11. THE ALLUVIAL SEQUENCES IN GUDBRANDSDALEN

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INTRODUCTION

A river represents opportunity and risk. River valleys great and small, across cultures and climatic conditions, have long been a focus for settlement within the landscape, as discussed throughout this volume. The flowing water is a source of food, water, energy, precious sediment for cultivation and a means of transport, but it is also an unpredictable source of danger and destruction to those that exploit it (Edgeworth 2011). In Nordic climes, the danger is primarily flooding on all scales, from events that rapidly wash away trees and buildings to those that slowly but stubbornly saturate crops and lower subsequent yields. To many, the word *flood* simply means an excessive volume of water, but floods also carry massive amounts of sediment and debris downstream, tearing materials from one place and depositing them elsewhere. This article considers the stratigraphical evidence from the archaeological sites excavated in 2011 and 2012 for the landscape alterations the River Lågen has naturally caused, more specifically by flooding, in terms of impact on the human population and the frequency of events. The archaeological sites revealed significant new information about human settlement on the banks of the River Lågen, in North and South Fron municipalities, Norway. After detailed on-site recording, samples were taken either from cores or from exposed stratigraphy for magnetic susceptibility (MS) and particle analysis in order to further detail the flooding sequence and impact.

Gudbrandsdalen is a major valley in central south-eastern Norway, orientated north-west to south-east. The glaciated valley is over 230 km long and ends in lake Mjøsa, Norway's largest lake. The River Lågen, sometimes referred to as the Gudbrandsdalslågen, flows along the valley and is sourced in the mountain ranges of Dovre, Rondane, and Jotunheimen. These ranges, which have the highest peaks in Norway and where much of the area reaches over 2,000 m.a.s.l., also support many small cirque glaciers and ice patches on the higher peaks, particularly in Jotunheimen. It is the seasonal glacial melt water that is the major source of the River Lågen via its tributaries. On the valley floor, the elevation ranges from c. 610 m.a.s.l. at the river Lågen's source at Lesjaverk, to c. 125 m.a.s.l. where it reaches Mjøsa. The climate is cool temperate, with mean annual rainfall less than 500 mm per annum in the valley base but up to 1,500 mm in the surrounding mountains (Støren, Kolstad, and Paasche 2012). For example, Hundorp, located in mid-Gudbrandsdalen and fairly centrally to the sites discussed in this text, has a mean annual precipitation of 460 mm, a mean annual temperature of 2.5 ˚C, an average July temperature of 14.9 ˚C, and a January mean of –11 ˚C (Norwegian Meteorological Institute 2013).

The sites referred to in this text were excavated under the auspices of the Museum of Cultural History, as specified in previous chapters. During excavation, it quickly became apparent that the exposed stratigraphy represented a complex sequence of flood events on all sites, making the archaeological preservation more piecemeal and the interpretation challenging. The occurrence of floods in Gudbrandsdalen is well documented in modern times, and the reader is referred to chapter 9 of this volume for more details. The effects of documented events have included damage to infrastructure, land, and livelihood and in the case of Storofsen, many lives were also lost. Evidence of flooding, therefore, is not merely a point of interest in the stratigraphy, as such events in the past would potentially have been equally devastating to the local population, both economically and socially.

It has long been speculated that the majority of the large gravel deposits in Gudbrandsdalen were not moraines, as initially thought, but the result of landslides and material brought down the valley sides by stream flooding (Mangerud 1964). This phenomenon has become more widely studied in recent years, leading to new phases and definitions of the processes that occur in valleys post glacial retreat. Ballantyne (2002) discusses the idea of paraglacial processes, where, in a nutshell, the initial release of pressure after glaciation results in rapid landscape readjustment, then gradually decreasing readjustments in landscape deposition,

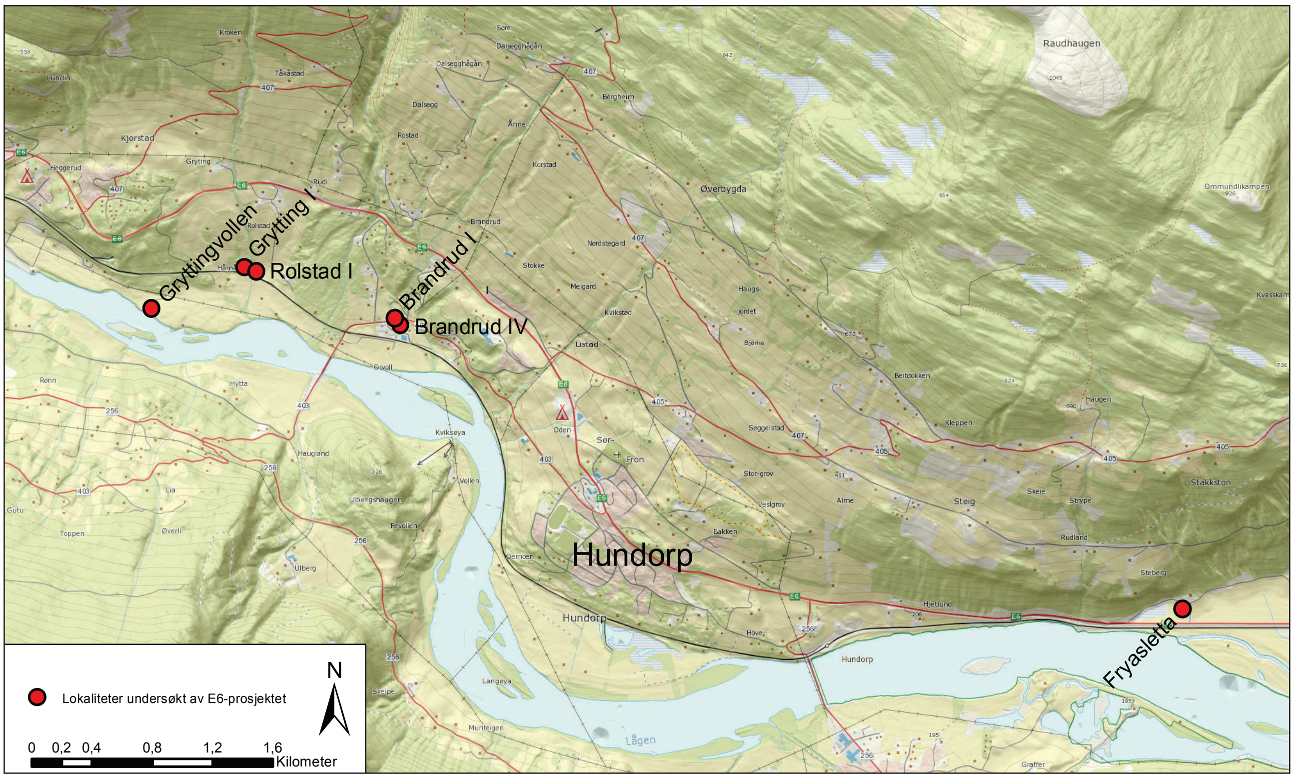


Figure 11.1. *The location of the sites in Sør-Fron municipality combined with LiDAR-data. LiDAR-data: Lars Pilø, Oppland fylkeskommune. Produced by Ingar M. Gundersen.*

leading to sediment and rock movements over time that aim to reflect the new energy balance and create an equilibrium. This can be in the form of collapsing moraines, rockfalls, colluvial fans, and larger slope failures / landslides. The landslides can be mobilised by floodwater, often sourced in spring melt from the upland glaciers and ice patches that feed the River Lågen. Flowing over part frozen or saturated ground, valley streams easily mobilise the poorly consolidated moraine and colluvial material on the valley slides, causing landslides of various scales. This material is primarily deposited in the alluvial fans that are found throughout this part of Gudbrandsdalen, usually where the slope slackens, changing the sediment movement from erosional to depositional (Knighton 1998). The term *alluvial* is generally applied to sediments mobilized and deposited by water. If the action is solely by a river, the term *fluvial* could be used; however, here the deposits include sediments moved by rainwater, overland flow, and rivers, so the term *alluvial* is applied. Colluvial deposits are created by gravity and range from very slow processes, such as soil creep, to massive landslide deposits. The foot of a slope tends to accumulate both alluvial and colluvial deposits, especially where a stream bed is located, the stream flowing either permanently or only in times of flood. Such deposits are referred to as alluvial fans. The archaeological sites of Brandrud and Grytting are located on such fans.

Geologically, Gudbrandsdalen and the River Lågen, with Jotunheimen to the west and Rondane to the east, constitute a complex sequence of intrusive and autochthonous rocks of Caledonian age. Much of the local geology is fairly soft sedimentary rocks and metamorphosed sedimentary rocks. These produce the coarse and fine silts that dominate the sediments deposited by the River Lågen, which in turn create the fertile pockets of floodplain soils. Several faults run through the area, connected to the igneous intrusions that dominate the higher elevations to the east and west. In places the bedrock is covered by thick moraine of mixed geology from several types of glacial processes.

LANDSCAPE FEATURES, SOILS, AND SEDIMENTS

All the archaeological sites referred to are described in more detail in related chapters within this volume. Of the five sites discussed here, Øybrekka is the furthest upstream, some 5 km west of Kvam. Grytting, Rolstad, and Brandrud I and IV are located close to each other near the current river course just 2–3 km north-west of Hundorp. The site of Fryasletta is located on the western edge of the plain Fryasletta, some 3.5 km east of Hundorp (See figure 9.2 in chapter 9 and figure 11.1 in this chapter).

Brandrud I and IV

The sites of Brandrud I and IV are located on land sloping very gradually down to the present course of the River Lågen, the current course being some 300 m south of Brandrud IV. To the west, currently by 300 m, is the River Augla, which in post-glacial times has created an alluvial fan, upon which the sites are located. In times of flood, the river creates a braided channel network over the fan, as evidenced by the numerous gravelled channel beds of various dimensions. Upstream, the Augla and the nearby Brandrudsåa have cut gullies through the poorly consolidated moraine and colluvial deposits. The rivers are prone to flooding, and the Augla has visible abandoned channels from previous high flow periods when it has shifted course (Ballantyne 2002; Mangerud 1964).

The soils at Brandrud are varied but generally poorly developed due to frequent erosion, truncation, or burial by floodwater and are therefore very immature. The area of the site and alluvial fan is dominated by leptosols, shallow fluvisols, and cambisols, and I suggest it has been for the majority of the current post-glacial period.

Where the River Lågen has deposited deep alluvium after a flood, a shallow fluvisol develops, temporarily providing excellent agricultural conditions, before this too is eroded or buried through further flooding. There is evidence for several such events in trenches 1 and 2 at Brandrud IV, and from the alluvial sediments under the Iron Age house at Brandrud I (Loktu and Gundersen chapter 14, this volume). The land has always been marginal for agriculture in terms of risk and climate; however, the alluvium would have created areas of relatively productive and easily worked land.

Grytting I and Rolstad I

The sites are located upon an alluvial fan and on the edge of the floodplain of the River Lågen. Running between the two sites is the River Lauvåa, a small stream that has cut a deep gully upstream but levels out somewhat at the site. This decrease in slope marks the transition to the alluvial fan and thus from a primarily erosional to a depositional environment (Knighton 1998). Both Rolstad I and Grytting I are located at the foot of the valley slope on cultivated land. The upslope cultivation, particularly at Rolstad, has resulted in fine colluvial deposits from more recent ploughing eroding the topsoil, which has accumulated over the archaeological deposits.

The soils at Grytting and Rolstad reflect their location on the edge of the floodplain. On the alluvial fan, the soils are generally regnosols and leptosols, that is, shallow topsoil's over mixed gravels from floods and mass wasting. Nearer the River Lågen, fluvisols have developed on the flood sediments, as at Brandrud.

The soil at Rolstad is classified as an umbrisol, which is a dark, slightly acidic, humic topsoil. It covers flood gravels found at less than 1 m in depth. This topsoil is a product of fine colluvium, and the compact gravels below are part of the alluvial fan and flood history of the site.

The River Lågen has migrated in recent times, and the palaeochannel is clearly visible in LiDAR imagery (Gundersen chapter 10, this volume). The former course is utilised by the river in times of flood, as in 2011 and 1995. The site is now on a slight terrace above the current Lågen floodplain, the river having incised into the lower floodplain, leaving the site presently less prone to flooding from the River Lågen.

Øybrekka

The archaeological site is located between 275 and 280 m.a.s.l. at the foot of a steep valley slope. The River Lågen flows c. 700 m to the south-west; however, the River Kolobekken joins the River Lågen at this point, and the confluence floodplain is just over 100 m from the site. The abandoned channel, Bakkaløken/Kaldbekken, is part of this confluence and floodplain. The River Lågen and its tributaries are sediment rich and have created multiple channel bars, and abandoned channels as the river has migrated with each flood event. The sediments on the site reflect its location on the edge of the floodplain. A further influence on the site is a small stream that currently flows north-west of the site, where it joins another small stream. It is clear from the stratigraphy that this stream once ran through the site and has shifted course several times during previous human occupation phases. The soils clearly reflect the contrast between the fine flood sediments from the Lågen, and the high-energy, coarse deposits of the stream bed and flood layers. The soil is classified as a haplic cambisols, which means it is a poorly developed soil without any abrupt changes up to 1 m in depth and is low in nutrients. This matches well with on-site observations, which indicated fine alluvium interspersed and cut by localised coarser, high-energy gravel deposits. Buried, cultivated topsoils were composed of alluvial silts and fine sands, some of which show truncation and reworking by floodwater.

Fryasletta

At Fryasletta, the valley temporarily widens from less than 1 km to 1.8 km as the River Lågen is met by tributary rivers, most notably the River Frya. The archaeological site of Fryasletta is located in this widening, just above the River Lågen floodplain, and on an alluvial fan situated at the base of a steeply graded bedrock rise. Over time, the River Lågen has migrated over the floodplain, as testified by the multiple channels and palaeochannels visible in topographic data. The river here is gently graded, sediment rich and depositional, meandering with point bars and pool and riffle formations together with associated mid-channel bars. Where the tributaries, such as the Frya and Våla rivers, join, small deltas have formed with mouth bars.

The nearby River Frya cuts through thick glacio-fluvial sediments, capped with more recent flood and landslide deposits (Mangerud 1964). The local soils are productive and would have been attractive for cultivation, although the need for stone clearance would be locally high. The soil types map the upper deposits of the area and confirm that the foot of the bedrock rise is dominated by rockfall/landslide deposition, with alluvium from the River Lågen dominating closer to the current river course. The area of the site is classified as a regnosol (eutric skeletic). This matches well with on-site interpretations, as this describes a fairly productive but shallow soil over gravels or bedrock. This is fairly local, with phaeozem soils on either side. In this case, this classification should be interpreted as describing a similar soil, but with greater depth of topsoil and subsoil (over 1 m) before meeting dense colluvial gravels. It simply means that the archaeological site is located on the topographical peak of the landslide/colluvial deposits and therefore at the local high point above the floodplain.

The rock face above the site is made of near vertical geological strata, most of which is composed of softer or poorly consolidated rock types, such as diamictite – a conglomerate – and metamorphic mudstones (phylites) and sandstones. The higher altitudes, and the mid slopes, are dominated by phylite, with the lower slopes and valley dominated by sandstones. The geological strata have contributed towards the frequency of large landslides at this site, which are dominated by local, angular boulders and gravels rather than reworked moraine.

METHODS

On-site recording

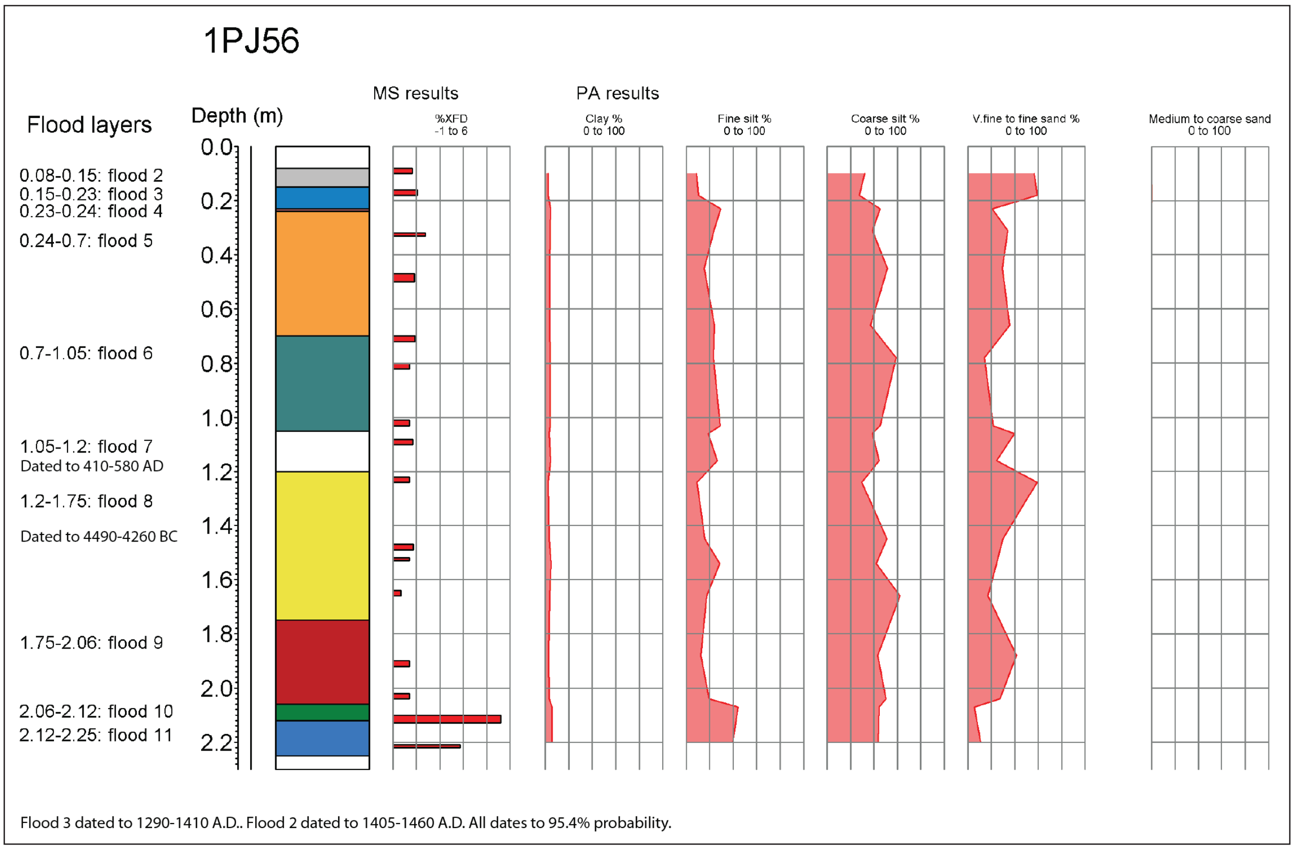
Detailed descriptions of archaeologically and pedologically defined layers were undertaken at representative sections, and samples were then taken for particle and magnetic susceptibility analysis. All sections were drawn, photographed, and described, including for Munsell colour, composition, and orientation. Samples were taken at stratigraphic and mechanical intervals down exposed sections with single use plastic equipment. At Gryttingvollen and Brandrud I, cores were taken in order to observe and sub-sample fine stratigraphy, and to obtain comparative sample data for the sequence of flooding from the River Lågen. The corer used was a Van Walt (Eijkelkamp) cylinder corer for hard soils. This uses clear plastic liners to take undisturbed soil samples for chemical and physical research. The cores are taken in sections of 300 × 50 mm and manually hammered into place. The cores can then be opened, described, and sub-sampled in laboratory conditions.

Laboratory methods

Magnetic susceptibility (MS)

The selected soil samples from the archaeological sites were sent for analysis by Petra Schneidhofer at the Vienna Institute for Archaeological Sciences.

To measure magnetic susceptibility, a sample to a small, alternating magnetic field, and the magnetisum of the sample is then recorded (Crowther 2003). Enhanced magnetism is generally caused by either burning or organic components in the sample (e.g. topsoil or midden material). There are several methods of analysing magnetic susceptibility; here, frequency dependent was employed. The sample is measured at high and low frequencies and the results compared. A statistically significant difference between the frequency results is suggested to be caused by the presence of superparamagnetic particles. These are caused by bacterial action, burning, or secondary pedogenesis and can be connected to human activity and enhanced organic inputs in the soil (Dearing 1999; Fassbinder, Stanjek, and Vali 1990). For more details and the complete analytical results, the reader is referred to Schneidhofer (2013). The method has proven successful in archaeology for a variety of research applications. It is an affordable method for detecting human activity, such as direct settlement, cultivation, and related erosion, and 'natural' events, such as buried soils. The motivation for applying the method to the sites in Gudbrandsdalen was to detect periods of stability and settlement within the flood deposits as well as flood events which, due to later soil processes, are difficult to see in situ.



Flood 3 dated to 1290-1410 A.D.. Flood 2 dated to 1405-1460 A.D. All dates to 95.4% probability.

Figure 11.2. *Particle analysis and magnetic-susceptibility results from flood layers identified in core 1PJ56, Gryttingvollen.*

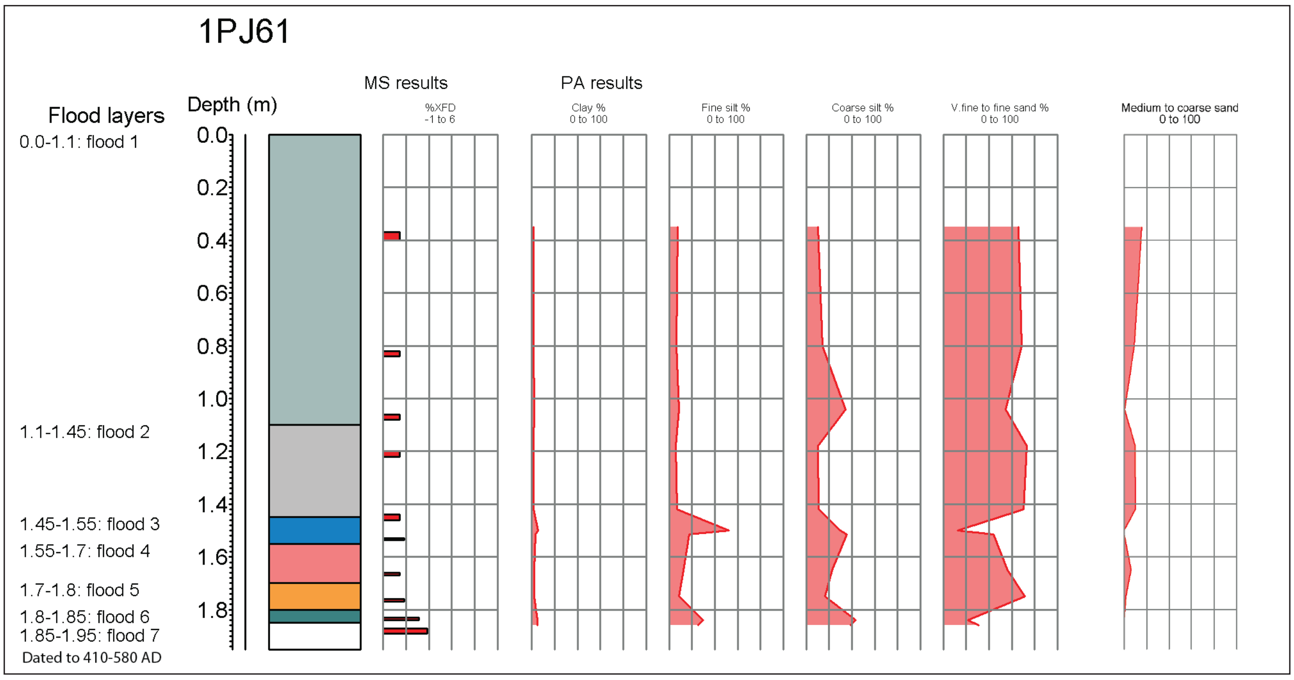


Figure 11.3. *Particle analysis and magnetic-susceptibility results from flood layers identified in core 1PJ61, Gryttingvollen.*

Particle Analysis (PA)

The analysis of selected samples was undertaken by Mufak Naoroz at the Department of Geosciences at the University of Oslo, using a Beckman Coulter LS 13 320 particle size analyser. The prepared samples were pre-treated with a sodium hexametaphosphate solution (calgon) and placed in an ultrasound bath for 3–5 minutes prior to analysis with the instrument. This is essential to defloccate (remove the binding charge) of the clay fraction.

Sometimes referred to as grain size analysis, this technique counts the proportion of clay, silt, and sand with a diameter of under 1 mm (in this case) in a sample. The instrument uses a laser counter rather than the traditional sedimentation method and is therefore quicker, more cost effective, and more accurate for finer grain sizes (Pansu and Gautheyrou 2006). The separation of the larger fraction (over 1 mm) was done manually by sieving pre-dried samples.

RESULTS

Comparative cores

The purpose of the two overlapping cores taken at Gryttingvollen was to quantify the sediments known to originate from the River Lågen during known flood events and to compare these findings with the data from the archaeological sites. The cores taken on the floodplain at Gryttingvollen (figure 11.1) indicate the high frequency of flood events, and there is a general conformity in particle sorting and size throughout the cores. Particle analysis results suggest there are at least four floods represented by core 1PJ61 and nine in core 1PJ56; the layers in figures 11.2 and 11.3 are combined with observations. In addition, buried topsoil horizons were identified and radiocarbon dated, the results implying the cores represent an extended period of time, although the deposits are of course secondary. The increased magnetic susceptibility in flood 10, core 1PJ56, is below a buried topsoil, radiocarbon dated to 4490–4260 BC, placing the topsoil development in the Neolithic. The base of 1PJ61, labelled flood 7 and also a buried horizon with a corresponding increase in magnetic susceptibility, is dated to AD 410–580, that is, the early migration period. As flood 7 is potentially found in both cores, it can be assumed that the lower half of core 1PJ56 dates from the Roman Iron Age and earlier and the upper half represents the last 1,500 years. The great insecurity in dating flood layers must be stressed, and this is demonstrated by the date 4490–4260 BC from flood 8b in core 1PJ56. The sample was taken in a silt-rich lens with charcoal flecks at a depth of c. 151 cm. This date throws into question the reliability of all the other dates, as it seems highly unlikely that flood 7 is over 4,000 years younger than flood 8b. Given the location of the cores in a sandbank close to the modern river channel, it is likely that this represents in-washed material eroded from upstream by floodwater.

The sediments' size and sorting does vary slightly from one core and flood to another, but this reflects the fact that flow and deposition are not uniform over space or time. They have broad similarities, from which a general 'signature' for the Lågen can be constructed. This can clearly be seen in the results from particle analysis. There is a consistent dominance of particles of between 40 and 200 µm, that is, coarse silt and very fine sand, which is typical of fluvial sediments transported by high-order rivers.

Brandrud I and IV

Based upon results and observations, primarily from trench 1A at Brandrud IV, there is a clear distinction in particle size and sorting between deposits. The samples from the upper strata are skewed toward finer particle sizes (less than 1 mm) and have a dominance of silt (c. 60–70%) in the matrix. These are clearly alluvial deposits from the River Lågen flooding, and they have a distribution similar to some samples from cores 1PJ61 and 1PJ56. The lower strata samples are composed of poorly sorted sediment, and although on site they were interpreted as fine, gravel-free lenses, the particle analysis suggests they are dominated by sands. Some of the layers analysed in the comparative cores were also dominated by well-sorted fine sands; however, the degree of sorting is not evident in the Brandrud samples.

The magnetic susceptibility results, combined with on-site observations, confirmed all four identified buried and cultivated horizons. In addition, the results identified a truncated soil that may have been a stable cultivated layer (layer 1052). Hence, soils have been inundated or washed away several times but have, upon stabilising once more, been resettled.

Overall, the lower strata indicate the dominance of landslide deposits and the limited influence of the River Lågen. The Lågen once flowed nearer the site than it does now, which is evidenced in the increasing silt-rich deposits between archaeological levels 2 and 1 (see Loktu and Gundersen chapter 14, this volume), suggesting that as a result of Gammelofsen (c. 50–1 BC), the river shifted course closer to the site and thus dominated the deposition sequence. The palaeochannel is visible in LiDAR data (see Gundersen chapter 10, this volume). The dominance of fine alluvium disappears after Storofsen and could mark the point where the river once again shifted course to the present channel.

Grytting I and Rolstad I

The Rolstad I samples selected for particle analysis are from flood layers that have stabilised into topsoil horizons. These have a distinct particle size distribution, with a lower percentage of coarse silt and a far greater proportion of fine silts. In addition, the consistently significant frequency dependent magnetic susceptibility results are consistent with the in-situ interpretation that a considerable proportion was composed of fine colluvium. The site is at the foot of a steep valley slope that is cultivated, which has resulted in a fine, homogenous, and over-deep umbric topsoil, and these processes appear also to have occurred in the past. These topsoil horizons are interspersed with fairly massive but occasionally well sorted gravel layers, representing at least two major stream flood episodes, the more recent being Storofsen (AD 1789) and the older the Merovingian period flood (c. AD 600–800; see Villumsen chapter 16, this volume).

Despite the sites being in close proximity, the surface geomorphology varies considerably between Rolstad I and Grytting I. The latter is located centrally on the alluvial fan, whilst the former is more to the periphery. Different land use and the weaker slope gradient immediately above Grytting I means there is little fine topsoil colluvium present and several more massive landslide/flood layers intercutting over the site. The present stream course has superseded several older channels, which have been backfilled with later flood deposits. The selected samples were taken from an exposed section in a trench cut from the modern upper B horizon, that is, after the topsoil had been mechanically removed. The upmost horizon had associated archaeology in terms of postholes and hearth features from a substantial Iron Age longhouse (see Villumsen chapter 15, this volume). The location appears to have been equally at risk from high floodwater from the Lågen and the nearby valley streams. The River Lågen did flow closer to the site in the past, as identified by airborne LiDAR imagery (Gundersen chapter 10, this volume), and the river still utilises the older channel in times of flood. Dating the channel shift precisely to its current course is impossible; however, as the site is so close to Brandrud I and IV, the shift after Gammelofsen perhaps also applies here.

Øybrekka

The highest frequency dependent magnetic susceptibility values are from Øybrekka. This is perhaps not surprising given the quality of the soil here and the clear evidence of soil improvement and cultivation over a long period of time. With the exception of the clearly defined stream channels cut through the site, the majority is fine colluvial and alluvial deposits on a moderate but workable gradient of slope. The site has been repeatedly cultivated after each flood inundation, probably using natural fertilisers, causing the high magnetic susceptibility values. The particle analysis results confirm, with one exception, the predominance of alluvium from the Lågen. The particle analysis results are essentially very similar to those from Rolstad and represent very similar layers and processes from fine colluvium and cultivation.

Fryasletta

With regard to the lower stratigraphy, there has been some speculation over the nature of the charcoal lens identified in several trenches. The layer is discussed further by Macphail (chapter 27, this volume). Directly above this layer is a water-lain deposit of very fine silts with some humic material. If the source of this charcoal layer were indeed a forest fire, after such an event, subsequent precipitation would erode the exposed topsoils, which could account for this thin, inconsistent layer. It is partly truncated and reworked by the massive colluvial layer above, representing Forrskredet, dated to c. 350–200 BC. The stratigraphical sequence suggests that prior to the forest fire, the river was slowing migrating away from a course that flowed over the site. At this point in time, a meander bend was gradually migrating away from the site, and the river subsequently migrated across the floodplain, eventually allowing the cultivation of the area in, possibly, the Bronze Age. The proximity of the river is testified by the lower deposits of finely laminated silts and sands representing low-energy, seasonal deposition. The very fine silts are also gleyed, suggesting the area was waterlogged for extended periods each year. Seasonal ice-wedge formation is also seen in these deposits, again indicating little or no current and therefore the very edges of a broad, shallow river channel.

Subsequent to the river migrating away from the site, there formed four main landslide layers that are clearly visible in the exposed sections; however, there is evidence for additional landslides within section 1A, resulting in an estimate of at least seven significant flood/landslide events. As mentioned previously, the site of Fryasletta sits on the peak of the alluvial/colluvial fan that has no permanent stream or river as a source for material. In the topography above the site, there is evidence for a stream bed flowing down the steep bedrock face and intersecting the site. The stream appears ephemeral, only active in times of very high discharge, or has totally abandoned that course. Slightly to the east of the site, both above and below the site's elevation, is an active stream bed, which could represent the new course.

Over time, the influence of the Lågen decreases, as it migrates away; however, its influence does not disappear altogether. In the upper layers, directly below the Storofsen deposit, is fine, laminated silt alluvium, which originates from the edges of a larger Lågen flood.

DISCUSSION

The significant frequency dependent magnetic susceptibility results are connected to increased organic content and can therefore be used to identify periods of topsoil development and thus stability, despite the fact that some of these layers are heavily truncated by later flood erosion. Enhanced organic content can also be the result of in-washed topsoil during heavy rainfall or flood; therefore, the results need to be considered in the stratigraphic context and in combination with other physical properties. Particle analysis quantifies in-situ observation by distinguishing between the source of flood and the source of the sediment. From this, the migration of the River Lågen can be proposed, giving a landscape context for previous settlement and land use as well as the overall picture of flood risk in terms of frequency and magnitude. The results have aided the identification of seven flood events from the section at Fryasletta, at least 14 major and minor flood events at Grytting, and up to 16 events at Brandrud IV (Cannell and Gundersen 2014).

Grytting and Brandrud are both located on alluvial fans associated with larger tributary streams. The fans are composed of complex sequences of intercutting colluvial and alluvial deposits. At Brandrud IV, there is more evidence for temporary stability and cultivation, as the influence of the Lågen in the depositional sequence is greater, creating well drained, fairly stone-free alluvium highly suitable for cultivation. These soils are often truncated and cut by later stream channels and landslide deposits, as they are at Grytting I. The magnetic susceptibility results clearly show the difference between the sites; there is only one significant result for Grytting I from 16 samples, and that is not particularly high (2.22 *X*fd %). This significant result is for layer 1014, sample P150-5, which is the layer that contains a rubified lens. This layer is below the excavated house and suggests earlier settlement, as discussed by Villumsen (chapter 15, this volume) and Macphail (chapter 27, this volume). A common phenomenon in alluvial environments is that several episodes of settlement become buried under sediment (Passmore, Waddington, and Houghton 2002), which strip-and-map archaeology is unfortunately not designed to uncover. Here, the project has adapted the excavation strategy to improve the chances of recovering complex vertical stratigraphy; however, as this was not considered at the evaluation stage on the majority of the sites, resources were limited. This one significant magnetic susceptibility result from Grytting I compares to six from Brandrud IV out of 19 samples, some of which are twice the frequency dependent magnetic susceptibility value of the Grytting sample. This suggests that the land near Brandrud IV was not only more suitable and attractive for agriculture but also less susceptible to being eroded away by floodwater. The settlement evidence on both the sites suggests houses were replaced and settlement was fairly continuous over much of the early Iron Age until around AD 600, suggesting the value of the land in cultural and economic terms outweighed the perceived danger.

At Grytting and Brandrud, the lower layers have consistently low frequency dependent MS results, most often zero. This suggests a change of influence in the deposition processes. The lower deposits represent processes dominated by poorly sorted high-energy stream deposits and a less stable landscape. The soils certainly have a lower humic content and no evidence of well developed topsoils. As there is no indication in the sediments that there has been poor drainage at any time or that the layers have been subject to extensive leaching, the conclusion is that the stratigraphy, with allowances for the frequent truncation of layers by floods/landslides, points to changing depositional and thus environmental factors.

The site of Fryasletta should only be directly compared to other sites in this text with good degree of caution. The location in terms of geology and topography, and the lack of proximity to a perennial stream or river are important factors in the development of the deep, clear stratigraphy. The clarity of the stratigraphy increases the value of the site for interpretative purposes, as it is highly likely that floods caused by intense spring melt are represented at Fryasletta and Brandrud/Grytting; however, the sequential developments at Brandrud and Grytting are much more complex. As indicated previously, the exposed section 1A at Fryasletta contains evidence of cultivation and topsoil stability and up to seven large landslide deposits. The landslide material is predominantly sourced from the rock face elevation behind the site, although there is some reworked moraine material as well. The vertical, soft metamorphic geology appears to be particularly vulnerable to erosion. Over the rock face, there are traces of ephemeral or abandoned stream beds, which have evidently been utilised during extreme flood events. It is therefore possible that Fryasletta, especially the upper stratigraphy, represents only extreme or high-return-interval floods and not the repeated risk and inundation from short return interval floods.

Støren, Kolstad, and Paasche (2012) used varves (seasonal lake deposits) to investigate changing flood regimes in upland lakes that receive a large proportion of inputs from seasonal glacial melt water. One of these lakes is within the Lågen catchment, Meringsdalsvatnet, located to the west of Gudbrandsdalen. Cored varve sequences are frequently used in palaeoclimate studies and geomorphology to understand landscape process and climate changes over time, as they offer annual sequences, often extending over thousands of years (Walker 2005). As this lake is over 1,700 m.a.s.l. and is primarily fed directly from glacial melt water, differences in landscape processes over time are minimal. The record in Meringsdalsvatnet suggests that high magnitude flood events have occurred throughout the Holocene; however, in the past 3,000 years, the frequency of both lower- and higher-magnitude events has increased. The climatic influences that account for these changes are discussed by Nesje et al. (chapter 9, this volume). A fundamental weakness in the use of varves from a pro-glacial lake is that they represent glacial fluctuations alone; however, other influences will also have acted upon the river lower in its course (Støren, Dahl, and Lie 2008). At a glance, there are strong suggestions from the archaeological sites that, overall, the flooding impact from the River Lågen increases at Brandrud and nearby Grytting and the overall return interval of high-magnitude flooding events on a par with Storofsen decreases, matching well with the lake-deposit record.

Whilst there is no doubt that the flooding regime has altered over the course of the Holocene in Gudbrandsdalen, to conclude that these specific sites have flooded more or less is difficult, as they do not represent more than the past 3,000 or so years. Despite the apparent increase in massive flood-induced landslides seen at Fryasletta, we lack the detailed records for earlier periods; as so often in river valleys, channel migration has removed the evidence. What is clear is that the flood risk has been apparent throughout the dated occupation of the archaeological sites and that this risk has not deterred settlement. It must have had a negative and occasionally catastrophic impact on settlement during the extreme flood events evidenced during the excavations. From the data, it is impossible to say if one or any of the recorded events were greater or less than recorded events such as Storofsen, which caused widespread loss of life and livelihood, despite the temptation to do so based on the mass of the deposits. Deposition and later erosion are dependent on numerous variables, such as sediment supply and antecedent conditions both in terms of climate and land use, and vary greatly over short distances.

Relevant to perhaps Øybrekka and Rolstad more particularly, in terms of topsoil erosion, is the relationship between colluvial deposits and human activity – indeed, the human impact on the environment. The influence of land use and human occupation over time has a reoccurring theme, which is that deforestation and subsequent cultivation causes soil erosion (Brown 2009; Dreibrodt, Nelle, and Lütjens et al. 2009; Parker et al. 2008). Deforestation, for example, has a large impact on run-off, and thus on the lag time between peak precipitation and peak river discharge. Eroded soils are deposited elsewhere as colluvium or alluvium; however, Zolitschka, Behre, and Schneider (2003) go further and suggest that human impact on the landscape far outweighs climatic influences with regard to colluvial deposits. This is more relevant to fine colluvium than the massive landslides seen in Gudbrandsdalen, but the changing land use has inevitably changed the local environmental response to precipitation and flooding. There will always be a connection between climate and human activity, as humans are subject to climate changes, especially in such marginal, and therefore vulnerable, agricultural environments such as Gudbrandsdalen.

Although Zolitschka et al. (2003) look at German and Støren et al. (2008) look at Norwegian case studies, the increase in flood and colluvial deposits in both cases occurs in the early pre-Roman Iron Age. This begins with the Hallstat period in c. 800 BC in Germany but not until 500 BC in Norway, and very likely even later in Gudbrandsdalen. This matches the data Støren et al. (2012) present on flood frequency as attested from varves in glacially fed lakes. Agricultural expansion and the increased impact of human settlement occur in tandem with the increasing flood impact and reduced return interval. Edgeworth (2011), in his study of the dynamism between human settlement and rivers, states that humans have long been a part of the water cycle and landscape processes and that one cannot be extracted from the other. That is not to suggest that the flood sequences in Gudbrandsdalen were significantly altered by human activity as far back as 3000 BP, but the landscape responses to flood and the processes in between events have become increasingly affected by human occupation and land use. Rivers such as the Lågen offer fertile, rejuvenating soils, and their risks have in human perception, from the archaeological evidence, always been mitigated by the potential reward.

From the available evidence, it seems likely that the flooding increase as seen in the lake-sediment records is also represented in the sequences exposed in Gudbrandsdalen at Grytting, Brandrud, and Fryasletta. Without doubt, the frequent high-magnitude floods recorded between 3000 BP and the present day is represented, and the processes do not appear to have altered over this period. However, projecting this back prior to the lowest layers in the archaeological trenches cannot reliably be done, as the evidence is not present. For this, we have to rely on indirect evidence and regional data.

The magnetic susceptibility and particle analysis results indicated that Lågen flood deposits can confidently be identified from tributary and overland flow deposits. This allows the shift in influence from the river Lågen as a proxy for channel migration at Grytting/Brandrud and Fryasletta and also emphasises that the landslides and tributary floods were equally, if not more, devastating than the floods from the River Lågen itself.

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