Social Buildings: Soil Geochemistry and Anthropogenic Patterns from Late Iron Age Finland

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ABSTRACT
We present geochemical data of soils sampled from two Late Iron Age (A.D. 550–1050) buildings at Bartsgårda on the Åland Islands, Finland. The houses had different constructions and use-patterns, one being an intensively used dwelling house, rich in finds, whereas the other, scarce in finds, had a more specialized character, linked to ceremonial rather than domestic activities. Systematic and targeted feature sampling was carried out to analyze 190 samples using energy dispersive X-ray fluorescence spectrometry (ED-XRF). Our main aims were to 1) contribute to and supplement the archaeological identification of floor levels and activity areas based on the vertical and horizontal distribution of geochemical soil anomalies in the excavated deposits; 2) compare and contrast the anthropogenic activity signals and possible differences in the use and function of the two houses based on the geochemical enrichment patterns; and, 3) test an ex situ analytical strategy for geochemical characterization of archaeological soils. Although the long-term use of the site as a livestock paddock introduced some complexities, based on the geochemical and micromorphological data, the houses had several activity levels and markedly different anthropogenic profiles.

Introduction

In this article, we report on results of a pilot study in which archaeological soils were sampled during small-scale field-school excavations of two separate northern European Late Iron Age (A.D. 550–1050) buildings on the Åland Islands, Finland, and subjected to multi-element geochemical analysis via energy-dispersive X-ray fluorescence spectrometry (ED-XRF). Our main aims were to 1) contribute to and supplement the archaeological identification of floor levels and activity areas based on the vertical and horizontal distribution of geochemical soil anomalies in the excavated deposits; 2) compare and contrast the anthropogenic activity signals and possible differences in the use and function of the two houses based on the geochemical enrichment patterns; and, 3) test an ex situ analytical strategy for fast and cost-efficient geochemical screening and characterization of archaeological sediment samples.

Today, the use of geochemical prospection at archaeological sites has been extended from a focus on phosphorus/phosphate to favor multi-element approaches. Phosphorus (P) levels, which are naturally low in soils, can increase due to human activity associated with P-rich plant and animal tissue and bones, burials, animal husbandry, waste, feces, ashes, and soil fertilizer; yet, phosphate levels do not always systematically vary according to the intensity of human activity, especially in agricultural contexts (e.g. Middleton 2004; Cook et al. 2006; Holliday and Gardner 2007, 308; Oonk, Slomp, and Huisman 2009; García Álvarez-Busto, Laca, and Fernández González 2019, 148). Furthermore, numerous recent investigations demonstrate that, in addition to P level determination, multi-element soil analysis can provide detailed and valuable evidence of various human-related activities and aid in identifying settlement patterns, social organization, and the use and function of spaces (e.g. Middleton 2004; Barba 2007; Wilson, Davidson, and Cresser 2008, 2009; Fleisher and Sulas 2015).

Furthermore, we wanted to contribute to the recently growing number of geoarchaeological investigations that seek to establish sampling and analytical processes that allow fast and affordable identification of anthropogenic chemical enrichment in archaeological soils. Therefore, we pursued a strategy that identifies “spatial patterns of variation” and archaeologically significant data patterns, rather than focusing on intra-site precision (Hayes 2013, 3194; see also Barba 2007; Wells 2010; Frahm et al. 2016). There are recent studies that have attempted soil analysis using portable XRF on-site, or even in situ, but soil moisture, compactness, grain-size, and mineralogical composition affect in situ results of unprepared sediment samples (e.g., see Hayes 2013; Hunt and Speakman 2015; Frahm et al. 2016; Lubos, Dreibrodt, and Bahr 2016; Williams, Taylor, and Orr 2020; Kennedy and Kelloway 2020; Williams, Errickson, and Taylor 2021 for discussion). In our strategy, on-site systematic sampling, combined with feature-specific sampling, was carried out across several excavated mechanical layers per excavated area, and ex situ geochemical analyses of marginally processed soil samples were run in a laboratory context via lab-based instrumentation.

Targeted research excavations are testing grounds for new methodologies and approaches, as well as a venue for research and experimentation (Farid 2000, 28). Furthermore, research excavations remain an urgent necessity for furthering knowledge about the past in regions that remain outside the scope of developer-funded archaeology (Sharples 2017, 7). Our study, the first of its kind in Finland, was conducted within the framework of field-school excavations for undergraduate students at the University of Helsinki. The site is situated in one of the world’s largest archipelagos, as
measured by the number of islands: the Åland Islands, which constitute an autonomous province of Finland with a community of about 30,000 inhabitants living across 60 islands in an archipelago of almost 27,000 islands, skerries, and offshore rocks located in the northern Baltic Sea between Finland and Sweden (ÅSUB 2021, 23; Figure 1). Åland has seen no large-scale, developer-led archaeological excavations comparable to those conducted in mainland Finland or indeed in many other regions that escape being perceived as marginal. Therefore, this pioneering study, which furthers our understanding of the variety of traces left behind during lived daily activities and thus contributes to the general archaeological fieldwork praxis, also represents a major contribution to Ålandic history and research.

The Site and Excavations

During two weeks in 2020 and 2021, small-scale excavations were undertaken at Bartsgårda, in the parish of Finström, situated centrally in the Åland Islands (see Figure 1). The site was first recognized and mapped in the very beginning of the last century by Björn Cederhvarf and Hugo Sommarström (see, for details, Ilves and Perttola 2020) in the pioneering days of archaeology on the islands. It consists of a large northern European Late Iron Age (A.D. 550–1050) burial ground with over 100 grave mounds, mainly round stone cairns covered by a sandy mound erected on top of the cremation burials, and an adjacent settlement area with remains of so-called stone foundation houses. Stone foundation houses, mostly rectangular, three-aisled structures built with roof supporting posts, were constructed with low dry-stone walls set on the outside of an inner wood-wall house structure. During the Nordic Late Iron Age, houses built in such a manner are typical of the Åland Islands; however, although fewer in number, there are also timber structure houses from the same period documented on Åland (Ilves 2018).

One of the remarkable aspects of the site at Bartsgårda is the discernible number of features indicating stone foundation house remains. In contrast to the large number of scattered and single farmsteads characterized by few building remains—the preferred form of settlement in the Late Iron Age Åland Islands—there are over 30 potential stone foundation houses visible at Bartsgårda, clustered in complexes east and northeast from the area with burial mounds (see Figure 1). Unfortunately, the site as a whole fell from memory due to insufficient documentation and the absence of analyses following the first discovery, so much so that the number of stone foundation houses associated with this site in the official register of ancient monuments on Åland is just five (see The Government of Åland 2021). This latter estimate was based on the landscape survey conducted 25 years after the first discovery, despite the fact that the surveying archaeologists noted in their documentation that, in addition to the visible five foundations, “several of these are perhaps covered by the forest” (Drake and Ramsdahl 1929–1930, 4).

Following the recent second re-discovery of the large settlement area at Bartsgårda (Ilves and Perttola 2020), the University of Helsinki decided to connect their field-school excavations and teaching of archaeological methods to the study of the site, which holds huge potential for nuancing our knowledge of past settlement dynamics in the insular setting of Åland. The main aim of the excavations was to determine the exact nature, function, and chronology of the features in the settlement area, as well as to acquire material for analyses within the framework of the current study.

The excavation trenches for both the 2020 and 2021 seasons were 10 m long and 2 m wide. These 20 m² investigation areas, about 40 m apart and within different topographical settings, were both placed perpendicular to two different house-like features, crossing the walls of the structures; about 7 m of the trenches were inside the respective stone foundations and 3 m outside. During the investigations in 2020, the trench was placed on a roughly south-north oriented structure with a clearly visible stone frame, measuring about 13 m in length and about 7 m in width (House 1), situated centrally in the northern part of the area along with remains of other stone foundation houses. During 2021, the investigation area was focused on a partially visible structure estimated to be about 17 m long and 6 m wide (House 2), likewise located in the northern part of the settlement, but which was the most peripheral of the visible features in that area (Figure 2). Furthermore, House 2 is situated on a topographically lower part of the site and as a result is distinctively separated from the central area with the remains of stone foundation houses.

The excavation methods employed were also the same during both seasons. Excavations were conducted manually. Trenches were divided into 1 × 1 m squares and then into 50 × 50 cm quadrants; after removing the 5 cm thick turf layer, they were excavated in 5 cm mechanical layers. The entirely sterile level was reached at a depth of 0.35–0.4 m measured from ground surface at House 1 (i.e. up to seven mechanical layers were investigated) and at the depth of 0.35 m at House 2 (i.e. six mechanical layers were investigated), after which the remaining feature bottoms, postholes, pits, and ditches were excavated contextually.

The strategy for soil sampling was somewhat different between the two excavation seasons. In 2020, samples of 0.5 L of soil were systematically collected from each mechanical layer, starting from the top of layer 2, from the investigation quadrants following the central axis of the trench (see Figure 2). Thus, 20 soil samples were collected from every fully excavated layer, of which 14 samples came from the area inside and 6 samples from an area outside of the stone foundation. In addition, a number of features, such as postholes and areas under the stone foundation, as well as spots related to specific in situ finds and/or observations, such as a gold-plated brass pendant (Holmqvist and Ilves 2022; Figure 3A) and the remains of a burned tree, were sampled, as well. In total, 149 soil samples were collected during the 2020 season, but not all of these samples were analyzed; we excluded sediments that were only partially sampled, as well as samples collected from uncertain contexts, which resulted in 126 samples collected in 2020 being analyzed. Working with the material collected in 2020, however, we questioned our excessive sampling of each 5 cm thin mechanical layer at a Late Iron Age site of the given character, doubting the actual benefits of such a high-resolution analysis. Therefore, in 2021, only every other layer was systematically sampled, still starting from the top of layer 2 and still from the investigation quadrants following the central axis of the trench to facilitate appropriate contextualization with the already-collected material. This resulted in 20 soil samples from each sampled layer, of which 15 samples were taken from the area inside the stone foundation and 5 samples from an area outside of it.
Sample size was reduced to ca. 0.25 L of soil, because the actual analysis did not need excessive amounts of soil per sample. Only a few specific contexts beyond the systematic sampling of the mechanical layers were sampled. In total, 64 soil samples were collected during the 2021 season, and all of these samples were analyzed.

It was already clear during the course of the excavations that in both studied cases the discernable walls of stones, although somewhat differently built, were connected to building structures (see also below). Archaeological traces recovered from the studied portions of the areas that fell outside of the stone walls of the respective houses clearly indicated that human activities were not restricted to the interior of the buildings. The chronological context was quickly provided by the diagnostic finds that were unearthed, mainly glass beads characteristic of the Nordic Late Iron Age, which were found in both studied structures. This dating based on artifacts has since been complemented with radiometric dating (Table 1), supporting the Iron Age origin and use of both studied buildings. However, the difference in the function of the houses and in the main types of activities associated with these structures became obvious when the turf layer was removed from House 2 in 2021. Despite the small size of the excavation trenches, the finds from House 1, both in their character and variety, as well as its constructional features, indicated that it was a dwelling house, intensively used, with several construction phases and changes.

House 2, although it also had several activity phases, had a clearly different function(s) not connected to subsistence and domestic behavior, but to ritual activities. It is clear that, in its final phase, part of the inside of House 2 had been intentionally sealed with a thin and uneven layer of heavily burned, though not sooty, stones—this layer was exposed directly under the turf. The unexpected and unparalleled find of a large, flat, snow-white limestone slab with the underside covered with red substance, most probably ochre (Figure 3B), inserted into the otherwise granite and sandstone wall of the house, further indicated ritual activities and meanings connected with this building.\(^1\)

In addition, the meagre find material from House 2, consisting mainly of different types of pottery sherds but also fragmented burned bones, also distinguished it from House 1. These houses, which were in use during the same period, had different functions and social roles, making the comparison of soil geochemistry and anthropogenic patterns related to these buildings potentially very rewarding.

**Sample Processing, ED-XRF Analysis Protocols, and Micromorphological Analysis**

After the sampling on-site, the soil samples were transported to Helsinki for ex situ (laboratory) analysis. Our aim was to apply an analytical strategy that “best balances analytical quality and preparation time” (Frahm et al. 2016, 115).
Accordingly, sub-samples of ca. 5 g were taken from the sample bags, and organic materials and grains larger than sand (> 2 mm) were removed. The sub-samples were placed in plastic sample-cells with 4 μm polypropylene XRF thin-film windows (Premier) and air-dried in a room temperature, dust-free space for 14 days prior to analysis (adjusted after e.g. Middleton 2004; Vyncke et al. 2011; Hayes 2013; Frahm et al. 2016; Bam, Akumah, and Bansah 2020; Williams, Taylor, and Orr 2020). Next, the ex situ dried, marginally processed (not homogenized) samples were analyzed with laboratory-based ED-XRF instrumentation. This strategy was chosen because the turnover times and costs of the geochemical analysis of soils can become delimiting factors in detecting human activities on the basis of chemical concentrations of floors or sediments, for which purpose intensive and systematic sampling of large sample numbers are required (Middleton 2004; Barba 2007, 441). However, excessive sample processing, i.e. sample homogenization, is not always a necessity in order to acquire the data accuracy and analytical resolution needed to approach the research questions typically proposed in the geochemical prospection of archaeological soils: for instance, comparing elemental concentrations of different archaeological layers and contexts or archaeological and natural soils.

The analysis of control samples, i.e. off-site contemporary soil samples unaffected by human activities, is often recommended for geochemical investigations of archaeological soils; however, suitable control-sample sampling contexts can be difficult to find (Middleton 2004, 50; Vyncke et al. 2011). In our case, the actual site and its associated surrounding area had been in use for settlement activities during the Iron Age, as well as medieval times; thereafter, as indicated by the historical maps available, it was used as a pasture for a long time, as it still is today. Hence, it was not practically possible to find off-site samples with natural values of phosphorus and other potentially anthropogenic elements. Sampling at a further distance from the site would bring into question the contemporary nature of the control soils. However, as the excavations were conducted within the framework of a field-school, for pedagogical reasons some samples were analyzed.

Figure 2. The position of excavation trenches in the northern part of the settlement. The division of trenches into 50 × 50 cm investigation quadrants with sampling tracks (inside the red lines) following the central axis of the trenches marked on the mechanical layer 4 plan drawing of both houses.

Figure 3. A) A gold-plated Viking Age brass pendant during the discovery process; B) the discovery of a large, flat, snow-white limestone slab with the underside covered with ochre with the red coloration of the soil underneath also clearly visible.
more-or-less sterile soils starting from mechanical layer 6 were excavated and sampled systematically during the 2020 season. This provided us with samples that fulfilled “the best available non-human-impacted sources of contemporary sediment” (Middleton 2004, 50). Although still somewhat anthropogenically affected, the values measured from the samples taken from this layer were treated as a baseline, the “geological background” (see Cook et al. 2006, 631–632; Vyncke et al. 2011). Near-surface soils were not sampled. In total, 190 samples were analyzed for this study (for the complete dataset, see Supplemental Material 1).

The geochemical data was acquired with a Rigaku NEX-DE VS bench-top ED-XRF spectrometer housed at the University of Helsinki Laboratory of Archaeology. The instrument was operated in an analysis mode with the beam diameter adjusted to 10 mm to quantify major, minor, and trace element concentrations in the soil samples. The reported values per sample are mean values of three consecutive runs. The samples were analyzed using a sample spinner, in a helium atmosphere, using a tube voltage of 60 kV, 35 kV, and 6.5 kV and a measuring time of 60, 60, and 100 s for high-Z, mid-Z, and low-Z elements; the spectrometer’s software and fundamental parameters were used in data quantification. The IBM SPSS 25 statistical software was employed for principal component analysis (PCA; Figure 4) and generating data plots to identify and visualize data structures, trends, and anomalies (e.g. concentrations of elements Al, Si, P, Ca, Zn, Sr, Ba, Fe, Zr, and Rb). Element concentrations close to the detection limit were not considered in this paper.

The ED-XRF data accuracy and precision were controlled by analyzing a reference sample (SRM 76a Burn Refractories) with the soil samples (total of eight runs); the measured standard sample values are in good agreement with the certified concentrations (Supplemental Material 2). The accuracy tests show relative errors below 10% for MgO, Al₂O₃, SiO₂, and Fe₂O₃ and below ca. 20% for K₂O, TiO₂, and SrO. For P₂O₅, a light element with a certified concentration close to the detection limit (at 1.02 wt%), the measured values show increased relative error. The precision tests, illustrating the repeatability of the analysis, show good precision values, with the relative variation between the eight measurements being less than 7% for all the major oxides, apart from the lightest detected elements MgO and K₂O, which show slightly higher relative variation (17 and 22 wt%, respectively).

Furthermore, in order to aid the interpretation of the geochemical data, three undisturbed soil monoliths were sampled and analyzed from House 1 excavation profiles: #1 = northern profile, layer 4–5, square 202.5/507.5 (outside the house); #2 = northern profile, layer 4, square 201.5/500.5 (inside the house); and, #3 = southern profile, layer 5, square 200.0/501.5 (inside the house) (see also Figures 2, 5). The soil monoliths were impregnated with a clear polyester resin-acetone mixture and prepared as 70 × 40 mm thin-sections (at Terrascope) for soil micromorphological analysis using a petrological microscope under plane polarized light (PPL), crossed polarized light (XPL), oblique incident light (OIL), and fluorescent microscopy (ultra violet light—UVL) at magnifications from x1 to x200/400. The micromorphological analysis was conducted by Dr. Richard I. Macphail at the University College London Institute of Archaeology (Macphail 2022).

### Results and Discussion

The data patterns of the soil samples collected from Houses 1 and 2 were compared by running a principal component analysis (PCA) on both sample sets individually (see Figure 4 for biplots of the first two PCs; the first three PCs represent 82.25% and 70.01% of the total variation in the datasets of Houses 1 and 2, respectively). The PCA tests were run with Al₂O₃, SiO₂, P₂O₅, K₂O, CaO, Fe₂O₃, ZnO, RbO, SrO, and BaO concentrations as variables. These elements represent variation in both the anthropogenic patterns and the geological background values (e.g. Fernández et al. 2002; Middleton 2004; Cook et al. 2006, 632; Wilson, Davidson, and Cresser 2008, 2009; Oonk, Slomp, and Huisman 2009; Knudson and Frink 2010; Vyncke et al. 2011; Dirix et al. 2013; Fleisher and Sulas 2015; Sulas, Munch Kristiansen, and Wynne-Jones 2019; Kennedy and Kelloway 2020; Choi et al. 2020); thus, their patterns were considered useful in identifying differences between floor/activity layers and local soil characteristics (the last soil layer analyzed for this study from under House 1). Furthermore, this set of elemental values were detected practically in all analyzed samples in quantities that can be reliably quantified, whereas other elements that could be potentially useful in detecting anthropogenic enrichment, e.g., Na, Mg, and rare earth elements (REEs), were not always detected due to the detection limits of the instrumentation used (see Table 2 for House 1 data, Table 3 for House 2 data, and Supplemental Material 1 for data of individual samples).

### Table 1. Radiocarbon dating results.

| Lab. Nr. | House | Excavation Unit | Layer | Material   | ¹⁴C ± | CAL 1 sigma (68.2%) | CAL 2 sigma (95.4%) |
|----------|-------|----------------|-------|------------|-------|---------------------|---------------------|
| Ua-68765 | 1     | 201.0/505.0    | 3     | nutshell   | 1434 29  | a.d. 651–770        | a.d. 645–772        |
| Ua-68768 | 1     | 200.0/501.0    | 5     | nutshell   | 1227 30  | a.d. 707–875        | a.d. 686–884        |
| Ua-68771 | 1     | 200.0/504.0    | 4     | cereal     | 1147 30  | a.d. 776–975        | a.d. 776–989        |
| Ua-68766 | 1     | 201.5/504.5    | 3     | nutshell   | 1140 28  | a.d. 777–974        | a.d. 776–991        |
| Ua-68769 | 1     | 201.5/503.5    | 6     | nutshell   | 1138 29  | a.d. 777–975        | a.d. 776–991        |
| Ua-68764 | 1     | A005 feature   | nutshell |            | 1118 28  | a.d. 893–977        | a.d. 876–993        |
| Ua-68770 | 1     | 200.5/500.5    | 4     | seed       | 1105 30  | a.d. 896–991        | a.d. 886–1016       |
| Ua-68767 | 1     | 201.5/505.5    | 5     | nutshell   | 1081 29  | a.d. 899–1016       | a.d. 893–1021       |
| Ua-72572 | 2     | A004 feature   | organic |            | 1350 26  | a.d. 651–756        | a.d. 645–772        |
| Ua-72577 | 2     | K04 feature    | charcoal (Betula sp.) |            | 1338 27  | a.d. 634–771        | a.d. 649–772        |
| Ua-72576 | 2     | A003 feature   | charcoal (Picea abies) |        | 1334 27  | a.d. 656–771        | a.d. 651–772        |
| Ua-72574 | 2     | A002 feature   | charcoal (Betula sp.) |            | 1317 26  | a.d. 662–772        | a.d. 656–773        |
| Ua-71864 | 2     | 400.0/809.5    | 4     | nutshell   | 1305 30  | a.d. 667–772        | a.d. 659–773        |
| Ua-72573 | 2     | A001 feature   | charcoal (Betula sp.) |            | 1290 26  | a.d. 674–772        | a.d. 667–773        |
| Ua-71867 | 2     | 401.5/803.0    | 4     | nutshell   | 1165 30  | a.d. 776–948        | a.d. 775–975        |
| Ua-71865 | 2     | 401.0/804.0    | 2     | seed       | 1152 31  | a.d. 776–973        | a.d. 775–989        |

**IOSACal v0.4.1**
Despite the small size of the excavation trench, the results of the 2020 season verified the nature of the investigated structure as an aisled building, intensively used during the Nordic Late Iron Age as a dwelling house, yielding a great amount and a wide variety of finds. The archaeological investigations further revealed that the area immediately outside the walls of this house (excavated area of 6 m² in total, investigation squares 200–201/507 to 200–201/509) had also been modified and in active use during the same period (Ilves 2021).

House 1 was, in its final phase, a construction with low dry-stone walls set on the outside of an inner wooden wall structure. As the excavation trench crossed one of the long walls of the house (the eastern wall), it was clear that this wall was built with a single row of larger boulders, placed on the ground surface and facing the outside of the building, with a packing of smaller stones inside supporting the inner wooden wall of the house. This building method, which has many parallels on the Late Iron Age Åland Islands (e.g. Hackman 1940; Kivikoski 1946; Dreijer 1955; Núñez 1994), means that the width of the stone walls themselves might be substantial, and there can be a considerable difference between the inner and outer dimensions of the house. The excavated portion of the stone wall of House 1 measured 1.2–1.5 m in width, and, as the trench also exposed the inner edge of the opposite western long wall, the width of the space freely accessible for use inside of this stone foundation house can be estimated at about 5 m (see also Figure 2). However, the excavations also revealed that this building had several construction phases. There are strong indications, in the form of remains of postholes covered by the stones that were part of the stone frame, that before the

Figure 4. The PCA plots of ED-XRF data of soil samples analyzed from House 1 (top) and House 2 (below); concentrations of Al₂O₃, SiO₂, P₂O₅, K₂O, CaO, Fe₂O₃, ZnO, Rb₂O, SrO, and BaO used as variables. The first three PCs represent 82.25% and 70.01% of the total variation in the datasets of Houses 1 and 2, respectively.
construction of the stone foundation, the house was a timber structure. In addition, two central roof-bearing postholes that were unearthed showed signs of these posts being replaced at least once.

Based on the stratigraphic observations during the excavations and finds distribution, mechanical layer 3 clearly had the most finds connected with this building, while layers 4 and 5 also exhibit burned traces from logs or planks within the dark cultural soil, reminiscent of a fire horizon inside of the house. Furthermore, the major constructional phase observed in the change of the structure of this building to a stone foundation house is stratigraphically tied to mechanical layer 4. Unfortunately, an attempt at a specific vertical dating of the building and related activities, i.e. dating short-lived samples chosen from different mechanical layers, was unsuccessful (cf. Table 1)—the radiocarbon dating proved unsuitable in resolution. Most notably, however, although perhaps not surprisingly, in the case of House 1, there is a strong agreement between the archaeological findings and those obtained from the geochemical study.

The PCA results for the House 1 samples show significant anthropogenic anomalies in the mechanical layer 4 geochemical concentrations, which are distinctively different from the sample values that were treated as a baseline (layer 6) (see Figure 4, Table 2). Samples collected from the top of layer 4 show increased P₂O₅, CaO, ZnO, SrO, BaO, Fe₂O₃, ZrO₂, and Rb₂O levels, all of which are elements that have been identified in ethnographic and archaeological soil analysis as enriched in association with activity areas (e.g. food and waste areas, middens, hearths, and metal working areas: see Oonk, Slomp, and Huisman 2009; Sulas, Munch Kristiansen, and Wynne-Jones 2019; Williams, Errickson, and Taylor 2021). The CaO, TiO₂, CuO, ZnO, Rb₂O, SrO, Y₂O₃, ZrO₂, and BaO concentrations measured in layer 4 are double or higher compared to the baseline values (see Figures 4–8, Table 2). Especially enriched concentrations of Ca, Zn, and Sr have been associated with functional areas deriving from charcoal and bone in the deposits (Wilson, Davidson, and Cresser 2008). Vyncke and colleagues (2011, 2274) found that K, Mg, Fe, P, and Sr values “directly reflect anthropogenic chemical residues” in floor samples. High barium and strontium values (< 3500 ppm and < 1600 ppm in, e.g., layers 3 and 4 and features A004, A006, and A009 of House 1) signal deposition of plant and animal tissues in the deposits and may, together with Ca, Na, Mg, K, and Sr, relate to marine materials (mammal and fish bone) and their processing (Cook, Clarke, and Fulford 2005; Wilson, Davidson, and Cresser 2008; Knudson and Frink 2010; Misarti, Finney, and Maschner 2011; Fleisher and Sulas 2015). High Ca and P values have also been linked to food preparation activities (Middleton 2004, 56). This is in accordance with the results from the osteological analysis of House 1 material demonstrating the presence of both food preparation and refuse deposits, as well as the notable presence of marine food debris—different types of fish, waterfowl, and seals (Kangasmaa 2021).

It is noteworthy that although phosphorus values increase layer by layer in this building, the levels measured from and below layer 4 are in the same range, suggesting that P₂O₅ was leaching throughout the layers and probably derives from the long-term use of the site, including from the post-settlement activity as a paddock for livestock. In farmlands, soil geochemistry can be significantly enriched by modern land-use, and this can appear especially in P, Ca, Mg, Cu, and Zn values, among other elements (Oonk, Slomp, and Huisman 2009). The micromorphology samples also showed secondary phosphate staining, most likely resulting from anthropogenic activity/deposits above. Therefore, the P values alone are not very useful in detecting horizontal or vertical activity-related enrichment patterns. Layer 3 is the most find-rich archaeological layer in this house, resting on top of a level connected to a possible fire event and a change in the construction of the house, and the combined finds, stratigraphic, and geochemical evidence provide a strong indication that samples collected from the top of mechanical layer 4 belong to traces from the main floor level of House 1.
| Layer | Coordinates (X/Y) | Layer/Feature | Na₂O ppm | MgO ppm | Al₂O₃ ppm | SiO₂ ppm | P₂O₅ ppm | K₂O ppm | CaO ppm | TiO₂ ppm | Cr₂O₃ ppm | MnO ppm | Fe₂O₃ ppm | NiO ppm | CuO ppm | ZnO ppm | Rb₂O ppm | SrO ppm | Y₂O₃ ppm | ZrO₂ ppm | BaO ppm | Pb ppm |
|-------|------------------|---------------|-----------|--------|-----------|----------|----------|--------|--------|--------|----------|--------|-----------|--------|--------|--------|---------|--------|---------|---------|--------|--------|
| 2     | 200.5 500.0–509.5 | Archaeological sediment, under top-soil | 3.20 0.97 | 9.64 70.46 | 2.84 2.72 | 5.00 0.92 | 0.16 0.30 | 6.20 31 | 68 175 | 381 54 | 533 824 | 29     |           |        |        |        |         |        |         |         |
|       |                  |               | σ 0.13   | 0.60 2.14 | 0.42 0.52 | 0.99 0.27 | 0.13 0.10 | 0.91 13 | 32 110 | 42 71  | 123 142 | 11     |           |        |        |        |         |        |         |         |
| 3     | 200.5 500.0–509.5 | Archaeological sediment, soil above event/ floor level | 1.08 9.12 | 63.37 3.60 | 2.96 6.78 | 1.54 0.41 | 10.46 34 | 136 954 | 228 595 | 91 951  | 1218 216 |        |           |        |        |        |         |        |         |         |
|       |                  |               | σ 0.39   | 1.10 7.19  | 0.95 0.79 | 1.85 1.23 | 0.20 0.58 | 17 121 | 324 142 | 368 58 | 1019 376 | 504    |           |        |        |        |         |        |         |         |
| 4     | 200.5 500.0–509.5 | Archaeological sediment, event/floor level | 2.52 7.19 | 54.37 4.57 | 3.69 11.48 | 1.73 0.015 | 0.62 6.20 | 31 68 | 170 428 | 717 129 | 312 43 | 396 400  | 20     |           |        |        |        |         |        |         |         |
|       |                  |               | σ 0.72   | 3.05 0.99  | 0.60 2.72 | 0.48 0.008 | 0.27 8.77 | 244 674 | 199 376 | 504 89 | 318 208 | 6      |           |        |        |        |         |        |         |         |
| 5     | 200.5 500.0–509.5 | Archaeological sediment, soil under event/ floor level | 3.61 1.36 | 11.30 63.75 | 5.67 2.33 | 6.66 0.78 | 0.01 0.33 | 6.41 25 | 121 739 | 170 373 | 54 469 | 862 13   |        |           |        |        |        |         |        |         |         |
|       |                  |               | σ 0.69   | 0.38 2.00  | 1.58 0.25 | 0.22 0.015 | 0.10 0.91 | 13 121 | 324 142 | 368 58 | 1019 376 | 504    |           |        |        |        |         |        |         |         |
| 6     | 200.5 500.0–509.5 | Natural soil exposed under archaeological layers | 2.70 1.34 | 10.99 64.34 | 5.73 2.55 | 6.32 0.97 | 0.01 0.22 | 6.49 30 | 91 612 | 176 351 | 42 460 | 784 15  |        |           |        |        |        |         |        |         |         |
|       |                  |               | σ 0.42   | 0.41 1.59  | 2.50 0.51 | 0.26 0.30 | 0.007 0.14 | 1.91 15 | 74 290 | 87 13  | 186 141 | 8      |           |        |        |        |         |        |         |         |

Table 2. ED-XRF geochemical results of soils samples analyzed from House 1; selected elemental concentrations reported for each mechanical layer excavated (mean values) and each individually excavated feature. The complete dataset with individual sample results for each analyzed element is given in Supplemental Material 1.
Table 3. ED-XRF geochemical results of soils samples analyzed from House 2; selected elemental concentrations reported for each mechanical layer excavated (mean values) and each individually excavated feature. The complete dataset with individual sample results for each analyzed element is given in Supplemental Material 1.

| Layer | Coordinates (X/Y) | Layer/Feature | Na$_2$O | MgO | Al$_2$O$_3$ | SiO$_2$ | P$_2$O$_5$ | K$_2$O | CaO | TiO$_2$ | Cr$_2$O$_3$ | MnO | Fe$_2$O$_3$ | NiO | CuO | ZnO | Rb$_2$O | SrO | Y$_2$O$_3$ | ZrO$_2$ | BaO | Pb ppm |
|-------|------------------|---------------|--------|-----|-------------|--------|---------|--------|-----|--------|-------------|-----|-------------|-----|-----|-----|---------|-----|---------|-------|-----|-------|
| 2     | 401.0 800.0–809.5 | Archaeological sediment, activity layer | (µ n = 20) | 2.60 | 1.23 | 10.64 | 70.70 | 2.08 | 2.49 | 3.70 | 0.90 | 0.008 | 0.32 | 6.86 | 20 | 43 | 416 | 174 | 269 | 54 | 423 | 574 | 21 |
| 4     | 401.0 800.0–809.5 | Archaeological sediment, secondary activity layer | (µ n = 20) | 3.42 | 1.20 | 10.90 | 70.49 | 2.68 | 2.37 | 3.74 | 0.85 | 0.004 | 0.24 | 6.09 | 16 | 53 | 330 | 125 | 265 | 46 | 446 | 618 | 12 |
| 6     | 401.0 800.0–809.5 | Archaeological sediment, soil under activity layers | (µ n = 20) | 2.91 | 1.08 | 10.93 | 71.64 | 2.03 | 2.84 | 2.99 | 0.87 | 0.003 | 0.11 | 6.43 | 3 | 49 | 213 | 159 | 283 | 47 | 585 | 615 | 17 |
| 3     | 401.5 804.0      | Bottom of the layer of heavily burned stones | 9.08 | 56.20 | 4.48 | 0.84 | 11.80 | 1.59 | 0.466 | 10.30 | 226 | 1150 | 637 | 45 | 524 | 1160 |
| 3     | 401.5 805.0      | Bottom of the layer of heavily burned stones | 9.43 | 61.20 | 4.10 | 0.86 | 9.97 | 0.90 | 0.577 | 9.69 | 765 | 523 | 87 | 427 | 818 | 19 |
| 3     | 401.5 806.0      | Bottom of the layer of heavily burned stones | 1.31 | 11.20 | 6.00 | 5.79 | 7.76 | 0.79 | 0.11 | 0.451 | 7.73 | 32 | 510 | 18 | 310 | 686 | 16 |
| 5     | 401.0 806.0      | Under the limestone slab covered with ochre | 1.04 | 11.50 | 65.70 | 2.08 | 0.73 | 6.07 | 0.76 | 0.436 | 8.71 | 81 | 1290 | 30 | 240 | 110 | 454 | 576 |
The other archaeological sediments analyzed related to House 1, from mechanical layers 2, 3, and 5, all form individual geochemical clusters representing their stratigraphic units, but they are compositionally more related to the background values rather than to the enriched layer 4. This is particularly clear for samples taken from the top of layer 5, the mechanical layer excavated under the main floor level, which showed a weak anthropogenic signal and clustering close to the layer 6 samples in the PCA plot. The micromorphological sample (#3, Figure 7E–F) associated with layer 5 (southern profile, inside the house) showed fuel ash waste, calcitic ash traces, traces of food (burnt, fine bone), ashed monocotyledonous plants, and likely latrine waste (phosphate nodule).

The mechanical layers studied above, as well as below, layer 4 belong to other use-phases of House 1 that, based on the evidence from the rather extensive radiocarbon dating (see also Table 1), had been in use for about 350 years. In this

![Figure 6. Geochemical concentrations of TiO$_2$, CaO, Fe$_2$O$_3$, ZnO, Rb$_2$O, SrO, ZrO$_2$, BaO, and Y$_2$O$_3$ detected in House 1 mechanical layers 4 (event/floor level) and 6 (baseline soil) and House 2 layer 2 (activity level) via ED-XRF.](image-url)
sense, the clusters formed by the archaeological layers in the 
PCA plot of House 1 also have chronological significance, 
signaling differences in the intensity of use-patterns of the 
house, with the level of activity peaking in relation to the 
layer 4 phase but present on a lesser scale during the phases 
represented by mechanical layers 5, 3, and 2 accumulated 
under and on top of layer 4.

We also analyzed soil samples from many separate tar-
tected contexts in House 1. Among these were the in situ 
deposits of three artifacts: a brass pendant discovered inside 
the house (see Figure 3A), a copper-alloy chain, and an iron 
knife that were found outside of the stone walls. For com-
parison, Sulas, Munch Kristiansen, and Wynne-Jones (2019) 
reported that the most artifact-rich areas showed 
high concentration values of, e.g., Ba, Rb, and Zr in deposits.

Figure 7. Photomicrographs of soil micromorphology samples #1–3, showing A) #1 fill of ditch A009, humic soil broad burrow fill with charred material, probable iron phosphate nodule (P) present (PPL, frame width ca. 4.62 mm); B) #1 wood charcoal, fine charcoal-rich fabric and woody remains (PPL, width 4.62 mm); C) #2 charred organic residues, including fish bone (center) (OIL, width ca. 0.9 mm); D) #2 fine charcoal-rich refuse with fine fish bones (FB) (PPL, width ca. 4.62 mm); E) #3 rubefied burnt inclusions and ashed monocotyledonous stem slag (OIL, width ca. 4.62 mm); and, F) #3 probable phosphate nodule of presumed latrine waste origin (PPL, width ca. 0.9 mm).

Based on the multi-element values of the soils under the arti-
fact findspots related to House 1 at Bartsgårda, the iron knife 
context shows a weak anthropogenic signal and the chain soil 
identifies with the sterile soil, which is possibly not surprising 
considering their find locations. The pendant, documented 
in mechanical layer 2 inside the house, close to the western 
stone wall, has context values that are within the range of 
the sterile soil, apart from CuO and ZnO, which, at almost 
3000 and 1200 ppm, showing significant post-depositional 
leaching from the brass artifact (an alloy of copper and 
zinc; see Holmqvist and Ilves 2022). The alloy of the cop-

er-alloy chain has not yet been analyzed. Its context, 
although having strong FeO₂, ZnO, SrO, ZrO₂, and BaO 
enrichment in line with the floor layer values inside the 
house, does not display a similar CuO anomaly; however, 
this could be related to the chain’s smaller contact area 
with the soil, compared to the pendant’s larger disc shape 
and relatively corroded surface.

In addition, feature samples from small pits A005 and 
A006, located inside the house, and postholes A004 and 
A010, both related to the stone walls of the building, show 
significant anthropogenic enrichment and cluster with the 
floor/event-layer samples. The soil sampled from the bottom 
of the large ditch A009 running inside the house shows 
anomalously high metal values, e.g. iron (ca. 15 wt%), copper 
(< 1600 ppm), zinc (< 3100 ppm), and zirconium (< 2450 
ppm), which may be linked to the storing and/or accumu-
lation of metal artifacts or materials in this ditch (see also 
Sulas, Munch Kristiansen, and Wynne-Jones 2019 for 
the elemental enrichment of packed soils in pit features). 
In this context, it is relevant to note that there were indications 
of on-site metalworking in the form of metal droplets discov-
ered in the house. Micromorphological analysis of soil 
sampled from the northern profile in connection to ditch 
A009 (#2; Figure 7C–D) indicated tramped and compacted 
spread of house refuse, showing minor middening, including 
fire installation residues (charcoal, burnt minerogenic peat/
wetland turf ash, burnt gravel, and silica stem slag from 
the ashing of monocotyledonous plants), mixed with wood 
fragments and fish bones.

Furthermore, some feature samples cluster together and 
share an enrichment pattern that is slightly different from 
the layer 4 samples or the above-mentioned features. These 
include samples taken from under the eastern stone wall, 
by and from the western stone wall, from the central roof-
bearing postholes A007 and A008, and from pit A002, situ-
ated in the area outside of the stone foundation. Compared 
to the floor/event layer samples, these samples have higher 
rubidium and zirconium values, and their levels of, e.g., 
iron, strontium, zinc, yttrium, and barium are significantly 
higher compared to the baseline soil layer mean values. 
The fact that the samples taken from nearby and under the 
stone wall form a cluster with the samples from the roof-
bearing postholes may relate to the specific accumulation 
patterns of rubbish and dust in these contexts, due to, e.g., 
the cleaning or sweeping of the floor towards these structures 
(Hudson and Terry 2006, 398–401; Wilson, Davidson, and 
Cresser 2008, 2009). Feature A002 belongs to the area outside 
of the stone-framed building; however, this area had also 
been strongly modified by contemporary activities associated 
with the house. Furthermore, an adjacent activity area, poss-
ibly another building, can be hypothesized immediately east 
of House 1 (see also Ilves 2021). The micromorphological 
sample (#1, Figure 7A–B) taken from the northern profile, 
outside the house, contained fire charcoal waste, wood, and
phosphate residues, clearly belonging to a layer of house occupational waste.

Some feature samples, e.g. taken from the very bottom of roof-bearing postholes A007 and A008, cluster with the values from the baseline soil; in these cases, the values probably derive from sampling soil belonging to the primary fill of the features. For the soil sampled under the large sandstone stepping stone in front of the eastern stone wall, which displayed baseline values, it is reasonable to suggest that the soil represents the sterile level. On the other hand, the soil sampled under the burned tree, inside the building in connection to the western stone wall, clearly shows anomalous values and clusters separately from all the other samples analyzed from House 1, showing above-baseline values for multiple elements (e.g. CaO at 29.5 wt%). Furthermore, the soil excavated under the eastern wall (200.5/506.5) displays a particularly high zirconium concentration at ca. 5400 ppm.

Potential localized activity areas inside and outside the buildings were examined by looking at the horizontal distribution patterns of the concentration values that were measured for samples systematically collected from each quadrant along the central axes of both of the excavation trenches (see Figure 8 for activity layers [House 1 layer 4 and House 2 layer 2] compared to baseline soils in House 1 layer 6). In House 1, the layer 4 values show consistent enrichment of P₂O₅, CaO, and Fe₂O₃ throughout the house interior (200.5–506.5), showing a minor decrease on top of and under the eastern wall (200.5/507.5–508.0) and then rising again further away from the stone frame (200.5/508.5–509.5). P₂O₅ and CaO show the highest values in the center space of the building (200.5/
503.0–503.5), whereas Fe₂O₃ appears enriched towards the eastern and western walls of House 1. ZnO is the highest (< 3000 ppm) inside the house (200.5/501.0–505.5), but ZnO values drop below 1000 ppm at the eastern wall and increase again further away from the stone frame, remaining, however, below the in-house levels at 2000 ppm. There appears to be a concentration of high SrO values (1400–2000 ppm) in the eastern part of the building (200.5/505.5–507.0), although SrO values are relatively high throughout the house interior and exterior when compared to the baseline layer 6 values. The highest BaO values (above 2500 ppm) were detected inside the house within a ca. 1.5 m range from the eastern and western walls (200.5/500.0–501.5 and 200.5/504.4–506.5) and enriching again towards the end of the trench (200.5/508.5–509.5).

It appears, based on the enrichment derived from domestic activities and daily-life, e.g. enriched values of P₂O₅, SrO, and CaO linked to food preparation and storage, that these activities were localized in the central part of the house and some other specific locations. Then, there are elements that appear generally elevated due to human activities compared to the natural soil concentrations. For instance, the highest Rb₂O levels (ca. 700 ppm) of layer 4 were detected outside the eastern wall in squares 200.5/508.0 and 200.5/509.5. The Y₂O₃ levels, on the other hand, remain slightly increased (ca. 60–260 ppm) throughout the sample track compared to layer 6 values (always below ca. 70 ppm). Then again, similarly to the pit structures, there are some elements, e.g. iron, that show elevated values near the walls, possibly associated with the accumulation of materials near the walls from sweeping or other cleaning of the central space. The soil micromorphology (#3) also showed iron mottling close to the edge of the western wall.

All in all, although we cannot know the exact activities behind the enriched values of each of these elements, there is a strong, systematic domestic anthropogenic signal detected throughout House 1 and its outdoor space. In addition, there are, for instance, elevated copper and zirconium levels that imply the processing of metals (e.g. metalworking and storing of metal equipment) in specific spots in the house. ZrO₂ shows systematically high concentrations (ca. 800–1600 ppm) throughout the sampled track compared to baseline values that remain below 850 ppm, yet there is also a localized anomaly with a clearly increased ZrO₂ level at ca. 2500 ppm inside House 1 in square 200.5/504.5, where an anomalous CuO value at ca. 3100 ppm was also detected. Although the chemical signal of metal enrichment is clear for this spot, this particular anomaly was not manifested in any archaeologically visible terms.

**House 2**

The building studied during the 2021 season, also dated to the Iron Age, was of a different character than House 1, both in terms of construction and use (Ilves 2022). This is also reflected in the geochemical data.

Although in the case of House 2 the excavation trench also crossed one of the long walls of the house, the eastern wall, and revealed the stone frame, the construction of the wall was somewhat different than House 1 (Figure 9; see also Figure 2); furthermore, the wall construction is divergent from all the other studied stone foundation houses on Åland. The eastern wall of this building, with a total width of 1.5 m, was raised on top of the layer of stones and was built with two parallel rows of larger boulders spaced 0.25 m apart from each other, facing the outside of the building, and an interior packing of smaller stones in connection with the inner row of boulders. Within the filling of smaller stones, posts were placed in deeply dug holes supported by a substantial stone packing, as indicated by one of the recovered postholes. The excavation trench did not reveal any opposite wall of stones, if there had originally been one. However, opposite to and at a distance of about 6 m from the posthole with substantial stone packing in the eastern wall, a structurally similar posthole was documented in the western side of the building. This should not be automatically taken to mark the other long wall of the house, although there are a few cases known from the islands where stone foundation houses have only a partial stone frame combining stone- and timber-framing (e.g. Dreijer 1958). The size of this building remains unclear. Nor did the excavation trench reveal parallel roof-bearing postholes in the central part of the house, although the limited size of the investigation area needs to be taken into consideration in this connection. At the same time, at an equal distance from the described large postholes in the eastern wall and in the western side of the building, respectively, a smaller but still considerable posthole was unearthed. This posthole showed clear signs of the post being replaced at least once. Furthermore, this central post separates two activity areas that have left different archaeological markers in the stratigraphy of the building.

On the eastern side of House 2, the area between the central posthole and the wall of stones exhibits stratigraphy that is markedly different from the western side. From the inside edge of the stone wall to the central posthole, within a 2.5 m wide area, there are at least four levels clearly distinguishable. A thin black layer of very fine black particles lay on top of the sterile soil. A thicker, light grey-brown layer overlay this black layer and was in turn covered by a dark cultural soil. On the very top, revealed directly under the turf, a layer of heavily burned stones was situated. The spread stone material in this uppermost cultural level of burned stones might originate from hearths. The bottom part of this layer was also connected to a larger amount of finds clearly dominated by ceramics. However, it was as good as empty of any macrofossil evidence (Vanhanen 2021) and the osteological material was scarce, which makes it unlikely that the fireplaces from where the material originated were used for domestic purposes. The western side of House 2 had not been sealed with a layer of heavily burned stones and had a simpler stratigraphy with a dark cultural soil on top of the sterile level. Due to this very marked difference, which is connected to the central posthole mentioned above, it is reasonable to suggest that there might have been a wall separating these areas, which were most probably used for different purposes.

Similarly to House 1, the excavation area extending beyond the stone wall of the building revealed that the area immediately outside of House 2 (excavated area of 5 m² in total, from the westernmost quadrants in investigation squares 400–401/807 to 400–401/509) had also been modified and was in active use during the same period. Furthermore, in this case, the edge of the excavation trench was in contact with a feature visible before the excavations, which, through investigations, was clarified to be of an
The archaeological sediments sampled in House 2 do not show similarly distinctive enrichment patterns indicative of a rich activity level as did mechanical layer 4 from House 1. In terms of archaeological finds, mechanical layers 2 and 3 represent almost equally the richest archaeological sediments in House 2, but the find count in general is very low from this house. In fact, the anthropogenic signal of the House 2

Figure 9. House 2 features discussed in this article; stones represent mechanical layer 4, while discolorations represent mechanical layer 6. In the photo, part of the trench profile displays the stratigraphy of at least four clearly distinguishable levels. Inside the red lines are investigation quadrants with sampling tracks.
archaeological soils (excluding a few anomalies) is so weak that multi-element data processing was required to visualize the difference between the archaeological and baseline soil samples, as the values of individual elements do not show significant differences in comparison to the reference soil levels (see Table 3, Figures 6, 8–9). The phosphorus and iron contents of these layers, for instance, do not differ from the reference soil baseline; thus, it can be most informative to apply combinations or clusters of elements to investigate traces of human disturbance in the geochemical concentrations of the soils (see Fleisher and Sulas 2015).

In the PCA plot (including Al2O3, SiO2, P2O5, K2O, CaO, Fe2O3, ZnO, Rb2O, SrO, and BaO data) the mechanical layers 2, 4, and 6 of House 2 cluster separately from the reference soils (House 1 layer 6), but there is also overlap. There were no significant differences detected in the vertical stratigraphy; instead, layers 2, 4, and 6 show similar geochemical profiles and cluster together in the PCA plot.

The horizontal distribution, however, shows some enrichment spots that appear as outliers in the PCA plot. These are three samples from square 401/809, outside and farthest from the stone walls of the building (sample nos. 40, 59, and 60 of the 2021 sample set in Supplemental Material 1), that show enrichment of Al, Fe, Rb, Sr, Zn, and Ba in comparison to the reference soil values. This area coincides with the low stone and soil wall of anthropogenic nature, which to a certain degree explains the enrichment. In addition, there are a few spots where the chemical values may indicate localized activities, perhaps from the processing or storing of food, linked to different activity phases of House 2. The layer 4 sample from square 401.0/806.0 shows P and Ca values that are above the layer average but are not clearly anomalous compared to the reference soil averages, and soil sampled from squares 401.0/801.0 and 401.0/807.0 (sample nos. 43 and 35 from layer 6) shows elevated iron levels (ca. 13 wt% vs. the baseline soil average at 6.5 wt%). However, there is not enough archaeological evidence to link these enrichment patterns to any particular activity.

The soil samples analyzed from the layer under the heavily burned stones in squares 401/804–806 provide the clearest anthropogenic anomaly in House 2, from a soil chemistry point of view, with increased CaO (ca. 8–12 wt%), Fe2O3 (ca. 8–10 wt%), and ZnO (ca. 800–1100 ppm) in contrast to the baseline values. This area also displays phosphorus values above the archaeological soil average, indicating accumulation of organic residues connected to this area, e.g. due to the presence of organic waste residue in this space (Fleisher and Sulas 2015; Holliday and Gardner 2007). The enriched values, especially Ca, probably relate to burning activities and wood ash (Middleton 2004, 56), being therefore tenable findings in connection to the layer of heavily burned stones.

The soil excavated under the limestone slab covered with red pigment in square 401.0/806.0 (see also Figure 3B) displays slightly increased iron values and double the zinc level compared to the baseline soil mean values (ca. 9 and 6.5 wt%; 1300 and 600 ppm, respectively). Both iron and zinc are common anthropogenic markers; Zn may link to brass production, but can also derive from burning of wood, dung, or occupational waste (Cook, Clarke, and Fulford 2005, 808; Wilson, Davidson, and Cresser 2008; Oonk, Slomp, and Huisman 2009; Dirix et al. 2013; Choi et al. 2020 and references therein). However, the source of iron and zinc enrichment in this context must be connected to the mineral pigment on the stone.

Compared to House 1, the anthropogenic signals from House 2 are overall more complicated to interpret, especially as many of the key anthropogenic elemental values (apart from Fe2O3 and Y2O3; see Figure 6) present values that are within the range of, or even below, the baseline values of House 1’s measurements. This can be explained by the different spatial and topographical location of the trenches at the site and the possible resulting soil variations, which may have reduced the usability of House 1 layer 6 values as a baseline for House 2 activity levels. It is also possible that the layer 6 values of House 1, although significantly lower compared to the other layer values from the house, are in fact enriched as a result of leaching from the upper layers. House 1 was very intensively used, over a long period of time and had multiple activity layers. Furthermore, contamination from the long-term paddock use must be taken into consideration. All of this leads to the conclusion that the mechanical layer 6 values from House 1 that were treated as a baseline may not represent a true baseline for the entire site and for House 2, in particular. At the same time, the geochemical data, together with the significantly weaker anthropogenic signal in terms of finds, indicates a completely different use-pattern for the spaces associated with House 2 at Bartsgårda.

The P2O5 values from House 2 remain below 3 wt% throughout the sampled track. These values are significantly lower than the phosphorus values detected from House 1 (including layer 6), suggesting both a lower intensity of use and less exposure to livestock-derived contamination. However, there is a mild yet systematic increase in layer 2 P2O5 values (> 2 wt%) in the middle of the house (401.0/803.0), and this enriched pattern continues outside the eastern wall and extends until the eastern end of the trench (401.0/809.5). Related patterning can be observed in the CaO values, which remain under 3.5 wt% in the western end of the track and then rise to 4–6 wt% from the middle of the house (401.0/803.0) onwards, dipping slightly when outside the building. Again, Fe2O3 shows the lowest layer 2 concentrations in the western part of the track (< 6 wt%), which then rise to 7–9.5 wt% for the eastern part of the house. The Fe2O3 values measured from the exterior space samples (401.0/807.5–809.5), at 6–7 wt%, are higher than in the western interior, yet not as elevated as in the eastern interior space. Similarly, the trace elements ZnO, SrO, and BaO all start to enrich from square 401.0/803.0, with the values remaining higher than in the western interior or outside the eastern wall of House 2. This geochemical data correlates with the observations made during the excavations, i.e. the possibility that the interior of House 2 was separated by a wall, and that these separate spaces within the building were used for different purposes. However, the measured ZrO2 and CuO values appear fairly consistent throughout the track. The same applies for Y2O3 and Rb2O, which are represented by fairly modest concentrations in House 2 (see Figure 6), apart from a Rb2O anomaly (at 650 ppm) in square 401.0/807.0.

The geochemical patterns of the studied houses and related areas are distinctively different, which is in line with the archaeological observations, and further suggests that the two houses had very different functions. The anthropogenic patterning of House 1 has a very domestic nature, whereas the use-patterns of the House 2 spaces indicate...
alternative uses. Weakened anthropogenic signals in the geochemical data, sometimes even under the baseline values, can derive from specific use-patterns, sporadic use, or the efficient cleaning of the space (see Middleton 2004, 56). For example, patios and pathways, and spaces for festivities, rituals, ceremonies, or entertaining—essentially, spaces that were cleaned and kept clear of animal and human waste and activities that produce organic waste—can have low artifact densities and limited enrichment in anthropogenic residues, e.g., P, Fe, and trace element values (Fernández et al. 2002; Hudson and Terry 2006, 398–401; Fleisher and Sulas 2015).

Conclusions

The aims of the current study were to 1) contribute to and supplement the archaeological identification of floor or activity levels based on the vertical and horizontal distribution of geochemical soil anomalies in two houses and their adjacent areas, which were the subject of small-scale field-school excavations in 2020 and 2021 at the settlement site in Bårsgårda, on the Åland Islands; 2) examine potential dissimilarities in the anthropogenic activity signals associated with the two studied buildings which might indicate different uses and functions of their spaces; and, 3) test the feasibility of a rapid and cost-efficient sampling and analytical strategy for the geochemical characterization of archaeological sediment samples.

In line with the archaeological observations, the multi-element geochemical data indicated several activity/floor levels for both of the studied houses and furthermore revealed that these buildings had very different use-strategies and functions. In both cases, the activity areas also clearly extended to the space outside of the buildings' walls. In addition, there were related features and other localized enrichments in the excavated contexts that appear to be connected to specific activities that took place within different spaces. The significantly anthropogenically-enriched layers of House 1 suggested domestic activities and multiple use-phases for the house, although of clearly varied intensity. The anthropogenic signal from House 2 was notably weaker, suggesting that its space, which was functionally separated into distinct areas, was used only for a shorter period and/or periodically, for specific activities such as festivities or ceremonies, and possibly carefully cleaned after each use.

Our results demonstrate that the chosen strategy, including systematic and feature-specific sampling on-site, followed by ex situ (laboratory-based) ED-XRF analysis of air-dried, non-pulverized samples, was successful. It provided detailed evidence of the vertical and horizontal variation in the geochemical concentrations of the soils sampled from the two houses and also the different uses and functions of the houses. We were able to successfully establish a labor- and cost-efficient sampling and analytical routine for the geochemical analysis of archaeological soil samples to facilitate the detection of anthropogenic signals. However, the long-term use of the site as a livestock paddock, which continues today, introduced some complexities for our sampling strategy and data interpretation. The phosphorus values measured, especially in connection to House 1, showed significant enrichment continuing into the lowest excavated levels, and the P values leaching from the surface soil practically prevented the use of P values for archaeological interpretations. This underlines the need for a multi-element approach, instead of relying on P values only, which at least in this case study proved to be too contaminated to be useful for meaningful archaeological interpretations of past activities.

The contamination by the long-term land-use at the site probably also explains why the P levels detected in the House 2 activity layers were lower than those measured from the more-or-less natural soil beneath House 1. Due to the more central location of House 1 at the site as a whole, it is also possible to speculate that this particular area has suffered more livestock-derived contamination, leading to the generally higher P levels measured for this building. This leads us to conclude that although identifying undisturbed, similarly-dated control soil samples at an archaeological site (or its immediate vicinity) is a common problem for archaeological soil prospection, seemingly natural under-house layers can be used cautiously as geological baseline representatives. A comparison between the datasets from the two studied buildings indicated that, in addition to P, other typically anthropogenic elements were also probably enriched due to leaching. It is possible that the intense use of House 1 is reflected in the element concentrations of the layer excavated under the building, and thus this layer may not be representative of the true geological baseline but should rather be treated as a relative baseline for the house in question. The actual baseline values for the site are probably below those detected for (the generally low) anthropogenic elements in House 2 activity levels, but it is practically impossible to find on-site natural sediments with “true” values, mainly because of the modern land-use. These circumstantial factors at the site do not, however, prevent relative comparison between the houses and the anthropogenic signals derived from their contexts, as well as related interpretations of their functions and use-strategies. However, in hindsight, sampling the more-or-less natural soil layer also exposed beneath House 2 could have benefitted our understanding of the modern contamination effects at different parts of the site. The relative baseline values for House 2 probably would have clarified the variation in the enrichment patterns between the different House 2 layers and contexts. In particular, house-specific baseline values would have helped us to evaluate the relative differences between the two individually anthropogenically-enriched houses.

Our analytical strategy, although working within the limited size of the excavation trenches, provided information on clear anthropogenic patterning and identifiable differences between the examined contexts and structures, with a fast turnover from on-site sampling to data interpretation. The sampling and sample processing strategies were adequately rigorous to answer the proposed research questions and to reveal high-definition anthropogenic patterning of past activities at the site. Accordingly, knowing that reliable data quality and adequate analytical resolution for the needs of this kind of research can be achieved quickly and affordably, even for large numbers of soil samples, in the next endeavor, we will collect many more samples, and from each archaeological layer, not only from the single tracks and features, but from the whole width of the excavated area, especially in cases of layers estimated to have potentially higher information value. As a key lesson, we recommend collecting baseline soils under each excavated
structure individually in order to assist in the evaluation of location-specific circumstances, such as contamination due to modern land-use, that could potentially affect the elemental concentrations of archaeological sediments. In sum, systematically collecting soil samples while excavating is the most important factor, and decisions on what samples to process and analyze can be made later in the laboratory.

Endnotes

1. Limestone occurs naturally on the Åland Islands, and the occurring types of limestone tend to contain reddish calcareous clayey inclusions associated with disruptions in the sediment. The coloration is, however, usually not obvious on the worn surface and mostly visible when the cobbles of limestone are split. In the case of the limestone from House 2 in Bartsårdä, the red substance was in loose lumps, covering only one of the worn surfaces, and the pigment was also abundant in the soil directly underneath the stone (see also Figure 3B). These circumstances point towards the red substance being human-related ochre.

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References

ÅSUB. 2021. Statistik årsbok för Åland 2021 / Statistical Yearbook of Åland 2021. Mariehamn: Ålands statistik- och utredningsbyrå. Accessed February 14, 2022. https://www.asub.ax/sites/www.asub.ax/files/attachments/page/statistik_arsbok_for_aland_2021_0.pdf.
Bam, E. K. P., A. M. Akumah, and S. Bansah. 2020. “Geochemical and Chemometric Analysis of Soils from a Data Scarce River Catchment in West Africa.” Environmental Research Communications 2: 035001.
Barba, L. 2007. “Chemical Residues in Lime-Plastered Archaeological Floors.” Geochaeology: An International Journal 22 (4): 439–452.
Choi, Y. J., J. Lampel, S. Fiedler, D. Jordan, and T. Wagner. 2020. “A New Method for the Identification of Archaeological Soils by Their Spectral Signatures in the vis-NIR Region.” Journal of Archaeological Science: Reports 33: 102553.

Cook, S. R., A. S. Clarke, and M. G. Fulford. 2005. “Soil Geochemistry and Detection of Early Roman Precious Metal and Copper Alloy Working at the Roman Town of Calleva Atrebatum (Silchester, Hampshire, UK).” Journal of Archaeological Science 32: 805–812.
Cook, D. E., B. Kovacevich, T. Beach, and R. Bishop. 2006. “Deciphering the Inorganic Chemical Record of Ancient Human Activity Using ICP-MS: A Reconnaisance Study of Late Classic Soil Floors at Cancún, Guatemala.” Journal of Archaeological Science 33: 628–640.
Dirix, K., P. Muchez, P. Degryse, E. Kaptijn, B. Muñiz, E. Vassilieva, and J. Roblome. 2013. “Multi-element Soil Prospection Aiding Geophysical and Archaeological Survey on an Archaeological Site in Suburban Sagalassos (SW-Turkey).” Journal of Archaeological Science 40: 2961–2970.
Drake, E., and C. Ramsdahl. 1929–1930. “Finström 1929–1930.” Kulttuurymääritys palveluikkuna, digitized fieldwork report. Accessed October 27, 2021. https://www.kyppi.fi/palveluikkuna/raportti/read/hae_lite.aspx?id=104878&ttpyyppi=pdf&kansio_id=60.
Dreijer, M. 1958. “Hustomtinngarna i Tjudnäs.” Åländsk Odling 1955: 28–69.
Dreijer, M. 1958. “Berättelse över utgrävningen av hustomtningarna 2 och 5 i Kohagen i Kvarnbo 1958.” Excavation report in the archives of the Museum of Åland, Mariehamn.
Farid, S. 2000. “The Excavation Process at Çatalhöyük.” In Towards Reflexive Method in Archaeology: The Example at Çatalhöyük, edited by I. Hodder, 19–35. Cambridge: McDonald Institute for Archaeological Research.
Fernández, F. G., R. E. Terry, T. Inomata, and M. Eberl. 2002. “An Ethnoarchaeological Study of Chemical Residues in the Floors and Soils of Qe’eqhi’ Maya Houses at Las Pozas, Guatemala.” Geoarchaeology: An International Journal 17 (6): 487–519.
Fleisher, J., and F. Sulas. 2015. “Deciphering Public Spaces in Urban Contexts: Geochemical Survey, Multi-Element Soil Analysis, and Artifactual Distributions at the 15th–16th-Century AD Swahili Settlement of Songo Mnara, Tanzania.” Journal of Archaeological Science 55: 55–70.
Frahm, E., G. F. Monnier, N. A. Jelinski, E. P. Fleming, B. L. Barber, and J. B. Lambon. 2016. “Chemical Soil Surveys at the Bremer Site (Dakota County, Minnesota, USA): Measuring Phosphorous Content of Sediment by Portable XRF and ICP-OES.” Journal of Archaeological Science 75: 115–138.
García Álvarez-Busto, A., A. Laca, and A. Fernández González. 2019. “Revealing the Monastic Kitchen: Chemical Analysis of the Soil Inside the Monastery of Cornellana (North-West Spain).” Archaeometry 61 (1): 145–160.
The Government of Åland. 2018. “Register over ancient monuments on Åland.” Accessed October 27, 2021. https://aland.maps.arcgis.com/apps/webappviewer/index.html?id=9d7cc07ab04000ca620038c4d6146eca.
Hackman, A. 1940. “Två åländska Husgrender Från Yngre Jarnåldern.” Finskt Museum XVII: 67–84.
Hayes, K. 2013. “Parameters in the Use of pXRF for Archaeological Site Prospection: A Case Study at the Réamue Fort Site, Central Minnesota.” Journal of Archaeological Science 40: 3193–3211.
Holliday, V. T., and W. G. Gardner. 2007. “Methods of Soil P Analysis in Archaeology.” Journal of Archaeological Science 34: 301–333.
Holmqvist, E., and K. Ilves. 2022. “A Compositional Study of a Gold-Plated Viking Age Pendant from the Åland Islands.” Fornvännen 117: 63–67.
Hudson, S. R., and R. E. Terry. 2006. “Recovering Social and Cultural Dynamics from Plaster Floors: Chemical Analyses at Ancient Chunchumil, Yucatan, Mexico.” Journal of Archaeological Science 33: 391–404.
Hunt, A. M. W., and R. Speakman. 2015. “Portable XRF Analysis of Archaeological Sediments and Ceramics.” Journal of Archaeological Science 53: 626–638.
Ilves, K. 2018. “Stone Foundation Houses of the Late Iron Age and Early Medieval Åland and new C14-Dates from the Settlement of Kulla.” Fennoscandia archaeologica XXXIV: 59–82.
Ilves, K. 2021. “De arkeologiska undersökningarna i Bartsårgård år 2020.” Excavation report in the archives of the Museum of Åland, Mariehamn.
Ilves, K. 2022. “De arkeologiska undersökningarna i Bartsårgård år 2021.” Excavation report in the archives of the Museum of Åland, Mariehamn.
