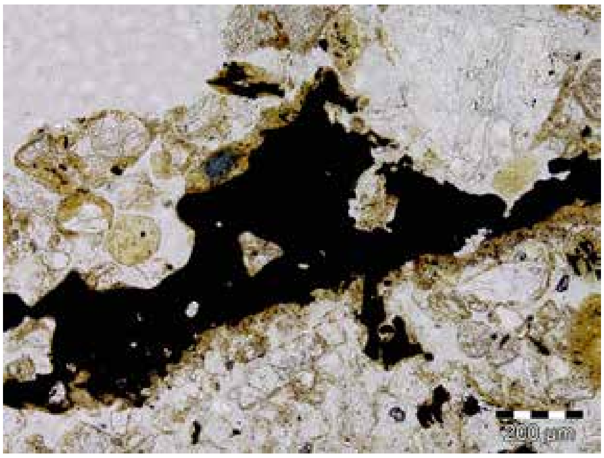

Figure 9. Mi-3, remains of turf moder, microscope magnification: x25, PPL, depth: 27 cm.

dieval period as well (Høeg 2007). The pollen from the present-day turf layer was dominated by pine (*Pinus*) and heather (*Calluna*), with small amounts of grass (*Poaceae*) and herbs and some pollen of cereals (*Cerealia*), rye (*Secale*) and buckwheat (*Fagopyrum*). Buckwheat prefers well-drained, sandy soils and requires little nutrition, which means that it could have thrived well in the poor sandy soils of Grundsetmarka. As the pine forest in the area is approximately 60–100 years old, these traces of cultivation must be older than this, but younger than the underlying layers dated to the Middle Ages. Pollen samples from layers dated to the Middle Ages contained mainly pine (*Pinus*) and heather (*Calluna*), indicating an open pine forest in the area at that time (Høeg 2007).

Soil micromorphology results

Thin section Mi-1 has an area of about 71 cm^2 containing fairly heterogeneous material. Three areas with different dominating soil microfabric types (SMTs) were identified and are described in Table 3. Thin section Mi-2 has an area of about 36 cm^2 with fairly homogeneous material. Two areas with distinct soil microfabric types (SMTs) are described in Table 4. Thin section Mi-3, with an area of about 70 cm^2, again contained fairly homogeneous material. Four areas with distinct soil microfabric types (SMTs) are described in Table 5.

Discussion

The overall interpretation arising from the analysis of the thin sections (Tables 3, 4 and 5) confirms the presence of sandy material rich in charcoal and other organic inclusions, which is in accordance with the field observations. The podsolic character of the profile (Figs. 2 and 3, Table 1, Holm & Berg-Hansen 2007:15f) is well represented by the thin sections Mi-1 and Mi-2 taken from the same point but at different depths. A movement of illuvial clay and very fine charcoal fragments adhering to sand grains down the profile is indicated both in Mi-1 (area 3, Table 3) and in Mi-2 (area 1, Table 4).

The high number of charcoal fragments (Mi-1, Mi-2, and Mi-3), together with the common silt cappings and coatings facing in all directions (Fig. 4), are indications of mechanical or physical disturbances. Many of the fine (sand-size) charcoal fragments appear to be isolated (having no contact with the surrounding material) and to have well-rounded edges, presumably because they were physically added and mixed into the soil. Three leached areas (E horizons, Table 1) could be recognized in the

Table 3. Description of thin section Mi-1 at 20–33 cm below the surface of profile 7.

Micro-stratigraphic unit		Mi-1 –1	Mi-1 –2	Mi-1 –3
Depth [cm]		20–24	20–24.5	24 (24.5) –33
Structure	**Microstructure**	spongy and single grain, locally bridge grain and pellicular grain	single grain	spongy structure with chamber, crack and single grain structure, locally channel structure
	Porosity and total void space (TVS)	dominant interconnected packing voids (20–200 µm, few chambers (500–1000 µm), TVS : 45%	dominant interconnected packing voids (20–200 µm), few vertical chambers (200 x1800 µm), TVS: 25%	dominant interconnected packing voids (20–200 µm), common chambers (up to 8000 µm), TVS: 50%
	Coarse fine (c/f) related distribution	c/f: 80 : 20, single space enaulic and coarse monic	c/f: 95 : 5, coarse monic	c/f: 85 : 15, close porphyric to coarse monic
Mineral material (> 10 µm)		subrounded mineral grains (20–500 µm), dominant quartz	subrounded to angular mineral grains (20–500 µm), dominant quartz	rounded to subrounded mineral grains (10–600 µm) dominant quartz.
Organic material (> 10 µm)	**Plant remains**	Frequent longitudinal (up to 700 µm) and transverse root sections (PPL: orange/ reddish brown, few to frequent tissue residues (PPL: dark brown/orange)	Frequent elongated plant residues (up to 8 mm)	Frequent sections of roots and plant residues up to 1000 µm (PPL: orange, XPL: high interference colours)
	Fungal remains		few fungal hyphae	-
	Pollen grains	1 cf. *Betula /Corylus,* 1 undefined, 1 cf. Ericaceae, 1 cf. *Alnus*	-	(in area with decomposed wood remains:) 1 cf. *Ulmus,* 2 undefined
Charcoal and burned organic material		Common charcoal (up to 2500 µm), partly microdispersed and/or with visible cell structure, transverse twig section	Frequent charcoal (single fragments up to 2 mm), partly micro-dispersed	Frequent fine dispersed charcoal fragments, (single fragments up to 1.3 mm)
Micromass and birefringence (b-) fabric in XPL		Undifferenciated b-fabric	Undifferenciated, locally striated b-fabric	Undifferenciated, locally striated b-fabric
Fine mineral (fine organic) < 10 µm) in PPL		Yellowish brown, amorphous orange/ brown and black (PPL)	amorphous black and yellowish brown (PPL)	amorphous orange, yellow and black (PPL)
Inorganic residues of organic origin		Few phytoliths	Very few phytoliths	Very few phytoliths
Pedofeatures		Few/frequent silt coatings on minerals (10–30 µm), few ellipsoid excrements (PPL: black), light orange groundmass impregnations	Few silt coatings, orange-brown and yellow (PPL) clay impregnations of the groundmass, on minerals and on organic residues	Common silt coatings (up to 80 µm) and nodules on minerals/in the matrix, dusty clay impregnations, slight autofluorescence of the matrix in UV light
Soil microfabric type (SMT)		“heterogeneous, anthropogenic”	”heterogeneous, leached”	“silty coatings”

Table 4. Description of thin section Mi-2 at 40–48 cm below the surface of profile 7.

Mi-2 –2	Mi-2 –1	Micro-stratigraphic unit	
44 (45)–47,5	40–44 (45)	**Depth [cm]**	
Single grain, bridge grain, slightly prismatic	single grain, locally bridge grain or slightly spongy	**Microstructure**	**Structure**
very dominant compound voids, single chamber (2,2 x 1,3 mm), TVS 20%	dominant compound voids, few chambers up to 1000 µm, TVS 30%	**Porosity and total void space (TVS)**	
C/f: 95 : 5, monic	C/f: 90 : 10, monic, locally chitonic	**Coarse fine (c/f) related distribution**	
sub-rounded to subangular mineral grains (up to 600 µm)	rounded to subangular blocky mineral grains (up to 600 µm), few rock fragments (up to 1.5 mm), dominant quartz, few plagioclase	**Mineral material (> 10 µm)**	
Frequent sections of roots and plant tissue with visible cells (up to 2 mm)	amorphous plant residues (50–400 µm), few plant tissues with visible cell structure, frequent cork tissues up to 1mm (PPL: orange, XPL: low birefringence), root sections up to 200 µm (XPL: low birefringence)	**Plant remains**	**Organic material (> 10 µm)**
-	hyphae fragments (40 µm)	**Fungal remains**	
-	-	**Pollen grains**	
Frequent/common silt and (phosphate ?) impregnated charcoal (up to 5 mm)	Frequent microdispersed charcoal, frequent impregnated (silt/phosphate) charcoal (400–600 µm), partly strongly destructed	**Charcoal and burned organic material**	
undifferentiated b-fabric (medium birefringence)	undifferentiated, locally striate b-fabric	**Micromass and birefringence (b-) fabric in XPL**	
Orange brown and greyish brown (PPL)	Yellowish and orange brown (PPL)	**Fine mineral (fine organic) < 10 µm) in PPL**	
Few phytoliths	Very few phytoliths	**Inorganic residues of organic origin**	
Dominantly leached groundmass, frequent dusty clay in pores, fabric pedofeatures: compaction, horizontal layering, micropan	Common silt capping/coatings on minerals (in all directions, up to 60 µm), fabric pedofeature (passages/bioturbation)	**Pedofeatures**	
"silty anthropogenic"	"leached heterogeneous anthropogenic"	**Soil microfabric type (SMT)**	

field. Since an undisturbed profile with only natural development will, if freely drained, not contain more than one E horizon, this profile has obviously not developed naturally but under a strong anthropogenic impact.

To understand the history of the site, it is important to find out when and why the processes of leaching/podsolisation took place. The two lowermost E horizons (Table 1) are represented in the thin sections (Mi-1, description area 2, Table 3; Mi-2, description area 2, Table 4; Mi-3, description area 3, Table 5), but none of these microstratigraphic units (description areas) are entirely free of fine materials. In particular, the leached area in Mi-2 (description area 2) occasionally shows some dusty illuvial clay in the pore spaces. This presence of B horizon-type material suggests that the soil horizon had already been leached before it was affected by disturbances and/or a new down-profile movement of silt and clays from above.

The micromorphological data (Tables 3, 4 and 5) were interpreted using the concepts of microfabric types and microfacies types (Courty 2001; Goldberg & Macphail 2006), so that the primary step in the process

Table 5. Description of thin section Mi-3 at 25-39 cm below the surface of profile 7.

Mi-3 –4	Mi-3 –3	Mi-3 –2	Mi-3 –1	**Micro-stratigraphic unit**	
30.5 (32.5)–36	28–30.5 (32.5)	26–27	25–26 and 27–28	**Depth [cm]**	
spongy, chamber, crack and single grain, locally channel	single grain	single grain, locally bridge grain	single grain, pellicular and intergrain micro aggregate	**Microstructure**	**Structure**
interconnected packing voids (20–400 µm), common chambers (up to 4 mm), TVS 35%	interconnected packing voids (20–700 µm), few planes (up to 4 cm x 1mm), TVS 25%	dominant packing voids, chambers up to 700 µm, TVS 45%	packing voids, chambers up to 500 µm, few to frequent channels (10-30 µm), TVS 30%	**Porosity and total void space (TVS)**	
C/f: 95 : 5, coarse monic	C/f: 98 : 2, coarse monic	C/f: 85 : 15, monic and chitonic	C/f: 70 : 30, monic, enaulic and chitonic	**Coarse fine (c/f) related distribution**	
(sub)rounded mineral grains (10–600 µm), dominant quartz	Subrounded(angular) mineral grains (20–600 µm), quartz	(sub)rounded blocky mineral grains (10–700 µm)	(sub)rounded mineral grains (10–600 µm)	**Mineral material (> 10 µm)**	
frequent sections of roots and plant residues up to 2 mm (PPL: orange, XPL: high birefringence, (locally low)	horizontally clustered plant residues (up to 3 cm), PPL: orange/ yellow, XPL: high birefringence), single leaf section (XPL: low birefringence)	few root sections and amorphous plant remains, few sections of cf. grass/grass roots (up to 4 mm), PPL: orange, XPL: high birefringence	frequent sections of roots (500 µm, PPL: orange, XPL: no birefringence), frequent remains of cf. turf moder	**Plant remains**	**Organic material (> 10 µm)**
-	few fungal hyphae	-	few fungal spores, partly clustered in pores, few hyphae	**Fungal remains**	
-	-	-	1 pollen grain of *Plantago*	**Pollen grains**	
charcoal, fine dispersed or clustered, partly with phosphatic/silt impregnations	very few micro-dispersed charcoal fragments (up to 200 µm)	frequent fine dispersed charcoal (up to 150 µm), without visible cell structure	horizontal layers phosphate impregnated charcoal (up to 7 mm), in, partly visible cell structures	**Charcoal and burned organic material**	
undifferenciated, locally strial or striated b-fabric	undifferenciated, locally strial b-fabric	undifferentiated and striated b-fabric with medium to low birefringence	striated b-fabric (cappings and coatings)	**Micromass and birefringence (b-) fabric in XPL**	
amorphous orange, yellow and black (PPL)	amorphous black and yellowish brown (PPL)	orange/yellow and bgeyish brown (PPL), black (PPL) dotted	amorphous yellow/ greyish brown, locally black dotted	**Fine mineral (fine organic) < 10 µm) in PPL**	
Very few phytoliths	No phytoliths recorded	No phytoliths recorded	Few to frequent phytoliths	**Inorganic residues of organic origin**	
silt coatings (up to 80 µm) and black nodules on minerals and in groundmass, silt cappings on turf moder (facing upwards), matrix slightly autofluores-cent in UV light	few thin (up to 20 µm) silt cappings (PPL: greyish/ brownish black (PPL), nodules on minerals	horizontal layering and compaction, silt infillings, thin (20 µm) silt cappings /coatings, few silt aggregates (800 µm), few black nodules	black spots, silt cappings/coatings on minerals (PPL: greenish/ yellow, up to 80 µm), single (1,5 mm) silt aggregate ("agricutan"), few black nodules	**Pedofeatures**	
"silty coatings"	"heterogeneous/ Homogenous, leached"	"silty, homogenous, layered"	"heterogeneous anthropogenic"	**Soil microfabric type (SMT)**	

Table 6. Radiocarbon datings, sorted by age, oldest on top of table.

Lab. No.	Context	Wood-type	^{14}C-years BP	Calibrated age, (1σ)
T-18690	Cultivation terrace, R10	Pine	2560±80	805–540 BC
T-18691	Cultivation terrace, R12	Pine	2115±55	195–45 BC
T-18689	Cultivation terrace, R9	Pine	1785±50	AD 215–330
T-18687	Cultivation terrace R7, with micromorphological analyses	Pine	1595±80	AD 400–560
T-18692	Tar kiln	Pine	1205±65	AD 730–945
T-18693	Tar kiln	Pine	1120±65	AD 880–1000
T-18688	Charcoal pit	Pine	1070±50	AD 900–1015
Tua-6261	Cultivation terrace, R12	Deciduous tree	995±40	AD 1010–1040
T-18686	Cultivation terrace, R7, with micromorphological analyses	Pine	925±75	AD 1025–1220
T-18685	Charcoal pit	Pine	810±75	AD 1170–1285
Tua-6260	Cultivation terrace, R5	Birch	805±30	AD 1220–1260
T-18684	Hunting pit	Pine (wood)	20±35	Younger than AD 1955

was the characterisation and identification of features, inclusions and soil/sediment microfabric types (SMTs). In relation to the associated data, it was possible to recognize soil microfacies types correlating with one or more SMTs. The soil microfacies types identified are assumed to represent contemporaneous activities or events within different areas at the site. According to this concept, the following phases in the history of the site could be identified:

Phase 1. Transfer of partly burned materials

The frequently and randomly occurring charcoal fragments in description area Mi-2-2 (Table 4) are rather large (up to 5 mm in diameter) and have infillings/cappings of silty material. These dusty clay coatings and infillings, together with isolated and micro-divided charcoal particles, may be associated with clearance by burning (cf. Courty et al. 1989:128). The possibility of a kind of slash-and-burn cultivation at the locality was suggested and discussed by Holm and Berg-Hansen (2007:32f). Charcoal favours the dispersal of clay coatings (Courty et al. 1989:129) and these together with the infillings may partly originate from weathering of ash during a younger period in history, when the soil became acidic as a consequence of podsolisation (cf. Courty et al. 1989:113). Any calcitic ash will have been leached out due to these later acidic conditions.

An undisturbed *in situ* event of clearance by fire would have penetrated deep into the soil and would have left behind fragments of burned soil (Gebhardt 1993:335) and presumably a larger amount of organic residues. The microfabric of the description area is characterised by finely mixed amorphous and partly rather coarse (up to 2 mm) organic material (e.g. root sections and other plant tissues) at various stages of decomposition. Burnt fragments may have disappeared on account of fragmentation and leaching processes, and organic material may have been decomposed and destroyed, but such processes would have required either biological or mechanical disturbance. The most likely explanation is that the soil material was subject to pronounced anthropogenic mixing and reorganisation, probably including the transfer of material from neighbouring localities. The transferred material may have been mixed with humus-rich matter, but nearly all fine fractions must have been lost, probably through later degradation processes and wash-out.

The above-mentioned rather large, randomly occurring charcoal fragments appear to have become isolated and most of them are impregnated with orange (PPL) precipitations, presumably of phosphates (Fig. 5) resulting from chemical reactions between compounds in the charcoal, e.g. potassium and faeces, and are associated with a general presence of major human activity. They may also indicate sheep or cattle grazing in the presumed slash–and-burn area around the site (Courty et al. 1989:130, 187). The above-mentioned already slightly podsolised soil may lend weight to the idea that the surrounding area may have been used for grazing domestic animals (but it may also indicate a coniferous forest).

This description area shows the highest compaction of all the thin sections (TVS: 20%), and its lower part has a slightly prismatic structure while the central part is characterized by a denser and somewhat platy structure with slightly parallel and horizontally

Table 7. Latin, English and Norwegian names of the plants mentioned in the text or in the Tables (Lid & Lid 2005).

Latin names	English names	Norwegian names
Alnus	Alder	Or
Betula	Birch	Bjørk
Brassica rapa ssp. Rapa	Turnip	Nepe
Corylus	Hazel	Hassel
Ericaceae	Heather	Lyng
Fagopyrum	Buckwheat	Bokhvete
Pinus sylvestris	Pine	Furu
Ulmus	Alm	Alm

oriented dusty silt and clay formations. These deposits take the form of connecting bridges between the sand grains, forming crusts (Fig. 6), and they may be remains of a former land surface that was turned over and mixed in by human activity (Courty et al. 1989:129), or else they may represent illuvial deposits at the contact/compaction zone in the base of a plough zone (Charles French pers. comm.).

To sum up, the lowermost layer analysed here was in all likelihood not formed naturally, since it would appear that people built it up, partly with burned material that presumably originated from a nearby area. People had presumably cleared an area which was already subject to human impact and possibly used for grazing domestic animals by burning it over. According to the radiocarbon dates (see Introduction), these events seem to have taken place around AD 400–560 (1595±80 BP), i.e. in the Migration Period. Two of the dates obtained for the terraces are from the early Iron Age, one from the Roman Iron Age and one from the Migration Period (see Table 6).

There are also other traces of human activity at Grundsetmarka in the early Iron Age. There are six dates for the above-mentioned cairn field which overlap with the early Iron Age dates for the terraces (Holm 2007). The pollen analyses show farming with fallow periods on the cairn field in this period (Overland & Hjelle 2007). Grundsetmarka also has iron extraction sites with a type of slag generally dated to the early Iron Age (Larsen 2004), and some pits have also been excavated and dated to the period AD 250–560 (Mikkelsen 1986). No objects have been found to indicate that the farm of Grundset was established in the early Iron Age. The question of whether or not the farming on the terraces and the cairn field was connected with Grundset remains open. What is evident, however, is that the forest of Grundsetmarka was actively used for multiple purposes in the Iron Age.

Phase 2. Cultivation on the site

The different microfabric types existing at the same depth in Mi-1 (description areas 1 and 2, Table 3) are obviously the result of incomplete mixing of soil layers. The material represented in these two adjacent description areas shows different shades of colour, orange/yellow and pale yellow respectively, with sharp boundaries. Such traces of poor mixing are typically a result of digging or less intensive ploughing. The same phenomenon can be observed in description area 3 of Mi-1, and area 4 of Mi-3. There are other similarities between the four microstratigraphic units (description areas): The microstructures are spongy or at least slightly spongy and the porosities are high. There are traces of channels in places, and the material consists of many silt and clay coatings and cappings and contains abundant residues of roots and plants (Tables 3–5). These characteristics may, together with other indications, be associated with former cultivation activity (Courty et al. 1989:131f; Gebhardt 1992). The high frequency of micro-dispersed charcoal has presumably been caused by fragmentation through cultivation (Macphail et al. 1990). The coarse charcoal fragments in this layer are frequently impregnated with silty material and an orange-yellowish (PPL) amorphous staining, which presumably originates from phosphate precipitations. These impregnated charcoal fragments seem to underline the presence of sheep and cattle grazing in the vicinity (see above), and suggest that material from those areas was transferred to the site of this profile. It is likely that the people concerned were conscious of the soil-improving effect of these materials (Woodward 1994; Guttmann et al. 2005).

The mineral grains in this layer vary somewhat in size whereas eolian sands normally have small variations in texture (grain size). The single mineral grains up to 1–1.5 mm in size that are present in description area 1 of Mi-2 obviously originate from nearby soils and were probably mixed in with other transferred material, including decomposed wood remains (Table 3, description area 4).

The occurrence of pronounced reddish/orange (PPL) phosphate-iron concretions would be typical of cultivated fields, but no such concretions could be detected in this profile, which was quite well leached, so that these phosphate compounds had obviously been washed out together with most of the fine organic material, which is also essential to render the soil suitable for cultivation. The previous existence of higher phosphate concentrations may be indicated by a slight autofluorescence of the groundmass visible under UV light (Table 5).

To sum up, the layer representing parts of the B horizon at depths of 30–45 cm (Table 1) seems to have been cultivated in the manner described by Holm and Berg-Hansen (2007).

Phase 3. Fallow periods or abandonment

Description areas 2 of Mi-1 and 3 of Mi-3 correspond to the E (B) horizon (Table 1), and are strongly leached. The boundary between the $B_{(2)}$ horizon discussed above and this layer is relatively distinct ("abrupt to wavy", Table 1), indicating that leaching of the E (B) horizon (during podsol formation) took place after cultivation had come to an end. In earlier studies weak E horizons have been observed after a few hundred years, while the formation of mature podsols has usually taken more than 1000 years (Mokma et al. 2004; Sauer et al. 2008).

Although charcoal particles are still frequent in this layer, only a few fine or micro-dispersed charcoal fragments are present, and no charcoal fragments with silty or phosphate compound impregnations could be observed. The frequency of silt cappings and coatings, and also the porosity (25%, Table 3 and 5), may be seen to be greatly reduced relative to the second phase (see above). Some fungal hyphae were recorded. In experimental soil studies, Gebhardt (1992:380) observed a slight correlation between traces of faunal activity and uncultivated soil plots. The dominance of a single grain structure and the coarse monic distribution of the material do not indicate any kind of possible aggregate formation in an earlier period that would be typical of a cultivated soil.

Summing up, the layer represents either a long fallow period after earlier cultivation or the abandonment of the field.

Phase 4. Cultivation and manure with ashes and turfs

The transition between the materials representing microfacies 3 and microfacies 4 in description area 1 of Mi-1 and area 1 of Mi-3 is characterized by long (up to 2 cm) and wide (up to 1700 μm), predominantly horizontally oriented and clustered plant residues (Fig. 7). These are described in Table 5, description area 3 of Mi-3, (interpreted as phase 3), but it is obvious that these plant residues were only partly mixed into the lower layer (phase 3). They are not burned, and the reason for their good preservation may be the presence of the plant's own polyphenols, chemical substances that control decomposition.

A piece of leaf roughly 3 mm long (400 μm wide, Table 5, area 3) in the lowermost part of this layer (Fig. 8) has a fairly clearly visible internal structure and seems to represent the leaf of a moss (cf. FitzPatrick 1993:158).

Bakkevig (1998:57) suggested that people may have dug up peat and mixed it into the field, thus increasing the nitrogen content. Here at Grundset, however, the main purpose for which peat material was used may have been stabilisation and further building of the terraces. Collins and Coyle (1980) examined the long-term effects of peat additions (to a luvisol in Ireland) and found that additions of up to 3 cm improved the structure and encouraged faunal activity (FitzPatrick 1993:231).

Superimposed on this layer of unburned plants is another layer of horizontally oriented material that is dominated by charcoal particles and fragments up to 2.5 mm in size (Table 5, description area 3, 1, SMT: "heterogeneous anthropogenic"). Some of these presumably represent fragments of twigs, but micro-dispersed charcoal is also common. This layer also displays residues of black (PPL, OIL) turf-like material (Fig. 9, Babel 1975:440), the black colour of which is attributable to intact plant remains with partly visible internal structures tainted by the humification products of the more easily decomposed plant substances (e.g. pectin, cellulose and proteins) to give a humus related to the moder type. In the presence of arable cultivation, however, such moder-like formations usually undergo further powerful decomposition processes, resulting in the formation of what is known as "pitch peat" (Babel 1975:440; Greve et al. 1999). The material in this layer at the Grundsetmarka site seems to include a variety of such pitch peat (cf. Sageidet 2006:14) and also many other forms of micro-dispersed carbonized organic material similar to the turfs shown in micrographs from earlier case studies (Simpson et al. 2005:367; Babel 1975:442f; Sageidet 2007a, b).

The importing of turfs from a larger area to improve the structure of the soil in a smaller area and its ability to retain moisture and nutrients is has been referred to as concentration farming (Stoklund 1990), and is connected with agricultural techniques that were prevalent in early Medieval times (Mücher et al. 1990), in the Iron Age (Behre and Kučan 1994:136) and in the late Bronze Age (Spek et al. 2003). Anthropogenic soils resulting from the manuring and cultivation of fields have been identified at many sites in north-western Europe (see, for example: Conry 1974; Davidson & Simpson 1994; Simpson 1997).

At Grundset, people seem to have added a mixture of turf, loose ash, wood remains and possibly other humus-rich materials to the sandy soil, probably to improve it for cultivation purposes. The organic debris of twigs and branches may have been burned in the vicinity as part of some kind of fire clearance technique (see above, cf. Steensberg 1993).

The microfacies type described and interpreted here occurs in two successive layers in thin section Mi-3. There was probably a new period of cultivation following on from the original one, as indicated in the uppermost part of thin section Mi-3, and this obviously continued further up in the profile, as suggested by Holm and Berg-Hansen (2007).

Phase 5. New fallow periods

Description area 2 in Mi-3 (Table 5) is fairly homogeneous in appearance, with few organic residues and very few coarse charcoal fragments. Apart from some silty pedofeatures and turf fragments which were probably mixed in from the layers above or below, it bears similarities to the material of phase 3 (Mi-1, description area 2, Table 3, Mi-3, description area 3). There are frequent occurrences of micro-dispersed charcoal fragments, however, and a dominance of rounded or sub-rounded mineral grains which are slightly compacted and horizontally oriented. These features indicate that the layer was exposed for some time and subject to trampling.

Cultivation at Grundset

Each of the three microfacies indicating earlier agriculture may represent several seasons of cultivation, arable fields that are intensively managed over long periods do not show any internal stratigraphy, as soil material from different levels deposited during the entire period of cultivation is usually mixed in by soil management and by the soil fauna. At Grundsetmarka, the remains of an internal stratigraphy are clearly visible, apparently underlining that in this case there were lengthy fallow periods between the cultivation periods.

Pollen analysis and/or microfossil analysis are methods that can usually help us determine what people may have cultivated a particular site. Single pollen grains and sections of microfossils may also be detected in thin sections (Sageidet 2009). Pollen preservation conditions were obviously poor in the sandy soils at Grundsetmarka (cf. Høeg 2007), and this is also the reason why only a few pollen grains could be detected in the micromorphological analysis.

Few phytoliths were recorded in the thin sections, whereas phytoliths are common in soils and sediments where monocotyledonous plants like grass or cereals have been grown or cultivated (Courty et al. 1989). The small numbers of phytoliths in the samples from Grundsetmarka may be a slight and indirect indication that people may not have used the terraces for hay production or cereal growing, but the concentration of phytoliths in thin sections is known to be dependent on a variety of factors (Marco Madella pers. comm.).

Decomposition processes proceed fairly rapidly in sandy soils by comparison with other soil types, and efforts at soil improvement may only have had an effect for a relatively short time. The reasons for preparing such sandy soils for cultivation (by building up terraces and improving the soil quality) might have included the fact that the crops grown matched the soil properties, e.g. rye (*Secale cereale*), buckwheat (*Fagopyrum*), cabbage, or turnip, all of which thrive in sandy soils (Schübeler 1889).

Farming took place at Grundsetmarka on two substrates, till and sand, the cairn field mentioned above being situated on till deposits where the soil is rich in stones. The morphology of the cairns and terraces is quite different, reflecting the two types of accumulation, although the actual farming methods may not have differed greatly. Pollen analyses of samples from a bog close to the cairn field indicate, as mentioned, a kind of "bush fallow" situation with limited use of manure and frequent periods of lying fallow. Microfacies type 1 was in all likelihood not formed naturally but built up with partly burned materials, pointing to a type of farming which did not last for long, using charred material as a fertiliser. This is the same fertiliser as is used in the "bush fallow" technique, where bushes are grown on an abandoned field and then cut down, dried and burned before beginning a new cycle of cultivation. The two types of fossil field differ mainly in being situated on different sediment types, sand and till.

The ^{14}C dates indicate that the terraces were used in the Middle Ages as well, probably with the same techniques as earlier, adding charred material and turf for fertilisation. Grundset was a fairly large farm in the Middle Ages (Holm 2007), and as the terraces were quite close to the farm, they were probably used periodically as fields by the farmers from Grundset.

The forests of Grundsetmarka were evidently actively used in the Middle Ages, as a large number of charcoal pits have been found there, generally dated to the period AD 900–1300, and also several iron extraction sites with a type of slag that is generally dated to the period AD 600–1300 (Larsen 2004). The cairn field mentioned above was also in use in the Middle Ages. The farming methods were more intensive than in the earlier period, however, and the pollen analyses show an assemblage of herbs indicating the use of manure and a fairly permanent type of farming (Overland & Hjelle 2007).

It had been suggested prior to the excavation that the terraces may not have been in use in the Middle Ages, and that the forest was mainly used for charcoal production during that period (AD 900–1300). Both the dates for the cairn field and those for the terraces themselves, however, show that not only were charcoal and iron made during the Middle Ages, but cultivation also took place in that period.

Pollen of *Cerealia*, *Fagopyrum* and *Secale* has been found in the present-day turf layer on the top of the terraces (Høeg 2007), indicating that cereals had been cultivated in the area without any tilling of the soil with a spade or by any other means. This last episode of cultivation, probably by some kind of slash-and-burn technique, is younger than the Middle Ages and may have occurred in the 17th or 18th century. Slash-and-burn cultivation was quite common in the forests of eastern Norway in that period (Holm 2007).

Conclusions

The soil profile in the sand terrace investigated at Grundsetmarka had developed under strong anthropogenic impact. The micromorphological analysis revealed five microfacies types: transfer of partly burned material, cultivation on the site, fallow periods or abandonment, cultivation and manuring with ash and turf, and new fallow periods. Based on these types, the history of the site may be outlined as follows:

People seem to have built up the profile with mixed and partly burned material transferred from the surrounding area. The burned material presumably originated from the nearby use of fire for clearance purpose. These clearance events and the construction of the terraces, dated to around AD 400–560 (1595±80 BP), presumably did not take place in a natural forest, but in an area already subject to substantial human impact. The area may previously have been used for grazing domestic animals.

Once prepared, the terraces were obviously cultivated, as indicated by features such as traces of digging (or possibly ploughing), a spongy, porous microstructure, silt and clay coatings, phosphate impregnations and micro-dispersed charcoal. People were probably conscious of the soil-improving properties of charred material mixed with animal faeces. This initial cultivation phase, possibly bridging several seasons, was followed by a longer fallow period or abandonment of the field.

Later, people obviously added new material to the profile, probably to improve the soil for new cultivation. This time, apart from loose ashes and wood remains, the mixtures of materials transferred to the site included substantial amounts of turf and presumably other humus-rich material. These new cultivation activities may have started around AD 1025–1220 (925±75 BP). The analyses reveal at least two successive new periods of cultivation, interrupted by a distinct fallow period. Both the second and third cultivation phases may have included several seasons of cultivation.

The poor eolian sands of Grundsetmarka with their pine trees and heather are not what one would consider a likely location for fossil fields. The excavations and micromorphological analyses nevertheless show that even these marginal soils were indeed used for farming purposes, and give evidence for the terraces being of cultural origin. Thus this interdisciplinary approach, linking the cultural and natural sciences, has succeeded in yielding results that neither of the two disciplines could bring about alone.

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