27. E6 GUDBRANDSDALEN PROJECT (BRANDRUD, FRYASLETTA, GRYTTING, AND ØYBREKKA), OPPLAND, NORWAY: SOIL MICROMORPHOLOGY (WITH SELECTED MICROCHEMISTRY, BULK SOIL-CHEMISTRY, CARBON-POLYMER, PARTICLE-SIZE, AND POLLEN ANALYSES)

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INTRODUCTION

During the summer and early autumn of 2012, a series of sites following the E6 highway improvement corridor along Gudbrandsdalen, Oppland, Norway, were excavated (Ingar M. Gundersen, Lise Loktu, Linn Trude Lieng, and Tina Villumsen, Museum of Cultural History, University of Oslo; figure 27.1). The sites investigated in this chapter are located along the river Lågen, and archaeology was buried by a variety of alluvial and mass-movement sediments, the latter associated with the steeply sloping and unstable eastern valley side. The background discussion of valley-side instability and dating of the river Lågen flood events is presented elsewhere in this volume (Gundersen, this volume). A geoarchaeological study and associated sampling campaign was carried out by Rebecca Cannell (Bournemouth University; Cannell, this volume). Undisturbed monolith samples for soil micromorphology were collected by Cannell from the E6 sites of Brandrud, Fryasletta, and Grytting, while Linn Trude Lieng collected monoliths from the Øybrekka site. Cannell also collected a series of bulk samples for particle-size and magnetic-susceptibility analyses, which are reported on separately by Cannell (this volume) and Petra Schneidhofer (Schneidhofer and Cannell 2013). While the some excavations were still open, the author was able to briefly visit in September 2012 and took additional samples from the sites of Brandrud, Fryasletta, and Grytting. The chief aim of the soil-micromorphology study was the investigation of charcoal-rich layers. Some of these were tentatively associated with prehistoric agriculture, while others appeared to pre-date these cultural horizons.

SAMPLES AND METHODS

The following monoliths were assessed and subsampled for thin-section soil micromorphology and other analyses (Courty, Goldberg and Macphail 1989; Goldberg and Macphail 2006). Bulk sample analyses focused on material from Fryasletta.

Fryasletta: Thirteen monoliths were subsampled and produced eighteen thin sections. A number of bulk samples were also analysed from subsamples of Monolith 42 (Context 1150, and associated layers), and small bulk samples taken in the field, including six bulk chemical analyses and a series of pollen assessment samples (Figures 27.2–27.3).

Brandrud: Six monoliths were subsampled and produced ten thin sections.

Grytting: Three monoliths were subsampled and produced six thin sections and two bulk chemical analyses.

Øybrekka: Four monoliths produced four thin sections.

Investigative methods included bulk soil studies generally and particle-size, carbon-polymer, and pollen analysis specifically on Monolith sample P42, layer 1150 and associated contexts at Fryasletta by Johan Linderholm (Umeå University, Sweden), John Crowther (University of Wales, UK), Marie-Agnès Courty (CNRS, France), and Gill Cruise (University College London, UK) respectively. Bulk soil-chemistry (loss-on-ignition – LOI – and fractionated phosphate) and magnetic-susceptibility 'five-parameter analyses' were carried out by Johan Linderholm, (University of Umeå) as applied to numerous Norwegian sites along the E18 (Viklund, Linderholm and Macphail 2013) and other stretches of the E6. Crowther and Cruise employed standard methods, while Courty carried out binocular assessments (details in Macphail, Cruise, Courty and Crowther 2013b). Soil-micromorphology analyses involved the processing of 26 monoliths in order to make 38 thin sections. These were analysed using a petrological microscope under plane polarised light (PPL), crossed polarised light (XPL), and oblique incident light (OIL), and using fluorescence microscopy (blue light – BL), at magnifications ranging from x1 to x200/400 (Courty et al. 1989; Stoops 2003; Stoops, Marcelino, and Mees 2010). Microfeatures of interest in Samples M42A (Contexts 1150 and 1150) and M63A (Contexts 8, 9, and 10) underwent SEM/EDS (energy-dispersive X-ray spectrometry; Weiner, 2010).

RESULTS

Bulk soil studies

Johan Linderholm's chemistry and magnetic-susceptibility 'five-parameter analyses' data for Fryasletta and Grytting contexts are presented in Figure 27.4. John Crowther's particle-size analysis determined that layers 1150–1151 are a silt loam (see below for details). A carbon-polymer analysis by Marie-Agnès Courty identified a number of carbonaceous materials in layer 1150. There was an abundance of possible extra-terrestrial impact-relevant components particularly, coloured

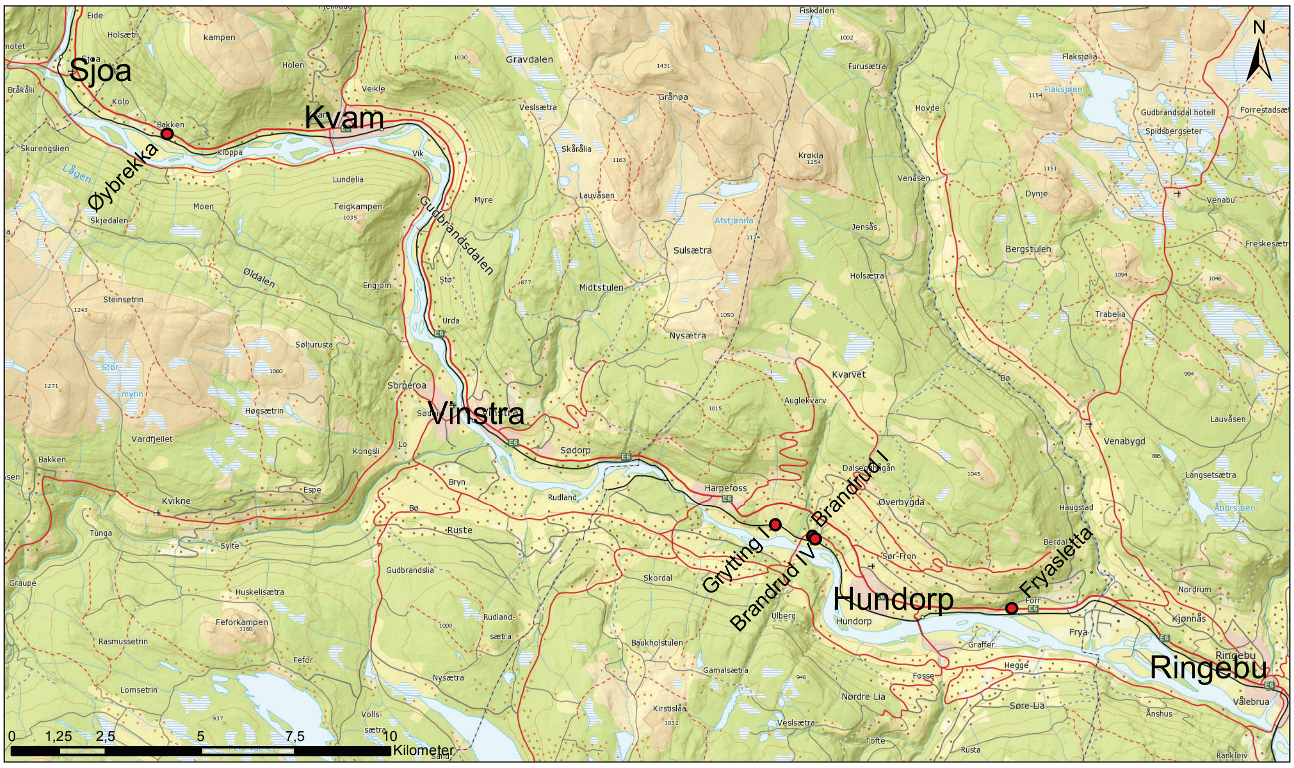

Figure 27.1. E6 Gudbrandsdalen project, Oppland, Norway; location of studied sites Brandrud, Fryasletta, Grytting, and Øybrekka along the river Lågen. Map: Ingar M. Gundersen.

Figure 27.2. Fryasletta: Profile 1a, Trench 1. Field sample P42 (thin sections M42A and M42B) across alluvial layers 1152, charcoal-rich 1150, and 1151 (see Fig. 3). Samples M9 and M10 were also collected across 1150 elsewhere in this trench.

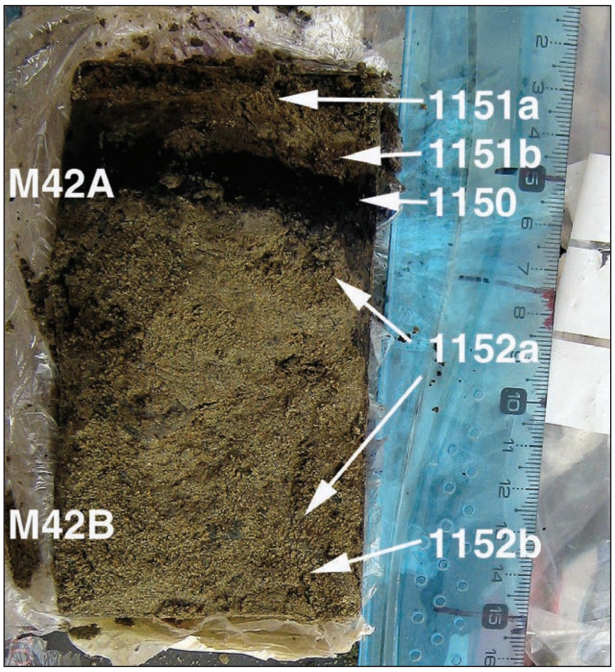

Figure 27.3. Fryasletta: Monolith P42, showing location of thin sections M42A and M42B and investigated alluvial sediments 1152, charcoal-rich 1150, overlying silt loam 1151b, and fine sandy 1151a. (See Fig. 3).

carbonaceous filaments, and vitreous char together with other typical components (i.e. angular quartz with shiny faces), but all these indicated a secondary accumulation rather than an in-situ impact.

Pollen analysis

Eight layers from Profile 1A, Trench 1, at Fryasletta were assessed for their pollen preservation and content (see Macphail et al. 2013b). Only layer 1150 proved to be worth counting. Pollen data from layer 1150 are presented in Figure 27.5, where pollen percentages and pollen-preservation data are included. Pollen nomenclature is based upon standard authorities (e.g. Moore, Webb and Collinson 1991). Large numbers of pollen grains were too badly deteriorated for identification, so these were recorded as unidentifiable. Several grains and spores were also too badly deteriorated to permit confident identifications, and these are recorded as *cf.* or undifferentiated or unknowns.

Arboreal taxa are dominated by *Pinus* and *Betula.* High frequencies of degraded grains were recorded for both taxa with over 90% of birch (*Betula*) and over 40% of Pine (*Pinus*) being in this condition. The presence of such high levels of degraded grains is normally associated with re-deposition and especially with the inwash of silts (Birks 1970; Lousley 1944). Weathering and biological activity also result in very high levels of pollen deterioration. Records for *Alnus* and *Corylus t.* are fewer but are better preserved. *Corylus t.* includes both *Corylus avellana* (hazel) and *Myrica gale* (bog myrtle), a wetland shrub. The better preservation suggests the likelihood of alder (*Alnus)* growing contemporaneously with the sediments although relatively low frequencies are indicative of either few trees or wet woodland growing at some distance.

Herbaceous taxa are dominated by *Epilobium angustifolium t.*, reaching 31% of the count with few other

Sample	MSlf	MS550lf	CitP	CitPOI	Pppm	PQuota	LOI
Fryasletta							
1142 (agric.)	77	63	47.1	80.7	350	1.71	2.7
1146 (agric.)	68	60	51.1	91.6	400	1.79	3.2
1151 (dark silt loam)	49	124	38.2	120.6	530	3.16	5.8
1150a (charcoal)	71	156	26.2	103.6	450	3.95	7.1
1152a (silt loam)	73	53	85.9	99.8	430	1.16	1.1
1152b (sandy alluvium)	76	57	74	89.7	390	1.21	1.6
Grytting M409							
L4 stakehole	101	166	34	95	410	2.81	3.7
L2 reddened hearth	87	85	67	76	330	1.14	1.2

Low-frequency magnetic susceptibility (MS); 2% citric-acid-extractable phosphate P2O5 (P); loss on ignition (LOI) at 550 °C.

Figure 27.4. 'Five-parameter analysis', Grytting (Johan Linderholm, MAL, University of Umeå).

	No. counted	Percentage count
Trees and tall shrubs		
Alnus	16	7
Betula	40	18
Corylus t.	5	2
Pinus	49	23
cf. *Hedera*	1	< 1
Herbaceous taxa		
Cyperaceae	1	< 1
Epilobium angustifolium t.	68	31
Fabaceae undiff.	2	1
cf. *Geranium*	2	1
Unknowns	2	1
Spores		
Polypodium vulgare	1	< 1
Pteridium	27	12
Pteropsida (mon.) indet.	2	1
Pteropsida (trilete) indet.	1	< 1
Total	217	100
Pollen preservation		
Normal	70	32
Crumpled	24	11
Corroded	2	1
Degraded	108	50
Split	13	6
Total	217	100

Figure 27.5. *Pollen analysis of a sample (PMM42, 2.5 cm) from Fryasletta, Norway.*

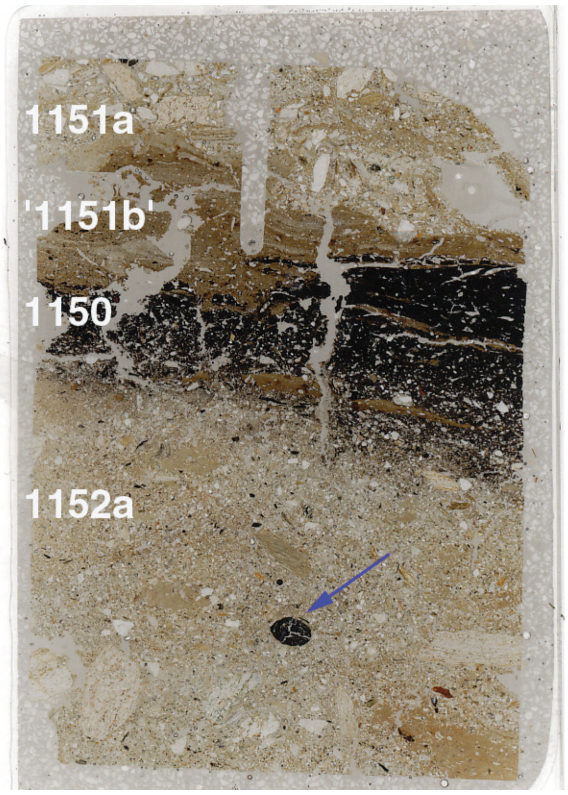

Figure 27.6. *Fryasletta: Scan of M42A (see Figs. 2–3), with sandy upper 1152a containing an example of twig wood charcoal and showing relict silt-loam layering. Layer 1150 is composed of brown silt loam and a concentrated layer of wood charcoal and wood char. Layer '1151b' is an upward extension of a silt-loam deposition associated with 1150 ponding (see Table 2 for pollen analysis). Overlying 1151a is erosive, poorly sorted sand and gravel alluvium. Frame width is ~50 mm.*

herbaceous taxa being noted. Preservation is variable, with some grains being quite poor and others being good. The high frequency of this pollen type is interesting in this context, as it includes the plant known in English as rosebay willowherb or fireweed. It is widespread in Eurasia, where in its natural habitat, it is characteristic of two types of communities. These are the tall-herb and scrub vegetation of mountain slopes and ledges, and also the secondary vegetation of forests disturbed by fire, wind-throw, or clearance (summarised in Rodwell 2000:419–421). In this second situation, burned areas provide nutrient-rich ash and moisture suitable for re-colonisation by plants that are able to benefit from this situation. Rosebay willowherb produces large amounts of seed, grows rapidly, and overtops lower-growing herbaceous taxa, thus producing dominant colonies that also spread by vegetative growth. Apparently, rapid colonisation is vital, as the favourable conditions in burned areas exist only for a short time, with the supply of nutrients being used up within two or three years. One of the commonest associates in this type of community is *Pteridium* (bracken), which is here recorded as 12% of the count. *Pteridium* in all its various forms grows throughout the world and is able to rapidly establish itself from spores in a wide range of new habitats including those disturbed by fire. It is worth noting that *Pteridium* and rosebay willowherb (*Epilobium angustifolium)* were some of the most commonly occurring plants found growing on bomb sites in the City of London during the Second World War (Lousley 1944).

SOIL-MICROMORPHOLOGY AND DISCUSSION

The soil-micromorphological study of four E6 Gudbrandsdalen sites (Brandrud, Fryasletta, Grytting, and Øybrekka) involved the analysis of 77 layers/contexts from 38 thin sections. Layer 1150 (1151) at Fryasletta was a focus of interest because of its widespread nature and possible occurrence at other

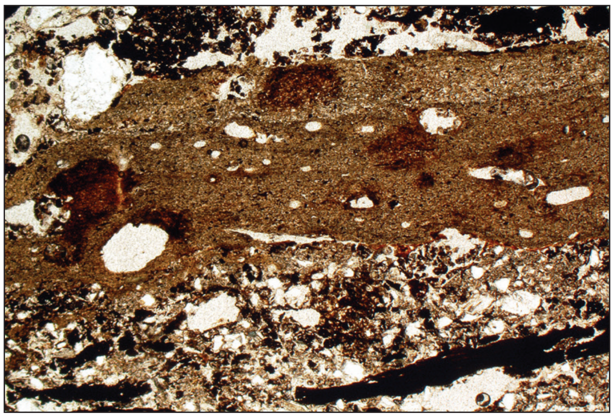

Figure 27.7. *Fryasletta: Photomicrograph of M42A, Context 1150 – lowermost laminated fine and coarse silts ('silt loam'; note weak iron staining – not rubification) and uppermost 1152a – biomixed humic sediment and fine charcoal in sandy alluvium. Iron-stained silt loam with 5.92–7.06% Fe and 0.0–0.71% Mn (EDS – energy-dispersive X-ray spectrometry). Plane-polarised light (PPL), frame width is ~4.62 mm.*

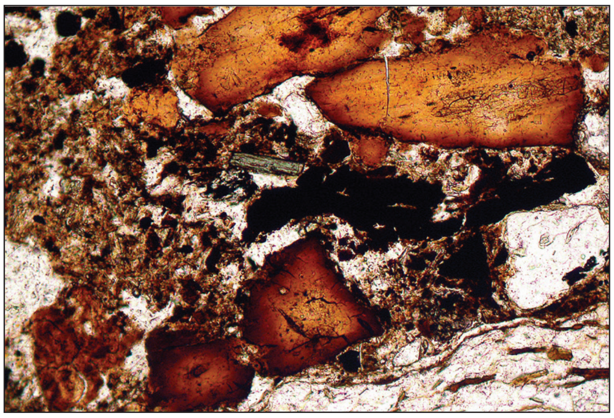

Figure 27.8. *Fryasletta: Photomicrograph of M9B; 1150 silt-loam infill affecting sands and gravels of 1153. Orange-coloured (rubified) burned bone and fine charcoal (originally riverside small-carnivore scat?). PPL, frame width is ~0.90 mm.*

sites along the E6 (I. M. Gundersen, KHM, UiO, pers. comm.; Figures 27.2, 27.3, and 27.6). This layer was therefore subjected to additional analyses (carbon-polymer, particle-size, pollen, and chemical- and magnetic-susceptibility analyses). Detailed analyses and interpretations of individual layers have already been given in Macphail et al. 2013b. General findings for each of the four sites are presented here. In addition, a second overview section deals with (a) natural site formation processes (fluvial, mass-movement, i.e. landslide, and cool-climate phenomena), (b) the Bronze Age wildfire event (Fryasletta 1150), and (c) agricultural land use (manured cultivation and animal management and pastures). Interpretations are based mainly upon intrinsic soil-micromorphological features.

Fryasletta

Fluvial activity

The Lågen stream has deposited a number of sediment types. Only the moderately high-energy sands and gravels and lower-energy sands and silts were sampled and studied. At Trench 1, Profile 1A, moderately high-energy, poorly sorted silts, sands, and gravel sedimentation, which often show upward fining and which can be erosive (e.g. layers 1149, 1152b, 1153), are evidence of a migrating stream within a braided river system. These are essentially minerogenic (1.1% LOI). Seasonal spring melt and/or rainstorm events also led to floods and the deposition of a low-energy silt loam (e.g. layers 1150, 1151). One example of these sediments is silt-dominated (71.6% silt), with fine sand (13.5%) and a low clay content (11.3% clay; Figure 27.7). This is consistent with other particle-size analyses (Cannell's 'Frya report extract', pers. comm.; Cannell article 11 in this volume). This silt loam is an overbank sediment deposited under developing localised ponding conditions. There are also instances of silts being sorted ('fining upwards') as stream energy diminished, or ponding water settled, and this also led to the concentrated deposition of organic-matter fragments. Small variations in energy resulted in charcoal deposition (1150), for example within silts 1152a, below, and 1151b, above, when flooding eroded and transported local soils and sediments. Elsewhere at Fryasletta and along the E6, silt loams also include charred byre waste and humic soil eroded from cultural soils and settlements – see below. At Area 4, Profile 4B, Section 1, layer 1145 is alluvium containing much reworked organic agricultural soil material. At this location, there is also a sequence of pasture-soil formation (L10) over alluvial sands and gravels, with the soil sealed by a low-energy silt loam (L9), that was itself buried by higher-energy sands and gravels. The latter resulted from a migrating stream within the braided river system.

It can also be noted that these silt loams are ideal for recording frost-induced lenticular microstructures (Van Vliet-Lanoë 2010), with such features in 1151 and 1152a and in the silty part of 1144. At Trench 5, Profile 5A, Section 1, silt loams were also affected by ice lensing (L5, L12).

Mass-movement

It is less easy to recognise the extent of landslide deposits from thin sections and section drawings alone. Nevertheless, at Trench 5, Profile 5A, Section 1, mass-movement seems to have reworked a number of different materials, including presumably relict

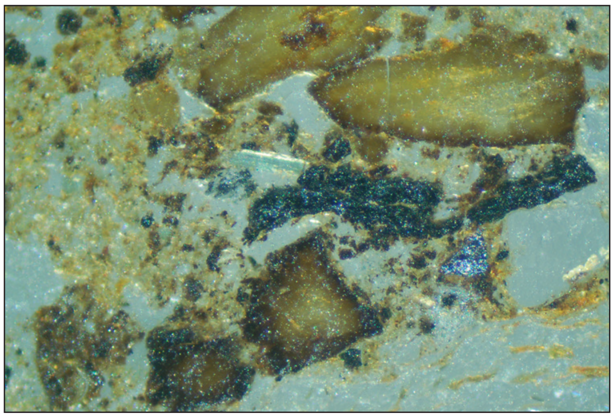

Figure 27.9. Fryasletta: As Fig. 6, under oblique incident light (OIL), showing rubification and blackening from heating.

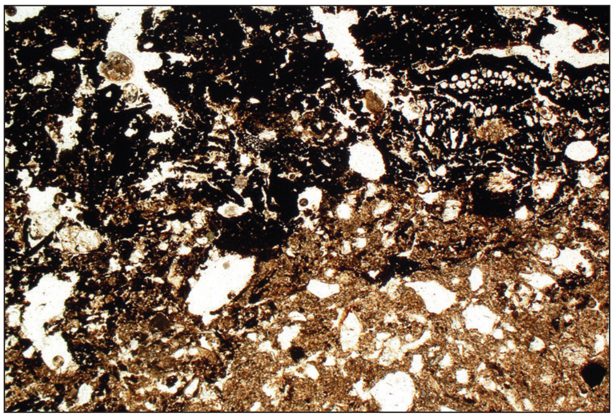

Figure 27.10. Fryasletta: Photomicrograph of M9A (1150); charcoal, wood char and bioworked wood char over humic and fine charcoal-rich silt-loam sediment (originally ponded sediments). PPL, frame width is ~4.62 mm.

periglacial-soil deposits (within L12) and soils containing byre waste (L8). Similarly, eroded relict periglacial soils occur at Section 2, in L12. At Area 4, Profile 4B, Section 1, mass-movement deposits involve cultural soil material (1142a, 1142b, 1145, 1146, and other examples of 1146). Such deposits can show typical features of having been water-saturated, for example collapse structures and textural intercalations (Fedoroff, Courty and Guo 2010; Mücher, van Steijn and Kwaad 2010).

Bronze Age wildfire? Layer 1150/1151

This discussion focuses on data from thin sections M9A, M9B, M10A, M10B, M42A, and M42B (layer 1150 and associated layers 1149, 1151, 1152, and 1153) and findings from the pollen analysis, bulk chemistry and magnetic susceptibility, and a carbon-polymer assessment.

The micromorphology of the thin sections was complemented by microchemical studies of M42A employing SEM/EDS, with field- and laboratory-subsampled layers also being the subject of (a) pollen and (b) binocular investigation of carbonaceous inclusions within 1150 (see above). 'Flood layers' record typical alluvial sediments that vary from moderately high-energy sands and gravels and associated weak soil formation in them to finer, overbank, low-energy stream/ponding deposits. These are silt loams (Figures 27.2, 27.3, 27.6, and 27.7). Of particular interest are silt-loam sediments that contain concentrations of wood charcoal and wood char and that have associated radiocarbon dates of 3218 ± 41 BP (Trench 6, layer 9) and 3599 ± 50 BP (Trench 7, layer 12; probably late Stone Age / early Bronze Age; I. M. Gundersen and L. Loktu, KHM, UiO, pers. comm.). In contrast, the supposed oldest agricultural layer is dated to 2841 ± 34 BP and 2932 ± 34 BP.

In reality, layers 1150 (the most charcoal rich) and 1151 and 1152 (essentially minerogenic) are contemporaneous and result from the same flood and ponding event. They will therefore be discussed together. It is clear from the concentrated presence of wood charcoal and char, including coniferous wood, that this sediment records a major wildfire event affecting the woodland of Gudbrandsdalen (the river Lågen). Other, much less frequent evidence of this fire are fine fragments of burned bone (riverine small mammal scat?; Figures 27.8–9) and an example of burned mollusc shell. The intensity of the fire led to the formation of wood char (Figure 27.10) and apparently special carbonaceous (polymer) fragments. The pale reddish colours of the silt loam are not those of heat-formed rubification, but secondary iron staining (also noted by Cannell's 'Frya report extract', pers. comm.); hence, there is an enhanced MS550 as a proxy measure of this iron – the pale reddish colours therefore record iron and not rubification (Figure 27.5; Figure 27.7). This further demonstrates that the charcoal is not the result of an in-situ wildfire, an inference already suggested by the carbon-polymer assessment. Numerous deteriorated pollen grains are also consistent with sedimentary re-deposition of organic matter. In addition, it can be noted that a small concentration of phosphate records not only ground-water movement but also the nature of the humus of the original site, as this has an anomalously high PQuota (3.2–3.9); a UK example of natural peat has a PQuota of 6.8, for example. The location of the fire developed a typical post-fire invasive vegetation characterised by both *Epilobium angustifolium t.* (fireweed / rosebay willowherb) and *Pteridium* after the fire. It is always possible, of course, that this records widespread clearance fires.

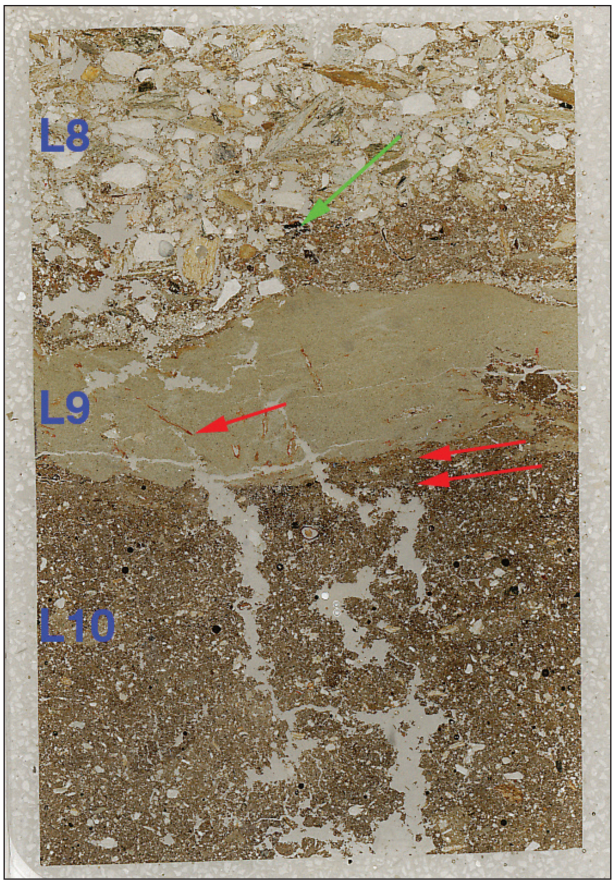

Figure 27.11. *Fryasletta: Scan of M63A, with alluvial silt (L9) sealing humic pasture soil L10. L8 records later higher-energy fluvial sands and gravel deposition; humic soil and charred dung (green arrow) have also been eroded. Red (iron-stained uppermost turf, Fig. 10) and green arrows mark areas of EDS analyses. Frame width is ~50 mm.*

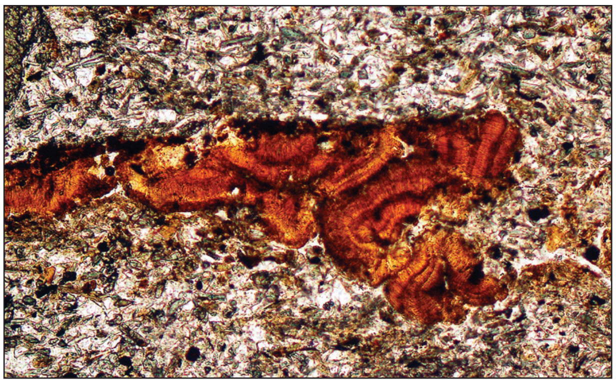

Figure 27.13. *Fryasletta: Photomicrograph of M63A, layer 9; minerogenic alluvial silts, with reddish brown secondary iron-void infills ('ferrihydrite'?). PPL, frame width is 0.90 mm.*

Agricultural soils

Cultivation soils were identified on the basis of several criteria. Such criteria have been developed across north-west Europe, with studies from the UK and Scandinavia, including Norway. These criteria are detailed in the overview of all sites (see below). In addition, post-depositional effects of stream flow, flood

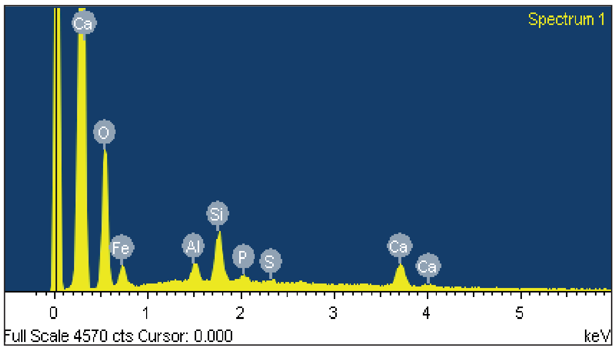

Figure 27.12. *Fryasletta: Photomicrograph of M63A, uppermost layer 10, a 'laminated mull' humic pasture topsoil with blackened/aged 'grass' leaf litter of poorly drained soil, sealed by alluvial flood silt. PPL, frame width is ~4.62 mm.*

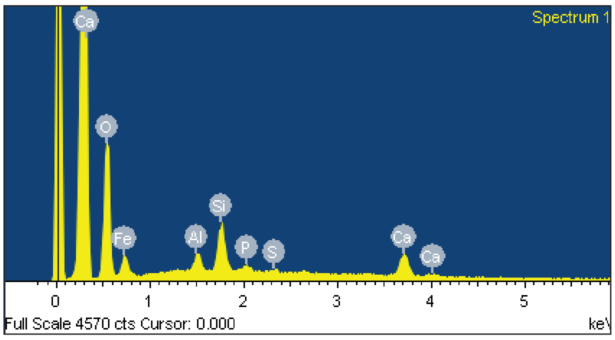

Figure 27.14. *Fryasletta: As Fig. 11, X-ray spectrum of iron-void infills (EDS analysis); iron is dominant (43.2% Fe), with 1.73% P, 6.33% Ca, and 0.59% S (relict root?). Local silts contain 5.54% Fe and 0.24% P.*

inundation, and mass-movement on the various agricultural soils are also stated in the overview.

At Fryasletta Trench 1, Profile 1A, the stream-eroded remains of a probable agricultural soil were identified in 1146. Here, the humic soil shows high levels of biological activity due to the addition of organic manures, which probably derive from the byre, giving it a 'plaggen soil'-like appearance (Bakels 1988; Goldberg and Macphail 2006); the soil had an enhanced phosphate content and PQuota despite being affected by groundwater leaching. A good Norwegian analogue of soils ameliorated by manuring was studied at Hørdalsåsen, Vestfold, where soil micromorphology and fractionated phosphate chemistry both identified dung inputs and raised levels of biological activity (Viklund et al. 2013). The situation at 1142 is more complex, as it appears that the manured, cultivated soil has been left fallow (not tilled) before being buried. This was less humic than 1146 but had a comparable phosphate and PQuota consistent with manuring. At Trench 5, Profile 5A, Section 2, layer 9 is a cultivated soil manured with byre waste, whereas at Section 2, layers 1138/1139 have a more complex history. Here, pasture soils may have been manured with a spread of both byre and settlement waste (including burned clay). (Both 1142 and 1146 had MS and MS550 values likely recording small inputs of burned mineral material related to manuring; Figure 27.4.) In Area 4, Profile 4B, Section 1, layer 1142 was divided into two subunits because the manured agricultural soil was affected by the overlying mass-movement mudslide deposit. Here, an earlier agricultural soil (1146), which was enriched in both byre and settlement waste, also lost structure when buried by a water-saturated mudslide sediment. Other agricultural soils at this section were also influenced by mass-movement and other slope (creep?) deposits, with these overlying thick sediments causing soils to also become compacted.

Locally, on the south-west side of Area 4 (Profile 4B, Section 1), a related but different land use was found. The lowest layer analysed (L10) shows a Bw/Bwg horizon of a moderately poorly drained, thin, brown soil formed over alluvial sands and gravels ('Gleysol'; Figure 27.11). Upwards, L10 records A1hg horizon turf-soil development (Figure 27.10). Specifically, this is classified as a 'Laminated Mull' pasture soil (Barrat 1964), where wet conditions led to the incomplete decay of grass litter; grass or possibly *Cyperaceae* (sedge) fragments have become decayed ('browned'; Babel 1975). This area can therefore be termed a Lågen river water meadow. Turves from a very similar environment were analysed from the makeup of the Gokstad Viking Ship Burial Mound, Sandefjord, Vestfold. Multidisciplinary studies including chemistry (involving fractionated phosphate), pollen and macrofossil analyses found that the turves came from a wet sedge-dominated pasture (Macphail, Bill, Cannell, Linderholm and Rødsrud 2013a). The uppermost, silt-loam-sealed part of layer 10 at Fryasletta also included probable fragments of dung. This layer 10 and the overlying layer 9 (silt-loam alluvium) are phosphate enriched. In layer 10, organic fragments are iron-phosphate impregnated (0.0–0.81% P, 0.0–0.45% S, 2.60–7.93% Ca, 10.0–11.7% Fe), while voids within the layer 9 alluvium can be infilled with amorphous iron-phosphate (1.49–1.73% P, 0.0–0.59% S, 5.17–6.33% Ca, 43.2–50.8% Fe; Figures 27.13–14). These secondary phosphate features testify to the precipitation of phosphate from the locally flooded pasture soils, probably under standing-water conditions (flood ponds; Cruise et al. 2009). For a short time too, wetland plants rooted into this alluvium. Lastly, it is worth noting that the overlying higher-energy sands and gravels of layer 8 include an example of phosphate-stained byre waste (0.36–0.48% P, 3.62–5.53% Fe), consistent with models of longhouse animal management.

Brandrud

At Brandrud I, layers 1121 and 1122 record various alluvial sediments of different character, from silts to higher-energy sands and gravels, with silt loams recording flood ponds. These finer sediments were also subject to ice lensing at times. Excavations at Trench 1 and Brandrud IV revealed humic alluvium (1047) over coarse-braided stream sediments (1048). Here and elsewhere along the Lågen river valley, humic alluvium is the result of the erosion of humic soils, some clearly of agricultural origin, when charred byre waste and dung are also deposited. An example of this is layer 1083 at Brandrud IV, Trench 2.

A number of agricultural soils were analysed. For example, at Brandrud I, Trench 1, alluvial-sediment layers 1121 and 1122 overlie thick, inundated, cultivated Ap horizons (layers 1123 and 1125). These were bioactive and still rich in the organic remains of manuring (Figure 27.13). Groundwater (inundation) effects led to much iron staining of the organic

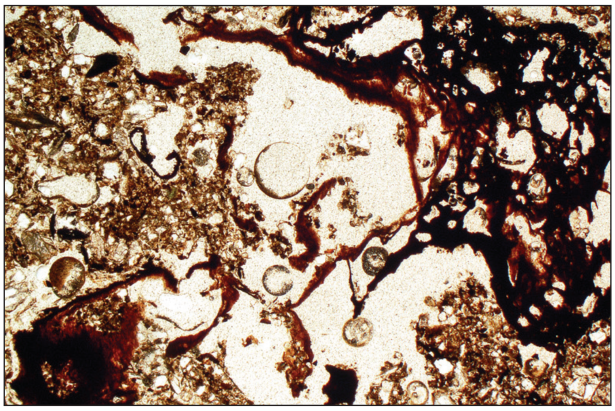

Figure 27.15. *Brandrud: Photomicrograph of M1B (Brandrud 1, L1123); reddish brown and blackened charred, humified byre waste with iron staining. PPL, frame is ~2.38 mm.*

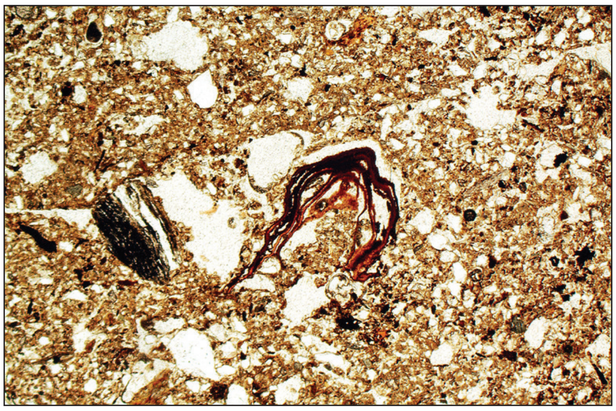

Figure 27.16. *Brandrud: Photomicrograph of M151, layer 1083, Brandrud IV, Trench 2; bioworked humic silts include layers of fine, charred byre waste, including this humified possible tree bud (centre). PPL, frame width is ~4.62 mm.*

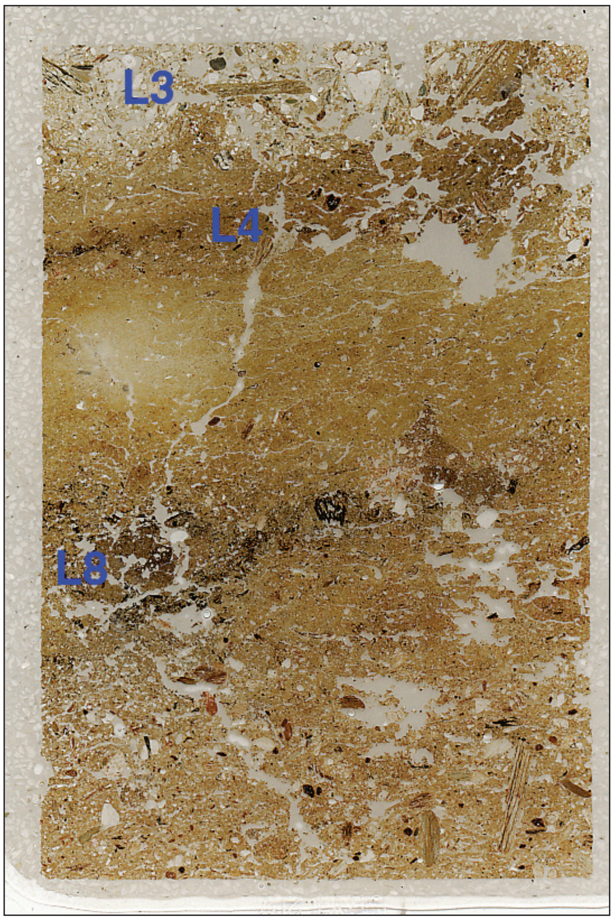

Figure 27.17. Grytting: Scan of M207 (Trench 1, Profile 2), showing complex stratigraphy. There is a relict lenticular microstructure (from ice lensing) as well as a bioworked concentration of weakly burned soil containing charred byre waste (L8; see Fig. 16). L4 also has a similar lenticular microstructure and charcoal-rich lens that is water-lain. L3 records higher-energy sand and gravel alluviation. Frame width is ~50 mm.

remains, but no phosphate was picked up by EDS, probably because of hydromorphic leaching (Lindbo, Stolt and Vepraskas 2010). There is a complex soil sequence at Brandrud IV, Trench 1, where layers 1050 and 1051 testify both to the inundation of a manured agricultural soil formed in silty alluvium and to the fact that this location was also affected by woodland rooting / woodland. Similarly, alluvium (1051) seals settlement soils (1052, 1054) which has been enriched by a spread of charred byre and settlement waste. In Trench 2, stream sediments (1077) overlie eroded and mixed agricultural soil remains where, again, manure includes charred organic matter. Layer 1083 is a low-energy flood (ponded) sediment, where flooding picked up and locally(?) deposited charred byre waste, likely including tree-bud fragments. It is evidence of the use of woody browse in over-wintering stock (Myhre 2004; Viklund et al. 2013; Figure 27.14).

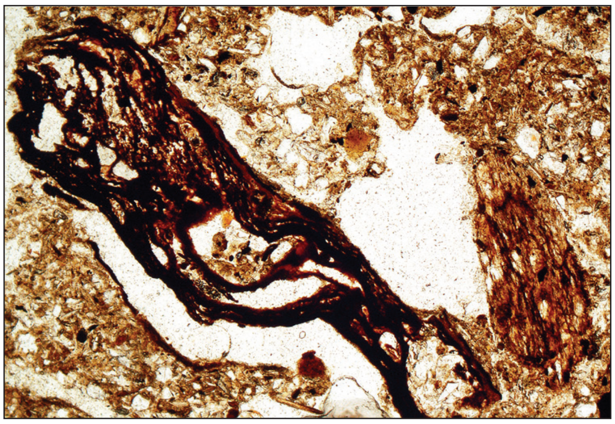

Figure 27.18. *Grytting: Photomicrograph of M207 (Trench 1, Profile 2), L8; reddish brown and blackened, charred byre waste, which was also iron (and P?) stained. PPL, frame width is ~2.38 mm.*

Grytting

Numerous examples of alluvium were studied, including high-energy sands and gravels (L3) and lower-energy silt-loam sediments (L4 and L8) at Trench 1, Profile 1. Ice lensing also affected these silt-loam sediments in places. A longer sequence was analysed from Trench 2, Profile 4, where a number of mainly coarse (e.g. L2, L6, and L11) sediments were analysed, alongside examples of lower-energy silts, such as L5. This 'yellowish silt' is this colour because it is humic, the stream having picked up / eroded fine organic matter from the local and upstream soils. It can be noted that inundation of soils leads to soil slaking and the liberation of organic particles, that are then floated or transported away – this subject will be dealt with in more detail later in the overview. Such organic matter includes charcoal and charred organic matter (cf. 'The Stumble', Essex and Goldcliff, Gwent; Bell, Caseldine and Neumann 2000; Macphail, Allen, Crowther, Cruise and Whittaker 2010). 'Burned Layers' at Trench 1, Profile 1 include what appears to be eroded charred byre waste and charred humic soil clasts (layers 4 and 8), as also recorded at Fryasletta layer 8 and Brandrud layer 1083, for example. Equally, at Trench 2, Profile 4, the lowermost soil studied (L11) is again what seems to be the compacted remains of an agricultural soil formed in alluvium, while the overlying L8 (within layer 9a) is rich in charred byre waste (Figures 27.17–18). Even flood sands and the gravelly layer 2 include a fragment of seemingly ferruginised dung that is of settlement origin. However, these lower charcoal-rich layers at Grytting achieved unexpectedly early dates (calibrated 4500–4340 BC, 3500–3120 BC, and 2860–2490 BC), that is, the transition from the Mesolithic to the Neolithic (I. Gundersen and T. Villumsen, pers. comm.). Obviously, this poses some

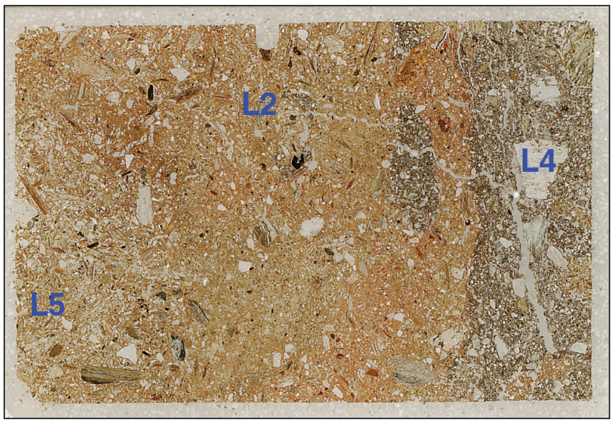

Figure 27.19. *Grytting: Scan of it shows background basal soil sediment (L5), a hearth with rubification (reddening) from use constructed from fine loam (L2), and a later stakehole fill of humic soil (L4; see Fig. 16, Table 1). Width of scan is ~75 mm.*

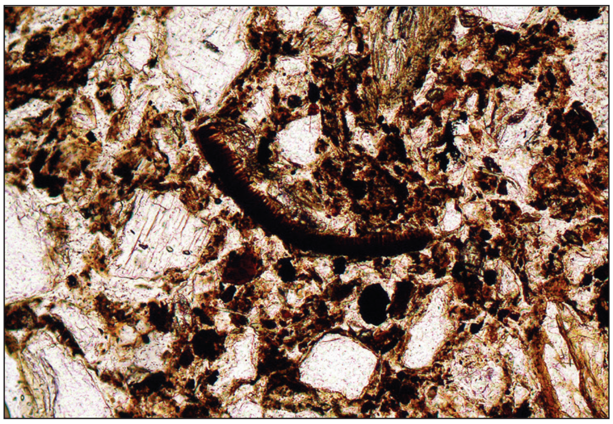

Figure 27.20. *Grytting: Photomicrograph of M409 (Cut 2, S319 and S276; see Fig. 15); humic-soil stakehole fill (L4) with possible charred seed-case residue (centre). Humic (3.7% LOI) soil is moderately phosphate rich (410 ppm P2O5), with a high PQuota of 2.81, consistent with dung being present – possibly marking a change in the use of space or structure (Table 1). PPL, frame width is ~0.90 mm.*

problems. Either (a) the charred manuring byre-waste material has been misinterpreted and is in fact wildfire material (as detailed from Fryasletta) or (b) very early manured agriculture did in fact take place or (c) dating material was composed of relict (older) charcoal and agricultural activity was in reality carried out at a later date. These layers may thus remain enigmatic.

A single study of an AD 200–600 settlement / house feature was carried out at Grytting (Cut 2, S319 and S276). Here, soil micromorphology and magnetic susceptibility (MS = 87 units, MS550 = 85 units; χlf 10-8 m3 kg-1) confirmed that a hearth (L2) had been constructed of a probably specially collected sandy loam sediment and that a later stakehole (L4) recorded a different use of space/structure which was more associated with animal management; it had a dung- and organic-phosphate-enriched humic fill (Figures 27.19–20). Bulk soil analyses found for example that the burned hearth (L2) was also poorly humic (1.2% LOI) compared to the stakehole fill (3.7% LOI), which showed a moderate phosphate concentration predominantly of organic phosphate (410 ppm P2O5; PQuota = 2.81), as found in dung-enriched deposits (Engelmark and Linderholm 1996; Goldberg and Macphail 2006).

Øybrekka

At 141001, Profile A, Section 1–2, sandy and silty alluvial layers L11, L5, and L3 were investigated. The silty layer L5, for example, showed a marked lenticular and ice-lensing structure (Van Vliet-Lanoë 2010). It was also noted that the lowest alluvium studied (L11) is much more minerogenic than L3, which is humic because of the erosion and flooding of local soils, including agricultural soils. At this section, there is a layer of concentrated fine pelletised charcoal and wood char (L28), some of which has been burrowed down into the upper part of L11 (Figure 27.19). There is also a preserved fragment of what is probably a charred tree bud (cf. reference material in Macphail and Crowther 2012; Figure 27.20). This layer and its silt-loam minerogenic component are clearly similar to that of 1150 at Fryasletta, where pelletisation and bioworking of wood-charcoal-rich sediments had also taken place. This charcoal layer could also be of a wildfire origin. It is unknown whether the ice lensing in the overlying ~0.20–0.30 m thick silts of L5 records a long period of stability after these ponding episodes, but the uppermost part is strongly bioworked and mixed with humic and charcoal rich material of byre-waste origin (L4). In these manured soils, the presence of sclerotia is likely indicative of fungal working of dung. The presence of mammillated excrements, of probable earthworm origin, testifies to soil amelioration. Upwards, the boundaries between L3 alluvium and agricultural soil L9 are diffuse because of this in-situ bioworking of the agricultural soil layers.

Natural site-formation processes

Fluvial, mass-movement (landslide) and cool-climate phenomena

As described for four sites, migrating stream action within a braided river system has led to higher-energy sands and gravels and lower-energy silt-loam sediments being encountered within sequences at the same location (channels, channel margins, and overbank deposition). Silt-loam sediments have also preferentially recorded frost action (Van Vliet-Lanoë 2010). These silt-loam sediments are important because they seem to record low-energy flood and/or ponded

Figure 27.21. *Øybrekka: Scan of M11 (141001, Profile A, Sections 1–2) showing silty and sandy L11, charcoal-rich, silty L28 and broadly layered silt loam L5, which includes a band of gravel. There has been bioworking of L28 material down-profile into the top of L11, including a charred tree-bud fragment (arrow; see Fig. 20). Frame width is ~50 mm.*

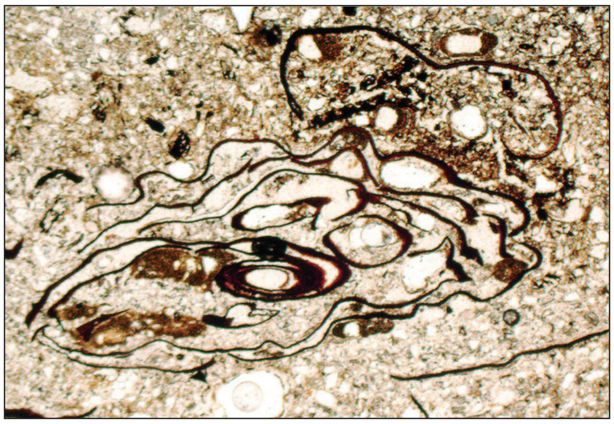

Figure 27.22. *Øybrekka: Photomicrograph of M11 (141001, Profile A, Sections 1–2); uppermost L11 with bioworked humic sediment from L28 above. This includes a charred fragment of a tree bud. PPL, frame width is ~4.62 mm.*

deposition, where organic matter released from soils can be concentrated (see below). Mass-movement landslide/mudslide deposits show microfeatures of having been water saturated, affecting the underlying agricultural soils by slaking them and coarsely mixing them with minerogenic sediments. Some of the latter include soils and clasts of probably periglacial origin, as present in solifluction deposits, for example (Fedoroff et al. 2010; Van Vliet-Lanoë 2010).

Part of the effect of flooding is the liberation of organic inclusions within soils because soils lose their structure. Heavy objects like pottery do not move, but charcoal floats and often spreads over a larger area than it covered originally. This has been demonstrated at a number of sites (Bell et al. 2000; Macphail et al. 2010). It is therefore possible that the charcoal in 1150 may not necessarily be far travelled and that charred byre waste present in silt-loam alluvium is also of relatively local origin.

Bronze Age wildfire event

Although best studied in Fryasletta layers 1150/1151, an 'early' wood-charcoal-rich layer within a silt-loam alluvium is also present at Øybrekka. The combined soil-micromorphological, EDS and pollen analyses indicate a wildfire (or widespread woodland clearance) event at Fryasletta, where woodland burning allowed pioneer plants (e.g. *Epilobium angustifolium t.* – fireweed / rosebay willowherb – and *Pteridium*) to invade. The resulting wood charcoal and char that is indicative of enhanced temperatures were transported possibly locally by flood water; soil humus was also redeposited. An example of a burned mollusc and fine burned bone of probable riparian carnivore-scat origin were also picked up and deposited. Similar burned bone fragments have also been recorded from burned Allerød forest soils. A binocular assessment of these charcoal and wood-char (carbon polymer / carbonaceous) materials in layer 1150 by M.-A. Courty found an abundance of possible impact-relevant components, particularly coloured carbonaceous filaments and vitreous char together with other ones (e.g. angular quartz with shiny faces), which could suggest that the wildfire occurred through a meteor impact (Courty 2012; Courty et al. 2008). This is unproven, however. On the other hand, such extra-terrestrial events have been recently recorded at Chelyabinsk, Russian Federation (15 February 2013), and in the last century at Tunguska, Siberia (1908).

Agricultural land use

Soil-micromorphological studies, composed of both experiments and analogue archaeological investigations, have mainly been carried out in conjunction with environmental studies, employing pollen, macrofossils, chemistry, and magnetic susceptibility (see reviews in Courty et al. 1989; Goldberg and Macphail 2006: 202–207; Lewis 2012; Macphail 1998; Macphail, Courty, and Gebhardt 1990). Soil-science studies formed the basis of this application. In north-west Europe, there has been a long-term practice of manuring to improve infertile soils, with manure coming from both the byre and the settlement in general, and this has had the effect of raising the level of biological activity in soils. Experiments and archaeological studies in Scandinavia have also shown that manuring raises the level of biological activity and is associated with phosphate enrichment and a raised proportion of organic phosphate – for example in sites along the E18, Vestfold (Engelmark and Linderholm 1996; Viklund, Engelmark and Linderholm 1998; Viklund et al. 2013). It can also be noted that studies along the E18 found that settlement-feature deposits and cultivated soils contain charred byre waste, which include woody browse (see also Myhre 2004). The presence of charred dung and ferruginised dung residues as well as byre waste that includes woody material (wood charcoal and charred tree buds) in bioactive soils – which are humic because of humified dung inclusions – supports the identification of manured cultivated soils at the four sites analysed. 'Mixed farming' included the presumed housing of stock in longhouses, although no analyses were carried out (cf. Løken 1999; Viklund et al. 2013). Only the stakehole fill through a hearth at Grytting indicated in-situ presence of dung-rich house deposits (cf. Butser Experimental Farm; Macphail, Cruise, Allen, Linderholm and Reynolds 2004; Reynolds 1979). It was therefore also important to see minor evidence of both fallowing and pasture-soil development across the Fryasletta site, with very strong evidence of an in-situ water meadow pasture soil enriched with dung (and background phosphate) at Area 4, Profile 4B, Section 1.

CONCLUSIONS

Twenty-six monolith samples from the four E6 sites of Brandrud, Fryasletta, Grytting, and Øybrekka were employed to make thirty-eight thin sections for a soil-micromorphological study of seventy-seven layers. Three thin sections also underwent SEM/EDS analysis. A limited pollen study and a binocular assessment of carbonaceous materials were focused on an assumed Bronze Age charcoal-rich layer at Fryasletta (layer 1150). A very restricted particle size (x1 sample – Fryasletta) and selective chemistry and magnetic-susceptibility study (x6 samples – Fryasletta and Grytting) were also carried out. While the river Lågen sands and gravels are the result of channel and channel-bank deposition, lower-energy silt loams record overbank sedimentation; there is evidence that these are also associated with ephemeral areas of standing water and ponds. These silt loams were especially prone to developing features associated with frost action. Mass-movement slope deposits included both relict periglacial soils and locally reworked cultural soils. They also show evidence of being typically water saturated, which affected the soils they buried. Flood inundation and the occurrence of high-water table effects on the Gudbrandsdalen soils had several results, including the probable widespread hydromorphic leaching of soil phosphate. In addition, flood water often slaked soils, allowing easy erosion. This is because these soils could lose structural integrity. Sometimes, buoyant materials like charcoal and fine humus were released, and these organic materials became redeposited within some flood-silt loams. Archaeological analogue studies suggest that if in-situ ponding occurred, such charcoal-rich layers may be localised to the source of this charcoal. Two types of charcoal-rich layers have been recognised in general: 'early' wood charcoal and wood-char layers (e.g. Fryasletta 1150 and Øybrekka 28), and 'later' ones associated with the agricultural landscape, including charred dung and byre waste. The latter is sometimes of woody-browse-fodder origin (e.g. tree-bud fragments). In addition, enigmatic charred byre-like layers occur at Grytting, but these have very early (Mesolithic–Neolithic transition) dates and for the present remain unexplained. At Fryasletta, the supposed Bronze Age wood-charcoal- and wood-char-rich layer of 1150 within a silt-loam alluvium sediment (1151b, 1152a) is not in-situ evidence of a possible wildfire but probably a localised record of this. The binocular assessment (by M.-A. Courty) found an abundance of coloured carbonaceous filaments and vitreous char in particular, with examples of transformed quartz, which could be possible meteorite-impact-relevant components, and such an event could have initiated a wildfire along this part of Gudbrandsdalen (also possibly recognised at Øybrekka some 25 km to the north). There is no proof or other indications of this, however, and so for the moment, this possible widespread event can best be associated with a wildfire or deliberate woodland-clearance fires. The pollen study (by G. M. Cruise) of the charcoal-rich silt loam found *Pinus*, *Betula*, *Alnus*, and *Corylus* to be present. More importantly, woodland burning seems to have allowed pioneer plants to invade the location of the wildfire (e.g. *Epilobium angustifolium t.* – fireweed / rosebay willowherb – and *Pteridium*). Soil humus containing this pollen was also eroded and probably locally deposited, which is indicated by small phosphate concentrations with a typically high organic-phosphate content, as found in natural topsoil humus and peat. Agricultural soils were also investigated, and manured cultivation was recognised by heightened levels of biological activity in humic soils enriched with dung and charred byre waste, for example. Sometimes, small amounts of settlement waste were also found. Two bulk chemistry and magnetic-susceptibility analyses supported this view, and these findings are overall consistent with Scandinavian experimental data and agricultural soil studies elsewhere in Norway, where other ameliorated 'plaggen'-like soils have been investigated. A single thin section and complementary bulk chemical- and magnetic-susceptibility study of a settlement structure at Grytting showed a change in space from 'domestic' (hearth) to one where dung residues and organic phosphate were found in a stakehole. Animal management along the valley is also implied by the ubiquitous occurrence of dung and byre remains in the cultivated soils. Some traces of possible pasture use / fallowing were found within the agricultural soils at Fryasletta. Here, one location at Area 4, Profile 4B, Section 1, clearly recorded the presence of a poorly drained water-meadow pasture soil ('laminated mull' topsoil). The dung residues and background phosphate concentrations (EDS data) are both consistent with a grazed landscape (as found at Viking Gokstad, Vestfold) and standing flood waters that inundated the site and sealed the soil with a silt-loam alluvium.

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