Ann-Marie Hansson and Sven Isaksson

ANALYSES OF CHARRED ORGANIC REMAINS

Charred organic remains from a selection of archaeological excavations were analysed to determine the biological origin of their content. Analysis methods focused on microscopic examination searching for micro- and macrobotanical remains, and chemical analysis searching for proteins and lipids. In combination, these methods revealed interesting details of the content of each sample. It was possible to trace lipids and proteins, as well as cereals, seeds of weeds and other plant- and fungal remains. The results form the basis of a classification of charred organic remains, presented elsewhere, and shed important new light on ancient Swedish diet.

Introduction

In the article by Ann-Marie Hansson in this volume entitled "Grain-paste, porridge and bread: Ancient cereal-based food", five separate findings of charred organic remains are examined and a detailed classification is presented. These five remains were recovered from different archaeological investigations of varying periods, ranging from the Bronze Age to the Viking Age:

Findplace	*Date*
Birka, Björkö, Adelsö par., Uppland	Viking Age
Västergården, Bergshammar par., Södermanland	Vendel/Viking Age
Vrå, Knivsta par., Uppland	Bronze Age
Harrsjöbacken, Bureå par., Västerbotten	Roman Iron Age
Folåsa, Rappestad par., Östergötland	Middle Iron Age

The present article describes the analysis methods upon which that classification is based. Ann-Marie Hansson conducted the microscopic analyses and Sven Isaksson the chemical analyses.

Microscopic investigations were conducted on only four of the samples, whereby remains of plants and fungi were observed. The fifth sample, burial bread from Birka, had been previously analysed for its botanic content by Hjelmqvist (1984:263). Earlier investigations of similar nature on charred prehistoric bread have been carried out in Sweden by Rosendahl (1909; 1912; 1915) and by Hjelmqvist (1982; 1983; 1984; 1990).

Chemical analysis of charred or carbonized organic remains has previously been confined mainly to material surviving on pottery sherds (Slytå & Arrhenius 1979; Arrhenius & Slytå 1981; Arrhenius 1985; Arrhenius & Lidén 1989; Deal 1990; Eriksson 1991). In those projects trace-elements, proteins, amino acids, lipids and microfossils were targeted, in attempts to identify the biological origin of the charred remains. On the basis of the results obtained in those investigations, it seemed promising to apply chemical analysis in the classification and characterization of remains of charred food other than that adhering to vessels. In the present investigation, analyses of protein-content, lipid-content and fatty-acids have been combined with microscopic analysis for four of the samples. The fifth sample, that from Folåsa, was subjected only to SEM-analysis.

The microscopic analysis

by Ann-Marie Hansson

Method

The method used involved immersing the charred organic sample in 30% hydrogen peroxide (H_2O_2) and 25% ammonia (NH_4OH) 1:1, to bleach and separate the individual components from one another and thus identify the cell-wall pattern and other microremains. Duration of immersion in the chemical solution depended on the solubility of the material. In one case, the sample was also heated. In choosing analysis samples from the charred material, care was taken to avoid outer surfaces which could contaminate the samples and give mislead-

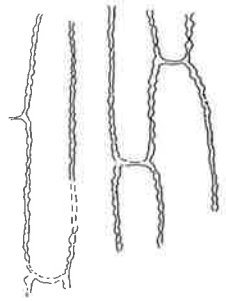

Fig 1. Longitudinal cells of wheat (Triticum *sp.), c. x570. Drawing: Ann-Marie Hansson.*

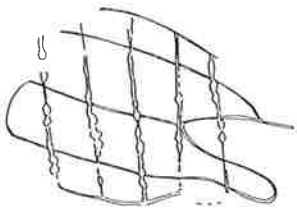

Fig 2. Transverse cells of wheat (Triticum *sp.). C. x600. Drawing: Ann-Marie Hansson.*

ing results, while also avoiding unnecessary damage to this unique and sometimes fragile archaeological material. Since each sample in the present investigation was treated individually, working-procedures will be described for each case in turn. Samples which are subjected to microscopic analysis are of minute size. This means that where only one sample was taken from a piece of charred material, this sample need not be representative of the whole charred piece. In such cases it cannot be ruled out that other species also occur in unexamined sections of the piece.

In general, the working-methods adopted here can be compared to the similar methods described for charred material as published by, for example, Jessen (1956: 175), Hjelmqvist (1982:236; 1984:263) and Hajnalová (1989:96).

Rosendahl employed different procedures and other chemicals in his analyses of charred prehistoric bread at the beginning of this century (1909:42f; 1912:1f). Hjelmqvist mentions that in some cases treatment of a sample in chloral hydrate ($CCl_3CH(OH)_2$) produces a clearer and sharper image of cell structure than is obtainable from hydrogen peroxide (H_2O_2) (1982:238; 1984: 263). These methods only work when the degree of charring is less than 100%. Objects which appear to be charred to the naked eye are sometimes only 80–90% charred, particularly the interiors of large objects (Körber-Grohne 1991:15). Further evidence that bread and other apparently carbonized organic remains are in fact not fully carbonized, is the fact that they still contain identifiable proteins, which would be impossible if the degree of charring was 100%.

Charred bread-like remains, Västergården

Södermanland, Bergshammar par., Site 6. SHM 6575/87

A small sample, c. 5 mm in diameter, was gently loosened from one of the larger fragments of this bread-like material, following the procedure described above under "Method". The sample was first cleaned by ultrasound and then immersed in hydrogen peroxide and ammonia in a glass test-tube for four hours. After subsequent centrifuging, the sample appeared fully dissolved, and a whitish transparent material, some millimeters in length, was seen to float around in the tube. This material was removed by pipette and placed into distilled water. Under the binocular microscope (x20) it was possible to discern a regular continuous structure, but identification of origin was impossible.

There now remained at the bottom of the test-tube, only a minimal amount of dark material which, when the chemicals were replaced by distilled water, was sufficient for one slide (using glycerol/ethanol 1:1). A fine scum layer could be discerned floating high up in the test-tube.

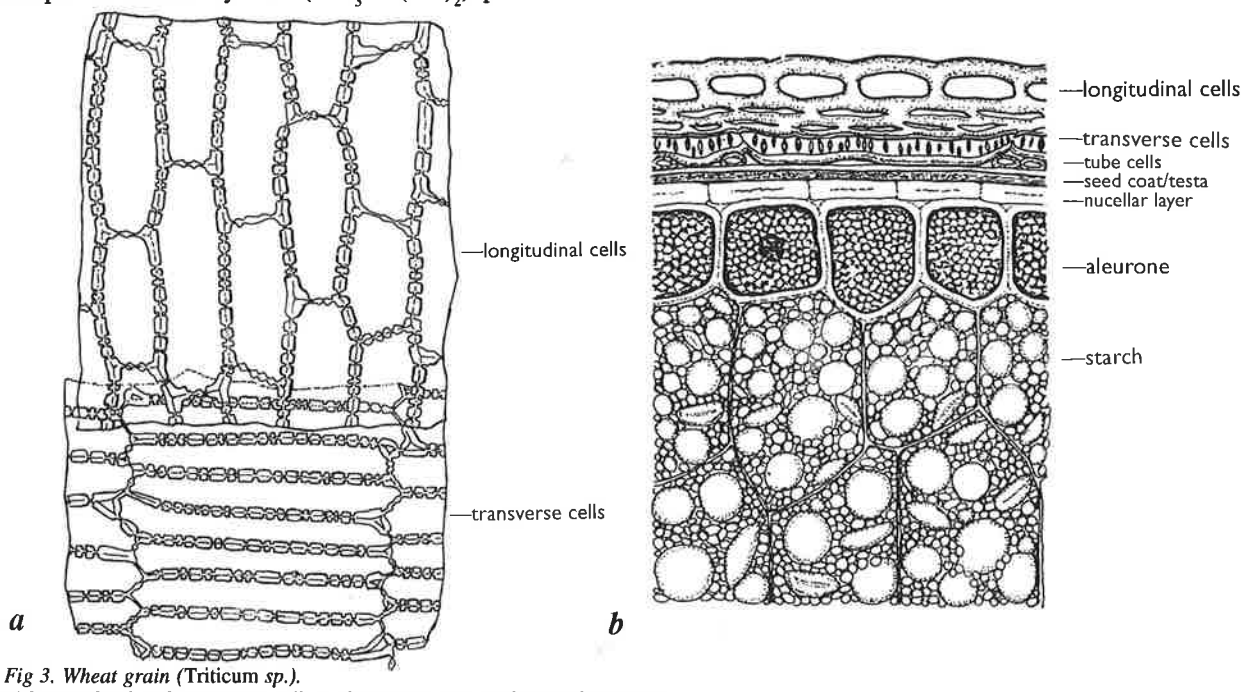

Fig 3. Wheat grain (Triticum *sp.).*
a) longitudinal and transverse cells in the pericarp, viewed from above, x400.
b) diagrammatic representation of the outer cell layers. Drawing: Helena Malmström, after Gassner 1931, p. 25, figs. 13 and 15.

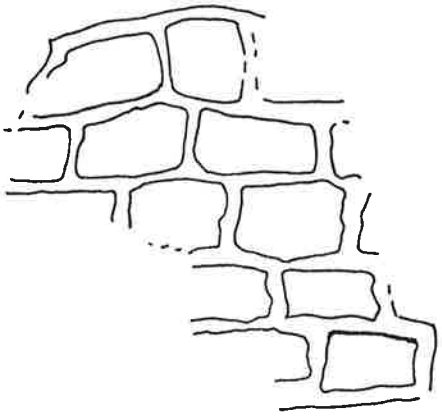

*Fig 4. The second testa cell-layer in the seed of fat-hen (*Chenopodium album*), c. x300. Drawing: Ann-Marie Hansson.*

One further attempt was made to obtain additional sample material. This time, ultrasound cleaning was omitted and the immersion time in hydrogen peroxide and ammonia was reduced to one hour. During the subsequent centrifuging, the material, instead of sinking to the bottom of the tube, now floated on the surface as a scum-like mass. The liquid below this scum was removed by pipette. Distilled water was poured into the tube and the procedure was repeated many times. The floating mass, when examined under binocular microscope, proved to be amorphous and could not be microscopically identified – possibly it was of animal origin.

Remaining on the slide and identified by phase contrast microscope (x400) were longitudinal (fig. 1) and transverse (fig. 2) cells from the pericarp of wheat (*Triticum*). The transverse cells were to some extent degraded. The cells formed regular rows with abutting end walls. The side walls were thick and pitted, while the end walls were thin and straight, as is typical for wheat. Emmer wheat (*Triticum dicoccum*) and einkorn (*T. monococcum*) have a structure similar to wheat but their side walls are relatively thin (Hopf 1954:Pl. II; Hjelmqvist 1982:238); the transverse cells also vary in length and depth, depending on their position on the grain (Dickson 1987:101). Only some of the cell layers in the pericarp of wheat (*Triticum*) are of diagnostic value, such as the longitudinal and transverse cells mentioned above (cf. fig. 3a). Testa cells occurred, but those

Fig 5. Cells from Saccaromyceteae, diameter c. 7 µm. Drawing: Ann-Marie Hansson.

of wheat are unfortunately indistinguishable from those of rye (*Secale*) (Dickson 1987:100). No fragments from husks (palea and lemma) were found. This could indicate bread wheat. The fruit of the grass family (Poaceae), to which cereals belong, can be defined as a special type of nutlet, called caryopsis. For the position of the various cell layers see fig. 3b.

Cells from the second testa cell layer of fat-hen (*Chenopodium album*) (fig. 4) were also found, as well as a single pennate diatom. The latter could be a secondary intrusion. At magnifications of x1000, traces of mould fungi were discerned, including high numbers of cells of cf. Saccaromyceteae (fig. 5) and a few slightly sickle-shaped spores, probably conidia, from Ascomycota. The pointed ends had fallen away, but the cross septa were still visible (fig. 6) (cf. Smith 1946:44, 96; Booth 1971; Ellis 1971; Dissing et al. 1981:60).

The sample also contained phytoliths (fig. 7a) probably of the grass family (cf. Poaceae) (cf. Piperno 1988:247ff; Vuorela 1989–1990:144f).

Charred bread-like remains, Vrå

Uppland., Knivsta par., Site 16, A 1969, layer 3, Fno. 20228

Method of analysis as above, excluding ultrasound treatment, owing to the fragile nature of the sample. The slide samples contained much material, but without any visible cell pattern. Additional samples were taken from regions where botanical remains could be clearly detected by binocular microscope (x10), and further analyses were carried out. In these new samples, a few phytoliths (fig. 7b) were found. These, too, probably belonged to the grass family (cf. Poaceae) (cf. Piperno 1988:247ff;

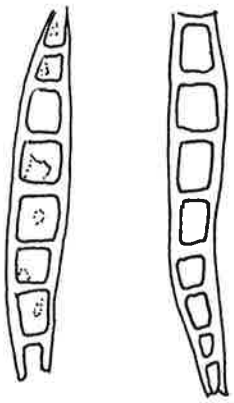

Fig 6. Spores, probably conidia, from Ascomycota, length c. 14 µm. Drawing: A-M. Hansson.

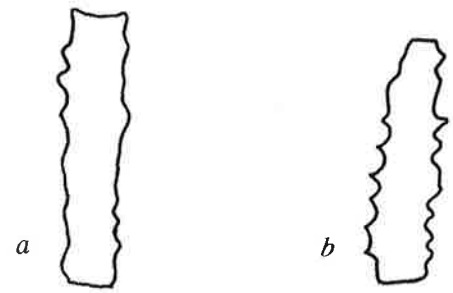

Fig 7. Phytoliths (Poaceae). a) in sample from Västergården, length c. 55 µm. b) in sample from Alsike, length c. 50 µm. Drawing: Ann-Marie Hansson.

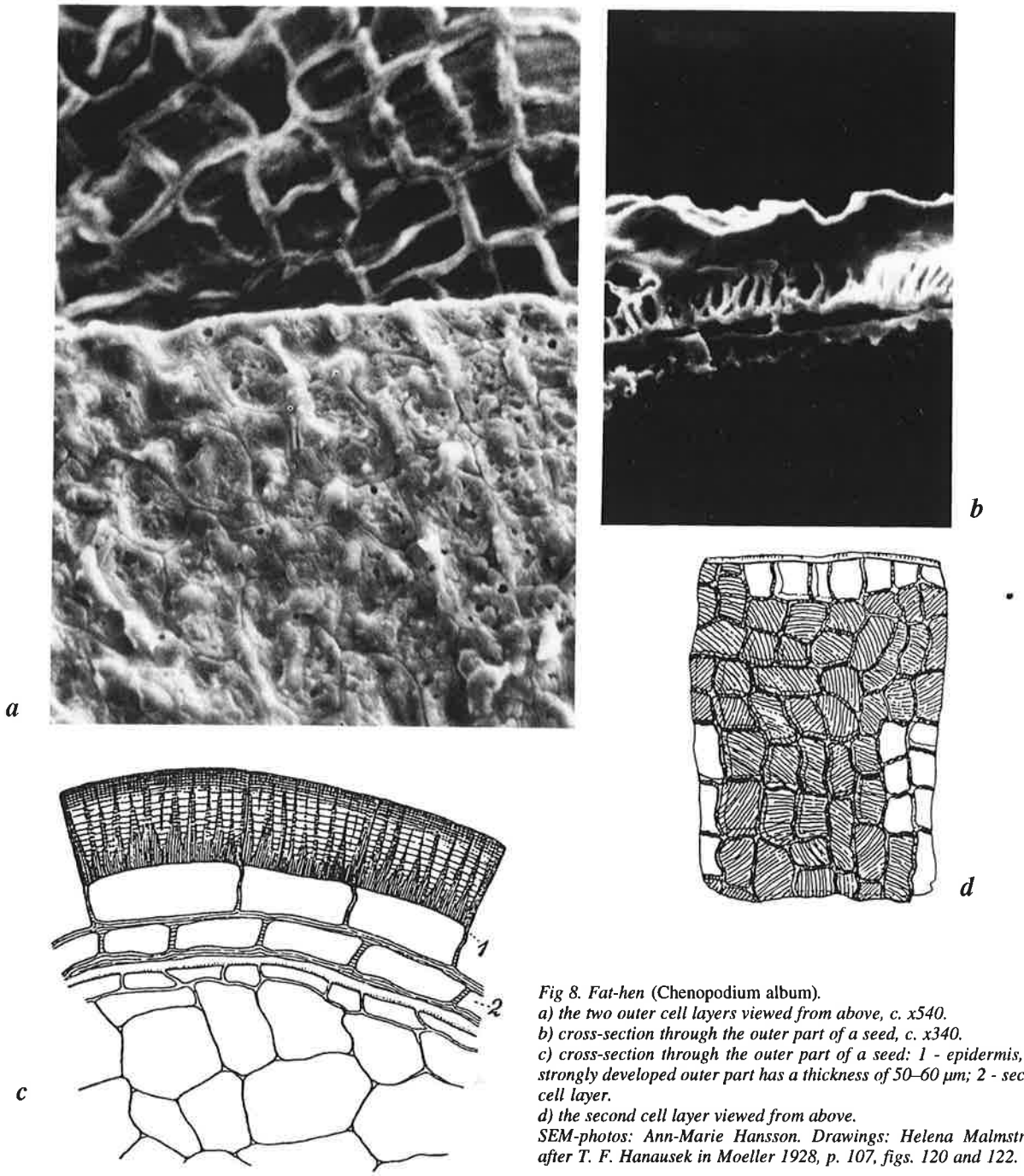

Fig 8. Fat-hen (Chenopodium album).
a) the two outer cell layers viewed from above, c. x540.
b) cross-section through the outer part of a seed, c. x340.
c) cross-section through the outer part of a seed: 1 - epidermis, the strongly developed outer part has a thickness of 50–60 µm; 2 - second cell layer.
d) the second cell layer viewed from above.
SEM-photos: Ann-Marie Hansson. Drawings: Helena Malmström, after T. F. Hanausek in Moeller 1928, p. 107, figs. 120 and 122.

Vuorela 1989-1990:144f). One pollen grain from birch (*Betula*), and one from pine (*Pinus silvestris*), could be traced by phase contrast microscope (x400). It was impossible to determine if the pollen grains were secondary intrusions or original. In general the results were negative, indicating that the method was not suitable for this specific charred organic substance.

Charred residue from a cooking pit, Harrsjöbacken,

Västerbotten, Bureå par., A2

The same initial procedure was followed here. The sample was very firm and was determined to be suitable for ultrasound treatment. Thereafter, the sample was immersed for two days in hydrogen peroxide and ammonia, and subsequently heated. Only a small part of the sample dissolved. This was examined on glycerol/ethanol slides under phase contrast microscope. No cell pattern or identifiable microfossils could be discerned.

Charred organic remains, faecal in origin (?), Folåsa

Östergötland, Rappestad par., Site 32. SHM 5147/77

Plant tissues were visible already on preparatory examination under binocular microscope (x10). Some small fragments with possible botanical content, were re-

moved from a surface fracture. On examination in scanning electron microscope (SEM), the botanical content proved to be parts of seed coats (the outer and the second cell layer) of fat-hen (*Chenopodium album*) (fig. 8a and 8b), wherein the second cell layer of the testa, with a clear but somewhat irregular network pattern is of particular diagnostic value (fig. 8c and 8d) (cf. the testa layer in Berggren 1981:176, Pl. 22, fig. 1). The sample also produced a fragment of a flax seed (*Linum usitatissimum*), which was easy to detect by its characteristic bent apex (fig. 9).

Reference literature used

Berggren 1981; Booth 1971; Colledge 1988; Dickson 1987; Ellis 1971; Gassner 1931; Hjelmqvist 1984; Hjelmqvist 1990; Holden 1986; Körber-Grohne & Piening 1981; Moeller (Griebel) 1928; Moore & Webb 1983; Påhlsson 1981; Schiemann 1948.

Seeds and fruits from the Archaeological Research Laboratory Reference Collecion have been employed for comparative analysis of cell structures.

The chemical analysis

by Sven Isaksson

These analyses are based on the observation that the amount and composition of certain organic compounds varies in accordance with their different biological and environmental origins. This is due to the differing utilization of these compounds in the metabolisms of living organisms, and the adaption of these organisms to different environments.

Immediately an organism dies, is killed, or picked, the decomposition processes are set in motion. These processes can be altered by human activities such as food preparation, which could involve thermic decomposition during cooking and frying, or biodecomposition during fermenting. Finally, the food residue gets deposited in its archaeological context.

Preservation

Important for the preservation of these compounds is the rate of deposition, and thereby the stability and porosity of the burial matrix. At this stage, the environment of the site and the micro-environment of the deposit, are both crucial for preservation, depending on climate, aeration, humidity, pH (Evershed et al. 1992:201), and the presence of other chemical substances, such as naturally occurring antioxidants. Bioturbation in the soil caused by soil-living mammals, insects, microrganisms, plants, fungi and algea, also contributes to decomposition and contamination. Furthermore, the properties of the compound itself have also to be considered. For instance, lipids (fat, waxes, etc.) that are hydrophobic, decompose slower than, and do not migrate in the same way as,

*Fig 9. Fragment of flax (*Linum usitatissimum*), c. x26. SEM-photo: Ann-Marie Hansson.*

sugars, soluble proteins, amino acids and trace-elements that are solvable in water (Heron et al. 1991:641–659; Limbrey 1975:41–42). There seem to exist some conditions of archaeological deposition that can protect certain compounds (in this case lipids) from decomposition (Skibo 1992:99).

Decomposition

The lipids in a sample will be altered by hydrolysis, oxidation and/or microbiological degradation (Evershed et al. 1992:195–203). Knowledge of the mechanisms of these processes is vital when interpreting the results of analyses (Isaksson MS). Critical for charred organic remains is thermolysis, since these samples have been exposed to heat. Thermolysis causes degradation by bond-breakage due to thermal motion. The heat acts as an initiator of autoxidation, and the different fatty acids respond variously to heat treatment. Polyunsaturated acids undergo rapid oxidation at room temperature, whereas monounsaturated acids undergo oxidation at elevated temperatures (Kumarathasan et al. 1992:110–111).

Sampling

Any equilibrium in the deposit, such as stable burial matrix and reduced decomposition processes, is disturbed upon excavation. The organic compounds become ex-

Sample	Protein (% by weight)	Lipids (% by weight)
Birka	0.70	0
Västergården	2.3	0
Vrå	0.26	3.3
Harrsjöbacken I	1.6	6.2
Harrsjöbacken II	-	2.0

Table 1. Results of the content analyses.

posed to air and light, initiating the processes of autoxidation and photosensitized oxidation. On account of this, excavation and sampling have to be conducted with extreme care. A sample must never be handled with the bare hand, owing to the risk of contamination, and should be stored in darkness, without access to oxygen, and/or deep-freezed until it can be analysed. For each analysis sample, corresponding reference samples should be taken from the surrounding soil.

All these sampling conditions are unfortunately seldom attended to. Of our samples, that from Birka was excavated some hundred years ago and that from Västergården some ten years ago. Neither has been stored under favourable conditions. The other two samples, Vrå and Harrsjöbacken, are recently excavated and therefore more promising. Harrsjöbacken is the only sample for which reference-samples were included.

Fatty Acids	Vrå (in % of fatty acid)	Harrsjöbacken I (in % of fatty acids)	Harrsjöbacken II (in % of fatty acids)
C8:0	0	38.6	3.92
C10:0	0	3.32	3.74
C12:0	0	4.80	6.42
C14:0	7.47	2.95	5.44
C16:0	22.4	4.61	22.4
C18:0	27.6	4.98	23.5
C22:0	0	7.20	0
C16:1	0	1.85	2.94
C18:1	0	1.85	13.4
C20:1	0	0	3.74
C18:2?	30.5	0	2.76
C18:3?	0	5.54	6.15
C18:4?	0	0	5.61
C22:6?	0	24.4	0

Ratios	Vrå	Harrsjöbacken I	Harrsjöbacken II
C18:0/C16:0	1.23	1.08	1.05
C16:1/C18:1	0.00	1.00	0.219

Table 2. Results of the fatty-acid analysis.

Chemical content analysis

The chemical pretreatment and analytical equipment used for the fatty-acid analysis are presented in figs. 10 and 11, and the protein quantification was made spectrophotometrically following Lowry (1951). The results of the content analyses are summarized in table 1.

Results

Interpretation of the protein analysis is somewhat tricky. As the protein content in the Harrsjöbacken sample roughly equals that in the two reference samples (Isaksson 1992a:68), it cannot be interpreted as having a protein-rich origin, such as meat, blood, cheese or certain seeds and nuts (Statens Livsmedelsverk 1988; Isaksson, unpublished data). In this light, the Birka and Vrå samples are exceedingly low in protein. Without any reference sample it is difficult to judge if the relatively high content of the Västergården sample represents the origin of the sample or of the site-environment. But by comparison to soils of other sites (Isaksson 1992a; 1992b; in press), the Harrsjöbacken reference samples have produced the highest values so far encountered. Usually the protein content of undisturbed soils lies below 0.5% by weight.

The absence of lipids in the Birka and Västergården samples might reflect post-excavational treatment and the long time-span since excavation. But if the original lipid content was high, there ought at least to be traces in the sample of the more stable lipid classes, such as saturated fatty acids and waxes.

The fatty-acid analysis

Previously, lipid origin has often been interpreted off signature (or origin-specific) fatty acids. As these acids often are polyunsaturated, they decompose very rapidly and their presence in lipids of archaeological origin is doubtful (Isaksson MS). Likewise, as the identification of the fatty acids according to the method used in this study is based on retention-time comparison, the identifications of linoleic acid (C18:2), linolenic acid (C18:3), octadecatetraenoic acid (C18:4), and cervonic acid (C22:6), have to be strongly questioned. These have thus not been used in the following interpretations. Instead, a fatty-acid ratio analysis was used, which method is presented and discussed in detail in a forthcoming paper (Isaksson MS).

In short, the most relevant ratios to work with in an analytical diagram seem to be C18:0/C16:0 (stearic acid to palmitic acid), and C16:1/C18:1 (palmitoleic acid to oleic acid). This gives different domains for the fatty-acid patterns of food-stuffs of different biological origin, with however some overlapping, as presented in fig. 12. Moreover, the C16- and C18-fatty acids are those which are most abundant in natural lipids (Statens Livsmedelsverk 1988).

Results

Only the two samples in which a loss of weight upon extraction was observed, were subjected to fatty-acid analysis, i.e. Vrå and Harrsjöbacken. The results are presented in table 2.

The Vrå sample showed a stearic to palmitic acid (C18:0/C16:0) ratio of 1.23, and a lack of palmitoleic acid and oleic acid. This lack is probably due to oxidation (Isaksson MS). The C18:0/C16:0-ratio is more stable and all reference-ratios above 0.8 are of terrestrial mammal origin. Further, the ratios above 0.8 exclusively represent entrail food-stuffs with one exception, which is beef of elk (*Alces alces*) with a C18:0/C16:0 ratio of 1.34 (Isaksson MS). The high amount of myristic acid (C14:0) is also an argument for an animal origin (Statens Livsmedelsverk, 1988). This calls for an interpretation of the lipids extracted from the sample, as of a terrestrial mammal origin, and probably from entrail fat.

A fatty-acid analysis of Harrsjöbacken sample I has been presented elsewhere (Isaksson 1992a), where it was interpreted as having a marine origin, owing to the presence and absence of certain signature fatty acids. Resting heavily on archaeological field-observations and an analysis of the blubber of modern grey-seal (*Halichoerus grypus*), an origin as residue of seal train-oil production was proposed for the sample (Isaksson 1992a:70). But even when using ratio analysis, this sample is complicated. The high C16:1/C18:1-ratio indicates a marine origin, but the C18:0/C16:0-ratio is too high to fit the marine group. Because of these problems, it was decided to make new analyses on a larger sample, to obtain a better yield, and thereby receive a more reliable result.

Harrsjöbacken sample II was taken from a specimen of the organic material separate from Harrsjöbacken I, and a sample measuring 0.988 g was used. There is a distinctive difference in the fatty-acid patterns of the two samples, and also in the ratio analysis. Harrsjöbacken II is clearly in the terrestrial mammalian domain of the analytical diagram. Furthermore, as in the case of the Vrå sample, this suggests entrail food-stuffs.

SAMPLE DRYING
In vacuum, with silica gel for 36 hours
EXTRACTION OF LIPIDS
The lipids were extraced ultrasonic by chloroform/methanol (2/1) for 30 minutes. The sample was centrifugalized and the extract collected.
CHEMICAL PRETREATMENT
O-acyl lipids were esterified and transesterified by 1% sulphuric acid in methanol. The process was done at 60°C, for 12 hours. The resulting methyl esters were extracted by hexane, adding saturated saline solution. The sample was evaporated to a few µl:s in a flow of nitrogen.
GAS CHROMATOGRAPHIC ANALYSIS

Fig 10. Sample treatment.

ANALYTICAL EQUIPMENT AND PROCEDURES
Hewlett-Packard 5890 Gas Chromatograph
Capillary Column HP-FFAP (crosslinked FFAP), polyethylen glycol - TPA modified, Polar, 50m x 0.32mm x 0.52µm
Flame-ionisation detector (FID)
Hewlett-Packard 3396A Integrator with calibration curves for 25 different fatty acids
N_2 carrier gas
Temperature program: Initial temperature 40°C, 1 minute hold; 25°C/minute to 120°C; 8°C/minute to 240°C, 60 minutes hold

Fig 11. Analytical equipment and procedures.

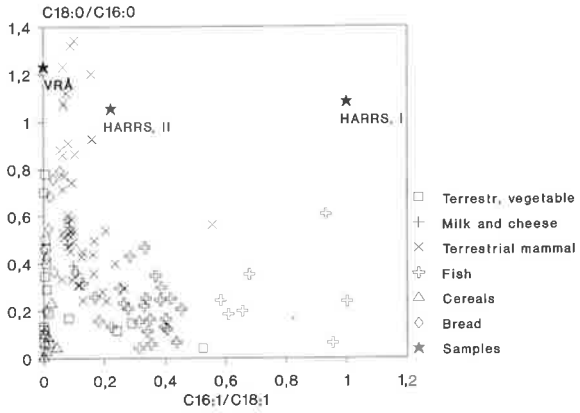

Fig 12. Fatty-acid ratio diagram used for origin-interpretation of lipid residues (from Isaksson MS).

Summary of the chemical and microscopical analysis

by Ann-Marie Hansson and Sven Isaksson

Microscopic analysis had previously been carried out on the sample from *Birka*, showing that it contained hulled barley (*Hordeum vulgare*) with the addition of oats (*Avena*) (Hjelmqvist 1984:263). The chemical analysis carried out in our study showed that the sample was low in both protein and lipids. This is probably the effect of undesirable post-excavational storage, but can also reflect low contents in the original substance.

In the *Västergården* sample, only wheat (*Triticum* sp.) was recovered. Swedish bread known from archaeological contexts is usually baked from flour composed of several types of cereals. Seeds of fat-hen (*Chenopodium album*) were also identified and these possibly should be interpreted as an intrusion of field weeds. The phytoliths which were recovered, most likely belong to the grass family (Poaceae). Cells of the mould fungi Saccaromyceteae occurred in relatively high numbers and can have been present in the original material, perhaps added to the dough in the form of sour dough; fungi from this family are used for beer production, even nowadays. Spores, probably conidia, from Ascomycota probably developed during a later secondary fermentation process. If this observation is correct, it indicates that the sample was rather poorly burned. The sample most probably had a high protein content originally, which could reflect the inclusion of blood and/or meat.

In the sample from *Vrå*, pollen grains from birch (*Betula* sp.) and pine (*Pinus silvestris*) were found together with a few phytoliths belonging probably to the

grass family (Poaceae). These botanical remains provide little information of value. Here the chemical analyses are of vital importance, as they show that the sample has a low protein content but is high in lipids, with only three saturated fatty acids reliably identified. The ratio of the palmitic acid to stearic acid, and the high amount of myristic acid, probably reflects a terrestrial mammal origin, possibly from some sort of entrail fat.

No botanical remains were recovered from the *Harrsjöbacken* samples. Here too, best information on the sample's content came from the chemical analyses, which show that the organic material is heterogenous in its lipid composition. The protein content in sample I from Harrsjöbacken was the same as that in the two reference samples analysed. The result of the fatty-acid analysis is more reliable for sample II from Harrsjöbacken, as a larger sample was used. The fatty-acid ratio analysis here indicates a terrestrial mammal origin, also from an entrail fat. It must be pointed out, however, that at present there is a lack of good reference data on the fatty-acid composition of marine mammal entrail fats.

The *Folåsa* sample, which was only examined by scanning electron microscope (SEM), revealed fragments of flax seeds (*Linum usitatissimum*) and fat-hen (*Chenopodium album*).

Conclusion

Charred organic remains are frequently found on archaeological excavations. Most likely, these are the remains of food. This artefact group has been sadly neglected, except in cases when bread was recognized by its shape. In the remaining cases, lack of interest probably reclects the difficulties involved in identifying content origin.

The various laboratory analyses which are here represented, clearly show the high value of using different types of examination in combination with one another. The analyses here conducted could be fruitfully complemented by trace-element analysis and in cases where a high protein content was identified, by amino-acid analysis. The present authors hope that in the future, more analyses of this type will lead to a clearer picture of prehistoric diet.

Glossary

Caryopsis (grain) = A fruit that resembles an achene (a simple single-seeded indehiscent dry fruit that develops from a monocarpellary ovary), with the exception that the seed wall fuses with the carpel wall during embryo development. The caryopsis is typical of cereals and grasses.

Carpel = The structure that bears and encloses the ovules in flowering plants. It normally comprises the ovary, style and stigma.

Conidium = An asexual spore produced by many fungi, especially ascomycetes. The haploid conidium can be uni- or multicellular and have different forms, attached to specialized erect hyphae termed conidiophores.

Phytolith (opal phytolith, silica body) = Silica accumulated in cells and tissues of grasses and also other plants. Phytoliths can serve as a taxonomic tool.

Apex = Point or top

Lipids = Fatty acids and their derivatives, and substances related biosynthetically or functionally to these compounds (Christie, 1989:11).

Equipment used

SEM, Super III A, ISI International Scientific Instruments

Phase contrast Microscope, Nikon Optiphot-2

Binocular low-magnifying microscope, Nikon SMZ U

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