Laborativ Arkeologi 10–11, pp. 43–53 (1998)

A kitchen entrance to the aristocracy – analysis of lipid biomarkers in cultural layers

Sven Isaksson

In this paper the importance of meat and dairy products in the food culture of Germanic aristocracy is stressed. This forms the archaeological basis for the tracing of animal products in soils through the analysis of biomarkers, i.e. sterols and their corresponding 5α-stanols. These compounds were extracted from soil samples collected from cultural layers at Vendel, Vendel parish, Uppland, Sweden. The analysis was done by gas chromatography/mass spectrometry. Through Principal Component Analysis and Student's t-test of the data statistically significant differences could be shown between areas of culinary and non-culinary character. These results confirm the assumption that this method can be used as a means to classify archaeological soils, here from a food-cultural approach.

Introduction

In January 1996 a project titled *SIV – Svealand in the Vendel and Viking Periods* was initiated (Arrhenius & Herschend 1995), with funding from the Bank of Sweden Tercentenary Foundation. The subtitle of this project is *Settlement, Society and Power*, reflecting that the investigation of social rank will be a major objective. As food and eating habits are strong inter- and intra-cultural markers (for example Douglas 1978, Montanari 1994) they will be amongst the topics studied (Lidén 1995:26–27, Isaksson & Hansson 1995:32–33). Models of aristocratic food culture are based on source-critical analyses of archaeological material, runic inscriptions, sagas and other written sources. These serve as points of departure for the deduction of hypotheses to be tested by the organic analyses of soils and ceramic. The present paper is a report on methodological considerations concerning the analysis of biomarkers of animal origin in archaeological deposits. But first I will provide some considerations as a background.

In an analysis of the strophe by Kormak Ogmundarsson on Sigurd Ladejarls "blot" in the saga of Hakon the Good, Herschend (1997) argued that the union of fire and water, e.g. meat boiled in a vessel, carried a strong symbolic weight in the pagan communal meal. The meat-hooks and cauldrons found in the boat-graves at Vendel and Valsgärde may be a manifestation of this image of the generous chief and responsible noble. The scenario of the charitable aristocrat is a cultural theme often reproduced in sagas and runic inscriptions (Backe et al. 1993:339f). For the understanding of a site from this perspective the tracing of meat and dairy product processing is vital. This is a difficult task even when finds of bone and pottery are made, for the handling of dairy products may leave few traces on the vessels and utensils that were used; when such finds are rare the problem is even more complex. Thus the aim of this work was to develop a method for the identification of activities concerning the handling of meat and dairy products when other traces are lacking.

The samples used in this preliminary study are from the settlement remains at Vendel, the excavation of which is part of the SIV-project (Isaksson 1997a). At least two buildings have been found, one of residential character and the other of economic character. By finds and radiocarbon dates the residential building can be dated to c. AD 450 – 850. This building was covered by several constructions, one of which may be a cooking house, possibly from the Viking Age (Isaksson, manuscript).

The stabling of cattle had been introduced in Sweden long before this time, providing lower loss of cattle and more effective milking than the preceding year-around pasture. There are several indications in the archaeological material that livestock breeding dominated over the cultivation of fields during this period (Myrdal 1988:200), something that has also been observed in the area of investigation, e.g. Vendel parish (Seiler 1997:63).

The dating of the settlement remains show that they are contemporary with the boat-graves at Vendel. The monumental location of the site is undeniable (Isaksson

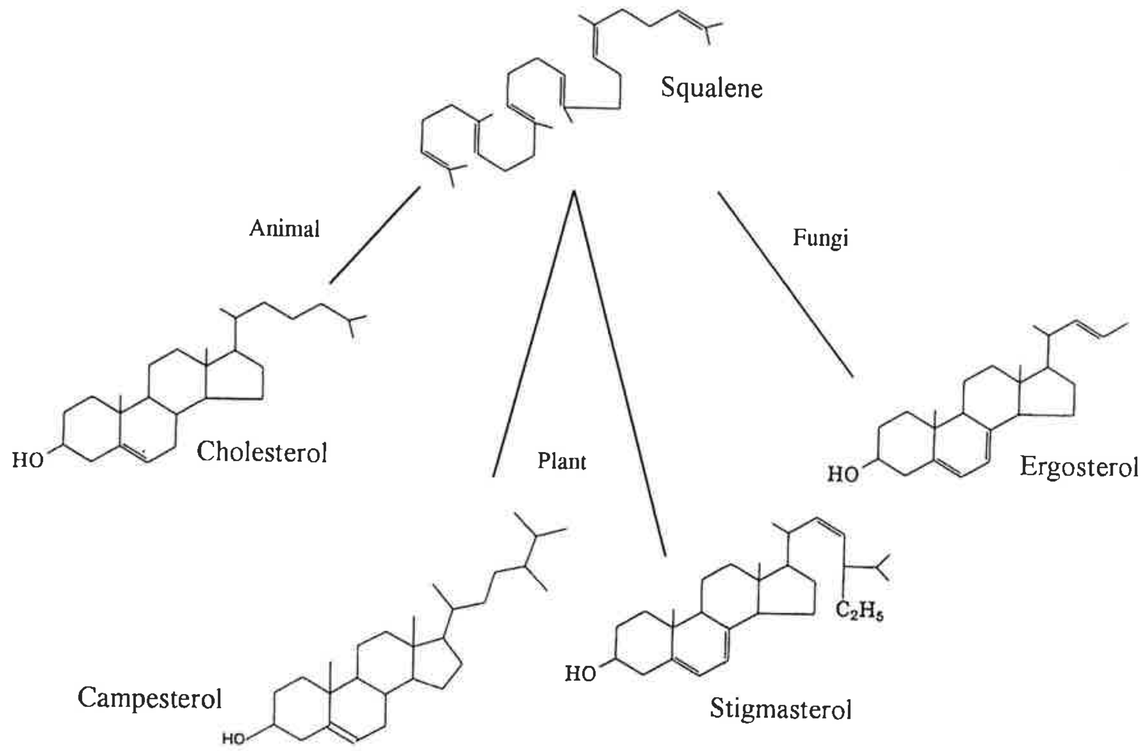

Figure 1. Different biosynthetical products of squalene.

& Seiler 1997), as is the spatial connection between the boat-graves and the settlement remains (Isaksson & Arrhenius 1995:15). The finds in the boat-graves show close ties to equivalents from Germanic Europe, demonstrating intimate contacts on a very high social level, perchance even reflecting a common *code of court*. Especially strong is the Frankish bond (Arrhenius 1980:13ff, Arrhenius 1985:197). This provides confidence for the use of Continental literary sources in the formulation of hypotheses concerning food habits in a high social strata. This approach has been advocated in other studies linked to Early Medieval Scandinavian lordships (Sawyer 1991:1ff). From the texts of several classic writers it is easily concluded that the prevalence of milk, cheese and meat was a common attribute of Germanic food culture (Montanari 1994:5ff). The high esteem of meat amongst food was particularly stressed within the ruling class. Meat was considered a symbol of power, a tool to generate vigour, physical energy and to sustain combat. In Frankish capitularies from the 9th century it is stated that the rendering up of arms and the forsaking of meat were both punishments used against those guilty of serious crimes, such as killing a bishop. This comparison of the two is as such a reinforcement of the status of meat, and the forsaking of meat was a sign of humility and marginalization (Montanari 1994:14–15).

The bone material of the excavated site is poor. To trace the handling of meat and dairy processing new ways must be sought. Soil organic matter derives from living organisms, such as plants, animals and microorganisms. The nature of soil organic matter may be influenced by human activities, e.g. food processing, and a relatively higher input of animal material (spillage and waste) might be found, and interpreted in archaeologically intelligible terms. The analysis of organic compounds found in soil-samples is a venture into the invisible artefacts of the cultural layers.

Selection of biomarkers

Due to differing chemical and biological properties the decomposition rate of organic compounds varies. Biological molecules that survive in favourable environments over long periods are often called biomarkers. To ascertain a firm correlation between an organic compound found in the soil and its history, knowledge of the structure is required (Eglinton 1969:20, Summons 1993:4, Hegdes & Prahl 1993:238). This is due to the fact that both general and specific features operate simultaneously in the biosynthetic pathways of living organisms, producing organic compounds with information individually encoded into the structure (Summons 1993:4). During the time of deposition, organic compounds are exposed to complex and deviate numbers of decomposition processes. Processes observed are for example hydrolysis, hydration, autoxidation, decarboxylation, β-oxidation, bioesterification, alcoholysis, all often induced by microbial attacks (Eglinton 1969:21, Heron & Evershed 1993:251–255, Mills & White 1994:34–35, Hita et al. 1996:24–27). Compounds encountered during analysis of a soil-sample may be unchanged, partly decomposed or compound synthesized during decomposition (Morrison 1969:569). All this must influence the selection of biomarkers. The questions to be asked are; What compounds will be deposited from the archaeological activity in question? Which of these have the highest potential of surviving? How may they change during deposition, and which are the decomposition pathways? What amounts may be expected? After answering these questions the analytical method may be selected.

The hydrocarbon squalene is a general precursor of divergent types of sterols, the type depending on the organism producing it (Summons 1993:4) (fig. 1). Sterols are structural lipids found in biological membranes of many living organisms. They also serve as precursors for a variety of products with specific biological activities, for example steroid hormones. With rare exceptions, bacteria lack sterols. This presents an opportunity to identify the source of a lipid material. Cholesterol may be found in meat and dairy products at a range between tens of milligrams to about one hundred milligrams per hundred gram edible part. For viscera food the content is higher, up to some hundred milligrams per hundred grams edible part (Statens Livsmedelsverk 1988).

Sterols are subjected to decomposition when deposited in the soil. Through a microbiological reduction of a double bond, by a series of enzymatic reactions, sterols are often transformed to 5α-stanols in the soil. There exists an alternative reductive pathway, where 5β-stanols are produced, but it has been shown to be a minor pathway in soils and sediments. However, the 5β-stanols constitute the major products of sterol reduction in mammalian intestines and have thus been used as markers of faecal input in archaeological soil (Gaskell & Eglinton 1975; Bethell et al. 1994; Evershed 1994; Evershed et al. 1997). Also, 5β-stanols dominate in lacustrine sediments made anoxic by enhanced aquatic production of organic matter (Meyer & Ishiwater 1993:196). It is however unknown if this is the case also in anoxic archaeological deposits. In lacustrine sediments there is evidence of oxidative pathways as well (Meyer & Ishiwater 1993:196), but none of the compounds produced by this pathway have been encountered in the present samples. Hence, aiming to trace handling of meat and dairy products, 5α-cholestan-3β-ol was selected as a biomarker for lipid-input of animal origin. Several soil-living organisms

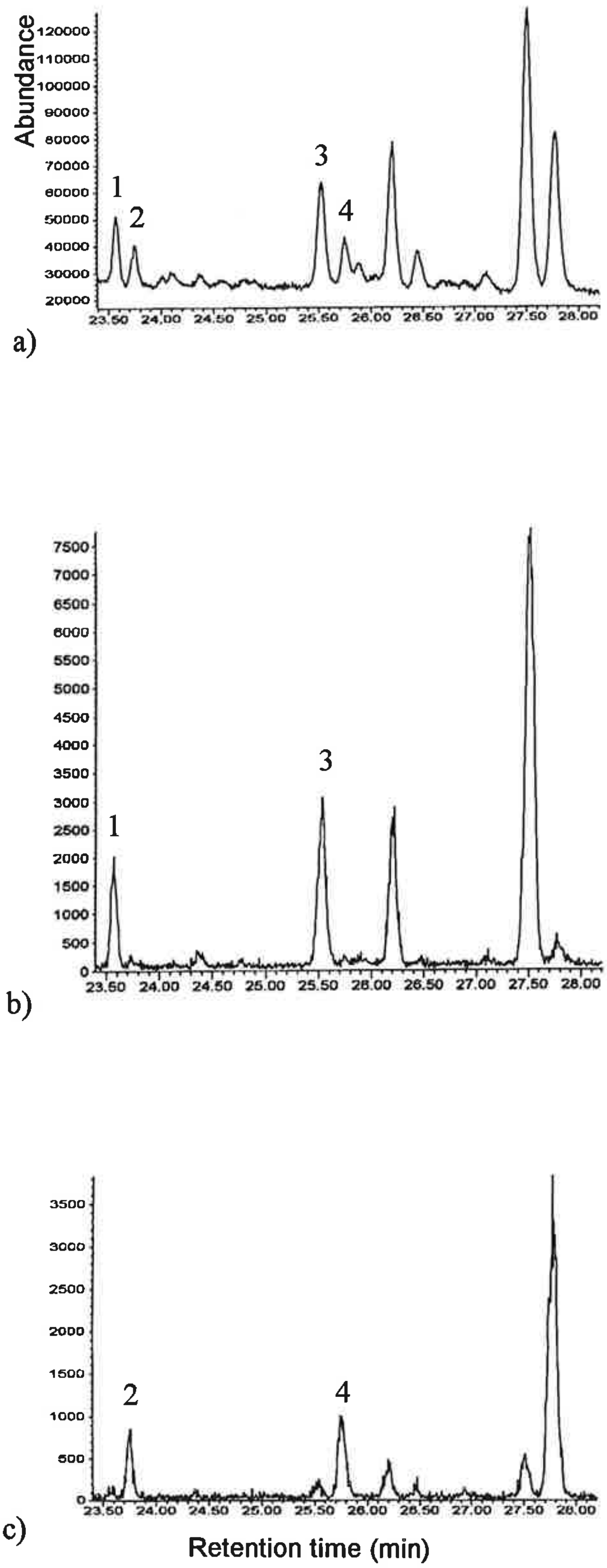

Figure 2. Examples of chromatograms, sample 29 from area B. a) total ion chromatogram (TIC), b) m/Z 129 ion chromatogram (sterols), c) m/Z 215 ion chromatogram (stanols). 1) cholesterol, 2) 5α-cholestan-3β-ol, 3) campesterol, 4) 5α-campestanol.

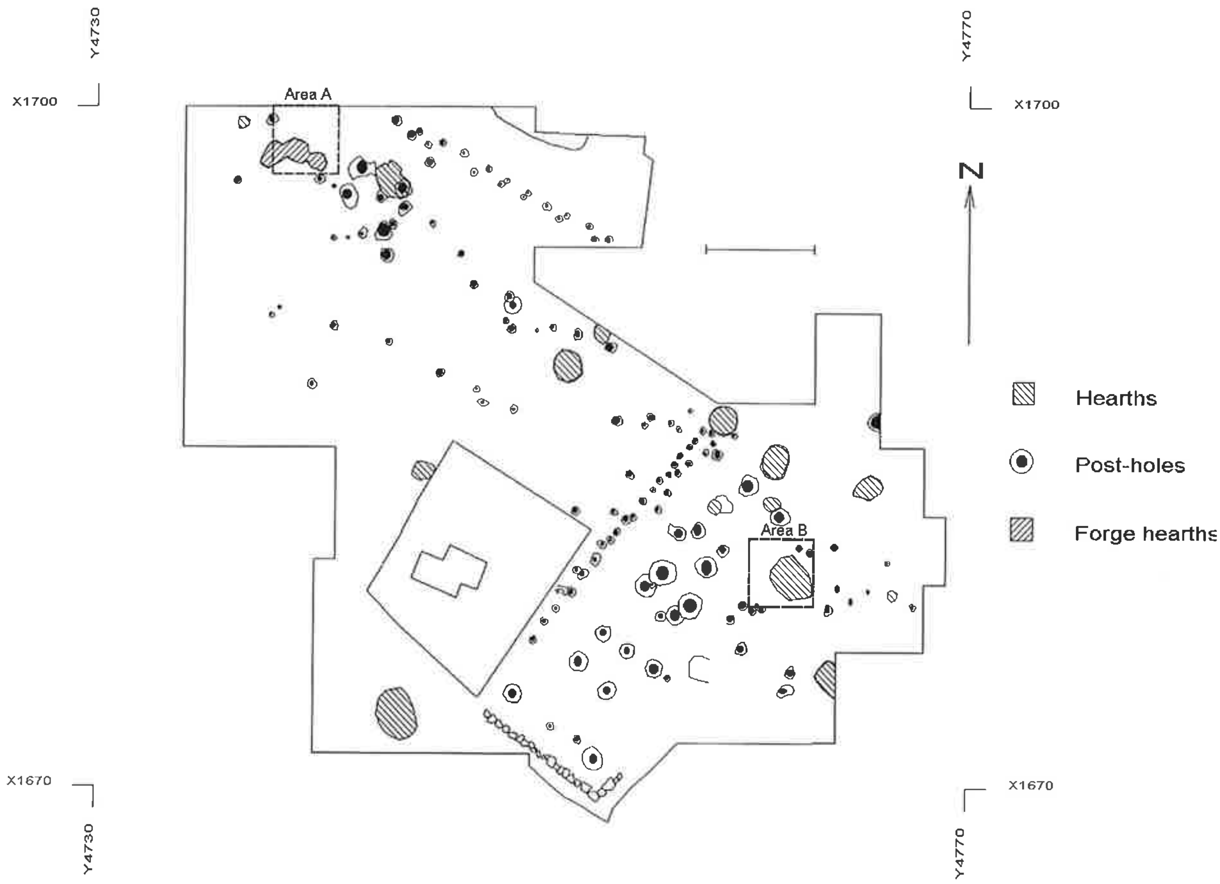

Figure 3. Map of the trenches at Vendel. The sample areas of this investigation are indicated. Scale as indicated.

produce cholesterol and therefore also 5α-cholestan-3β-ol. By comparing the relative intensity of 5α-cholestan-3β-ol with that of 5α-campestanol (a degradation product of the plant sterol campesterol, following the same pathway), and assuming that the natural input of animal and vegetable material is relatively constant, it may be possible to identify samples with an increased animal input.

For each sample the stanol ratio was calculated, i.e. the relative intensity of 5α-cholestan-3β-ol to 5α-campestanol ($r_{stanol} = I_{5\alpha\text{-cholestan-}3\beta\text{-ol}} / I_{5\alpha\text{-campestanol}}$). As 5α-stanols are produced constantly it is important to obtain data on the prevailing input of cholesterol and campesterol, which is why these were also included in the analysis; The resulting ratio was called the sterol ratio ($r_{sterol} = I_{cholesterol} / I_{campesterol}$). These measures were complemented with the relative intensities of 5α-cholestan-3β-ol to cholesterol ($r_{cholesterol} = I_{cholesterol} / I_{5\alpha\text{-cholestan-}3\beta\text{-ol}}$) and 5α-campestanol to campestanol ($r_{campesterol} = I_{5\alpha\text{-campestanol}} / I_{campesterol}$), which represents the magnitude of the ancient input relative to the recent input. The intensities of the different compounds were calculated by integration of ion chromatograms, where ions of m/Z 129 were used for sterols and the ions of m/Z 215 were used for 5α-stanols (fig. 2). These intensities were then used to calculate the above mentioned ratios. Furthermore, the total amount of sterols and stanols, and the amount of extraction products were also included.

Material

During the excavations of the Late Iron-Age manor at Vendel (Isaksson 1997a) samples were collected from every square metre of the different floor layers. Samples were taken as soon as possible after exposure, to minimise effects from light and air. The samples were frozen as soon as possible and so stored until analysed. For this investigation 18 samples from two different areas (A & B) of the site (fig. 3) was selected. Area A, dominated by finds of metalworking is situated within the above mentioned economic building. Area B, dominated by a large hearth and concentrations of Late Iron Age pottery, is situated in what may be a Viking Age cooking house placed above the earlier residential building (Isaksson, manuscript). For the purpose of testing the method area A was postulated as a non-culinary area and area B as a culinary area.

Methods

The samples were vacuum-dried and then dry-sieved through a 1mm sieve. This process results in a greater adsorbtion area per weight, and the adsorbtion to finer mineral fractions has been proposed as a protective matrix for organic compounds deposited in soils (Hedges & Prahl 1993:239, Heron & Evershed 1993:253), which would thus make the smaller fraction more suitable for extraction of organic compounds (Isaksson 1997b).

Five grams of soil were quantitatively transferred to an acid washed extraction jar. The extraction was performed by ultrasonification (2×15 minutes) in 25 ml chloroform/methanol (2/1, v:v). The samples were allowed to sediment for at least 48 hours and then centrifuged (1000–2500 rpm for 30 minutes). Five millilitres of the extract were removed and vaporised under a flow of dry nitrogen. The extraction products were quantified gravimetrically.

The samples were diluted to a concentration of 10 mg/ml and then separated by high-performance thin-layer chromatography (HPTLC) according to the method proposed by Henderson & Tocher (1992). The plates were eluted in one dimension on silica gel (Merck 5631 and 5628) using a solvent system consisting of hexane:diethyl ether:acetic acid (80:20:2, v:v:v). The Merck 5631 HPTLC-plates were sprayed with a strong oxidation agent and the separated compounds carbonised in an oven at 150°C. The plates were digitalized by a scanner for documentation and quantified by integration of the co-eluting sterols and stanols. From the Merck 5628 HPTLC-plates sterols and stanols were scraped off after detection by UV-light (254 nm) and collected for further analysis by gas chromatography/mass spectrometry (GC/MS).

Prior to analysis on the GC/MS the samples were treated with bis(trimethylsilyl)triflouroacetamid with 1% chlorotrimethylsilane (20 µl, in oven at 60°C for 15 minutes). The GC used was a HP6890 equipped with a HP-5MS capillary column (30 m×250 µm×0.25 µm). Pulsed splitless-injection was used and the injector operated at 300°C. The GC column oven temperature program was: 40°C for 2 minutes, increased to 175°C by 25°C/minute and finally to 280°C by 10°C/minute. Helium was used as carrier-gas at a constant flow of 1 ml/minute. The GC-MS interface had a constant temperature of 280°C. The mass spectrometer was a HP5973 operating through electric ionization (EI) at 70 eV, with an ion source temperature of 230°C. The MS was set to scan the 50–600 m/Z region. Data handling and collection was carried out with *HP Chemstation® 3.0* software.

The analysis results in quite a large set of data, which is suitably interpreted by statistical analysis. Defining natural groupings in multiple variables and interpreting them in terms of known behaviour may form a basis for classification of archaeological data of the present kind (Isaksson 1996:43–46). Thus, the data was first scaled, setting the mean to zero and the variance to one for the variables, removing the effect of different units of measurement. Then two principle

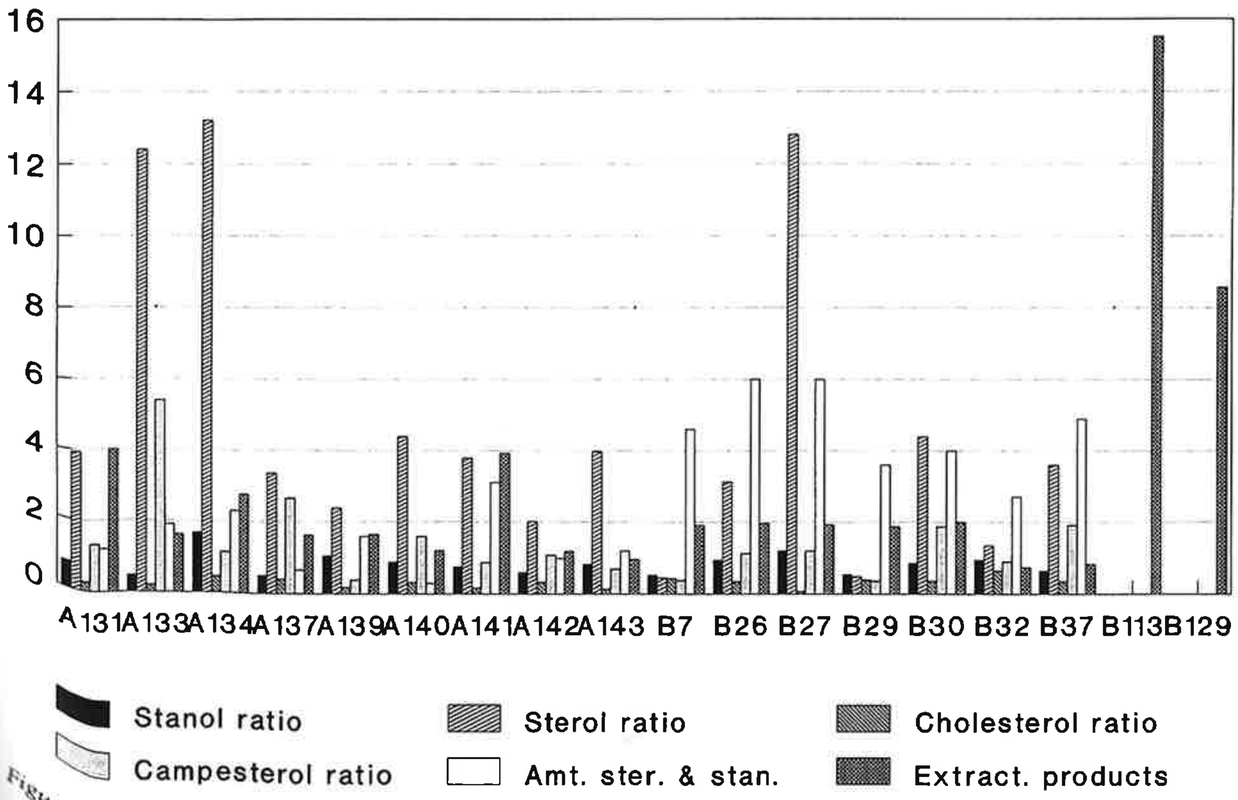

Figure 4. Bar-chart of the analytical results presented in table 1.

Table 1. Results of the analyses.

Area	Sample No.	Stanol ratio	Sterol ratio	Cholesterol ratio	Campesterol ratio	Amount sterols & stanols (µg/g)	Amount extraction products (mg/g)
	131	0.770	3.93	0.255	1.31	1.2	4.00
	133	0.470	12.4	0.202	5.39	1.9	1.61
	134	1.67	13.2	0.441	1.14	2.3	2.76
	137	0.500	3.35	0.396	2.65	0.66	1.62
A	139	1.04	2.38	0.172	0.395	1.6	1.66
	140	0.884	4.39	0.307	1.60	0.28	1.20
	141	0.749	3.79	0.171	0.864	3.1	3.93
	142	0.602	2.01	0.323	1.08	0.99	1.18
	143	0.820	3.97	0.141	0.680	1.2	0.950
	7	0.528	0.448	0.434	0.368	4.6	1.91
	26	0.938	3.12	0.337	1.12	6.0	1.95
	27	1.20	12.8	0.079	1.19	6.0	1.92
	29	0.543	0.485	0.394	0.352	3.6	1.86
B	30	0.850	4.38	0.363	1.87	4.0	2.00
	32	0.948	1.34	0.640	0.903	2.7	0.736
	37	0.649	3.60	0.349	1.91	4.9	0.816
	113	0	0	0	0	0	15.5
	129	0	0	0	0	0	8.57

components were calculated from the data set, using the Principal Component Analysis (PCA) of the STATISTICA *5.0* software package. These were plotted, revealing groupings corresponding to soils of different lipid input, as the distance in this type of graph represents a measure of similarity/dissimilarity in the original data set. The measures of each of these groups were then submitted to a Student's t-test, to reveal in which (if any) measures statistically significant differences between the groupings could be found.

Results

From the amounts of extraction products and sterol/stanol yielded (Tables 1 and 2 and fig. 4) it is obvious that the two areas differ. The mean values of these two measures are slightly higher for area B, whereas the standard deviation, variance and skewness is distinctively higher. The variance and the standard deviation are measures of variability, and skewness is a measure of the extent to which the distribution of the variable is skewed relative to the standard normal distribution. In an undisturbed soil the distribution should be close to the standard normal distribution and the skewness value close to zero. This may be interpreted as a slightly higher and more varied input of lipids in area B, and that the distribution in this area is further away from a natural distribution than that in area A. The stanol and sterol ratios are less expressive as to the distinction between the two areas, but more so for the characterization of each sample.

For this characterization the whole data set was used, and the two first principle components were calculated from the data set, as described above. Plotted

Table 2. Statistical summary and comparison of the two investigated areas.

	Stanol		Sterol		Cholesterol		Campesterol		Amount sterols & stanols		Amount extraction products	
Area	A	B	A	B	A	B	A	B	A	B	A	B
Average	0.834	0.627	5.49	2.92	0.268	0.288	1.68	0.857	1.47	3.53	2.10	3.92
St. dev.	0.363	0.415	4.22	4.06	0.106	0.217	1.53	0.731	0.866	2.27	1.17	4.94
Variance	0.132	0.173	17.8	16.5	0.011	0.047	2.35	0.731	0.750	5.13	1.38	24.4
Skewness	1.66	-0.524	1.48	2.14	0.468	-0.137	2.14	0.311	0.648	-0.759	0.981	2.07

Table 3. Statistical summery and basis for the definition of classes

Class	n	Stanol ratio	Sterol ratio	Cholesterol ratio	Campesterol ratio	Amount sterols &stanols	Amount extraction products
1	7	0.766±0.18	3.40±0.89	0.252±0.095	1.23±0.74	1.3±0.9	2.08±1.31
2	6	0.743±0.19	2.22±1.7	0.420±0.11	1.09±0.69	4.3±1.1	1.55±0.60
3	2	1.44±0.33	13.0±0.28	0.260±0.26	1.17±0.04	4.2±2.6	2.34±0.59
4	2	0	0	0	0	0	12.0±3.5
5	1	0.470	12.4	0.202	5.39	1.9	1.61

(fig. 5) these reveal groupings characterizing soils of different lipid input.

Discussion of analytical results

The following discussion aims at explaining the different groupings presented in figure 5 in chemical terms, by referring to the original data set, and then explaining the groupings in archaeological sense.

The samples were scattered in two main clusters (Clusters no. 1 and 2 in fig. 5). Four other samples were scattered in two different groups (No. 3 and 4 in fig. 5) and one sample is different from the others (A133). In table 3 the means and standard deviation of the measurements of each class are presented. Through the Student's t-test it was shown that there were significant differences between clusters 1 and 2 in the amount of sterols and stanols ($t = -5.32$, $p = 0.0002$) and in the cholesterol ratio ($t = -2.90$, $p = 0.015$). There was no significant difference between these two clusters in any of the other measures. This means that there has been a higher input of sterols and stanols into the cluster 2 soils and that the composition mainly differs in a higher relative content of 5α-cholestan-3β-ol. If the higher cholesterol ratio of the cluster 2 soils had been an effect deriving solely from a lower input of cholesterol, the sterol ratio should have been significantly lower in the class 2 samples. It might be argued that the slightly though not significantly lower sterol ratio of the class 2 samples is a reflection of this. But as the campesterol ratio is similarly lower it is more probably an effect of a slightly higher campesterol content in the cluster 2 samples.

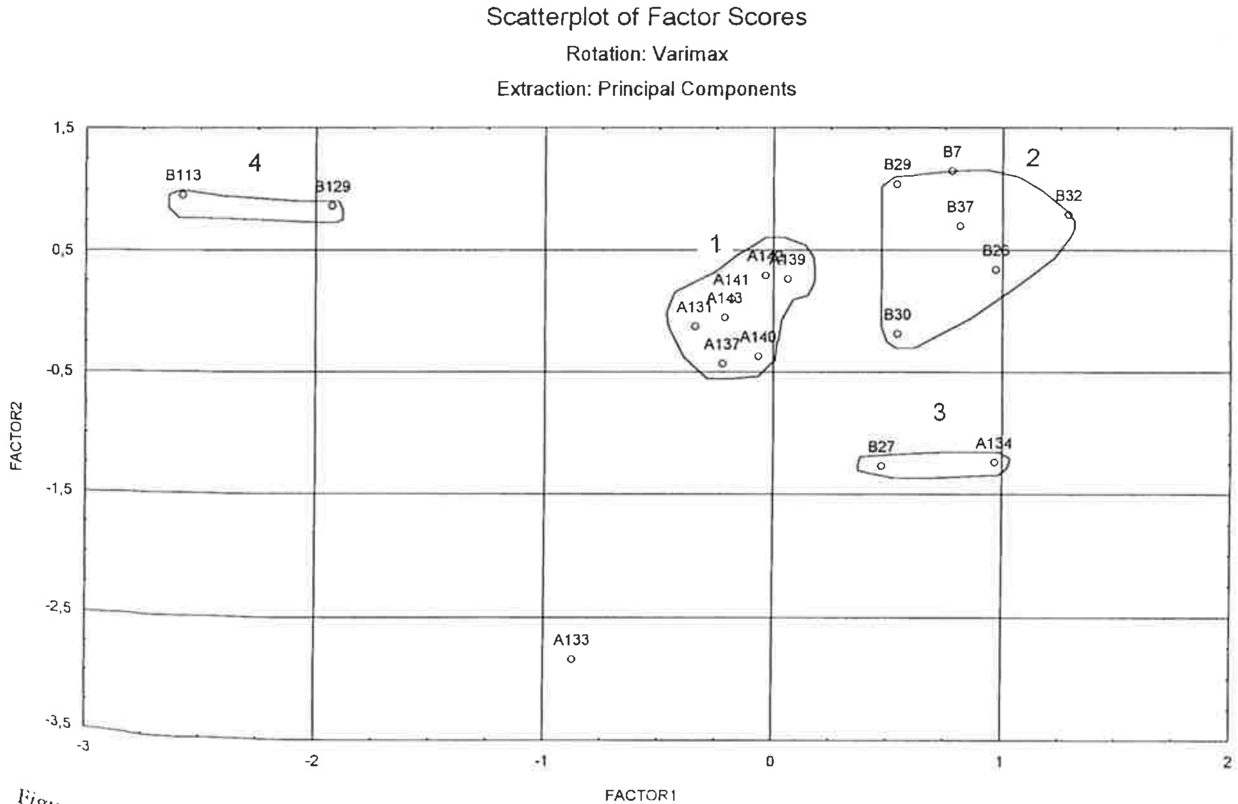

Figure 5. Plot of first two principle components.

4 18-5196

Table 4. Definition of the five classes.

Class No.	Definition
1	Archaeological deposit without enhanced input of lipids of animal origin
2	Archaeological deposit with enhanced input of lipids, of which a distinctive part is of animal origin
3	Archaeological deposit recently disturbed (dead animals, contamination etc)
4	Archaeological deposit with high amounts exractable organic matter other than lipids (thermal destruction)
5	Archaeological deposit with divergent input of plant lipids

Table 5. Class identification of individual samples and distribution on the site.

Sample No.	X-coordinate	Y-coordinate	Class
131	1699	4740	1
133	1699	4739	5
134	1699	4738	3
137	1697	4740	1
139	1698	4740	1
140	1698	4738	1
141	1698	4739	1
142	1697	4738	1
143	1697	4739	1
7	1678	4760	2
26	1679	4760	2
27	1678	4762	3
29	1680	4760	2
30	1678	4761	2
32	1680	4761	2
37	1680	4762	2
113	1679	4761	4
129	1679	4762	4

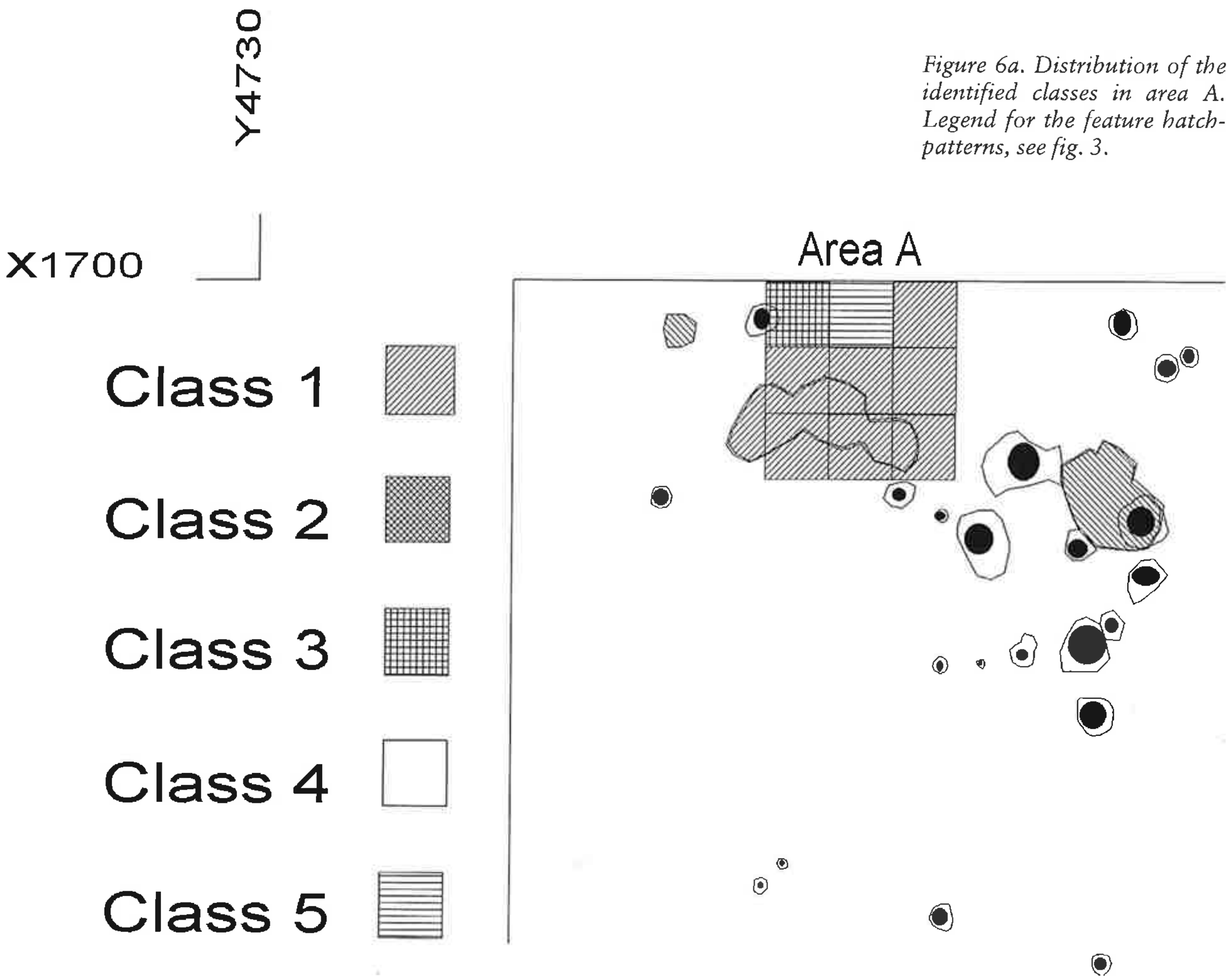

Figure 6a. Distribution of the identified classes in area A. Legend for the feature hatch-patterns, see fig. 3.

The remaining samples call for some consideration. The cluster 3 samples (B27 and A134) have higher stanol and sterol ratios in comparison with both the cluster 1 and 2 samples. This may be the result of a high content of cholesterol and cholestanol. It is tempting to interpret the high stanol ratio as a high input of 5α-cholestan-3β-ol, but as the sterol ratio is similarly high the measures are probably the result of relatively recent input of animal lipid material. The cluster 4 samples A113 and A129 were both taken directly on top of the hearth in this area. The analytical results show high amounts of extraction products, but no sterols and stanols could be detected in these two samples. The high extraction yield is probably from tars and pitches from the hearth, and the fire and high temperature of the hearth may have consumed any sterols originally dropped into it. Sample A133 (class 5) is characterized by a high sterol ratio and a high campesterol ratio. This indicates a low recent input of campesterol in this sample, and possibly also a high input of vegetable lipid material originally.

Archaeological inference

The soil-samples round the hearth in area B (Tables 4 and 5 and fig. 6) has received a high input of lipids and the composition of sterols and stanols show a high contribution of lipids of animal origin. Due to the lack of animal bone material this is the only solid proof for the handling of animal products yet from the Vendel site. Area B was postulated as a culinary area, from the presence of a hearth and of pottery, and this hypothesis is corroborated by the analysis. The mere presence of pottery as an indication of culinary practice is a weak generalization, as it has been shown on several occasions that pottery was used for other purposes than the preparation and storage of food (Hultén 1991:34ff, Heron & Evershed 1993:251; Isaksson 1997c). Fur-

Figure 6b. Distribution of the identified classes in area B.

thermore, the results justify a discussion on the archaeological topics stated in the introduction.

The *boiling of meat* as a strong symbol within the communal meal, and the *generous nobleman* were two cultural images or scenarios touched upon in the introduction. Another image from the same social context is that of the nobleman as the *hall-owner* (Herschend 1993). This hall is not used for domestic activities such as cooking, but mainly for the entertainment of equals and subjects, including primarily drinking and also eating. The cooking had to be done somewhere else, and the food brought in, as often stated in the sagas. The results of the present analysis may be used to substantiate the inference of a cooking house, a type of building that, on the few occasions it is mentioned in the sagas, is exclusively connected with large farms or chieftains' manors (for example Alving 1990:102, 216).

Through the deviate use of pottery in the grave-ritual of Central Swedish Migration Period female and male burials, Stig Welinder (1993:168) argues that pottery may have been used in this context as a material symbol of women in their role as *keepers and distributors of food and drink* (Hansson 1997:38). In this role women may also incarnate the *diplomat*. These cultural themes are reproduced in several sagas, in the Beowulf poem, on silver pendants and on several pictorial stones from Gotland (Enright 1996, Lindeberg 1997:103). Interestingly the eastern part of the excavated area, within which area B is situated, is dominated by finds that may be attributed as "female" (Isaksson 1997a:21). The impression is accentuated by the female Viking-Age burial-urn found some four metres to the north-east of the hearth in area B (Isaksson & Arrhenius 1995:5–6).

The Germanic connection was, as mentioned in the introduction, especially strong in Frankish material (Arrhenius 1980), and I would like to give some thoughts on one more category of finds from the boat-graves in this context. Maybe the most renowned king of the Franks was Charlemagne and some notes have passed down to us from his tables, mainly by the aid of his biographer Einhard. One of these notes is Charlemagnes preference of roasted meat from wild game over any other food. The devouring of wild game is easily linked to the identification then sought with *aggressive and ferocious animals*, which in its turn is connected to the positive view of the *great eater* amongst the Germanic aristocrats (Montanari 1994:22). Also, the cultural image of food roasted over an open flame has been claimed to be more closely tied to *untamed nature*, for example than that of water boiling in a pot (Lévi-Strauss 1978:479ff). It all recalls notions of *violence, vehemence and belligerence* (Montanari 1994:26). Be that as it may, it is intriguing however that spits for roasting have been found in several of the boat-graves.

The finds are there and so are the Germanic cultural scenarios of aristocracy, derived from the written sources and the archaeological material. The inference may now be made. The generosity required of the noble is revealed in the cooking house of the settlement area and the cauldrons of the graves, e.g. the public life of the aristocrat. Following the discussion above the roasting-spits may be seen as unveiling the ferocious warrior, the capable lord and the *individual* set aside from the *collective*. Maybe we here get a glimpse of the social tension between the individual and the collective as it has been discussed by Frands Herschend (1992:159ff), preserved in the ancient remains at Vendel. And maybe we discern through time the image of the proud Lady, as she is brought to us on pictorial stones and in the Beowulf poem, by connecting the feminine attributed finds with the cooking house: The Lady as the keeper and distributor of food and drink, and the diplomat.

With the analysis of further soil samples from the site and completion of ongoing decomposition experiments more aspects of food handling may be revealed. Another future project is the analysis of organic residue absorbed in the pottery collected in the cultural layers of the settlement.

Acknowledgement

I am grateful for comments and criticism on drafts of this paper by Professor Birgit Arrhenius and Dr Kerstin Lidén at The Archaeological Research Laboratory, Stockholm university, and by Dr. Clas Wesén at the department of Technical Analytical Chemistry, Lund university.

References

Alving, H. (ed.) 1990. *Isländska Sagor. Del 2*. Södertälje.
Arrhenius, B. 1980. *The chronology of the Vendel graves. Rapport från Stockholms Universitets Arkeologiska Forskningslaboratorium Nr 2*. Stockholm.
Arrhenius, B. 1985. *Merowingian Garnet Jewellery*. KVHAA Monografier. Stockholm.
Arrhenius, B. & Herschend, F. 1995. SIV Svealand in the Vendel and Viking Periods. Settlement, Society and Power. Ansökan till ett forskningsprogram.
Backe, M., Edgren, B. & Herschend, F. 1993. Bones thrown into a water-hole. In G. Arwidsson, A.-M Hansson, L. Holmqvist Olausson, B. -M. Johansson, M. Klockhoff, K. Lidén, H.-Å. Nordström (eds.): *Sources and Resources. Studies in honour of Birgit Arrhenius. PACT 38*, pp.327–342. Rixensart.
Bethell, P. H., Goad, L. J. & Evershed, R. P. 1994. The Study of Molecular Markers of Human Activity: The Use of Coprostanol in the Soil as an Indicator of Human Faecal Material. *Journal of Archaeological Science* 21, pp. 619–632.
Douglas, M. 1978. *The World of Goods: Towards an Anthropology of Consumption*. London.
Eglinton, G. 1969. Organic Geochemistry. The Organic Chemist's Approach. In G. Eglinton, & M. T. J. Murphy (eds.): *Organic Geochemistry. Methods and Results*. Berlin.

Enright, M. J. 1996. *Lady with a mead cup. Ritual, prophecy and lordship in the European warband from La Tène to the Viking Age.* Chippenham.

Evershed, R. P. 1994. Post-Mortem Transformations of Sterols in Bog Body Tissues. *Journal of Archaeological Science* 21, pp. 577–583.

Evershed, R. P., Bethell, P. H., Reynolds, P. J. & Walsh, N. J. 1997. 5β-stigmastanol and related 5β-stanols as biomarkers of manuring: Analysis of modern experimental material and assessment of the archaeological potential. *Journal of Archaeological Science* 24, pp. 485–495.

Gaskell, S. & Eglinton, G. 1975. Rapid hydrogenation of sterols in a contemporary lacturine sediment. *Nature* 254, pp. 209–211.

Hansson, A.-M. 1997. *On plant food in the Scandinavian peninsula in Early Medieval times.* Theses and Papers in Archaeology B:5. Stockholm

Hedges, J. I. & Prahl F. G. 1993. Early diagenesis: Consequences for Application of Molecular Biomarkers. In M. H. Engel, & S. A. Macko (eds.): *Organic Geochemistry. Principles and Applications.* New York.

Henderson, R. J. & Tocher, D. R. 1992. Thin-layer chromatography. In R. J. Hamilton, & S. Hamilton, (eds.): *Lipid Analysis.* Oxford.

Heron, C. & Evershed, R. P. 1993. The Analysis of Organic Residues and the Study of Pottery Use. In M. B. Schiffer (ed.): *Archaeological Method and Theory vol 5.* Tucson & London.

Herschend, F. 1992. Beowulf and St. Sabas: The tension between the Individual and the Collective in the Germanic Society around 500 AD. *TOR* vol 24. pp. 145–164.

Herschend, F. 1993. The origin of the hall in southern Scandinavia. *TOR* vol 25. pp. 175–199.

Herschend, F. 1997. *Livet i Hallen: Tre fallstudier i den yngre järnålderns aristokrati.* Occasional Papers in Archaeology 14. Uppsala.

Hita, C., Parlanti, E., Jambu, P., Joffre, J. & Amblès, A. 1996. Triglyceride degradation in soil. *Organic Geochemistry, vol 25 no 1/2.* pp. 19–28.

Hultén, B. 1991. On ceramic ware in Nothern Scandinavia during the Neolithic, Bronze and Early Iron Age. In E. Baudou (ed.): *Archaeology and Environment* 8. Umeå.

Isaksson, S. 1996. A protocol for the analysis of lipid residues in connection with prehistoric food habits. *Laborativ Arkeologi* 9, pp. 41–48.

Isaksson, S. 1997a. Arkeologiska boplatsundersökningar vid Vendel kyrka 1996. In B. Arrhenius & G. Eriksson (eds.): *SIV Svealand i Vendel och Vikingatid: Rapporter från utgrävningarna i Vendel,* pp. 5–31. Archaeological Research Laboratory, Stockholm University

Isaksson, S. 1997b. Soil-lipids in cultural layers. *ISKOS* 11.

Isaksson, S. 1997c. Rapport avseende analys av organiskt material ur fynd 495, Harrsjöbacken, Bureå sn, Västerbotten. Unpublished report.

Isaksson, S. Arkeologiska boplatsundersökningar vid Vendel kyrka 1997. Manuscript.

Isaksson, S. & Arrhenius, B. 1995. Rapport avseende 1994 års arkeologiska undersökningar vid Vendels kyrka, Vendel sn, Uppland. Unpublished report.

Isaksson, S. & Hansson, A.-M. 1995. Cultural layer research. In B. Arrhenius & F. Herschend (eds.): SIV Svealand in the Vendel and Viking Periods. Settlement, Society and Power. Ansökan till ett forskningsprogram.

Isaksson, S. & Seiler, A. 1997. Landskap, bebyggelse och exponering. In B. Arrhenius & G. Eriksson (eds.): *SIV Svealand i Vendel och Vikingatid: Rapporter från delprojekten vid Stockholms universitet,* pp. 69–75. Archaeological Research Laboratory, Stockholm University.

Lévi-Strauss, C. 1978. *The Origin of Table Manners.*Chicago.

Lidén, K. 1995. Kinship. In B. Arrhenius & F. Herschend (eds.) SIV Svealand in the Vendel and Viking Periods. Settlement, Society and Power. Ansökan till ett forskningsprogram.

Lindeberg, M. 1997. Gold, Gods and Women. *Current Swedish Archaeology, Vol 5,* pp. 99–110.

Meyer, P. A. & Ishiwatari R. 1993 The Early Diagenesis of Organic Matter in Lacturine Sediments. In M. H. Engel, & S. A. Macko (eds.): *Organic Geochemistry. Principles and Applications.* New York.

Mills, J. S. & White, R. 1994. *The Organic Chemistry of Museum Objects.* Second Edition. London.

Montanari, M. 1994. *The Culture of Food.* Oxford.

Morrison, R. I. 1969. Soil lipids. In G. Eglinton & M. T. J. Murphy (eds.): *Organic Geochemistry. Methods and Results.* Berlin.

Myrdal, J. 1988. Agrarteknik och samhälle under två tusen år. In U. Närman & , J. Lund (eds.): *Folkevandringstiden i Norden: En krisetid mellem ældre og yngre jernalder.* pp.187–226. Århus.

Sawyer, P. 1991. *När Sverige blev Sverige.* Alingsås.

Seiler, A. 1997. Bebyggelsearkeologiska studier kring Vendels sockens förhistoria: En första redogörelse. In B. Arrhenius & G. Eriksson (eds.): *SIV Svealand i Vendel och Vikingatid: Rapporter från delprojekten vid Stockholms universitet,* pp. 61–68. Archaeological Research Laboratory, Stockholm University.

Summons, R. E. 1993 Biogeochemical Cycles. A Review of Fundamental Aspects of Organic Matter Formation, Preservation and Composition. In M. H. Engel, & S. A. Macko (eds.): *Organic Geochemistry. Principles and Applications.* New York.

Statens Livsmedelsverk 1988. Livsmedelstabeller. The National Food Administration. Food composition tables.

Welinder, S. 1993. Pots, females and food. *Current Swedish Archaeology vol 1.* pp. 165–169.