MILJÖARKEOLOGISKA LABORATORIET

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Environmental archaeological analysis
of sediment samples retrieved
from bronze artefacts
Site L2021:2810
Alingsås, Västergötland

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Sample information

Analysis type: Macrofossil analysis of unfloated samples, soil chemical analysis, XRF- Metals and kat- och anions, NIR spectroscopy
Number of samples: 6 macrofossil sample, 6 soil chemical samples.

Introduction

The samples come from a depot for bronze objects that was found by a private person in April 2021 and then examined archaeologically. The depot was located under a stone block where animals dug out objects.
In three places the contexts were not influenced in the recent times. However, it is uncertain whether it is the original location of the objects or whether they have been moved by burrowing animals at a much earlier stage. In all contexts the soil was darker and more compact.

The aim of the analyses is to facilitate the assessment of how long the objects have been in place. The hope is also to find traces of other material that can increase the understanding of the deposit, and if it could be linked to a ritual activity or a more hoard like deposit.

Samples and context related information were provided by Johanna Lega, Förvaltningen för kulturutveckling, Göteborg.

Material

In figures 1 to 4, an overview of the findings and contexts are presented.

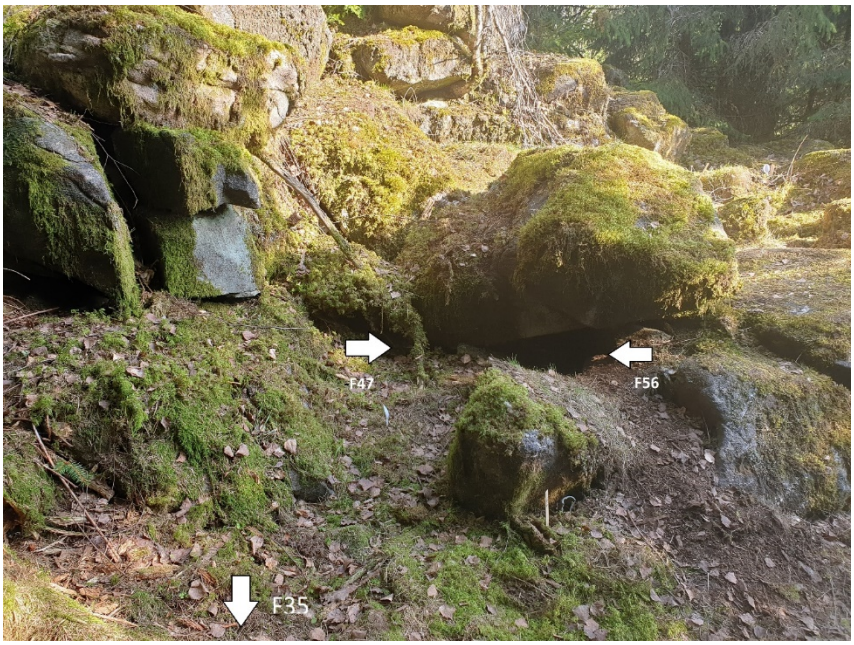

Figure 1. Location of samples in the boulder/stone aggregation and openings to a fox/badger' den.

Figure 2. Location of sample F35 in the boulder/stone aggregation.

Figure 3. Location of sample F47 in the boulder/stone aggregation.

Figure 4. Location of sample F56 in the boulder/stone aggregation.

Six samples were collected during and after excavation. F35 A and B, F47 A and B, F56 A and B (A stand for inside artefact and B nearby surroundings).

Methods

Macrofossil analysis

Before the analysis the samples were stored in a drying room (+30°) until the moisture has disappeared. Afterwards they were water sieved using sieve meshes of 2 mm and 0,5 mm. After sieving, the samples were sorted in two fractions (2 mm and 0,5 mm) in order to collect more easily not only the plant material but also other archaeological finds such as bronze, ceramics, etc. The samples volume before floatation was between 0,3 and 1,2 liters and after it between 95 to 200 ml. The results from the analyses have been presented in Table 2.

The amount of woody charcoal in the samples was estimated as relative proportion of the floated sample volume as follows: x = up to 25%, xx = up to 50%, xxx = up to 75%, xxxx = about 100%. The determination of plant species was done using reference literature for seeds (Cappers et al. 2012) as well as the laboratory reference collections. The names of the identified plants are given according to the Nordens flora (Mossberg and Stenberg 2018) and the Virtual Flora (Anderberg and Anderberg, u.d.). Swedish names of the identified plants are included in Table 2.
Sample processing and identification was performed by Kristian Hristov and Ivanka Hristova.

Soil chemistry

Prior to all analyses the samples were dried at 30°C. Samples were then passed through a 1.25 mm sieve and any presence of material of cultural significance noted (such as bone, charred material, ceramics etc.). The chemical methods employed here are the same as those used in Swedish soil chemical studies following the methodological approach of Engelmark and Linderholm (2008). The parameters analysed and abbreviations used are explained in Table 1.

Table 1. Geoarchaeological methods and abbreviations as used in this report.

Abbreviation	Method	Description
MS_{lf}	Magnetic Susceptibility	Magnetic susceptibility measured on 10g of soil, with a Bartington MS3 system with an MS2B probe (Dearing 1994). Data are reported as SI-units per ten grams of soil, (corresponding to X_{lf}, 10^{-8} m^3 kg^{-1}) (Thompson & Oldfield 1986).
MS550	Magnetic Susceptibility after burning at 550ºC	Magnetic susceptibility after 550° C ignition (units as above)
LOI (%)	Loss On Ignition	Soil organic matter, determined by loss on ignition at 550° C, in percent (Carter, 1993).
Cit-P	Inorganic phosphate content (mg P/kg dry matter, ppm)	Extraction with 2% citric acid (corresponding to the Arrhenius method (Arrhenius 1934))
Cit-POI	Total phosphate (mg P/kg dry matter, ppm) (inorganic & organic)	Extraction with 2% citric acid on ignited soil (Engelmark & Linderholm 2008)
P quota	**Cit-POI /Cit-P**	Ratio of inorganic & organic to inorganic phosphate

These methods have been developed and adapted for soil prospection and the bulk analysis of occupation soils and features. Analysed parameters comprise organic matter (loss on ignition [LOI, and pH], Carter 1993), two fractions of phosphate (inorganic [Cit-P], and sum of organic and inorganic [Cit-POI]) (Engelmark & Linderholm 2008, Linderholm 2007) and magnetic susceptibility (MS-χ_{lf} MS-χ_{hf}) and MS550-χ_{lf} (Clark 2000, Linderholm 2007, Engelmark & Linderholm 2008). These analyses provide information on various aspects concerning phosphate, iron, red-ox potential and other magnetic components and total organic matter in soils and sediments, and their relationship to phosphate.

Near infrared analysis was performed using a Analytical Spectral Devices (ASD) LabSpec 4, with a rapid probe analyser, featuring a detection range of 350–2500 nm, whose spectral sampling (resp. spectral resolution) was 1.4 nm (resp. 3 nm) in the visible and near infrared range and 1.1 nm (resp. 10 nm) in the short-wave infrared range (Linderholm et.al 2019). All PCA models was calculated using Evince-Prediktera software.

XRF analysis was conducted using a Thermo Scientific Niton XL5 Analyzer, connected to a Thermo Scientific^{TM} portable test stand. The reference calibration Soil mode was used for quantification.

Soil chemical analyses were undertaken by Johan Linderholm, Samuel Eriksson and Kristian Hristov.

Results

Soil-sediment chemistry and magnetic susceptibility analysis

Results from the different chemical and magnetic susceptibility analyses are presented in table 4.

The organic content of the samples varies between 7,5-17% (figure 5), which is normal for organic forest top soils with a lot of penetrating roots. The inorganic phosphate content is not terribly high other that in sample F35A (above 200 ppm) but this sample deviates from the others. In figure 5 it is clear the organic phosphate content is significantly higher in the outside samples than the soils from inside the rings. This shows the activity of soil biota and plants is larger in the more exposed samples.

MS values are generally high and correlates with Fe content, so it is probable that this is related to contributions from the local bedrock, rather than heat exposure.

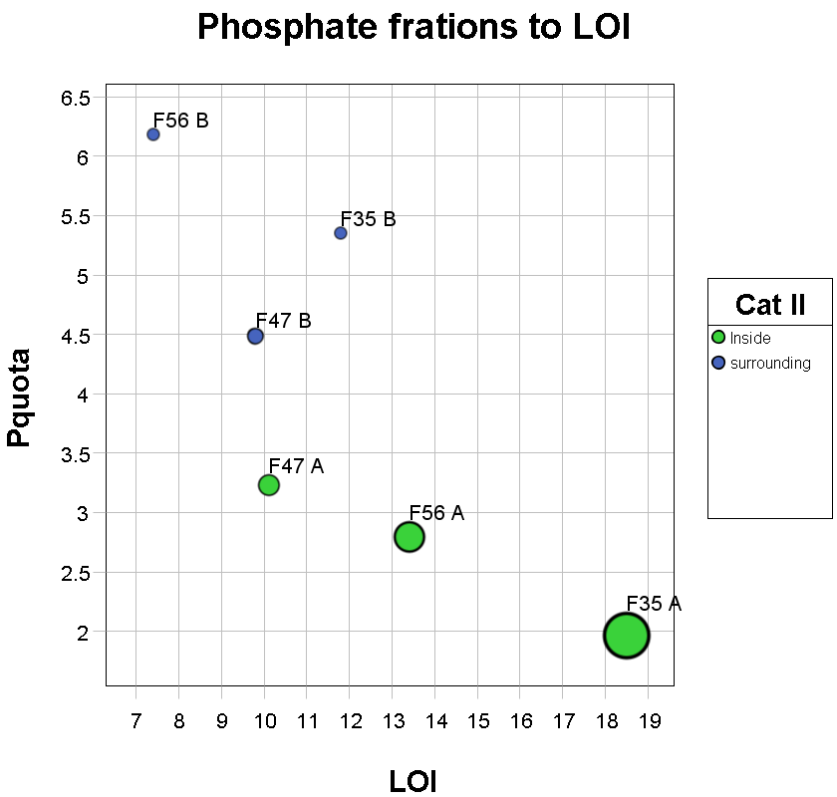

Figure 5. The Pquota to LOI showing the relative occurrence of organic phosphate among the samples. The relative size of the dots indicate the Cit-P content.

The level of general contamination of heavy metals of the soil materials reaches toxic levels at least to some biota (table 4). Elements like Cu, As, Pb, Ni, Sb and in three samples Cr show levels way above natural back ground levels. This also probably applies for Sn.

The copper content inside the rings is considerably high and even though lower in the surrounding samples, the Cu-content is way over natural background levels. This means that the rings must have been deposited and laid to rest for quite some time for this exchange between the artefacts and the soil matrix. Even though no copper finds were made inside of the F56 A inner sample (table 3), the Cu content is considerable meaning that the Cu-levels also in this case represent a state of "equilibrium" between the ring and the soil matrix.

Looking at figure 6, an overview on the multivariate correlation of variables in relation to the samples (objects). F35A stands out and is characterised by elements Cu, Ag, Sn, Sb, As, Pb and phosphate-concentrations. The LOI is also high and the reason for this is developed in the text below. Also, F47A and F56A have similar but less pronounced metal elemental and LOI pattering.

The outside samples are more related to "modern" processes.

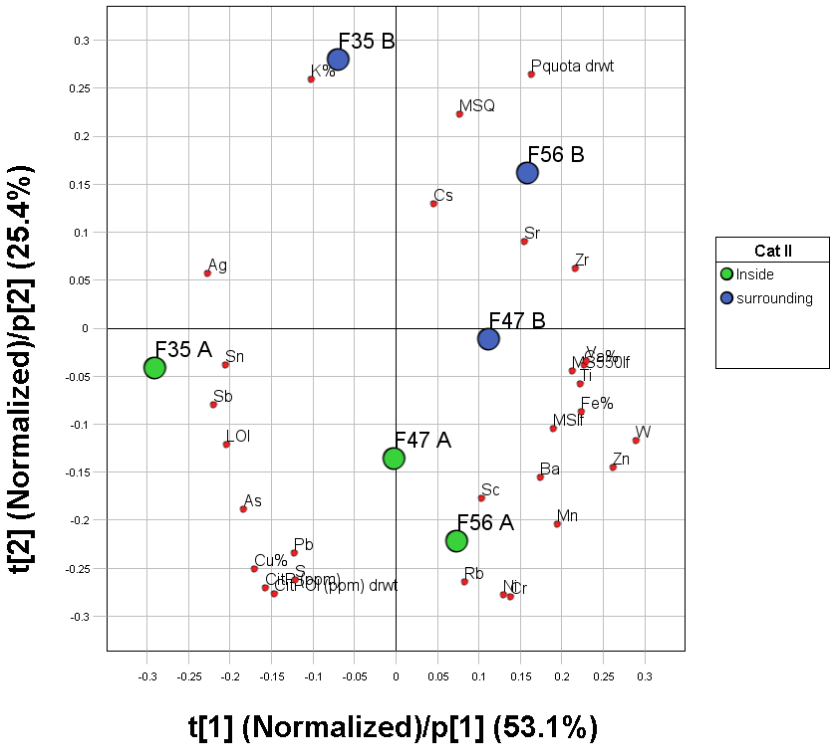

Figure 6. A PC model based on 6 objects and 30 variables. All data are mean centred, UV scaled, and log transformed prior to calculating principal components.

Figure 7 gives an additional dimension where the Sn to Cu is plotted with Ag as a third dimension in the plot. Again it is evident, that inside and outside sample responses differ, with F35A standing out.

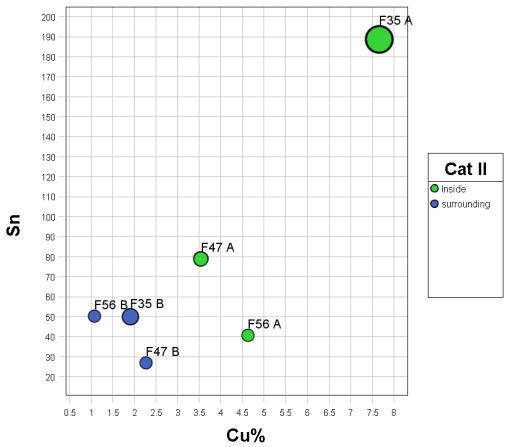

Figure 7. The relation Tin (Sn) to cupper (Cu) with points in relative size representing silver (Ag) content.

Turning to figure 8, a processed NIR spectra is presented.

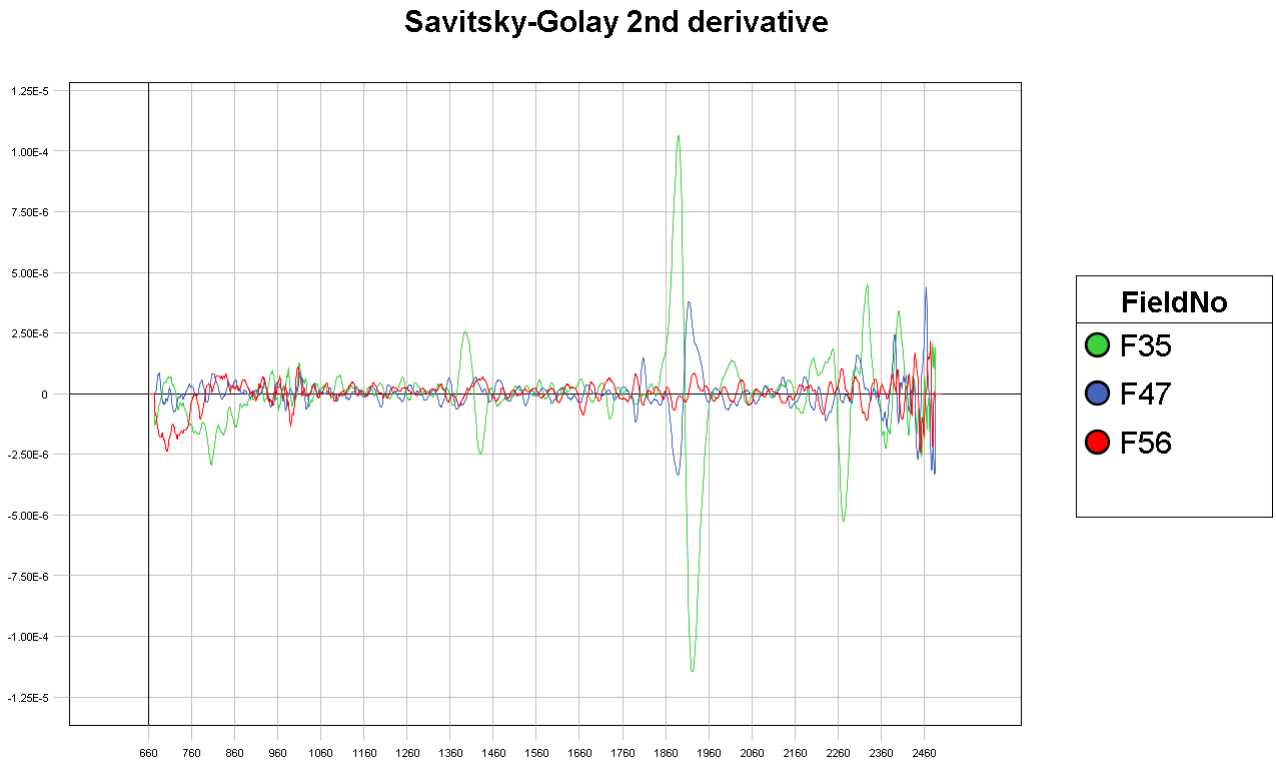

Figure 8. A model based on Savitsky-Golay preprocessing and 2nd derivative. Samples from inside the artefacts. Note sample F35 spectra and the deviation from the others. Negative peaks are the relevant ones to observe.

The response peaks shown figure 8, highlight bands especially around 1920 nm showing presence of phosphate (P-OH), protein $CONH_2$ (amine) compounds and water (lattice and adsorbed).

It is very different than that of peaks in figure 9. Here more carboxylic compounds responding around 1890 nm and F56B is again deviating probably because of the more exposed nature of deposition/location.

None of these findings have an easy explanation other than that there just may be a difference in the biological turnover in the soil because of the high metal content. This could be further elaborated using other techniques.

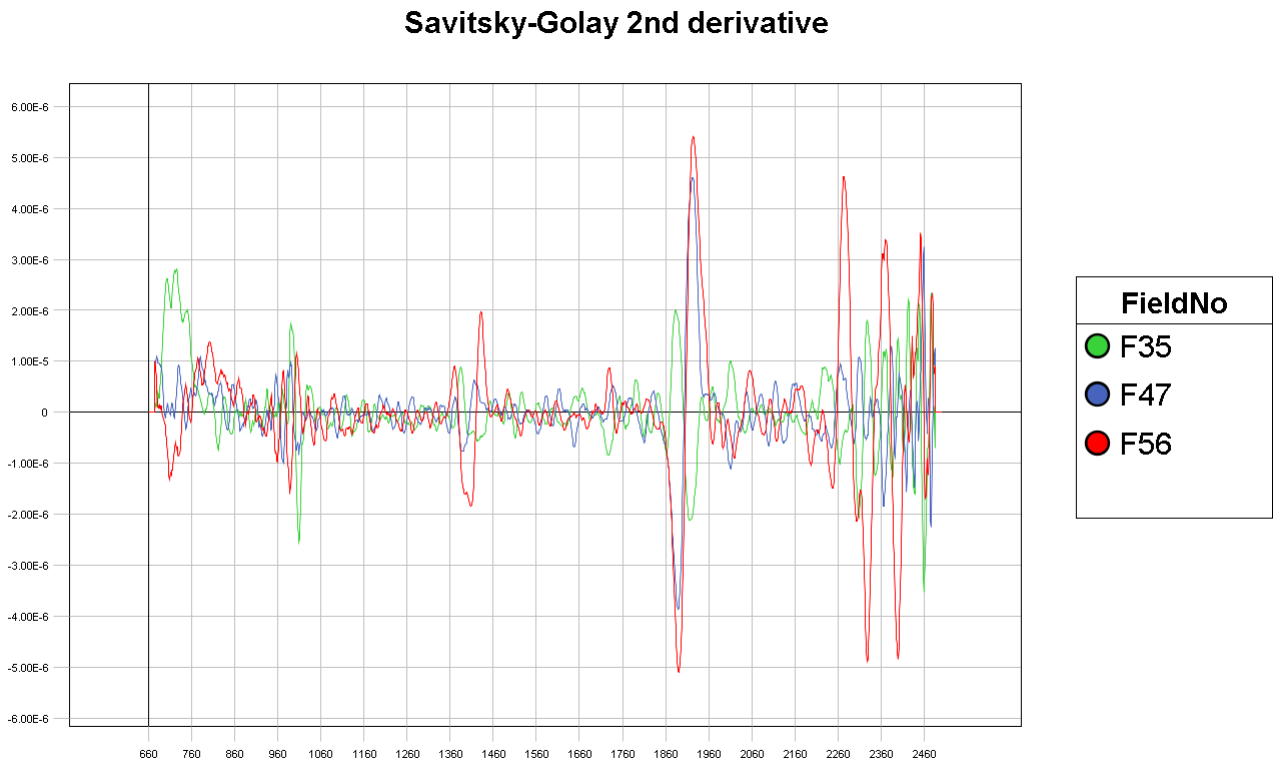

Figure 9. A model based on Savitsky-Golay preprocessing and 2nd derivative. Samples from outside context.

Macrofossil analysis

Six samples were analysed for macro remains. The amount of charcoals in the floated samples was around 25% to 50% of the floated samples volume. The preserved botanical material is scarce. All samples contained modern seeds. It is important to note that all samples, except sample number 21_0012_0005/ F56A, contained small bronze fragments between 1 and 20 mm, but also very small less than 1 mm.

Sample 21_0012_0001/ F35A
The sample volume before floatation was 0,9 liters and after flotation – 165 ml. The floated sample contained 25% charcoals. No botanical remains were found. Apart from that, many bronze fragments were selected, between 1 and 20 mm in size.

Sample 21_0012_0002/ F35B
The sample volume before floatation was 0,55 liters and after flotation it was 95 ml. The amount of charcoals was estimated to about 50% of floated sample volume. No other botanical material was found. Bronze fragments between 1 and 5 mm were present.

Sample 21_0012_0003/ F47A
The sample volume before floatation was 0.3 liters and after floatation it was 115 ml. The amount of charcoals in the sample was about 50% of the floated sample volume. One spruce needle (*Picea abies*) was identified. The selected bronze fragments were between 1 and 10 mm.

Sample 21_0012_0004/ F47B
The sample volume before floatation was 1 liter and after flotation – 230 ml. Half of floated sample volume consisted of charcoals. The botanical material was represented by few fragments of spruce needles (*Picea abies*), spruce seeds (*Picea abies*), and two seeds of the bean family (Fabaceae). The collected bronze fragments are between 1 and 6 mm.

Sample 21_0012_0005/ F56A
The sample volume before floatation was 0,7 liters and after flotation it was 120 ml. The amount of charcoals was about 50% of floated sample volume. Only two seeds of the bean family (Fabaceae) were found. This is the only sample lacking bronze fragments.

Sample 21_0012_0006/ F56B
The sample volume before floatation was 1,2 liters and after flotation – 200 ml. The amount of charcoals was estimated to about 50% of the floated sample volume. The identified plant remains comprised few fragments of spruce needles (*Picea abies*) and a fragment of hazelnut shell (*Corylus avellana*). Most of the bronze fragments are about 1 mm. In addition one bronze ring (d=4mm) and a fragment of bronze spiral (d=3mm) were found.

Discussion and Conclusions

The overall preservation of the botanical remains in the studied samples is scarce. The most common botanical remains were spruce needles. The large number of bronze fragments in the samples is considerable and reflect past and ongoing corrosion, but also from bioturbation causing fragmentation to occur.

It is hard to make interpretations of the botanical remains, as the possibility of contaminations is very high, having in mind the conditions of the archaeological contexts. Dating some of the plant remains could facilitate the determination of the time of contamination/disturbance if any. Pollen analyses of the patina from the bronze objects could give additional insight for the paleoenvironment and the archaeological context.

The characteristics of the infilled soils is not fully clear as to the formation. If there were organic remains in them already by the deposition is hard to say but the F35A is a strong candidate if this would be the case.

The soil chemical analyses also show very high quantities of several Bronze related metals that probably is derived from both fragmentation and dissolution and mobility. Most probably, these objects have been deposited for a longer period, and only disturbed by bioturbation from smaller and mid-size mammals.

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Figures and tables

Table 2. Archaeobotanical results from the studied sites.

MAL nr	21_0012_0001	21_0012_0002	21_0012_0003	21_0012_0004	21_0012_0005	21_0012_0006
Prov nr	F35 A	F35 B	F47 A	F47 B	F56 A	F56 B
Charcoal fragments	x	xx	xx	xx	xx	xx
volume before flotation (L)	0,9	0,55	0,3	1	0,7	1,2
volume after flotation (ml)	165	95	115	230	120	200
Picea abies (Gran/ Norway spruce) - needle			**1**			
Picea abies (Gran/ Norway spruce) - needle fragment				**8**		5
Picea abies (Gran/ Norway spruce) - seeds				**4**		
Fabaceae (Ärtväxter/ bean family) - seeds				**2**	**2**	
Corylus avellana (Hassel/ Hazel) - shell fragment						**1**
metal/bronze fragments	x	x	x	x		x
bronze ring (d=4mm)						x
bronze spiral (d=3mm) - fragment						x

Table 3. Other observations from the retrieved material.

MAL nr	Prov nr	metal finds
21_0012_0001	F35 A	many bronze fragments / from 1 to 20 mm
21_0012_0002	F35 B	bronze fragments / from 1 to 5 mm
21_0012_0003	F47 A	bronze fragments / from 1 to 10 mm
21_0012_0004	F47 B	bronze fragments / from 1 to 6 mm
21_0012_0005	F56 A	no finds
21_0012_0006	F56 B	few bronze fragments - 1 mm/ One fragment from bronze spiral (d = 3mm) and one ring (d = 4mm)
MAL nr		**Other**
21_0012_0001	F35 A	modern roots, stems, twigs, bark and seeds
21_0012_0002	F35 B	modern roots, stems, twigs and seeds
21_0012_0003	F47 A	modern roots, stems, twigs, bark and seeds
21_0012_0004	F47 B	modern roots, stems, twigs, bark and seeds
21_0012_0005	F56 A	modern roots, stems, twigs, bark and seeds
21_0012_0006	F56 B	modern roots, twigs and seeds

Table 4. Result from the phosphate, magnetic susceptibility, loss on ignition and XRF analysis. Marked in green are all values significantly above contaminated levels in general moraine and agricultural soils

MALNo	FieldNo	MSlf	MS550lf	MSQ	CitP (ppm)	CitPOI (ppm) drwt	Pquota drwt	LOI	Fe%	Mn	
21_0012_0001	F35 A	295	537	1,82	218	427	1,96	18,5	5,6	3765	
21_0012_0002	F35 B	345	756	2,19	44	236	5,35	11,8	6,8	3645	
21_0012_0003	F47 A	574	1032	1,80	95	307	3,23	10,1	9,6	14042	
21_0012_0004	F47 B	558	1110	1,99	61	272	4,48	9,8	9,9	13739	
21_0012_0005	F56 A	432	872	2,02	137	383	2,80	13,4	9,2	18755	
21_0012_0006	F56 B	486	964	1,98	32	200	6,19	7,4	10,1	14039	
MALNo	**Cu%**	**Sn**	**Ag**	**As**	**Pb**	**Ni**	**Sb**	**Zn**	**Ba**	**Cr**	**S**
21_0012_0001	7,7	189	145	380	605	155	146	<LOD	584	57	2146
21_0012_0002	1,9	50	51	121	234	83	51	47	561	55	1391
21_0012_0003	3,5	79	33	213	884	263	58	122	628	75	2142
21_0012_0004	2,3	27	16	129	412	246	29	136	718	81	1824
21_0012_0005	4,6	41	16	155	347	665	46	165	886	87	1696
21_0012_0006	1,1	50	<LOD	30	84	292	<LOD	206	797	63	1334
MALNo	**Ca%**	**K%**	**Rb**	**Sr**	**Ti**	**V**	**W**	**Zr**	**Cs**	**Sc**	
21_0012_0001	1,6	0,8	31,9	128	7649	136	<LOD	230	58	146	
21_0012_0002	2,1	1,0	33,9	171	9435	159	34	290	53	162	
21_0012_0003	2,3	0,8	40,7	138	12917	191	<LOD	271	56	153	
21_0012_0004	2,4	0,8	37,3	173	14189	218	57	323	67	171	
21_0012_0005	2,7	0,7	40,8	170	11770	190	68	297	46	236	
21_0012_0006	2,7	0,8	31,8	154	13600	218	<LOD	302	63	159	

Table 5. Concentration levels of contaminated soils/sediments (mg/kg).

Metaller	**SGU***	**Naturvårdsverket***		**SLU** (Eriksson et al 1997)
mg/kg	moraine	Moraine	Sediment soil type	Scania cultivated soils
As		10	7	4,1
Pb	20	25	25	17
Cd		0,3	0,15	0,27
Co	10	10	15	
Cu	25	25	30	10
Vanadin		40	60	
Zink	60	70	100	51

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