Pits, Pots and Prehistoric Fats
A Lipid Food Residue Analysis of Pottery from the Funnel Beaker Culture at Stensborg, and the Pitted Ware Culture from Korsnäs

Nathalie Dimc
Master’s Thesis VT 2011
Supervisors: Sven Isaksson & Elin Fornander
The Archaeological Research Laboratory
Stockholm University
Pits, Pots and Prehistoric Fats
A Lipid Food Residue Analysis of Pottery from the Funnel Beaker Culture at
Stensborg, and the Pitted Ware Culture from Korsnäs

Abstract
Investigating Neolithic pottery and vessel use could elucidate the duality between the
farming Funnel Beaker Culture and the hunter-gathering Pitted Ware Culture during the
Neolithic. The two archaeological groups differ on several accounts that are of great
importance when interpreting past societies. However, it is the suggested differential
subsistence economies that are of specific interest for this particular investigation. A
comparative study based on the absorbed fatty acids in the ceramic material from two
different Neolithic sites addresses the food cultures of the farming subsistence and the
contrasting, contemporary hunter-gatherer society and the differences in resource-use. The
investigation argues that food acts as an active social binder, and stress the importance of
incorporating this aspect when discussing past cultures. The results of the analyses display
difference in vessel use between the two sites as well as an intra-site difference at Korsnäs.
It is argued that these differences are indicative of deviating food-cultures and spatial
organisation at Korsnäs respectively. These results are combined with the previously
conducted osteological analyses and stable isotopic analyses an approach that contribute to
a more dynamic understanding of the Neolithic food cultures than what has been available
before.

Keywords: The Neolithic; Funnel Beaker Culture; Pitted Ware Culture; Food Lipid
Residue Analysis; GC-MS; Food Culture; Pottery; Spatial organization; Stensborg Raä 257;
Korsnäs Raä 447; Grödinge parish; Södermanland

Cover illustration: A ceramic vessel and the structure of cholesterol and an alkylphenyl
alkanoic acid: by the author.

Acknowledgements: I would like to thank my supervisors Sven Isaksson and Elin
Forander for their support and understanding nature as well as their seemingly bottomless
knowledge of the field that they have shared with me. A big thank you to Ole Stilborg for
participating in my experiment concerning absorbed fingerprints in the ceramic matrix, as
well as for our rewarding discussions about pottery. I send a thank you to Lars Larsson as
well, for providing me with the material from Stensborg. I would also like to thank Ida
Thorin for revising my English in hours of need.

I would like to thank my big family that comprise of my Mother, Father and Sister,
relatives, and friends for always being there for me. Of special importance are my class
mates in the Master class of 2011, Ida Thorin, Markus Fjellström, Hans Ahlgren, Joakim
Schyman, Eva Wesslén and Johan Hinders, since You have very much contributed to a
wonderful and rewarding time at AFL that I will cherish, always.

Finally, fellow inhabitants of the Green House: Ida, Markus, and Åsa – Thank you for
your patience and for the kitchen table.
Table of Contents

1. Introduction 3
   1.1. Preface 3
   1.2. Aims and Research Questions 3
   1.3. Methodology and Materials 4

2. Background 5
   2.1. Neolithic Research 5
   2.2. The Neolithic in Eastern Central Sweden 6
      2.2.1. The Funnel Beaker Culture 6
      2.2.2. The Pitted Ware Culture 6
   2.3. Neolithic Ceramic Assemblages 8
      2.3.1. Differing Ceramic Assemblages 9
      2.3.2. Funnel Beaker Culture Pottery 9
      2.3.3. Pitted Ware Culture Pottery 10
   2.4. Food Cultures 11
      2.4.1. Neolithic Food Cultures 11
      2.4.2. Deviating Food Cultures 12

3. Site Specifics 13
   3.1. Stensborg, Raä 257 13
      3.1.1. Recovered Artefacts and Structures 14
      3.1.2. Previous Interpretations 15
   3.2. Korsnäs, Raä 447 16
      3.2.1. Recovered Artifacts and Structures 18
      3.2.2. Previous Interpretations 20

4. The Food Lipid Residue Analyses in Archaeological Contexts 21
   4.1. Previous Research 21
   4.2. Fatty Acids and Their Derivatives 22
   4.3. Degradation of Organic Material 24
   4.4. Contaminations 25
   4.5. Gas Chromatograph Coupled to a Mass Spectrometer 26
   4.6. Interpreting Vessel Use 27
   4.7. The Food Lipid Residue Analysis 29

5. Materials 30
   5.1. Sampling Strategy and Selected Samples 30
   5.2. Selected samples from Stensborg, Raä 527 31
   5.3. Selected samples from Korsnäs, Raä 447 31
   5.4. The Absorption of Modern Fingerprints in the Ceramic Matrix 33

6. Results 34
   6.1. Results of the Food Lipid Residue Analysis with GC-MS 34
      6.1.1. Stensborg 34
      6.1.2. Korsnäs 34
   6.2. The Absorption of Modern Finger Prints 38

7. Discussion and Conclusion 40
   7.1. Vessel Use at Stensborg 40
   7.2. Vessel Use at Korsnäs 40
      7.2.1. The Interpretation of the Clay Disc 42
      7.2.2. The Interpretation of the Mini Vessel 42
      7.2.3. Deposited Base Fragments 42
   7.3. Concerning the Deviating Food Cultures 44
   7.4. Concluding Remarks Concerning Neolithic Vessel Use 44
   7.5. Absorbed Fingerprints 45

8. Summary 46

9. References 48

List of Appendices
   Appendix 1 - Table displaying the interpretation of each sample
   Appendix 2 - Detailed interpretations of the samples
   Appendix 3 - Table displaying the interpretation of the intentionally contaminated samples
Table 1. Neolithic periods and occurrences of the different "cultures": the Funnel Beaker Culture (FBC), the Pitted Ware Culture (PWC) and the Battle Axe Culture (BAC) in Eastern Central Sweden, as presented in Edenmo *et al.* 1997.

<table>
<thead>
<tr>
<th>Abbr.</th>
<th>Period</th>
<th>Date</th>
<th>&quot;Cultures&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>EN</td>
<td>Early Neolithic</td>
<td>4200-3300 BC</td>
<td></td>
</tr>
<tr>
<td>EN I</td>
<td>Early Neolithic I</td>
<td>4200-3650 BC</td>
<td>FBC</td>
</tr>
<tr>
<td>EN II</td>
<td>Early Neolithic II</td>
<td>3650-3300 BC</td>
<td>FBC + PWC</td>
</tr>
<tr>
<td>MN</td>
<td>Middle Neolithic</td>
<td>3300-2350 BC</td>
<td></td>
</tr>
<tr>
<td>MN A</td>
<td>Middle Neolithic A</td>
<td>3300-2700 BC</td>
<td>PWC</td>
</tr>
<tr>
<td>MN B</td>
<td>Middle Neolithic B</td>
<td>2700-2350 BC</td>
<td>PWC + BAC</td>
</tr>
<tr>
<td>LN</td>
<td>Late Neolithic</td>
<td>2350-1800 BC</td>
<td>EAC</td>
</tr>
</tbody>
</table>
1. Introduction
1.1. Preface
The archaeological interpretations of the Neolithic have previously been dominated by a focus on the differentiality between different groups of people, based on their material culture. This focus has resulted in the interpretation of the material assemblages from the Early Neolithic (EN) and Middle Neolithic A (MN A) in the Central Eastern parts of Sweden as remnants of two different groups, the Funnel Beaker Culture (FBC) and the Pitted Ware Culture (PWC). The FBC is associated with agriculturalists representing the first agricultural influence in Eastern Central Sweden (Edenmo et al. 1997; Welinder et al. 1998). The PWC on the other hand is associated with hunter-gatherer subsistence, with a diet based primarily on seal as indicated by the stable isotopic data and the osteological analyses of the recovered bones (Edenmo et al. 1997; Storå 2001; Fornander et al. 2008).

By complementing the interpretations of the material assemblages with the investigations of food and eating habits, discussions concerning the investigation of traces of ancient food cultures are possible. This approach provides a more nuanced view of prehistoric activities and resource use than what is possible through interpretations restricted to the differences between groups of people reflected in material culture (Hjulström & Isaksson 2005; Isaksson 2010). Furthermore, a combined methodological approach is suggested in this study, arguing that the combination between the previously examined osteological material, the published stable isotopic data and the results of the food lipid residue analyses from Korsnäs performed for this study will contribute to a more definable and understandable prehistoric food culture at the site than what has been available before.

One of the aims for this study is to highlight food as a cultural binder, suggesting that one of the fundamental differences between archaeological groups is their food culture. Of special interest is therefore the dichotomy of the FBC and the PWC and their suggested differences in resource use. One FBC assemblage from Stensborg Raä 257, and one PWC assemblage from Korsnäs Raä 447, at the Södertörn peninsula will be investigated through food lipid residue analyses in order to understand the vessel use at the sites.

The spatial organisation at the Korsnäs site is of further interest for this study and sampled sherds from different contexts within the site will be investigated. These investigations should be seen as a complement to the performed soil chemical analyses (Andersson et al. 2011), and the classifications of the pottery assemblages from Korsnäs (Dimc & Fornander 2011). The results of these investigations will possibly display differences in spatial organisation at the site, an investigative approach that previously never has been done.

Moreover, a series of investigations concerning the contamination of ceramic samples through modern fingerprints have been undertaken for this study. This in order to understand the extent of the absorption of modern compounds within the ceramic matrix. The primary focus of this pilot study has been the detection and characterisation of absorbed products related to modern fingerprints within ceramic blocks. Detecting these compounds, and understanding the extent of their absorption would contribute to the interpretation of prehistoric samples in future studies. The present study will directly benefit from these investigations, since several sherds have been subjected to unpreferable sampling and storage prior to the analysis in the laboratory.

1.2. Aims and Research Questions
The lipid food residue analyses will operate both at a regional and a local level, with the aim of contributing to the overall understanding of the Neolithic in Eastern Central Sweden. The analyses will yield results that can generate discussions concerning subsistence-patterns and the Neolithic menu. The Korsnäs site, ascribed to the PWC will
undergo detailed investigations aiming at understanding the spatial organisation at the site based on vessel use. Investigating the spatial organisation at Korsnäs would enable an understanding of the specific settlement, as well as the organisation of similar sites within the PWC in Eastern Central Sweden. The main questions can be summarised in the following points:

- How can the lipid food residue analyses of vessels deriving from two different Neolithic sites contribute to an understanding of different food cultures in Eastern Central Sweden during the Neolithic?
- What discussions are possible concerning an intra-site difference of vessel use at Korsnäs, based on the results of the lipid food residue analyses? Can the potential differences be indicative of a spatial organisation at the site?
- What interpretational possibilities lie in the combined results of the lipid food residue analyses; the previous stable isotope analyses, and the osteological analyses? Can they contribute to a fuller, and more nuanced understanding of the Neolithic food-cultures than what has previously been possible?

This study will also address a methodological question of importance for the lipid food residue analysis; the contamination through human fingerprints. Highlighting this aspect of the current method will hopefully contribute to the improvement of the prevailing methodology. The research question formulated for this investigation is:

- To what extent can human fingerprints and other residues be detected in the ceramic ware? Is it possible to detect how deep these possible contaminations absorb into the ceramic matrix?

1.3. Methodology and Materials
Food lipid residue analyses will be performed on sampled sherds from two Neolithic sites representing the FBC (Stensborg) and the PWC (Korsnäs) on the Södertörn peninsula. The comparative study intends to investigate the suggested duality between these subsistence economies. The results of the analyses from Korsnäs will be discussed in combination with the recovered osteological material and the published stable isotope data through a food-cultural approach (Hjulström & Isaksson 2005; Isaksson 2010). This approach is chosen due to the enhanced possibilities of obtaining a more nuanced understanding of the Neolithic food cultures when combining several methods of detecting food signals. Sampled sherds from both Stensborg and Korsnäs will be analysed through food lipid residue analyses, i.e. through the chemical separation of absorbed fatty acids in the ceramic matrix. The lipid distributions found in each sample indicate previous vessel use (Evershed 2001). It should be noted that the investigations of the Korsnäs site and the PWC is the main focus of this study. This focus is chosen due to the availability of, and accessibility to, the material, together with the opportunity to control the sampling during the excavations at Korsnäs in 2010.

Furthermore, an investigative study concerning the absorption of modern fingerprints will be performed. The study is based on the investigations of four ceramic blocks, that have been made subjected to varying amounts of contamination, constructed especially for this investigation. This investigation should be regarded as a pilot study aiming towards understanding the implications of analyzing sherds that have been handled with bare hands prior to the chemical analysis. Three samples will be drawn from different depths of each ceramic block, and they will be treated as prehistoric samples upon extraction.
2. Background

2.1. Neolithic Research

The transition from a hunter-gathering lifestyle to a farming subsistence, referred to as the Neolithic revolution, is argued to have taken place at the shift from the Mesolithic to the Early Neolithic (e.g. Zvelebil & Rowley-Conwy 1984). This transition has previously been considered to represent a sharp shift between these two subsistence-economies, and it has been much debated within Neolithic archaeology. Recent investigations however, claim that “the changeover from hunting-gathering to agriculture was a much longer and more drawn-out process than previously recognized” (Brown & Brown 2011:214). In contrast, it is argued that the economic transition to a farming subsistence in the Eastern Central parts of Sweden rather took place at the end of the Neolithic, at the onset of the Bronze Age (Eriksson et al. 2008). Regardless of the time and speed of the Neolithization process, it is commonly argued that when these transitions take place, they alter the way of life in a fundamental way. These conversions would leave traces in the materiality of peoples and thus in the archaeological material. Pottery use, floral and faunal remains, settlement patterning and different burial traditions are traits that are indicative of this transition (Welinder et al. 1998; Brown & Brown 2011:211pp).

During the EN the FBC displays an array of these Neolithic traits. Inland settlements, osteological material indicating the presence of domesticated animals and indications of agriculture and megalithic tombs are some of the most obvious features associated with the FBC. Further indications are FBC pottery and thin-butted axes (Welinder et al. 1998:61pp; Carlsson 1998:37-44). The FBC is seen as a part of a larger European complex associated with agriculture, where the Scandinavian groups represent the northernmost regions where these traditions were adapted (Hallgren 2008:71-76). In addition to this, the FBC is considered to represent the earliest established farming tradition in Eastern Central Sweden (Edenmo et al. 1997; Welinder et al. 1998).

In contrast to the FBC, a new material assemblage emerges in Eastern Central Sweden during Early Neolithic II (EN II) ascribed to the PWC. The PWC complex is commonly associated with a hunter-gatherer lifestyle based mainly on marine resources, as indicated by stable isotope analyses (Eriksson et al. 2008; Fornander et al. 2008). The PWC deviates from the FBC not only in dietary practices but also in terms of occupation patterns, the use of artefacts, burial traditions and social organisation (Edenmo et al. 1997; Welinder et al. 1998; Papmehl-Dufay 2006:14). The PWC is associated with large settlements at the coastline, where the characteristic PWC pottery is found shattered and scattered across the cultural layers, and with faunal remains dominated by seal, followed by pig (Edenmo et al. 1997:111f; Storå 2001:3-6). What becomes evident is that FBC and the PWC exhibit different traditions and use of resources during EN II, where the PWC is accentuated through a hunter-gatherer subsistence, post dating the Neolithic revolution.

When focusing on the subsistence-patterns of these two groups the differential use of resources is noticeable, and the duality gives rise to a number of theories explaining this phenomenon. These theories have been very much depending on the prevailing theoretical frameworks within the archaeology of the time. The cultural-history archaeology of the early 20th century explained differences within the material remains as strong proclamations of social identity and ethnicity, e.g. the differential decorative patterns on ceramic objects equal different social groups and their dispersion. Such interpretations imply that cultures and groups are closed entities, and that artefacts and traits are conveyed solely through people (Hodder 1979; Olsen 1997:28). These views led to the interpretation of the PWC material as being the results of migrations (Bagge 1949, see von Hackwitz:11) These interpretations of the archaeological material are however rigid explanations of a highly dynamic reality that marginalize the individuality of ancient peoples. Unfortunately,
these interpretative models remain to this day, and several current researchers are very much influenced by these views when interpreting the past (see Papmehl-Dufay 2006; Hallgren 2008; Pluciennik 2008; A.M. Larsson 2009; von Hackwitz 2009 for further discussions on the subject). These views were however generally forsaken during the functional archaeology of the 1970’s. A colder climate, an increasing seal population and exceeded use of the land were now seen as valid explanations as to why the agriculture in the inland was substituted by a hunter-gatherer lifestyle near the coast (e.g. Tilley 1982; Wyszomirski 1984).

The current field of research is rather uniform in the interpretations of the emergence of the PWC. The changes are generally seen as a socially enticed phenomenon that resulted in the “catagenesis” from the farming FBC to the wild, and individualistic, hunter-gatherer lifestyles (Carlsson 1998:48; Welinder et al. 1998). These transitions have been argued to occur either due to social tension (Carlsson 1998:48; von Hackwitz 2009:194), or due to the decreasing importance of agriculture; leading to a wider use of resources (Edenmo et al. 1997:112; Welinder et al. 1998:97, 107; Strinnholm 2001:112, e.g. von Hackwitz 2009:12).

2.2. The Neolithic in Eastern Central Sweden

2.2.1. The Funnel Beaker Culture

During the EN traits associated with the FBC emerge in the Eastern parts of Central Sweden. These traits differ from the features associated with the coast-bound aceramic hunter-gatherer societies during the Mesolithic (Lindgren et al. 1997). Inland settlements are now appearing together with traces of farming and domesticated animals. Even though the osteological material is generally scarce due to degradation, the bone assemblages that do appear are dominated by the remains of sheep/goat and pig and occasionally cattle (Khilstedt et al. 1997:112; Welinder et al. 1998:62; Hallgren 2008:242-245). The indications of farming mainly consist of seed impressions in the ceramic material and charred seeds (commonly wheat and barley) found deposited in pits or scattered in the cultural layer (Florin 1958; Edenmo et al. 1997:112; Welinder et al. 1998:62; Hallgren 2008:93).

Ceramic artefacts such as the funnel necked beakers appear together with collared flasks and clay discs, assemblages that in the Eastern Central parts of Sweden are characterized and classified mainly through the Vrå typologies (Florin 1958) (see the following section 2.3 for further details). In addition to this, The FBC is associated with a wide range of axes. The most common are the thin-butted and round-butted rock axes (Malmer 2002:30; Hallgren 2008:275). Findings of grinding stones and polishing stones have also been discovered in the region, alongside more foreign lithic elements such as the point-butted and thin-butted flint axes generally associated with the southern FBC in the south of Sweden (Malmer 2002:30f; Hallgren 2008:275).

The mortuary practices of the FBC complex involve the construction of megalithic tombs. However, these constructions are rare in Eastern Central Sweden, with the expectance of the Alvastra megalith (see Khilstedt et al. 1997). Nonetheless, investigations at Fågelbacken, Hubbo parish, Västmanland revealed a Neolithic grave field, with traces of poles and large assemblages of pottery (see Hallgren 2008:100-104). These recoveries display a varied burial tradition within the FBC, and a local variation of the FBC complex.

2.2.2. The Pitted Ware Culture

The PWC assemblages appear in the archaeological record in Eastern Central Sweden from EN II and are thus partially contemporary with the FBC. The earliest 14C-dates connected to PWC materiality in Södermanland correspond to EN II (Olsson 1996:441; Edenmo et al. 1997:183). However, the FBC and PWC deviate from each other on several accounts. The PWC are interpreted as, and associated with coast bound hunter-gatherers, representing a de-neolitization in the inhabited areas including the south-eastern and Eastern Central
parts of Sweden as well as Gotland and Öland; stretching as far north as Dalarna and Gästrikland (Wyszomirska 1984:40-43). The larger PWC complex has been interpreted as an influence from the Combed Ware Culture in the east (Wyszomirska 1984). Contrasting argumentations claim that the PWC developed from the FBC in the southernmost areas of its dispersion (Browall 1991:133; Carlsson 1998:48).

The settlement patterns of the PWC differ from that of the FBC, as the settlements are almost exclusively connected to the prehistoric coast line (Edenmo et al. 1997:173). The settlement pattern displays a tendency to agglomeration, which could be interpreted as the territory of one specific group within the PWC complex (Edenmo et al. 1997:175). Heimdal (2010) argues that Korsnäs (Raä 447), Kyrktorp (448) and Smällan (477) in Grödinge parish, Södermanland, could be seen as a possible agglomeration as these sites are contemporary during MN A, as well as geographically connected (Heimdahl 2010). However, Heimdahl also presents the possibility that the settlements were inhabited by three different groups; however, they most certainly had contact with each other (Heimdahl 2010).

The material assemblages most commonly associated with the PWC are the pottery, primarily decorated with incised pits (see section 2.3.3 for further details), tanged arrowheads and cylindrical cores (Edenmo et al. 1997:135-140). Noteworthy is that the dominating features of the PWC materiality are dependent on the region studied. Malmer (1966) argued that the PWC could be considered as an eastern cultural phenomenon based on the recovered pottery assemblages. In contrast, the PWC is argued to be a western cultural phenomenon when defined through the dispersion of recovered arrowheads (Malmer 1966:376). Bagge (1951) further suggests that the PWC should be divided into a northern and a southern group, based on the differences in the ceramic assemblages (Bagge 1951, see Papmehl-Dufay 2006:37-40).

Anthropo-zoomorphic figurines occur at PWC localities as well, commonly associated with the east. Zoomorphic figurines of burned clay depicting seals dominate the recovered figurine assemblages. However, anthropomorphic figurines have been recovered as well (Wyszomirska 1984:49). Of special interest is the small figurine from Korsnäs, made of bone/antler (see figure 1) (Olsson et al. 1994).

Burial practices within the PWC are also deviating from the monumentality of the FBC. Inhumations are the most occurring burial tradition at PWC sites in the Eastern Central Sweden where individual graves containing grave goods such as base fragments and intact mini vessels. Moreover, human bones are commonly found scattered over the occupational layers in this region (Carlsson 1997:49f; Malmer 2002:97).

The coastal focus is apparent with the PWC, both in terms of settlement patterns and resource use, as well as in cosmology. It is argued that the sea was perceived as holy and that the accentuation of the shoreline in PWC contexts can be compared with the monumentality of the megalithic tombs and/or the palisade enclosures associated with the FBC. The shattered pottery assemblages commonly encountered at PWC localities are interpreted as intentional activities, and highly unlikely to be the results of taphonomy (Carlsson 1998:52f; Stenbäck 1998:101; Gill 2003:121). Carlsson (1998) and Gill (2003) argue that the shores where PWC pottery has been found are places of ritual activity (ritual meals) associated with the dead, much like the practices at Alvastra pile dwelling (Carlsson 1998:52f; Gill 2003:121). Carlsson also highlights the fact that no complete vessels have been found in graves, except from the mini vessels (Carlsson 1998:52).
The lifestyle and activities associated with the PWC are still rather enigmatic and archaeologists have attempted to unwind what the traces of these groups represent through various methods and angles (Eriksson 2003; Papmehl-Dufay 2006; Linderholm 2008; Fornander et al. 2008; von Hackwitz 2009; Å.M. Larsson 2009). The current understanding of the PWC phenomenon is best summarized by Papmehl-Dufay (2006) and it mirrors the prevailing view of the PWC in this study.

“... the Pitted Ware Culture in eastern Sweden should indeed be seen as representing a large cultural entity with a specific way of living, specific myths of origin, specific perceptions of life and death and, not least, a specific socially embedded ceramic craft tradition. The latter included not only the production and design of ceramic vessels but also their use in specific contexts. It is important to emphasize, though, that numerous local identity groups were most likely included within this entity, and that when considering the pottery aesthetically as well as technologically and possibly also contextually there are some significant regional differences to be seen within the overall Pitted Ware Tradition /.../ so that it would perhaps be fair to speak of numerous “sub-traditions” within the overall Pitted Ware ceramic tradition.” (Papmehl-Dufay 2006:230).

2.3. Neolithic Ceramic Assemblages
The ceramic material offers a multitude of interpretational and analytical possibilities due to its low susceptibility to degradation. This leads to the fact that high frequencies of the material are often recovered at archaeological sites. This situation further contributes to the possibility of studying an array of ceramic artefacts and their possible use and importance in the everyday lives of past peoples (Stilborg et al. 2002:14). Pottery is associated with several culinary activities such as cooking and storing, as well as feasting. Pottery and vessel use is thus an important aspect to consider when investigating ancient food cultures.

Another important aspect of pottery within archaeological research is the possibility of chronologically dating the assemblages in order to get an indication of when these artefacts were in use (Stilborg et al. 2002:15). This has been made possible through the use of different ceramic typologies. These series are often associated with one specific area and/or with one specific archaeological group, and have therefore been used within archaeology as ethnic or cultural markers in prehistory, arguing that there is a correlation between the ceramic décors and peoples, e.g. FBC and PWC (Bagge 1951; Welinder 1987).

Even if these typological series are seen as remnants of earlier research, some of them are still used today. The Fagervik (Bagge 1951) and Vrå (Florin 1958) chronologies are of special importance as they present classifications of the Neolithic pottery assemblages that are applied in current research as well. These typologies are based on the categorization of ware, temper and décor of recovered material from the Fagervik settlement in Krokel parish, Östergötland, and the Vrå settlement in Brokvarn in Turinge parish, Södermanland in order to mirror an intra-site chronology (e.g. Bagge 1951; Florin 1958). However, it is of importance to mention that $^{14}$C-datings of food crusts adhering to the surface of recovered FBC vessels, as well as organic material that is contextually connected to the sherds show that both undecorated vessels and decorated vessels are contemporary variations. The same relationship can be seen in the different décor assemblages (see Hallgren 2008: 139f). Analyses of adjacent organic material found in PWC-related contexts display a chronological overlap in time when compared with the Fagervik series. Discussions concerning the earlier Fagervik groups (I and II) suggest that these sequences could represent a transition between the FBC and PWC pottery assemblages (Edenmo et al. 1997:136,169,183p; Olsson 1996b:441).

As mentioned above, recent investigations concerning the documentation of recovered pottery assemblages employ a more flexible system (e.g. Papmehl-Dufay 2006; Dimc & Fornander 2011), as suggested by Malmer (1963:114ff). This approach is preferred since there are several factors that could contribute to the differences within one ceramic
assemblage, local variations being one of them (Welinder 1987). The previously mentioned more flexible system that has become increasingly applied in recent research regards the different decorative patterns as independent units, where the presence and variations of these patterns are documented. This approach could be contrasted to the more rigid, classic systems where new symbol classes were created when previously unknown combinations were discovered (e.g. Florin 1938 and Bagge 1951, see Malmer 1963:114ff; Papmehl-Dufay 2006 and references therein for further discussions on the subject).

2.3.1. Differing Ceramic Assemblages
One of the most apparent characteristics applied when discussing the differences in FBC and PWC pottery assemblages in Eastern Central Sweden has been the quality of the ceramic ware, in combination with the presence of corded impressions on FBC pottery (Bagge 1951; Hallgren 2008:136,153).

Other distinctions between these ceramic traditions are the contextual use of décor and the placement of the particular patterns on the vessel itself. The FBC pottery seldom displays intricate decorated pottery at the settlements in the Mälardalen region, such vessels are rather found in burial contexts (Stilborg et al. 2002:64; Hallgren 2008:153). Moreover, the vessels that display more intricate décor are usually decorated on the body as well, and not only at the rim. In contrast, intricate décor on all parts of the vessel and contexts are common at all PWC related settlements (Hallgren 2008:153).

2.3.2. Funnel Beaker Culture and Pottery
A general description of the FBC pottery tradition could be summarized as coarsely granite tempered vessels, of non-calcareous clay. The vessels were coiled and joined through N- or U technique. They are often well burned and have a burnished exterior (Stilborg et al. 2002:59; Hallgren 2008:139). The vessel shapes are commonly s-shaped, with both high and low necks, where rounded bases dominate the recovered assemblages. The recovered vessels vary in the extent of adornment, both decorated and non-decorated vessels occur at FBC related sites. When decorated, the patterns are usually placed on the neck or just under the rim of the vessel (Florin 1958:87; Hallgren 2008: 139). The most occurring patterns on the FBC material are shallow pits in horizontal rows, cord- and twisted cord impressions, comb stamps and deeper pits (Hallgren 2008:139).

In addition to the typical funnel necked beaker there are other types of vessels and ceramic objects associated with the FBC that occur with relative high frequency, e.g. collared flasks, clay discs and lugged jars (Stilborg et al. 2002:59; Hallgren 2008:139,172-175). The collared flasks occur on most settlements ascribed to the FBC in the Mälardalen region, as well as in most contexts. However, in the southern parts of Scandinavia the artefacts occur most frequently in burial contexts (see Hallgren 2008:174 and references therein).

The clay discs are flat plates of clay (c:a 10-20 cm Ø; 1.5 -2.5 cm thick), sometimes with a thicker outer rim, occasionally adorned with impressions of fingers, imprints or cuts (Hallgren 2008:174). The material is often coarse and fully oxidised. The artefacts are found in contexts dated from EN I to MN B, thus found in PWC contexts as well. The artefacts have been interpreted as lids, baking [Figure 2. Sample SB9 from Stensborg. Decorated with line impressions, twisted cord impressions and a deeper pit possibly in an original horizontal band. Photograph by the author.]
plates and as cavalettes used when manufacturing pottery (Stilborg et al. 2002:140, Malmer 2002:29). The most common interpretation is nonetheless that the clay disc was used as a heat storing device. It is argued that the ware is fully oxidated as a consequence of repeated heating in high temperatures. This since the coarseness and thickness of the artefact would inhibit the ceramic ware to be fully oxidated during one firing (Stilborg et al. 2002:64,140).

2.3.3. Pitted Ware Culture and Pottery
The definitions of the PWC are primarily connected to the recoveries of the characteristic pottery with incised pits, and were originally associated with the Eastern parts of Sweden and Åland (Papmehl-Dufay 2006:37). The importance of pottery within the PWC in Central Eastern Sweden is apparent as large quantities of the material are recovered at sites associated with this group (Papmehl-Dufay 2006:38). “Counting the mere quantity of retrieved pottery, no Stone Age culture in Sweden can compete with the Pitted Ware culture. Sites are often easily recognized due to the sheer abundance of pottery sherds” (Å.M. Larsson 2008:82). As an example, around 365 kg pottery (excluding fragments <1 cm²) has been discovered at Korsnäs during the 1970 and 2009/2010 excavations, where 49 kg were recovered in 2009 within an area of 16.75 m² (Olsson et al. 1994; Fornander 2010, 2011).

The early typologies concerning PWC pottery are extensively described and categorized by Bagge (1951) and most recently by Papmehl-Dufay (2006) and Å.M. Larsson (2009). The chronologies describe the discovered material at the Fagervik settlement in eastern Sweden. Bagge divided the recovered PWC pottery into five different groups (I-V), where group I was interpreted as FBC pottery and group V as Battle Axe Culture (BAC) pottery (Bagge 1951; Hallgren 2008:136). Furthermore, Bagge argued that there were two different PWC groups; one settled in the southern parts of Sweden and the other one in the north, distinguished through the Fagervik chronology. The northern material was seen as chronologically younger, and was distinguished through a poriferous ware adorned with comb stamps (Bagge 1951). The assemblages found further south were non-poriferous, thus chronologically older, and displayed more complex décor sometimes applied vertically over the vessel (Bagge 1951). In addition to this, the southern assemblages were considered to be stylistically influenced by the FBC and the north eastern material as influenced by the Combed Ware Culture further east, in Finland (e.g. Papmehl-Dufay 2006:37).

The recovered assemblages found in recent years are, as mentioned above, generally not only categorized in accordance with the Fagervik series due to the many variations of the Pitted Ware patterns and the rigidity of the older typologies (see Papmehl-Dufay 2006; Fornander 2009; Dimec & Fornander 2011). Applying a more flexible system allows the many decorative variations to unfold and complex stylistic combinations and codes are avoided (see Papmehl-Dufay 2006:159 for a complete description of the method used for the Korsnäs material applied in Dimec & Fornander 2011).

The PWC décor is mainly found in horizontal rows on the upper parts of the vessels: particularly around the shoulder and at the neck. Vessels that are decorated on the rim and over the entire body occur as well (Bagge 1951; Papmehl-Dufay 2006; Å.M. Larsson 2009). The most common decorative features are the incised pits, crediting the ceramic tradition its name. It should be noted, that pits occur on vessels deriving from sites associated with the FBC and other traditions as well, however not as the dominating feature (Bagge 1951; Florin 1958; Papmehl-Dufay 2006:48; Hallgren 2008). The pits sometimes occur with other patterns such as herring-bone motifs, cross-hatching, and vertical or angled short lines, comb impressions and other forms and incisions as well. These decorations occur in an array of different combinations and sizes (Papmehl-Dufay 2006:47-64; Å.M. Larsson 2009). Interestingly enough, the pits are commonly cut across other decorative patterns (as seen in figure 3).
PWC vessels appear in a variety of shapes and sizes. The conically shaped vessels with carinated, straight, or slightly convex shoulders are nonetheless the most dominating vessel shapes (Papmehl-Dufay 2006:49). The sizes range from large pots (c:a 50cm Ø) down to miniature vessels (c:a 5-10cm Ø). This smaller category of PWC vessels are somewhat of an enigma. Some archaeologists argue that there are different sizes within this category and that a variety of uses could be traced in this variation. Others claim that these artefacts should be associated with children (Runcis 2002:105 see Papmehl-Dufay 2006:56f for more elaborate discussions on the subject). Alongside the vessels typically ascribed to the PWC, clay discs are found in the assemblages as well (Stilborg et al. 2002:71).

Other interesting aspects of PWC pottery are the contexts in which certain pottery assemblages are found. For example, intentionally deposited base fragments placed upside down have been found at several PWC sites (Papmehl-Dufay 2006:54). The most recent discoveries concern Sittesta (Raiä 68), Ösmo parish at Södertörn (Khilstedt et al. 2007), as well as at Korsnäs (Fornander 2011), some of which have been analysed in this study. The interpretations of these depositions and what they may represent focus on ritual activities and the ritualization of the shore (e.g. Carlsson 1998:52).

2.4. Food Cultures

2.4.1. Neolithic Food Cultures

When studying the culture of food in an archaeological material there are many sources and analytical methods that can aid us in our understanding of the social interactions connected to food and eating. Several investigations concerning Neolithic subsistence economies have been initiated based on different materials and questions. These results have provided us with a relatively straightforward understanding of that differences between groups are dependent on many factors, food culture being one of them (e.g. Lidén 1995a; Storå 2001; Eriksson 2003; Brorsson et al. 2007; Fornander et al. 2008; Isaksson 2009).

The diversity of different methods could be divided into two different sections, as described by Lidén (1995a); indirect and direct methods. Indirect methods provide information on what resources were available to past peoples, e.g. macro- and microfossil analyses, osteological analyses of recovered bone assemblages, food lipid residue analyses etc. (see Lidén 1995a:15 and references therein). The direct methods are more quantitative in their nature and investigate one specific meal e.g. the analyses of coprolites (Lidén 1995a:15f). In comparison to the mentioned methodologies Lidén stresses the importance of using stable isotope analyses on skeletal remains in dietary reconstructions, as they offer a more “long-term quantitative dietary information” (Lidén 1995a:16).

Hjulström and Isaksson (2005) present a more theoretical approach developed in connection to the By House & Hearth project, where a food-cultural model is applied to the investigations of food culture. This model differs somewhat from the traditional archaeological discussions concerning culture focusing on the materiality of archaeological
groups. Hjulström & Isaksson argue that culture should be seen as knowledge shared by groups of people, and that the traces of this knowledge could be traced in material remains (Hjulström & Isaksson 2005; Isaksson 2010). In much the same way as artefacts are active in the creation of cultural homogeneity, so is food, as taste and smell add to the social and cultural identity and thus act as a social binder (Isaksson 2010).

“Meal companionship ... is an important entity as it provides individuals with a social and cultural identity as ‘we who eat together’...Each meal companionship know what a specific dish should taste like, a knowledge that is recreated at each meal where the given dish is eaten” (Isaksson 2010:6)

Further argumentation compare the shared meals within the food culture with non-verbal sign systems, where the dishes are compared to signs within the given syntax (Isaksson 2010:6), much like the approach discussed by Hodder (1979) when discussing material culture. When applying this approach the archaeologist is equipped with several potential food signals that could be studied in order to understand ancient food cultures (see Hjulström & Isaksson 2005; Isaksson 2010).

However, when interpreting these food signals it is of the essence that there is an underlying understanding of what these signals represent. The method of use for this particular study is the food lipid residue analysis. This specific method enables the investigation of ancient vessel use through chemical separation of organic residues absorbed in the ceramic walls during the last uses of the ceramic vessel (Evershed et al. 2001; Craig et al. 2004). The results of these analyses are interpreted in terms of vessel use and possible prehistoric menus. It does not reveal different types of food that has not been cooked, prepared or stored in ceramic vessels (e.g. Olsson & Isaksson 2008), whereas osteological analyses may contribute to detecting these activities (Storå 2001). Nor can the food lipid residue analyses provide information concerning long-term dietary practices with an individual as provided by stable isotopic data (e.g. Lidén 1995a; Eriksson 2003). There is an obvious difference in how these signals should be considered and interpreted. Nonetheless, when applied in a correct fashion these different ways of investigating prehistoric food cultures provide a powerful combination that may bring about an understanding of the culinary language that could help us understand past subsistences.

2.4.2. Deviating Food Cultures

Several scientific investigations have been conducted on the FBC and PWC material, aiming at understanding what the differences in the archaeological record represent. Since one of the main aspects in this dichotomy is the differing subsistence economies ascribed to these groups, studies concerning their diet and culinary activities have been conducted on the material for some time.

One of the most common practices in any archaeological investigation is the osteological analyses of the disinterred bone assemblages found at the sites. The investigations of FBC material display a preponderance of bones adhering to cattle and sheep/goat, whereas the PWC sites display a dominance of seal bones, followed by pig (Aaris-Sørensen 1978; Rowley-Conwy and Storå 1997; Storå 2001). Furthermore, of special interest are the recovered remains of pig, which have been interpreted as traces of pig herding within the PWC (Welinder et al. 1998:82-83,151-152,183). However, both the osteological and the stable isotopic data from recovered pig bones indicate that the pigs were indeed not domesticated at PWC sites; at least not on a full-scale (Rowley-Conwy & Storå 1997:124; Eriksson 2004; Fornander 2006; Fornander et al. 2008).

Dietary studies of the recovered remains of humans and animals are extensive and have investigated material from areas within the Central Eastern parts of the Swedish mainland as well as Öland, Gotland and Åland. These investigations indicate a slight shift in the dietary patterns when compared to Mesolithic populations and supposed farmers, i.e. the
FBC. The diet is varied with a tendency to a higher degree of terrestrial input (Lidén 1995b). However, it is further argued that “the geographical location seems to be one of the major determinants of the diets” (Lidén 1996:5). These views have nonetheless been revised as of late, as seen in Eriksson et al. (2008), where it is argued that prehistoric food habits were governed mainly by culture. Moreover, the dietary studies presented by Lidén et al. (2004) display results that contradict the supposedly rapid shifts in dietary practices, showing a similar diversity in the diets during the Mesolithic and Neolithic periods (Lidén et al. 2004)

The isotopic investigations of material from sites that are interpreted as PWC localities display a primary marine protein intake with a dominance of seals and to a lesser extent fish (Lidén & Nelson 1995; Fornander et al. 2008; Eriksson et al. 2008). These results distinguish the PWC from the FBC. Furthermore, studies argue that the Neolithization process did not occur at the onset of the Neolithic (c:a 4000 BC), but rather at the end of the Neolithic (c:a 1800 BC) (Eriksson et al. 2008).

The investigations of vessel use within the FBC display that mixtures of food were prepared in the vessels, containing terrestrial animal and vegetable lipids with slight presences of aquatic animal products (Palomäki 2006). Analyses of large ceramic assemblages from the Neolithic have proven that there is a variety in vessel use around 3000 BC, where the vessels are being used for other purposes than cooking, e.g. not yielding traces of lipids (Brorsson et al. 2007: 431). The PWC vessels on the other hand display the opposite relations. A dominance of aquatic animal contents together with mixtures of vegetables is common (Papmehl-Dufay 2006; Ohlberger 2009). The difference between the two ceramic traditions thus lies in the more dominant use of aquatic resources in the PWC material compared to the FBC material. The combined investigations of these food cultural signals confirm the notion that the FBC utilises the terrestrial resources to a somewhat higher degree than the PWC.

Discussions concerning the recovered pig bones at PWC sites has as of yet not been thoroughly investigated, since the analytical methods described above (i.e. osteological and stable isotopic analyses) have not been combined in previous research, apart from Korsnäs. The pig bones have previously been interpreted as reflecting a complement in the PWC diet (Welinder et al 1998:183), or as traces of ritual feasting on wild boar since the stable isotopic data display a marine protein intake within the PWC (Fornander et al. 2008).

3. Site Specifics
3.1. Stensborg, Raä 257
Stensborg Raä 257, is situated in Grödinge parish (see figure 4), and has been interpreted as being occupied during the EN (Olsson 1996a; Larsson 2008:2). The settlement is found in a graben surrounded by block moraine and hills that descend in the west into a wider, lower dell (Olsson 1996a:12). The site is situated c:a 50 m.a.s.l. and it is estimated to cover a 300 x 200 meter wide area on a field that has been cultivated in modern times (Olsson 1996a:12). The south-west parts of the site slope down towards 35 m.a.s.l, and an adjacent hillside decline to the bottom of the valley at 25 m.a.s.l. (Olsson 1996a:12). Two smaller rivers flow through the terrain, cutting through the northern and southern parts of the site (Olsson 1996a:12). During the EN Södertörn was a larger island in an inner archipelagic environment, and Stensborg was situated in one of its larger inlets (Larsson & Broström 2010). The surrounding areas include a high density of ancient remains from the Mesolithic, Early and Middle Neolithic as well as from the Bronze Age and the Iron Age (Olsson 1996a:8, 10).
Stensborg was first discovered during the 1970’s by Sven-Gunnar Broström, and the site has since then been subject to several surface surveys where c:a 3400 objects have been collected (Broström 1996:69; Olsson 1996a:8,12; Larsson 2008:1). A test survey was initiated in 1985 due to the construction of Botkyrka golf course (see Olsson 1996a). A phosphate survey was conducted in connection to these excavations, and samples were taken across the site. Areas that displayed both high and low densities of recovered artefacts were covered, together with the presumed Neolithic shoreline (Olsson 1996a:14, 22; Risberg et al. 1991). The results varied from 4 P° to 110 P°. The highest levels were obtained in the middle of the site, in close connection to the impediment, where Broström had recovered a multitude of artefacts (Olsson 1996a:22, 25).

More extensive excavations were conducted in 2008 and 2009, as a result of the recovered artifacts found at the surface. An area of 26 m² was excavated in 2008 together with geophysical surveys performed by archaeologists from ARL (Archaeological Research Laboratory) at Stockholm University (Larsson 2008; Viberg 2008). The results of a phosphate survey yielded rather low values, and the potential cultural layers at the site were interpreted as being disintegrated by ploughing (Viberg 2008:10).

The excavations at Stensborg have focused on obtaining further knowledge of the site; if there were possible traces of features underneath the plowridge, and if so in what form. The excavated area was restricted to the impediment and the former farmlands that constituted of a southward declining shoreline during EN (Larsson 2008:3). The traces of cultural layers were scarce and only one feature was found in the southern parts of the site, interpreted as a posthole (Larsson 2008:3). Fragments of pottery were found in the filling of the posthole, and indications of axe production were discovered in the impediment (Larsson 2009:2).

The following excavations, in 2009, intended to investigate if there were additional features in the field, as well as the possibility of determining the form and function of these features. The top soil was removed in an area covering 1000 m², and a few features were unearthed. The discoveries led to continued investigations of the area where several small and shallow pits were distinguished, together with some larger features (Larsson 2009:3). The investigations at the impediment revealed a multitude of stone flakes. However, no distinguishable structures were detected (Larsson 2009:5).

3.1.1. Recovered Artefacts and Structures
The excavations in 1985 did not reveal any visible structures, although several fragments of tools and flakes of burned flint, pottery, burned clay and burned bones were discovered (Olsson 1996a:18). The disinterred pottery was highly fragmented, the total amount of 46 fragments weighed 67 g (Olsson 1996a:18f). Several different vessel types were identified, among them collared flasks. Two rim sherds from smaller vessels and a sherd with a small
knob deviated from the overall population (Olsson 1996a:19). The décor was diverse, cord- and twisted cord impressions, lines and line stamps as well as small round impressions were represented in the material. Two fragments with seed impressions are of particular interest (Olsson 1996a:19).

Some fragments of unburned bones were found in 1985. The osteological analysis by Hedelin shows that the bones were highly fragmented, and the distinguishable fragments have been identified as two fragments of pig (Olsson 1996a:41). Their fragmentation has inhibited the determination as to whether they represent domesticated pigs (Sus domesticus) or wild boar (Sus scrofa) (Olsson 1996a:41).

The discovered pottery assemblages in 2008 were primarily found in connection to the cultural layer. The décor consists of rows with cord- and staple impressions. Vessels with vertical lines were also represented in the material (Larsson 2008:6). In addition to the pottery, a small amount of burned bones from pig, a few axes and axe fragments have been found, together with flakes of greenstone and other lithic materials. Some flakes of flint were found as well, most of which have been subjected to intense heat (Larsson 2008:6).

The investigations in 2009 unearthed several features of varying size, form and function. An array of small and shallow pits filled with artefacts were found in the clay bed, together with some larger features (c:a 4.5 x 2.2 m), and smaller postholes (Larsson 2009:4). The unearthed features contained FBC pottery, burned clay and fragments of burned flint and stone axes. A stone object resembling a phallos with traces of red ochre was also found within these structures (Larsson 2009:4). A larger structure (1.6 x 1.4 m) with intentionally placed stones was found, resembling contemporary grave structures. However, no artefacts or other indications of inhumations were found (Larsson 2009:4). Furthermore, a remarkable amount of burned seed was found spread across the field in smaller depositions. Analyses of the material reveal that the seeds mainly consist of emmer followed by spelt, wheat, and naked barley (Larsson 2009:5). The traces of intense heating in combination with the lack of charcoal could indicate deliberate burning of seed (Larsson 2009:5). The continued investigations of the impediment (see figure 5) resulted in the discovery of more stone flakes. No visible features were however found (Larsson 2009:5).

**3.1.2. Previous Interpretations**

No organic materials suitable for 14C-dating were recovered during the excavations in 1985 and absolute dating has therefore not been performed. Suggestions concerning the dating of the site and structures are solely based on the archaeological recoveries and comparisons with the past shoreline (Risberg et al. 1991; Olsson 1996a:6, 27). However, the assemblages are unambiguous, the high amount of rediscovered pottery, burned flint fragments, flint axes and grinding stones attest to EN activities at the site (Olsson 1996a:26; Larsson 2008:6).

A discussion concerning different areas of activity within the site have emanated from the evaluation of the recovered artefacts and their contexts (Larsson 2009:2). The differences are seen between the impediment and the field. A multitude of stone flakes have been recovered in the north, without any clear traces of structures or cultural layers.
The field, however, shows traces of accumulated layers, features and different sets of artefacts (Larsson 2008, 2009). The total amount of artefacts and the unearthed features in the field are according to Larsson (2009) indicative of ritual activities, where objects of both local materials and foreign character have been deliberately fragmented, either by force or by fire (Larsson 2009:5). Axes in significant numbers, pottery and flint have all been subjected to this conscious demolition, and it is the remnants of these activities that have been deposited together with clay in the shallow pits that were found in the field. In addition to this there is the ritual burning of seed (Larsson 2009:6). The difference between the northern and southern parts of the site should however not be seen as chronologically dependent. Larsson rather suggests an interpretation based on different areas of activity within the site, supported by Olsson (1996a:27) (Larsson 2008:6).

Larsson draws comparisons with so called Sarup enclosures much like the ones found in Alvastra, where he sees the topography at Stensborg as natural boundaries, representing the palisades (Larsson 2009:6). A locality that has been suggested to display similar activities as the ones at Stensborg is the Vrå-settlement Brokvarn in Turringe parish, Södermanland (Florin 1958:117ff). These phenomena occur during the early stages of the Neolithic and have been interpreted as “the settlements of the dead” (Carlsson 1998:41, translation by the author), and it is argued that these places should be seen as the eastern equivalence of the Megalithic tombs (Carlsson 1998:41).

The large amounts of burned flint and seed within the site accentuate Stensborg from other contemporary settlements in the region (Olsson 1996a:26). The ceramic material differs qualitatively in comparison to the nearby sites, and the vast array of different types of artefacts contributes to the accentuation of Stensborg (Olsson 1996a:26). Olsson further argues that the topography of the sites within the region, and especially around Stensborg, with the closeness to the sea during the Neolithic, could indicate a varied subsistence where a combination of marine resources and farming at the upper levels of the sites were utilised (Olsson 1996a:27).

3.2. Korsnäs, Raä 447
The Korsnäs site Raä 447 is situated in Grödinge parish, Södermanland and has been investigated several times after it was first identified in 1930 by Ivar Schnell due to the recovery of PWC pottery in the fields surrounding Korsnäs gård (Olsson et al. 1994:5,54). The site is located on the north-eastern parts of the Södertörn peninsula, southeast of Malmösjön, and it is surrounded by north-southward ridges, arable dells as well as two narrow inlets in the east and the west respectively (Olsson 1994:5). The Korsnäs site is situated on a sandy slope about 23-38 m.a.s.l., where lakes and wood lands make up the natural boundaries of the area in the north and south/west (see fig. 4)(Olsson et al. 1994:5ff).

It is assumed that Korsnäs was situated on a smaller island in an inner archipelago during the EN and MN, as seen in the shore displacement curves by Risberg et al. (1991). The geology at the site consists of bedrock of gneiss and granite. Moraine is found on the ridges and glacial clays in the lower land areas (Olsson et al. 1994:5). A multitude of other Neolithic sites are found in the nearby area and at the Södertörn peninsula in general, all of which are situated around 25-35 m.a.s.l (Olsson 1996b). In addition to this, ancient remains from the Bronze Age and Iron Age are found in the region.

Stockholm University has conducted several excavations and phosphate surveys within the area, the first of which was held in 1933, and focused on the prehistoric shore line. Early investigations of the phosphate levels within the site displayed high levels, between 100- 900 P°, above 23 m.a.s.l. (Arrhenius 1931). Another phosphate survey was initiated in 1944 by Gustaf Arrhenius, as a part of further studies concerning the ancient shoreline
The south western parts of the site, first excavated in 1933, suffered extensive damage due to the planning of a gravel quarry in 1964, and a large portion (approx. 2000 m²) of the cultural layers were destroyed before an intervention was made (Olsson et al. 1994:57). A rescue excavation with the purpose of preventing that the cultural layers were completely destroyed was engaged by Stockholm Högskola (Olsson et al. 1994:57). The excavation was complemented by a phosphate survey conducted in 1969 by Eriksson (1971). The top soil removed in 1964 was dumped in heaps and parts of them were later sieved and controlled by Grödinge Hembygdsförening and Sven-Göran Broström (Olsson et al. 1994:57; Broström et al. 2008, 2009, 2011).

The Swedish Board of Cultural Heritage, UV, conducted several excavations at the site during the 1970’s and 1990’s, primarily in order to assess the damages caused in 1964, and because of continued damages of the site due to logging and heavy machinery as well as the expansion of Korsnäs gård (Olsson et al. 1994:57f). These excavations yielded large assemblages of pottery, and the investigations in 1970 revealed three possible and three definite graves (Olsson et al. 1994:20f). A quaternary geological survey was conducted by the Geological Survey of Sweden (SGU) as a complement to the 1970 excavations, where stratigraphic pollen samples were taken from a peat bog c:a 250 meters south-west of the excavation area (Miller & Robertson 1981).

A minor excavation was executed in 2002 by Stockholms länsmuseum (Stockholm County museum) due to the recovery of burned bones and BAC pottery together with two unearthed hearths and one Pre Roman Iron Age grave in the fields in the south-eastern parts of the site (Werthwein 2002).

The most recent investigations of the site have been conducted by ARL at Stockholm University. Seminar excavations were held at Korsnäs in 2009 and 2010 (see figure 6). These investigations yielded large amounts of Neolithic pottery together with about a thousand stone flakes, as well as stone tools, hazelnuts and animal bones (Fornander 2010; Fornander 2011). In addition to these findings the archaeologists unearthed another grave containing a partially preserved human skeleton, in 2009 (Fornander 2010).

The excavations in 2010 were conducted in five different areas within the site (see fig. 7), area A and B (Åkern), area C (Skogsbacken), and area D (Platån and the howe in the north). Two trenches were placed in the field (A and B) in order to obtain further understanding of what the recovered sherds of BAC pottery and the Pre Roman Iron Age grave could represent. Several test pits were investigated in the north-eastern parts of the site (area D), where the highest levels of phosphates have been obtained (500° P) (Arrhenius 1945; Eriksson 1971). Furthermore, a third area was excavated in direct connection to the area investigated in 2009 and in 1970; area C.
Moreover, studies of the soil chemical composition at the site were conducted in 2010 as a part of the master’s programme at ARL (Andersson et al. 2011). Soil samples taken during the 2010 excavations from area C and D were analysed for their lipid content and subjected to elemental analyses. The general purpose of these analyses was to investigate if there was a possible difference in spatial organisation at the site based on the soil lipid composition and the results from the elemental analyses (Andersson et al. 2011).

The fact that at least five graves, (possibly seven), have been discovered at the site is a good example of the significance of the area during the Neolithic. PWC graves and well preserved unburned bones in this quantity are unusual for the Eastern Central parts of Sweden due to the generally poor preservation conditions for bones (Edenmo et al. 1997:180f). Further excavations at the site are planned to take place in the spring of 2011, where students and personnel from Stockholm university and the department for archaeology and classical studies will investigate the northern areas of the site as well as some previously unexcavated areas near the field.

3.2.1. Recovered Artifacts and Structures

During the excavations in 1970 a large set of artefacts were disinterred, e.g. 231 kg pottery, 101 stone artefacts, approximately 3 000 stone flakes, 44 bone/antler artefacts and 17 kg of unburned animal and human bones (Olsson et al. 1994:25). Moreover, different features such as hearths and pits were revealed, together with six definite/ possible graves (Olsson et al. 1994: 20ff). The definite graves are described as “three intentionally deposited skeletons”, (Olsson et al. 1994:20f, translation by the author), while the possible graves are characterized as concentrations of human bones (Olsson et al. 1994:21)(see figure 8).
Notable is the fact that human bones were found scattered across the cultural layers as well (Olsson et al. 1994:20). No traces of features indicating buildings or similar structures were found.

Stable isotope analyses performed on the individuals recovered in 1970 as well as on material from the dump heaps accumulated in 1964 were conducted in 2006. The results display a primarily marine protein intake for the recovered individuals at Korsnäs, dominated by seal (Fornander 2006; Fornander et al. 2008). Furthermore, a total of 11 $^{14}$C-dates were performed on human and animal material from the dump heaps together with some material from the excavations in 1970. The results of these analyses fall within an interval ranging from 3350-2640 cal. BC (2σ), indicating activities during the whole MN A period (Fornander et al. 2008).

The recovered pottery from the excavations in 1970 is represented by the MN Fagervik III and IV series in the south-western parts of the excavated areas, whereas the north-eastern parts were dominated by EN Fagervik I, II and III décor assemblages (Olsson et al. 1994:59; Bagge 1951). Of special interest are the recovered mini vessels and sherds with polished edges suggesting a secondary use (Olsson et al. 1994:27f). The dispersion of stone artefacts did not display any visible areas of manufacture; however, the large amounts of rediscovered stone flakes and remnants of stone artefact production suggest local industry (Olsson et al. 1994:30, 43).

The recovered bone assemblage from the excavations in 1970 consisted of 17 kg animal bones, of which 325 g was burned (Aaris-Sørensen 1978). 97% (in weight) of the investigated material is of mammal origin. The total assemblage of mammal bones was calculated according to the number of identified specimens (NISP) and the minimum number of individuals (MNI). The results of these investigations show a preponderance of seal (Phocidae) and pig (Sus scrofa), species that together with moose (Alces alces) dominate the material by weight (Aaris-Sørensen 1978). The seals are dominated by harp seal (Pagophilus groenlandicus) and ringed seal (Pusa hispida). Some fragments of grey seal (Halichoerus grypus) have been discovered as well (Aaris-Sørensen 1978). Human bones were found in the graves and scattered over the cultural layers (Olsson et al. 1994:20). No traces of features indicating buildings or similar structures were found.
The recovered bones from the excavations of 2009/2010 are highly fragmented why it is difficult to discuss the material in detail; however there is a preponderance of elements of seal followed by fish and pig (Olander 2010; Fornander 2010, 2011).

The bones found in the grave in 2002 were interpreted as female, and a \(^{14}\)C-analysis of the recovered bones dated the grave to Pre Roman Iron Age (Werthwein 2002:6, 13). The excavations held in 2009 revealed yet another grave \(^{14}\)C-dated in line with the previously dated individuals from the Neolithic. The remains were found in a feature containing pottery and what is assumed to be ochre (Fornander 2010:11; Fornander 2011). Stable isotope analyses of the inhumated material show a primarily marine protein intake (Fornander 2011). Further features include a larger pit containing more than 3 kg PWC pottery and two non-erupted human molars. In addition to this 5 small postholes were investigated (Fornander 2010).

The investigations of the Korsnäs site during 2010 revealed several features and artefacts from the Neolithic in area C and D. Of special interest are the concentrations of pottery and postholes in area C and the deposited base fragments north of area D in connection to a presumed wetland area, as indicated by the soil chemical analyses i.e. the howe (Andersson et al. 2011) The recovered sherds comprise of 60 kg in area C and 21.7 kg in area D. The sherds are mainly decorated with pits in area C and with pits and comb stamps in area D (Fornander 2011), displaying an interesting difference in terms of a spatial organisation at the site. The areas A and B were situated in previously ploughed fields and revealed one possible posthole and two undefined features together with large assemblages of lithic artefacts, some PWC pottery and at least two sherds of BAC pottery (Fornander 2011).

In addition to this, the analyses of the soil chemistry at the site based on samples from area C and D show that there is a difference in spatial organisation at the site, as indicated by the soil lipid composition. The results of the elemental analyses display a spatial difference in the elemental composition in the soil in area C, possibly as a result of different activities. However, it is difficult to determine what specific activities that has yielded these differences (Andersson et al. 2011).

### 3.2.2. Previous Interpretations

The Korsnäs site has previously been interpreted as a larger base camp inhabited all year round for a longer period of time, based on the variation in the recovered bone assemblages and the archaeological material (Aaris-Sørensen 1978:16; Olsson et al. 1994:61). The different investigations of the recovered material from 2010 suggest a difference in spatial organisation at the site, where areas C and D display definable differences in the soil chemical composition as well as in the decoration schemes of the recovered pottery assemblages (Andersson et al. 2011; Dimc & Fornander 2011).

Furthermore, the analyses of the bone assemblages suggest a hunter-gatherer economy based on seal, moose and wild boar (Aaris-Sørensen 1978:16). These results are complemented by the stable isotope analyses of both human and animal bones displaying a primary marine food intake based on seal, alongside results suggesting that the recovered pig bones derive from wild specimens (Fornander 2006; Fornander et al. 2008; Fornander 2011). The results from the pollen analyses by Miller and Robertsson (1981), reveal human impact on the surrounding flora, however there are no traces of agricultural activities in the nearby region.
4. The Food Lipid Residue Analyses in Archaeological Contexts

4.1. Previous Research

“Archaeological residues are often a complex mixture of original molecules, degradation products, contamination from the burial matrix and finds processing, storage, etc. Further separation of the mixture, combined with identification of the components, is required” (Pollard, Batt Stern and Young 2007: 137)

In order to draw closer to an understanding of the ancient food cultures at Södertörn and the Neolithic in Scandinavia as a whole, lipid food residue analyses have been conducted on two different ceramic assemblages in this region. This methodology offers a great complement to the understanding of the Neolithic menu as opposed to solely base the interpretations on the traditional osteological analyses of the recovered bone assemblages, or the analyses of stable isotope analyses that focus on the main protein intake of the sampled individuals (see Lidén 1995; Storå 2001; Fornander 2006 and Linderholm 2008 for further discussions concerning Neolithic diet and menus). Investigating ancient activities through food lipid residue analysis however, concerns the prehistoric vessel use, i.e. the use of artefacts. It is of the essence to separate these variations of food culture in order to fully understand what the following results represent.

The first analysis of organic material in Swedish archaeological contexts was performed by Hjalmar Ljung in 1945 on the preserved contents of an Early Iron Age vessel, deposited in a bog (Arbman 1945). Further analyses of organic compounds in archaeological pottery were published in 1959, where the contents of a vessel found in a Viking Age Stone ship were investigated (Hagberg 1959).

During the 1970s a series of investigations were undertaken by Birgit Arrhenius (e.g. Slytå & Arrhenius 1979) which were intensified with the foundation of the Archaeological Research Laboratory at Stockholm University, where the investigations of prehistoric food and diet have been an integral part of the organisation (e.g. Arrhenius & Slytå 1981; Hansson 1987; Arrhenius & Lidén 1988). Internationally, the “modern era of the organic residue analysis” (Evershed 2008a:896) was an initiated by Thornton et al. (1970) and their investigation of bog butters. This paper was then followed by the publication of a multitude of investigations of organic compounds in archaeological materials (e.g. Morgan et al. 1973; Condamin et al. 1976).

The analysis of organic compounds in archaeology has been tightly connected to the development of the chemical methodology enabling the separation and identification of these specific compounds (Evershed 2008a:895f). During the 1980’s the methodological development was stabilized and the focus was rather shifted towards the archaeological source material and the degradative processes and contamination issues (see Isaksson 2000:12). During the years that followed several of these problems were investigated, e.g. the effect of migrating soil lipids (Heron et al.1991), the quantification and distribution of lipids in pottery (Charters et al.1993), as well as the assessment of microbial contribution to the degradation of fats (Dudd et al.1993).

The most recent investigations concern aspects of food culture and the identification of certain lipid compositions in archaeological contexts that aid in the understanding of past societies (e.g. Isaksson 2000; Hjulström & Isaksson 2005; Papmehl-Dufay 2006; Olsson 2008). The introduction and spread of agriculture has gained an increasing interest within the field as of late due to the applications of stable isotopic data. Measuring the carbon stable isotopes within the C16:0 and C18:0 fatty acids enable the distinction of ruminant and nonruminant adipose fats, as well as the identification of dairy products and highly degraded lipids (e.g. Evershed 1994; Evershed et al.1997; Mottram 1999; Dudd & Evershed 1998,1999; Craig et al.2005; Craig et al.2007; Mukherjee 2007). This provides
possibilities of interpreting archaeological material which is of great importance for the understanding of dietary and/or subsistence transitions such as the domestication of cattle or pigs.

Furthermore, investigations concerning the extraction and isolation of lipid species that previously have not been detected or considered as degraded have recently been put forward (Gregg 2009; Gregg & Slater 2010). A new methodology of using a micro-wave assisted extraction and liquid chromatography protocol has been proven useful when analysing potsherds from arid areas and/or of early pottery horizons (Gregg 2009; Gregg & Slater 2010).

4.2. Fatty Acids and their Derivatives
Fats, oils and waxes are typical lipids. However, in chemical terms these compounds are comprised of a diverse series of non-polar organic compounds that inherit a multitude of diverse functions. Their frequent occurrence in nature, as an important component of plant, animal and microbial membranes make them an important archaeological investigative tool (Christie 1987:42; Christie 1989:11; Isaksson 2000; Campbell & Farrell 2006:184; Evershed 2008a).

Lipids have previously been distinguished through their non-polar structure, arguing that they are insoluble in water (Lehninger et al. 1993:240; Campbell & Farrell 2006:184). Even though their insolubility is one of their most striking features, there are a multitude of lipid compounds that do dissolve in water, i.e. the lipids found in membranes. Christie (1987) argues that the previous classifications are rather loose description, since many of the compounds are different in both function and form, as well as in terms of their solubility. Nonetheless, there is no satisfactory description of these organic compounds as to this date. Christie (1987) is therefore suggesting a definition that has become widely accepted, and accurate in most situations: “Lipids are fatty acids and their derivatives, and substances related biosynthetically or functionally to these compounds” (Christie 1987:42).

This description includes cholesterol and bile acids, but it “does not include other steroids, fat-soluble vitamins, carotenoids or terpenes except in rare circumstances” (Christie 1987:42).

Lipids are often divided in two major groups: neutral and polar lipids. The neutral lipids are non-amphipatic and yield two types of primary hydrolysis products (Christie 1989:11). The primary compounds that represent this group are the tri-, di- and monoaoclyglycerols, as well as the free-fatty acids, sterols, sterol esters, wax esters, n-alkanes and long-chain ketones (Christie 1989:11). The second group, i.e. the polar lipids are amphipatic and yield three different hydrolysis products. The primary compounds in this group are: phospholipids, glycolipids and ether lipids (Christie 1989:11, for further discussions concerning the different properties of lipids, see Christie 1989).

The triacylglycerols differ somewhat from the other lipids in their structure and function since they accumulate in the adipose tissue of animals instead of in the cell-membranes (Campbell & Farell 2006:186). Most natural fats are made up of mixtures of different triacylglycerols (Lehninger et al. 1993). Of special interest in archaeological contexts is the possible determination of dairy products based on the presence and distribution of triacylglycerols in ancient samples (e.g. Dudd et al. 1998; Gregg & Slater 2010).
The most common lipid compounds are the fatty acids. Basically, the fatty acids are carboxylic acids with hydrocarbon chains of different lengths, that can be either fully saturated or unbranched, or containing one or more double bonds (see figure 9). These are the so called unsaturated fatty acids (Christie 1989:13). The most common fatty acid in animal and plant tissue would be the saturated acids, with straight chains of 14, 16 and 18 carbon atoms. These chains have both systematical and trivial names as well as abbreviated nomenclature (Christie 1989:12). As seen in table 2 below, the straight chain with 16 carbon atoms is abbreviated $C_{16}$ or $C_{16:0}$. The carbon chain’s systematic name is *hexadecanoic acid* and the trivial name is *palmitic acid* (Christie 1989:13).

<table>
<thead>
<tr>
<th>Systematic name</th>
<th>Trivial name</th>
<th>Shorthand designation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Octanoic</td>
<td>Caprylic</td>
<td>8:0</td>
</tr>
<tr>
<td>Nonanoic</td>
<td>Palargonic</td>
<td>9:0</td>
</tr>
<tr>
<td>Decanoic</td>
<td>Capric</td>
<td>10:0</td>
</tr>
<tr>
<td>Undecanoic</td>
<td>-</td>
<td>11:0</td>
</tr>
<tr>
<td>Dodecanoic</td>
<td>Lauric</td>
<td>12:0</td>
</tr>
<tr>
<td>Tridecanoic</td>
<td>-</td>
<td>13:0</td>
</tr>
<tr>
<td>Tetradecanoic</td>
<td>Myristic</td>
<td>14:0</td>
</tr>
<tr>
<td>Pentadecanoic</td>
<td>-</td>
<td>15:0</td>
</tr>
<tr>
<td>Hexadecanoic</td>
<td>Palmitic</td>
<td>16:0</td>
</tr>
<tr>
<td>Heptadecanoic</td>
<td>Margaric</td>
<td>17:0</td>
</tr>
<tr>
<td>Octadecanoic</td>
<td>Stearic</td>
<td>18:0</td>
</tr>
<tr>
<td>Nonadecanoic</td>
<td>-</td>
<td>19:0</td>
</tr>
<tr>
<td>Eicosanoic</td>
<td>Arachidic</td>
<td>20:0</td>
</tr>
<tr>
<td>Heneicosanoic</td>
<td>-</td>
<td>21:0</td>
</tr>
<tr>
<td>Docosanoic</td>
<td>Behenic</td>
<td>22:0</td>
</tr>
<tr>
<td>Tetracosanoic</td>
<td>Lignoceric</td>
<td>24:0</td>
</tr>
</tbody>
</table>

In addition to the saturated and unsaturated fatty acids there are polyunsaturated fatty acids. However, they are rare in archaeological contexts since they are highly fragile over longer periods of time due to their susceptibility to oxidative deterioration or autoxidation (Christie 1989:17). Nonetheless, we can detect their presence through the altered components that are formed when the polyunsaturated carbon chains are transformed through heating. The $\omega$-(o-alklyphenyl) fatty acids ($C_{16}$-$C_{22}$) are good examples of this since they are produced when unsaturated fatty acids are heated over 270°C (Evershed 2008a:901; Evershed 2008b).

Sterols are fused ring systems produced in the tissue of plants and organisms as components of membranes where they are found both in a free state and in esterified form. (Christie 1989:22; Campbell & Farrell 2006:190). The sterols are synthesized based on the organism that produces them, e.g. animals produce cholesterol, plants produce phytosterols (β-sitosterol, campesterols and stigmasterols) and fungi produce ergosterols (Christie 1989:22; Lheninger et al. 1993:642; Campbell & Farrell 2006:190). One of the precursors to the sterols in the biosynthesis of lipids is the hydrocarbon squalene. This compound is furthermore abundant in the human skin lipid composition (Evershed 1993:30). Squalene, is nonetheless not stable over archaeological time, as the sterols themselves are, and the presence of this compound within a sample is therefore indicative of modern contamination (Evershed 1993:30).

Table 2. Table of the saturated fatty acids. After Christie 1989:13. Edited by the author.
Waxes are found in animal, plant and microbial tissues where they frequently serve as protective coatings of their inherent organism, relating to their water-repellent properties. Furthermore, they are also functional as a storage form of metabolic fuel (Christie 1989:22; Campbell & Farrell 2006:189). The chemical nature of waxes is esterified mixtures of fatty acids to long-chained alkanols, i.e. wax esters. Beside these esters, biological waxes also contains of free fatty acids, ketones, long-chained n-alkanes and alkanols (Christie 1989:22f).

4.3. Degradation of Organic Material
The fact that lipids have the highest potential of surviving in comparison to other classes of biomolecules (i.e. carbohydrates, proteins and DNA), makes this group a preferable target when investigating organic material in archaeological contexts (Evershed 2001). It is of the essence to have an understanding of how these lipid compounds react to their burial environment; what possible changes that may occur and what soil chemical and microbial processes that result in the degradation of lipids (Dudd et al.1998b; Grupe 2001; Eriksson et al. 2005:91-108). In addition to the soil chemical processes, we have to take the human impact on these compounds in consideration as well, since the lipids of interest in this study concerns food and food processing, i.e. the altering of chemical substances (Eriksson 1995; Isaksson 2000:34pp; Evershed 2001:331; Evershed 2008a:901).

When dead organic matter (litter) enter the soil chemical matrix, the successive degradation of the material into smaller chemical compounds takes place as a result of biochemical processes during early diagenesis, i.e. the catalysis (Eriksson et al. 2005:91). Microorganisms have the largest quantitative impact on the degradation, followed by the micro fauna that disperse the litter and acts as an “indirect regulating and stimulating agent in the degradation process” (Eriksson et al. 2005:92, translation by the author). Furthermore, the preservation of organic material is dependent on several environmental features, such as temperature, humidity and pH (Grupe 2001:351). “Decomposition of dead organic matter is more a function of the burial environment than of the time elapsed since burial“(Grupe 2001:351)

The soil composition at the specific site is also of importance when discussing the degradation, or rather the preservation of organic material. Aspects such as soil density have an impact on the mobility of the groundwater and the influx of oxygen that could either create oxidizing conditions or reducing conditions in the soil (Eriksson et al. 2005: 187-197). A reduced environment is beneficial for the preservation of organic material as the microorganisms consume organic material in their respiration and through this also the available oxygen in the soil (Eriksson et al. 2005:188). A reduced soil that has low amounts of available oxygen is thus preferable when working with organic material in archaeological contexts.

The hydrophobic fatty acids are among the most likely lipid compounds to survive over larger scopes of time (Dudd et al.1998; Gregg & Slater 2010:833p). The enzymatic hydrolysis of triacylglycerols results in the release of free alkanoic acids that undergo a series of enzymatic reactions when degraded (e.g. Dudd et al. 1998b).

The first stage, the β-oxidation, is responsible for the largest depletion of fatty acids (Lehninger et al. 1993:485f). This oxidative process results in the removal of two carbon-units from the carboxylic end of the carbon chain and an acetyl-CoA. The second stage in the process includes the oxidation of the acetyl-CoA to CO₂ through the citric acid cycle (Lehninger et al. 1993:486). Sterols are also transformed through microbial activity and a series of enzymatic reactions. The reduction of the double bond in these specific compounds results in 5α-stanols (Isaksson 2000: 34).
The degradative processes in the lipid material caused by human alteration of the chemical compounds due to heating are visible in the formation of long-chain ketones with uneven numbers of carbon atoms (C_{29}-C_{35}). These compounds are formed when acyl lipids are heated over 300°C and are thus indicative of heated contents (Evershed 1995: 8878; Brorsson et al. 2007: 423). The ω-(o-alkylphenyl) fatty acids used as biomarkers in this study as a means of detecting marine animal input are a direct result of heated unsaturated fatty acids (Evershed et al. 2008).

### 4.4. Contaminations

The shards were sampled directly upon their retrieval during the excavations at Korsnäs. Ideally they have been handled with gloves and then wrapped in tin foil. Precautions were taken in order to avoid the risks of contamination from various lotions, cosmetics and plastic softeners. Even though these residues are modern and thus distinguishable from the ancient food signals, their quantity and mere presence intermingle with the ancient signals, making the interpretation more difficult, especially when the ancient signals are lower and highly degraded (Evershed 1993: 87-90; Isaksson 2000: 41).

Fingerprints of excavators and lab personnel are one possible source of contamination. These fingerprints are different than the various compounds that are related to plasticizers and other equipments in the laboratory. This since fingerprints introduces modern biological residues. The hydrocarbon, squalene, is one of the most abundant compounds in human skin lipids (Evershed 1993: 90), and serve as a good indication of modern contamination if detected in the sample. However, as the compound is polyunsaturated, squalene is highly fragile and thus degradable over longer periods of time (Evershed 1993:90).

Further products that can be indicative of human contaminations are cholesterol, as this product is found in the surface lipids of human skin as well. Even if human skin produce a preponderance of squalene, cholesterol still poses a problem since this sterol is more likely to survive over time. Interpreting detectable amounts of squalene as contaminations are relatively frictionless (Evershed 1993:90), interpreting a sample containing small amounts of cholesterol could possibly be more difficult. The problem concerning the relation with cholesterol and squalene should not disturb the interpretations of the ancient vessel use since the samples are handled in order to avoid contamination. However, if the disinterred sherds are stored for a long time prior to analysis, the possible traces of squalene would be degraded, yet the fingerprint would have left traces of cholesterol on the sherd. Consequently, the traces of cholesterol found on the sherds could possibly derive from modern fingerprints, or quite possibly the fingerprints of ancient vessel users. Why it is of importance to investigate the implications human fingerprints in the interpretation of ancient vessel use. Moreover, it should be noted that any fragile compounds found in great abundances, e.g. ω-3-fatty acids that are highly unlikely to survive over archaeological time should be considered as modern contaminations of the ancient biomarker signals (Evershed 2008a:899).

Other sources of contaminations such as the burial soil surrounding the sherds have been examined by Heron et al. (1990). Recently excavated pot sherds were analyzed together with adhering soil, in order to determine if the lipid alterations and contaminations were connected to the burial environment (Heron et al. 1990:641,643). However, the results of the investigations show that the lipid composition within the sherds differs significantly from the surrounding soil and that the possible contaminations deriving from soils are easy to detect, thus not serving as a direct problem (Heron et al. 1990:655; Evershed 1993:87).

The contamination of bacterial lipid compositions are more difficult to detect since many bacteria produce many of the chemical compounds produced in plants and animals as
well (Evershed 2008:88). In order to determine whether the sample is contaminated by bacterial lipids, the free fatty acids composition should be thoroughly investigated as branched \textit{iso}- and \textit{anteiso}- \textit{C}_{15} and \textit{C}_{17} fatty acids are characteristic of bacteria. On the other hand there are bacteria that produce straight chain fatty acids as well (Evershed 2008a:88), this source of contamination should therefore be discussed with precaution.

**4.5. Gas Chromatograph Coupled to a Mass Spectrometer**

When searching for the information that lay in the molecular analysis of absorbed compounds in ancient ceramic walls, the gas chromatograph in combination with a mass spectrometer (GC-MS) enable the preferable separation of these complex mixtures. The method also helps to determine the molecular structures and distributions based on retention times, elution patterns and mass fragmentation characteristic of the chemical structures (Evershed et al. 2001:331; Hjulström 2008). “The gas chromatograph separates the compounds of a mixture in time, and the mass spectrometer provides information that aids in the structural identification of each component” (Kitson et al. 1996:3). According to Christie (1989), this methodology has become one of the most powerful tools when it comes to the analysis of lipids, and fatty acids in particular (Christie 1989:7,161). The results of these analyses comprise the bulk material which is compared with naturally occurring flora and fauna exploited in the past, that is to say, the employment of the \textit{biomarker approach}. An approach that is recognized by a number of lipid scientists (e.g. Evershed 1993; Isaksson 2000; Papmehl-Dufay 2006; Hjulström 2008) (see Evershed 2008a for further discussion in archaeological contexts and Kitson et al. 1996 concerning the application of the GC-MS).

The first step consists of separating the different compounds from the matrix of the sample through an organic solvent. The sample is then injected in to the GC and volatilized through successive heating, thus enabling the compounds to be carried through a specially prepared column with the carrier gas, i.e. the mobile phase, of use for the specific method (in this study Helium (He)) (Kitson et al. 1996:3) The components that are present in the sample are separated due to their specific structure and boiling point, and sticks chemically to the coating of the column, i.e. the stationary phase of the process (Pollard, Batt, Stern & Young 2007:137) The solvent is evaporated as the temperature continues to rise, as do the specific compounds, and they are finally carried away with the Helium through the column and then registered in the mass spectrometer. The compounds that spend a little time in the stationary phase will elute quickly and the heavier ones will follow the gas into the detector in a later phase (Kitson et al. 1996:3; Pollard, Batt, Stern & Young 2007:144, 138).

The mass spectrometer acts as the identifying agent in the process. In the initial stage the compounds enter a so called ion source where they are bombarded with electrons until they fall apart in different fractions based on their chemical structure (Pollard, Batt, Stern & Young 2007:174f). The sample then continues to travel through the instrument and passes the quadrupole, comprising of four rods, on their way to the detector (Kitson et al. 1993:13). The rods are electrically connected together in opposite pairs, and the ion beam passes alongside the z-axis of the rods when they have been forced out of the ion source by a potential (Kitson et al. 1993:13). The rods carry a fixed potential (DC) together with an alternating radio frequency (RF), and the ion that pass the rods are sorted due to the alternation of the magnetic fields on the diagonally opposed rods (Kitson et al. 1993:13). When varying these fields in a fixed ratio, usually from low to high voltages, a few ions with a narrow mass-to-charge (m/z) range will pass and continue to the detector. The other ions are deflected into the rods (Kitson et al. 1993:13; Pollard, Batt, Stern and Young 2007:166f).
The results obtained in the detector are presented in a chromatogram, in which every peak corresponds to a mass spectrum which could be described as “a graphic representation of the ions observed by the mass spectrometer over a specified range of m/z values. The output is in the form of an x, y plot in which the x-axis is the mass-to-charge scale and the y-axis is the intensity scale” (Kitson et al. 1996:13). In addition to this, the height and width of the peaks, i.e. the peak area correlate with the actual abundance of the substances in the sample, and it is thus possible to determine the specific abundance of an element in the sample (Kitson et al. 1996:13; Pollard, Batt, Stern & Young 2007:144,139).

4.6. Interpreting Vessel Use
In order to calculate the amount of extracted compounds in each potsherd the total ion chromatograms were integrated, and the abundance was then quantified in relation to the previously added internal standard. These calculations depict the amount of µg lipids/g ceramic powder. When the total amount of lipids has been extracted from each potsherd, they were then calculated, examined and interpreted through their individual mass spectrum in search of biomarkers. The biomarkers of relevance for this study are cholesterol, phytosterols, wax residues, long-chain ketones, isoprenoid fatty acids, ω-(alkylphenyl) fatty acids, and terpenoids.

Most compounds, e.g. the fatty acids, long-chain ketones, triacylglycerols some sterols and terpenoids, were identified through their characteristic fragmentation patterns. However, due to the small amounts and/or separation difficulties, some of the residues, e.g. isoprenoid fatty-acids, ω-(o-alkylphenyl) fatty acids, terpenoids and some of the sterols and wax residues were investigated by extracting characteristic ion chromatograms. The combined signals for each sample were interpreted in accordance with the specific origin of the compound enabling the interpretation of the ancient contents in the vessels (see Isaksson 2000:40; Olsson 2004; Papmehl-Dufay 2006; Hjulström 2008; Evershed 2008a:898). “Sometimes, the structure of a single component is sufficient to define the origin of a constituent of an organic residue” (Evershed 2008a:898). The archaeological biomarker approach could be summarized as detecting and recognizing the chemical fingerprint of the compounds present within the samples (Evershed 2008a:898).

Furthermore, it is of the essence to highlight the fact that the presence of certain compounds within a sample is verified through the GC-MS analysis. However, the interpretations based on the origin of the specific compound, i.e. their chemical fingerprint are somewhat more difficult. The final interpretation of the present biomarkers is conclusions and archaeological interpretations, and should be considered as such (Brorsson et al. 2007: 422). In addition to this it should be noted that the fatty acids present in the sample derive from the constituents that contained the most fat, and this is not necessarily the main ingredients (Brorsson et al. 2007: 422).

The Ratio of Fatty Acids and Traces of Ruminant Animals
The first step in the interpretation concerns the ratio of stearic acid (C\textsubscript{18:0}) and the palmitic acid (C\textsubscript{16:0}). Terrestrial animals produce higher amounts of stearic acid, and aquatic animals and plants produce a preponderance of palmitic acid (Christie 1981:20); if the C\textsubscript{18:0}/C\textsubscript{16:0} ratio is high (i.e. above 0.48µg/g), the major contribution of the fatty acids in the sample derive from the adipose tissue of terrestrial animals (Isaksson 2000; Hjulström et al. 2008:11).

Further investigations of the ratio of the C\textsubscript{18:0,str} (C\textsubscript{18:0} straight) fatty acid concern the relative presence of the C\textsubscript{17:0,br} (C\textsubscript{17:0} branched) fatty acids. A high C\textsubscript{17:0,br}/C\textsubscript{18:0,str} ratio is indicative of fats deriving from ruminant animals (milk and adipose tissue) as the bacterial activities within the intestines of ruminantia produce more branched fatty acids and uneven
carbon chains than other animals (Christie 1981; Dudd & Evershed 1998b, 1999:1346; Hjulström et al. 2008).

Another indicative of ruminant animal products present within the samples is the triacylglycerols (TAG) that are the main component of adipose fats (Dudd & Evershed 1999). If the distribution of TAG is broad, the carbon atoms in the glycerol backbone range between 40-54, in comparison to 46-54 atoms, this is indicative of fats from ruminants as they produce shorter compounds than other animals (Dudd & Evershed 1999).

Distinguishing Fats from Ruminant Animals and Traces of Milk
Measuring the $\delta^{13}$C values of stable isotopes in separate fatty-acids (C$_{16}$:0 and C$_{18}$:0) through Gas Chromatography Combustion Isotope Ratio Mass Spectrometry (GC-C-IRMS) enables the distinction between ruminant and nonruminant animals as well as the determination of dairy products present in the sample (Evershed et al. 1997; Dudd & Evershed 1999; Mottram et al. 1999).

Sterols
Cholesterol is the major sterol produced by animals, and it plays a vital role in maintaining membrane fluidity in the cellular structure. The presence of cholesterol within the sample is thus indicative of animal products (Christie 1987:44; Evershed 1993:80; Isaksson et al. 2010:3264). Plants on the other hand produce an array of phytosterols, (e.g. β-sitosterol, stigmasterol or campesterol) and fungi produce ergosterol in its stead (Isaksson et al. 2010:3265). Detecting these different sterols contribute to the interpretation of the origin of the lipids present in the sample.

The biochemical precursor to the sterols mentioned above is the hydrocarbon squalene, which is one of the major constituents of human fingerprints (Evershed 1993:88pp; Isaksson 2000:34). When this compound is detected in the samples it is indicative of contamination since squalene is highly unlikely to survive over longer periods of time.

Aquatic Animal Products or Terrestrial Animal Products
The combination of a low C$_{18}$:0/C$_{16}$:0 ratio and the presence of cholesterol could indicate aquatic animal content. This sterol is sometimes the only distinguishable biomarker that separates lean fish from vegetable lipids (Olsson 2004). Furthermore, marine animal products are rich in ω-3-fatty acids that range from 16 to 22 carbon atoms, and when these compounds are heated ω-ω(alkylphenyl) fatty acids are formed (Matikainen et al. 2003:568; Hansel et al. 2004; Evershed et al. 2008) These compounds are far more resistant to degradation than the highly fragile ω-3-fatty acids and thus constitute effective marine biomarkers. Moreover, the linoleic fatty acid (C$_{18}$:3) is present in most plants and a sample with high amounts of C$_{18}$ could therefore be the result of a vegetable origin (Isaksson et al. 2005)

Traces of Cooking
The formation of long-chain ketones is a result of the heating of free fatty acids (Evershed 1995:8877f). These compounds have previously been interpreted as direct evidence of cooking (Evershed 1995). However, experimental studies concerning the formation of the long-chain ketones have proven that they do not form until heated to 350-450°C and are thus considered to represent burned food (Evershed 2008b:42). Further traces of cooking are the ω-ω(alkylphenyl) fatty acids mentioned above (Matikainen et al. 2003:568; Evershed 2008b).

Terpenoid compounds such as resinoic acids could be traces of the production of tars, or sealants when found in high amounts in the samples (Evershed 1993:82p; Brorsson et al. 2007:423). When the detected products occur in lower amounts this is more likely indicative of fire, soot and/or smoke (Brorsson et al. 2007:423). Investigating these compounds could elucidate the origin of the resin, i.e. pine (Pinacea) or birch (Betulacea)
(Brorsson et al. 2007:423). If the resin is the result of distillation of tars, methyl esters are formed as the resinoic acids react to the methanol (Brorsson et al. 2007:423). If these methyl esters are detected in the sample they are thus good evidence of tar production (Brorsson et al. 2007:423).

**Empty Vessels**

When the samples contain low amounts of lipids (<0.5µg/g) the sample has been interpreted as being empty (e.g. Dudd & Evershed 1999). These vessels are considered to reflect an additional type of vessel use alongside the vessel uses based on the presence of lipid compounds. That is to say, empty vessels have been used in other ways than the ones where lipids are found, they are not the result of degradation or insufficient methodology. Especially not since other vessels from the same location and strata display high amounts of preserved lipids, thus displaying the degree of preservation of organic compounds at the specific localities (e.g. Isaksson 2009:140). One factor that could be of importance to the interpretation of these empty sherds is the possible variation in the ware of the fabric. However, since the sherds from PWC sites usually are porous and the fact that lipids have been successfully detected, this should not pose as a problem for the specific contexts.

**4.7. The Food Lipid Residue Analysis**

The material investigated in this study consists of Neolithic pottery sherds that were disinterred during excavations in 2009 and 2010. The applied method is food lipid residue analysis of the organic material absorbed within the ceramic walls of the unglazed pottery. The method consists of six different steps: documentation, sampling, extraction, derivatization and analysis in a gas chromatograph coupled to a mass spectrometer (GC-MS). The final step consists of the interpretation of the obtained results.

**Documentation**

The sherds were dried in room temperature for up to a week in a lab. The sherds were then photographed, weighed, categorized and described in accordance with their décor. The colour was determined by means of the Munsell Color Charts (Munsell 1975). The sherds that displayed traces of possible organic residues on the surface were investigated in a microscope. However, when attempting to remove these residues, they were extremely difficult to separate from the surface and the residues were thus excluded from this study.

**Sampling**

The outer surface (c:a 0.5mm) was removed with a tile grinder in order to avoid contamination of soils and fingerprints. Another 0.5g of ceramic powder was then removed with the same tile grinder. The drill was cleaned with chloroform in an ultra sonic bath between each sample. This cleaning process is of the essence since the samples would be cross contaminated if sampled with a contaminated drill. The obtained powder was transferred to individual test tubes previously washed in n-hexane.

**Extraction and Derivatization**

Before the extraction of the absorbed lipids, an internal standard (40µg n-hexatriacontan (C36)) was added to each sample, in order to quantify the amount of extracted compounds in each potsherd. The absorbed lipids were extracted with chloroform (1ml) and methanol (0.5ml) (2:1), and then shaken thoroughly in a vortex, upon which the samples were placed in an ultra sonic bath for 2 x 15 minutes. After over-night sedimentation the samples were centrifuged at 3000 rpm for 30 minutes. The extracts were transferred to vials and the solvents were evaporated in a stream of nitrogen, and then dried in a vacuum.

The samples were treated with bis-(trimethylsilyl) trifluoracetamide containing 1-10% chlorotrimethylsilane, and then placed in a heating block at 70°C for 30 minutes. The
reagent was then evaporated in a stream of nitrogen. The derivatized lipids were dissolved in n-hexane, and 1µl was finally injected into the gas chromatograph.

**Gas Chromatography and Mass Spectrometry**

The analyses were performed by a Hewlett Packard (HP) model 6890 gas chromatograph supplied with a SGE BPX5 fused silica capillary column (15m x 220µm x 0, 25µm). The injection of the samples was performed by the *pulsed spitless* technique (pressure 17.6 Psi) at 325°C via a *Merlin Microseal™ High Pressure Septum* through an Agilent 7683B Autoinjector. The oven was programmed with an initial isotherm at a temperature of 50°C. The temperature was gradually increased with 10°C per minute until it reached the temperature of 350°C and was then followed by a terminating isotherm of 15 minutes. The carrier gas used for this method was Helium (He), and it was released at a constant flow with 2.0ml per minute.

The gas chromatograph was coupled to a HP 5973 Mass Selective Detector through an interface with a temperature of 350°C. The fragmentation of the separated compounds was carried out through electric ionisation (EI) at 70 eV, and the temperature at the ion source was 230°C. The mass filter that had the temperature of 150°C was set to scan in the range m/z 50-700 providing 2.29 scans per second.

**5. Materials**

**5.1. Sampling Strategy and Selected Samples**

The samples selected for this study were chosen in random from a well defined, formal population. The selection was primarily based on the research questions. The sampling strategy was established before the excavation (see Orton 2000:2 for further discussions). Using a formal sampling strategy results in the possibility of making valid statements about the specific population, and it enables discussions concerning estimations of certain parameters, such as spatial distribution at an archaeological site (Orton 2000:2; Hjulström 2008:15).

The population, i.e. all the recovered rim sherds during the excavation at Korsnäs in 2010, was established in accordance with the research questions for this study. Furthermore, certain aspects of taphonomy were also taken into consideration, i.e. the degradation of lipids over time, as well as the preservation of lipids in ceramic vessels (e.g. Charters *et al.* 1993; Evershed *et al.* 2008). The sampled sherds from both Korsnäs and Stensborg were therefore predominantly rim sherds. However, other types of sherds were chosen for analysis as well, due to their individual importance as artefacts and consequently the interpretation of the sites, e.g. mini vessels and base fragments from Korsnäs.

The sampled population was studied and evaluated through certain given parameters: size, décor and overall state. The sherds that were chosen had an intact interior surface from which the sample could be drawn; an eroded surface would add an element of uncertainty as to the preservation of lipids through time and were therefore excluded from the population (Evershed 2008a:35). The décor was secondary to the preservation of the sherd, however it was still of great importance when it comes to categorizing the material and determining whether the samples represent different vessels.

The strategy of choosing sherds from different vessels results in a varied population, something that is of importance for the archaeological interpretation, especially when applying research questions concerning the dispersion of vessels and spatial organisation at the sites. Studies based on the distribution of lipids within one vessel could however benefit from a sampling strategy based on multiple sampling from the same vessel, as it would elucidate the preservation and absorption of lipids within one single vessel, (e.g. Charters *et al.* 1993). This is not, however, the focus of this study.
5.2. Selected samples from Stensborg, Raä 257
The samples that were chosen from Stensborg, a total of eight sherds, represent the general vessel use at the site. Samples SB1, SB2 and SB3 derive from the posthole found in 2009 (x: 59989.7/y: 86775.7). Samples SB5, SB7 and SB9 derive from feature 3, a larger pit (4.5 x 2.2 meters) filled with clay embedded artefacts. Sample SB6 is the only sample that derives from an archaeological layer at Stensborg, i.e. layer 2. Sample SB8 represents feature 1, one of the shallow pits filled with artefacts that were found in the field. Features 1 and 3 are very similar with the exception of feature 3 being larger than feature 1. Ideally several contexts should have been sampled. However, due to the small amount of available sherds, the importance of analysing different vessels was prioritized.

5.3. Selected samples from Korsnäs, Raä 447
A total of 33 sherds were selected from Korsnäs in accordance with the given parameters stated above. The samples were collected from two different areas within the site; area C and area D (see figure 10).

Figure 10. Map of Korsnäs Raä 447, Grödinge parish, Södermanland. The excavated areas in 2010 are indicated by red squares and the excavation in 2009 by a blue square, after Fornander 2011. Phosphate levels after Eriksson 1971. Edited by the author.

Ten random samples were selected from area C, representing the occupational layer at the Korsnäs site (LC4). These samples were found scattered across the entire cultural layer, thus representing the overall activities in this strata. Additional samples were taken from
different exposed features in the LC4 strata, in order to investigate intra-site patterns of vessel use and possible differences of spatial organisation at the site. The relevant sherds were evaluated in the same manner as the former ones, and a sample of six sherds emerged and was chosen for analysis. The sherds represent five different features: AC31, AC15, AC38, AC37 and two samples derive from AC43 due to the sampling of two sherds within the same context.

Another ten samples were selected in the same manner from the second excavation area at Korsnäs, area D. Since the excavation strategy in this area differed from the other areas during the excavation, some interpretation of the excavation reports were needed in order to determine the different strata that correlated with the occupational layer in area C, i.e. LC4. The different horizons were discussed in collaboration with the excavation supervisor Elin Fornander, where aspects such as texture, colour and recovered artefacts were taken into consideration. These discussions led to the crystallization of five different strata within five different test pits: LD:22 within trench D2; LD:6 within test pit D5; LD:18 within test pit D2; LD:4 within trench D1, and LD:12 within test pit D1.

From area D three samples, two mini vessels and a ceramic disc were collected on the basis of their individual importance as artefacts. Two samples, representing each side of the sherd were drawn from the ceramic disc, in order to possibly understand this artefact further. The disc was flattened on one side (KPD40:1), where traces of scraping are visible, possibly as the result of scraping the clay against a flat, wet surface during manufacture. The other side (KPD40:2) has an accentuated rim (see figure 11).

The recovered mini vessels found in area D in 2010 were analysed for their lipid content (KPD56 and KPD70). One of the vessels was larger (c:a 4.5cm in height). The ware is porous and it seems as if the artefact has been constructed in such a way that the indented fingers of the potter as he/she held it is part of the décor (see figures 12 & 13).

The quest for possible discussions concerning an intra-site difference in spatial organization at the site resulted in another four samples that were sampled directly from test pit D6 due to the fact that concentrations of several deposited bases were found here. These depositions could represent a recurrent PWC phenomenon that is interpreted as being of ritual importance for the PWC (e.g. Carlsson 1998:52) and thus of importance for the interpretation of the organization at Korsnäs. Furthermore, these particular excavation units are situated somewhat isolated from area D as well as from area C and could therefore be indicative of a general difference in the spatial organization. However, three of these samples had not been taken care of with the same precautions as the former samples, thus introducing a higher risk of contamination. The analysis of these samples was still ventured due to the benefits of what the possible results could add to the interpretation of the site and the Neolithic as a whole.

![Figure 11. Sample KPD40 a clay disc, showing the flattened side of KPD40:1 and the accentuated rim of KPD40:2. Photograph by the author.](image)
5.4. The Absorbtion of Modern Fingerprints in the Ceramic Matrix

Since modern contaminations of prehistoric pottery samples are one of the largest obstacles encountered when analyzing ancient lipid residues, a controlled experiment was conducted in order to examine the extent of the absorbtion of modern contaminants. The experiments were conducted in close collaboration with Sven Isaksson at ARL. Four ceramic blocks were made in a lab environment. They were tempered to a degree of 20% with chemically cleaned sand, and fired at 500°C in an oven.

The four samples were subjected to different degrees of contaminations as a part of the experiment (see table 3). The ceramic block labelled FPA was blank, i.e. placed in a freezer until sampled and thus handled like a prehistoric sample. The second block, FPB, was sent to Ole Stilborg at SKEA (Stilborg Keramikanalys), in order to mimic the contamination of a technological examination of a ceramic sherd. Block FPC was subjected to a medium amount of contamination. It was touched, examined and held for some time with bare hands until finally wrapped in tin foil, and placed in a freezer together with the three previous blocks. The FPD block was heavily contaminated. The sample was held, rubbed and exposed to environments outside the lab for two days.

When the experiment was completed, all four blocks were sampled in accordance with the protocol described above, with the exception that no outer surface was removed in order to avoid contamination. The outer surface was instead sampled, together with a sample from the middle of the block, and a third and final sample was taken from the core. The samples thus represent the first, second and third millimetre of the block. This sampling strategy was used to detect the absorbtion of contaminations into the ceramic matrix.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Degree of Contamination</th>
</tr>
</thead>
<tbody>
<tr>
<td>FPA1</td>
<td>Blank</td>
</tr>
<tr>
<td>FPA2</td>
<td>Blank</td>
</tr>
<tr>
<td>FPA3</td>
<td>Blank</td>
</tr>
<tr>
<td>FPD1</td>
<td>Medium (O.S)</td>
</tr>
<tr>
<td>FPD2</td>
<td>Medium (O.S)</td>
</tr>
<tr>
<td>FPD3</td>
<td>Medium</td>
</tr>
<tr>
<td>FPD4</td>
<td>High</td>
</tr>
<tr>
<td>FPD5</td>
<td>High</td>
</tr>
</tbody>
</table>

Table 3. Table displaying sample names, total amount of lipids and degree of intentional contamination of the samples included in the study concerning the absorbtion of modern fingerprints.
6. Results

6.1. Results of the Food Lipid Residue Analysis

There were several sherds from Korsnäs that were contaminated with modern residues, and these samples were thus not included in the final interpretation concerning ancient vessel use at the site. Excluding these sherds even though there could be traces of ancient lipids present in the samples are of importance since it is impossible to distinguish which residues are representative of the ancient vessel use. The excluded sherds are: CKP10, CKP36, and CKP38 from area C, as well as KPD7, KPD36, KPD209, KPD70, KPD39, and FD136 from area D (see appendix 1). The original number of ten sherds representing the cultural layer in area C is reduced to eight, and the original group of five sherds representing the features in area C is decreased to four. The original group of ten sherds that should have represented the general vessel use in area D is decreased to seven sherds.

6.1.1. Stensborg

The sherds that were included in the final interpretation from Stensborg displayed a varied vessel use. The total amount of lipids in the samples varied from 1452 µg lipids/g ceramic powder to 1.6 µg lipids/g ceramic powder (see appendix 1). Two of the samples, SB3 and SB5 were interpreted as empty, i.e. displaying no, or very low, amounts of absorbed lipids within the ceramic walls. A total of four different variations in vessel use have been detected in the samples from Stensborg (see figure 14); vegetable; terrestrial animal/vegetable and terrestrial animal/aquatic animal/vegetable contents, and some empty sherds (see appendix 2 for detailed presentations of the different samples and their interpretations).

![Bar charts displaying vessel use at Stensborg, Raå 257. E= Empty; T/A/V= Terrestrial animal/Aquatic animal/vegetable; V= Vegetable; T/V= Terrestrial animal/vegetable; A/V= Aquatic animal/vegetable; A= Aquatic animal lipids.]

6.1.2. Korsnäs

The samples from Korsnäs varied in total lipid content from 1608 µg lipids/g ceramic powder to 0.04 µg/g ceramic powder (see appendix 1). There are a few sherds that have been interpreted as empty: KPD201 and KPD207, both representing area D. The vessels that were sampled in area C display five different variations in vessel use: terrestrial animal/aquatic animal/vegetable; vegetable; terrestrial animal/vegetable; aquatic animal/vegetable and aquatic animal lipids (see figure 15 below).
The total amount of samples from area C represents the cultural layer (LC4) as well as the revealed features within this stratum. When separating the vessels found in the cultural layer from the vessels recovered in the features a certain difference in vessel use is noted. There are no vessels interpreted as containing mixtures of terrestrial animal/aquatic animal/vegetable (TAV) found in the features (see figure 16). However, only one sherd containing the mixture of TAV is found in the cultural layer.

The vessels representing area D have been sampled from five different test pits and trenches. The samples derive from the same stratigraphic layer, corresponding with the strata in area C, i.e. LC4. The samples indicate a varied vessel use with three different variations: aquatic animal; terrestrial animal/vegetable; vegetable lipids; and empty sherds. The variation shows a domination of mixtures with terrestrial animal/vegetable lipid.

**Figure 15.** Bar charts displaying total vessel use at Area C, Korsnäs.
E=Empty; T/A/V=Terrestrial animal/Aquatic animal/Vegetable; V=Vegetable; T/V=Terrestrial animal/Vegetable; A/V=Aquatic animal/Vegetable; A= Aquatic animal lipids.

**Figure 16.** Bar charts displaying the differences in vessel use based on the archaeological context, i.e. if the vessels are recovered in features or in the cultural layer. E= Empty; T/A/V=Terrestrial animal/Aquatic animal/Vegetable; V= Vegetable; T/V= Terrestrial animal/Vegetable; A/V= Aquatic animal/Vegetable; A= Aquatic animal lipids.
compositions. That is to say, no aquatic animal influences in the general vessel use within area D (see figure 17).

![Area D](image)

**Figure 17.** Bar charts displaying total vessel use in area D. E= Empty; T/A/V= Terrestrial animal/Aquatic animal/Vegetable; V= Vegetable; T/V= Terrestrial animal/Vegetable; A/V= Aquatic animal /Vegetable; A= Aquatic animal lipids.

When comparing the results of the food lipid residue analysis from area C and area D, the Fischer Exact Probability test (two tailed) show that there is a statistically significant difference (p = 0.0147) between the two areas in the distribution of vessels concerning aquatic animal lipid contents and vessels without the aquatic animal lipid distribution.

![Distribution of Vessel Use](image)

**Figure 18.** Displaying vessel use based on Aquatic vs. other classes of vessel use in area C and area D.

The varying vessel use between the two areas within the Korsnäs site is further illustrated in the bar chart above (figure 18), where the preponderance of aquatic animal lipids found in the analyzed vessels from area C is evident. Furthermore, the results show a more varied vessel use in area C than in area D, which shows a definite dominance of terrestrial and vegetable lipids in the vessels (see figure 19).
When comparing the results of the analyses from Stensborg and Korsnäs there are differences in vessel use, in that the Korsnäs samples display more variation (see figure 20). Furthermore, the dominance of aquatic animal contents in the vessels from Korsnäs is evident, compared to the dominance of terrestrial animal/vegetable presence at Stensborg.

The Clay Disc
A total of two samples (KPD40:1 and KPD40:2) were drawn from the clay disc, so that a sample from each side of the sherd could be analysed. The results from the analyses show traces of terrestrial and vegetable lipids in both samples. However, sample KPD40:1 also shows traces of terpenes, i.e. traces of soot, coal and/or smoke.
The Mini Vessels
Two mini vessels were analysed in this study, however, one of these vessels (KPD70) was contaminated and finally excluded from the study. The result of the food lipid residue analysis shows vegetable content for the remaining sample (KPD56).

The Base Fragments
A total of four base fragments were analysed for their lipid content. However, two of them were excluded from the study due to contamination (KPD39 and FD136). The two remaining sherds (FD220 and FD228), representing the howe north of area D, show traces of aquatic lipids. FD228 also shows traces of ω-(0-alkyl-fenyl) fatty acids indicating heating of marine ω-3 fatty-acids.

6.2. The Absorbtion of Modern Fingerprints
The results of the study concerning the absorbtion of lipids related to fingerprints, display definite differences between the samples (as seen in figure 21). All the different numbers connected to the sample names indicate the sampling sequence. Number one represents the outer millimetre, number two represents the second millimetre and number three represents the third and inner millimetre.

As seen in figure 21, there is a definable gradient of lipids absorbed into the ceramic matrix. The three samples from the FPA block, i.e. the blank block, display negligible amounts of absorbed elements, less than 0.5µg lipids/g ceramic powder. The samples deriving from block FPC show a similar distribution, albeit being subjected to contamination. Sample FPB1 display a total amount of 1941µg lipids/g ceramic powder. The following two samples from the FPB-block, FPB2 and FPB3 display a similar amount of lipids to one another, 52µg lipids/g ceramic powder and 54µg lipids/g ceramic powder respectively.

Figure 21. Bar chart displaying the gradual absorbtion of contamination. The numbers 1, 2 and 3 adhering to each sample name indicate their succession. Number one represents the surface, number two represents the second millimeter and number three represents the third millimeter at the core of each block.
The samples that were drawn from the block subjected to the highest degree of contamination, FPD1, FPD2 and FPD3 display the highest amounts of absorbed lipids. Sample FPD1 contain 2025µg lipids/g ceramic powder. The second sample FPD2 show a decreasing amount of absorbed lipids: 517µg lipids/g ceramic powder, and the third and innermost sample display an even lower amount of absorption at 105µg lipids/g ceramic powder. The two blocks that show the most traces of contamination, FPB and FPD display a similar degree of absorbed elements at the surface approximately 2000µg lipids/g ceramic powder. The two inner samples from block FPB show a gradient in absorption (see figure 21), but the level of absorbed compounds seem to be focused around 50µg lipids/g ceramic powder. The three samples that were drawn from the most contaminated block, FPD show a gradient of absorbed elements, traceable from the surface to the innermost sample. Of interest are the samples deriving from block FPC, which was indeed handled with bare hands, however the samples resemble the distribution of absorbed lipids with block FPA, i.e. the blank block.

The detected compounds in the samples were dominated by squalene and cholesterol, followed by an array of plasticizers and polyunsaturated fatty acids. An attempt was made to investigate and interpret the samples in accordance with the protocol used for prehistoric samples. This was done in order to understand how these samples would have been perceived had the contaminations been unknown. The results from this interpretation display that samples FPA1 and FPA2 would have been interpreted as empty, and that sample FPA3 would have been regarded as contaminated/empty. The outer sample from block FPB (FPB1) would have been interpreted as contaminated, whereas the other two samples FPB2 and FPB3 would have been interpreted as containing aquatic animal products/vegetables due to detectable amounts of cholesterol, phytosterols and isoprenoid fatty acids together with a low C_{18:0}/C_{16:0} ratio (see appendix 3). Furthermore, all three samples drawn from block FPC would have been interpreted as empty. The outer sample deriving from block FPD, (FPD1), would have been regarded as contaminated due to high amounts of unsaturated fatty acids. The other two samples, FPD2 and FPD 3 displayed lipid compositions that would have been interpreted as aquatic animal/vegetable contents, had the samples been prehistoric. This interpretation is based on detected amounts of cholesterol and waxes and a low C_{18:0}/C_{16:0} ratio (see appendix 3).

Worth mentioning is the visible absorption of compounds related to human fingerprints on the surface of block FPD as seen in figure 22 below. There is a definite difference between the two blocks.

**Figure 22.** The visible contamination of block FPD prior to sampling. The block seen in the foreground is not handled with bare hands, and is added in order to elucidate the difference between the two blocks; it is not a part of this investigation. Photo by the author and Hans Ahlgren.
7. Discussion and Conclusions
7.1. Vessel Use at Stensborg
The analysed sherds from Stensborg (8 sherds) displayed a vessel use dominated by terrestrial animal/vegetable mixtures with presence of aquatic animal lipids (see appendix I). The results fall well in line with earlier investigations concerning vessel use from other FBC sites (e.g. Palomäki 2006), where mixtures containing terrestrial animal and vegetable lipids were prepared in the vessels. Based on the archaeological interpretations of the FBC as the first farming population in this region, the results from this study display a vessel use at Stensborg that could be expected of an early farming community. There is a terrestrial focus, yet we see a presence of aquatic animal products in the vessels as well. These results indicate that mixtures of different types of food have been prepared, cooked or stored in the vessels. It is of interest that Stensborg was situated at a deep inlet connected to the sea during the EN. The geographical position in the landscape would therefore enable a mixed resource use with both marine and terrestrial inputs, as suggested by Olsson (1996a).

Unfortunately the recovered bone assemblages at the site are highly fragmented and thus inhibit osteological and stable isotope analyses to be performed on the material. Such analyses would otherwise aid the interpretation of the prevailing food culture at Stensborg during the EN. At the same time Stensborg displays aspects of food culture that complement the results of the food lipid residue analyses, i.e. the recovered seeds found in the field as well as the recovered sherds decorated with seed impressions found at the site. The seed depositions are enigmatic and difficult to interpret in their own sense, however through a food cultural approach they contribute to the understanding of Stensborg as a community that is focused on terrestrial resources, even though the everyday diet at Stensborg is unknown.

7.2. Vessel Use at Korsnäs
A total of 19 sherds display the general vessel use at Korsnäs showing a preponderance of vessels containing aquatic lipids; 45% of the analysed samples contained aquatic animal products. When comparing these results with other PWC sites, such as Trössla and Överåda in Södermanland (Ohlberger 2009), and Högmossen and Brännpussen in Uppland (Brorsson et al. 2007), Korsnäs stands out as the one site with tendencies to a more varied vessel use than the compared sites (see fig 23).

![Figure 23](image-url)

**Figure 23.** Bar charts displaying the difference in vessel use at PWC sites in Södermanland and Uppland. A= Aquatic animal; AV= Aquatic animal/Vegetable; T/V= Terrestrial animal/Vegetable; V= Vegetable; T/A/V= Terrestrial animal/ Aquatic animal/Vegetable lipids.
The osteological analyses of the recovered bone assemblages from Korsnäs show a preponderance of seal and fish followed by pig (Olsson et al. 1994; Olander 2010). Furthermore, the inhumated individuals at Korsnäs have undergone stable isotope analyses that determined a primarily marine food intake dominated by seal (Fornander 2006; Fornander et al. 2008). The combined results of these investigations and the results from the food lipid residue analyses reveal a nuanced and dynamic view of the food culture at Korsnäs dominated by marine products.

The dominance of marine resources is seen in all of the investigated materials, something that enables discussions concerning ancient food cultures which are anchored in the source material in a desirable way. However, I do not argue that this is an all encompassing cultural trait for the PWC in general. Certainly, these food signals have been noted individually elsewhere (e.g. similar bone assemblages), and these results could possibly be used as evidence for a PWC cosmology and lifestyle centred around marine resources. Nevertheless, I would like to stress the importance of combining the investigation of several food signals when discussing food cultures, since it is the combination of several signals that offer this understanding of past food cultures as the one presented here.

Even though the results display a dominance of marine food signals at Korsnäs, the obtained results from the food lipid residue analysis reveal a statistically significant difference in vessel use between area C and D. While area C reveals a dominance of aquatic animal contents in the vessels, area D is accentuated through the dominance of terrestrial animal products mixed with vegetable contents. These differences thus indicate a variation in the Korsnäs menu, and a somewhat varied resource use. However, this menu is still dominated by marine resources.

Interestingly enough, there are no vessels containing aquatic products in area D, something that clearly distinguishes a difference in vessel use between the two areas. Moreover, when these results are combined with the tendencies of deviating decorative schemes between the two areas (Dimc & Fornander 2011), and with the soil chemical analyses (Andersson et al. 2011) the intra-site difference in spatial organisation becomes even clearer. However, it is as of yet difficult to distinguish what these differences represent. The fact that graves have been revealed in area C and consequently not in area D, could definitely be an important factor in the discussion concerning spatial organisation at the site. Still, area D has not been investigated enough to argue for the lack of inhumations, but based on the available archaeological records this is a distinguishable difference between the two areas that should be investigated further.

In order to further discuss the intra-site differences at Korsnäs, the contextual investigations should be put forward as well. When investigating the difference in vessel use between the cultural layer and the revealed features in area C, no evident differences could be detected in the general distribution. Furthermore, the features from which the samples are taken have been difficult to interpret archaeologically, and the comparison between the cultural layer and the features has therefore not yielded any substantial differences based on vessel use. At the same time, similar investigations were conducted on the soil lipid compositions showing higher amounts of lipids and more varied average chain lengths within the features (Andersson et al. 2011). The relation between the features and the cultural layer could possibly be found in the activities surrounding the “creation” of the feature, and not in the deposited vessel contents.

Variations in vessel use between different PWC sites have previously been identified (e.g. Brorsson et al. 2007), however, differences in vessel use within one PWC site has never been noted or studied before. These differences are of special importance when discussing the interpretation of PWC sites, their organisation and activities. The
investigations at Korsnäs have covered large geographical areas as well as covered several aspects of the investigative possibilities currently at hand within archaeology today (osteological analyses, phosphate surveys, stable isotopic analyses, elemental and lipid soil analyses, food lipid residue analyses). This has provided a nuanced view of the site. However, since it is more common with smaller excavations, smaller areas are thus investigated and the number of analytical possibilities is often limited. The differences in spatial organisation seen within Korsnäs provide further understanding of the implications of interpreting smaller areas based on their ceramic assemblages (Dimc & Fornander 2011), as well as through their vessel use. This is not to say that these investigations are redundant, however these spatial differences needs to be taken into account when working with PWC material.

A possible complement to the array of different investigations at Korsnäs that could shed further light on the prehistoric activities in this area is the investigation of the plant-specific groups of biomarkers that can be found in peat deposits for example. Investigations of such groups have proven to elucidate and reconstruct past forest compositions in combination with pollen analyses (e.g. Jansen et al. 2009). These investigations could possibly elucidate the spread of agriculture through the presence of seeds and/or plantago lanceolata. Since the Korsnäs bog is a suitable “soil archive” for these types of investigations it is of definite interest to investigate the possibilities of reconstructing the floral composition at Korsnäs during MN A, and complement this with the previously performed pollen analyses at Korsnäs.

7.2.1. The Interpretation of the Clay Disc
The two samples from the clay disc displayed terrestrial animal lipids in combination with vegetable lipids. However, one of the samples revealed traces of terpenes as well, i.e. on the flattened side of the disc. These traces could be indicative of subjection to soot/coal, smoke, and/or resins. Based on the results of this one disc, I find it hard to discuss recovered clay discs in general. Still, I would like to argue for the possibility that this particular disc has been used as a lid of some sort, where the flattened side is turned upwards thus being subjected to soot and coal to a larger extent than the other side. The terpenes could possibly be traces of sealants. However, these traces could have occurred through other activities.

7.2.2. The Interpretation of the Mini Vessel
Only one mini vessel displayed ancient vessel use, since the other sample was contaminated and thus excluded from this study. The remaining sample displayed vegetable contents. However, since there is only one mini vessel it is difficult to discuss what these results represent. Previously analysed mini vessels are found in the material from Sittesta, where one sample was analysed displaying aquatic animal/vegetable contents and traces of long-chain ketones, i.e. traces of heating - possibly cooking (Isaksson 2008). When comparing the results from the two mini vessels from Korsnäs and Sittesta, the vegetable lipid compounds are one common feature. However, the number of analysed mini vessels is still no more than two and I find it difficult to interpret the use of this vessel type further. Nonetheless, it is of interest to see that these small vessels have indeed been used for storing, preparing or possibly even heating different types of food. These results should therefore be complemented by further analyses of mini vessels in order to draw closer to a understanding as to how these vessels were used.

7.2.3. Deposited Base Fragments
The base fragments deposited near the Howe north of area D is an intriguing discovery, especially since the results of the food lipid residue analysis indicate aquatic products within the samples. One of the samples shows traces of long-chain-ketones and ω-(0-alkyl-
fenyl) fatty acids, indicating that the substances within the sample have been heated. The context in which these samples were rediscovered is of interest through a general archaeological point of view as deposited base fragments near wetlands or shorelines are interpreted as ritualized activities, connected to the PWC (e.g. Carlsson 1998:52f). Furthermore, it is interesting for the interpretation of Korsnäs as well, since it reveals a possible intra-site focus that would have affected the organization at the settlement. Foremost, this context is deviating from the general vessel use in the nearby area D, and this combination is, to say the least, very interesting.

Of special interest for the interpretation of this context is the deposited bases at Sittesta (Raää 68, Ösmo parish), which were found in connection to the ancient shoreline (Khilstedt et al. 2007). Some of these bases were analysed in regards to their lipid content together with some sherds from the habitation area at the site (10 samples in total) (Isaksson 2008). The analyses displayed low amounts of lipids in all but four of the samples (Isaksson 2008). One of these samples could have been contaminated, why the interpretation is uncertain, and another sample contained low amounts of long-chain-ketones (i.e. traces of heating) (Isaksson 2008). Three of the samples displayed vegetable contents and the third sample displayed a mixed content of aquatic, terrestrial animal and vegetable contents (Isaksson 2008). Interestingly enough, the samples attributed to the more profane contexts around the settlement were empty (Isaksson 2008). If applying the hypothesis that deposited bases is part of ritual activities at PWC sites, the content is of great importance for the understanding of the base fragments at Korsnäs, especially since these sherds differ in lipid content from the overall vessel use.

When comparing Korsnäs and Sittesta, deposited pottery bases at both sites deviate from the overall vessel use. Even though the vessel uses as such are fundamentally different between the two sites, this strengthens the hypothesis regarding the base fragments as being ritually deposited. The results consequently indicate another area within the Korsnäs site, as the analysed material from the howe deviates both from area C and D. Nonetheless, it should be noted that the base fragments found at the howe are no more than two, and thus representing only tendencies of a different vessel use and/or spatial organisation at the site.

Still, if the ritual aspect of the deposited base fragments is accepted, the correlation between the contents of these base fragments and the context is of great interest. This would imply ritual deposition of bases where exclusively aquatic contents have been stored (FD220), and cooked (FD228, traces of long-chain ketones and ω-(0-alkyl-fenyl)fatty acids).

Could the results previously mentioned indicate ritualization of the meal/content within the vessel? This conclusion could possibly be drawn based on the material from Korsnäs, since the presence of aquatic contents in the samples within the site is otherwise represented in Area C. These results could possibly indicate a ritual sphere in connection to the revealed graves. This however, is an assumption that needs to be based on further investigations concerning how the dead were perceived within the PWC. Bones found scattered over the cultural layers could indicate a different relationship to death than what is perceived as normative during historic and modern times. Nevertheless, when the contents of these base fragments are compared with the contents at Sittesta (2 V and 1 A/V) (Isaksson 2008:4f), another conclusion needs to be drawn for the PWC complex as a whole. The deposited contents seem to be vegetable based at Sittesta, with the expectance of the one sample containing both aquatic and vegetable contents. What could be said about this possible ritualization of deposited foodstuffs is that there was something connected to the vessels both at Sittesta and Korsnäs that had some element of recognition, e.g. décor or shape, which would signal what type of content that “should” be stored in the vessel.

43
Another possibility is that the vessel was constructed with the intention of being deposited and that only one meal was cooked or stored in these particular vessels.

Consequently, this would imply that the meal and the action of deposition were closely connected. Of interest for this discussion is the absence of terrestrial animal products in the analysed base fragments, since pigs are suggested to have been associated with ritual feasting (Fornander et al. 2008). Again, if the ritualization of deposited base fragments based upon five sherds (Sittesta and Korsnäs combined) is accepted, the concept of wild boar feasts have not been involved in the possible rituals that involved the deposition of the base fragments. A third possibility is of course that the discussed phenomenon is haphazard, especially since the assumptions are built on a total of five sherds. The sherd from Sittesta containing both aquatic and vegetable lipids could confirm this.

What is more, is that no empty base fragments have been found as of yet, indicating that it is the combination of the contents and the base that is of possible ritual nature. If the base in itself was the main reason as to why this phenomenon occurred, then it could be argued that they would have been empty. Again, a reverse view is also possible, i.e. that ordinary cooking vessels were deposited without any inherent symbolism. What is clear is that additional analyses on deposited base fragments are needed in order to investigate this phenomenon further.

### 7.3. Concerning the Deviating Food Cultures

The results of the food lipid residue analyses from the Neolithic assemblages reveal tendencies to a difference in resource use. The material from Stensborg displays a dominating use of terrestrial animal products when compared to the material from Korsnäs dominated by aquatic animal products. These results are of interest since differences are seen between these groups of people in the archaeological record as well.

Of special interest for the discussions concerning food as a cultural binder is the geographical location of these settlements during the EN /MN. Both Stensborg and Korsnäs were situated in an inner archipelagic environment with the possibilities of utilising an array of different resources. However, these different groups have chosen to focus on different resources. These choices could be indicative of food acting as a social binder and thus governing the choices of the dominating resources at the sites. However, it should be noted that the variation in resource use is an aspect that the two sites have in common, indicating that the food cultures at Stensborg and Korsnäs do not seem to be exclusive in their resource use. Moreover, it is of interest that Korsnäs display a food culture that is dominated by the use of aquatic animal products but with a varied menu. These nuances contribute to the understanding of the Neolithic food cultures as a whole, indicating that Neolithic groups of people were somewhat centred round a general food culture, as “we who eat...”.

Further investigations of the material and the measurement of stable isotopes within the lipid compositions could possibly reveal if these differences in resources use are indicative of deviating economies as well, since these investigations enable the distinction of ruminant and nonruminant animals. Such distinctions could elucidate whether or not the terrestrial animal lipid compounds are indicative of cattle or nonruminant animals such as pig for example.

### 7.4. Concluding Remarks Concerning Neolithic Vessel Use

To conclude, there are indications of deviating food cultures at Stensborg and Korsnäs, based on the analysed sherds. This is a putative conclusion when comparing Stensborg to the food culture at Korsnäs. This congruity is based on a multitude of investigations of several food signals, i.e. osteological analyses and stable isotopic data displaying a definite marine focus at Korsnäs. Moreover, there are indices of differential vessel use within the
Korsnäs site, where area C display a preponderance of aquatic contents and area D terrestrial animal/vegetable vessel use. Yet another space is detected in connection to the howe north of area D, where deposited base fragments have been showed to contain aquatic lipid compositions. Concentrating on the differences between area C and D it could possibly indicate a chronological difference between the two areas, a notion that need further investigations. However it is clear that there is a spatial difference between these two areas, based on the archaeological record (graves and pottery assemblages), the soil chemical analyses and the food lipid residue analyses.

It should be emphasized that the investigations of several food signals from the same site is a powerful tool when aiming at the investigation of ancient food cultures, as they complement each other and contribute to a more nuanced understanding of prehistory. Furthermore, the total array of different analyses performed on Korsnäs is unique and remarkable in its own sense. Conventional excavations on several occasions, osteological analyses, pollen analyses, phosphate surveys, soil chemical analyses, stable isotopic analyses and now food lipid residue analyses enable outstanding possibilities of understanding the site as well as the Neolithic on Södertörn, and as we have seen in this study, contrasting vessel use at Stensborg as an indication of deviating food cultures.

7.5. Absorbed Fingerprints
The study concerning absorbed fingerprints in the analysed blocks shows that the precautions taken with prehistoric samples are well founded, since the absorption of both squalene and cholesterol penetrate at least 3mm into the ceramic material and with considerable amount as well. Since the conventional procedure involves the removal of the first millimetre in order to avoid contamination, this poses as a real problem. Even though most contamination adheres to the first millimetre, there is still a considerable amount of both cholesterol and squalene in the second millimetres, i.e. from where samples are usually drawn.

However, if the contaminations are modern, i.e. recently “introduced”, the detection of squalene is a relatively sharp tool that could be used as reliable indication of contamination. The real problem is the instability of squalene making it degradable over long periods of time. Since human fingerprints also introduce cholesterol to the sample, a sterol that is stable over longer time spans, the situation when working with prehistoric contexts is this; the indication of modern finger prints (i.e. squalene) has degraded leaving cholesterol within the ceramic matrix. Detected cholesterol is conventionally interpreted as traces of terrestrial animal/aquatic animal products in the prehistoric samples. Cholesterol within the samples could consequently be the results of modern human fingerprints, where the squalene is degraded, something that is problematic foremost when analysing samples that have not been freeze, stored or handled in a desirable way.

Moreover, the most interesting aspect of this is the possibility that it is the prehistoric handling of the vessels that is seen in the samples. At the same time, the extracted samples are drawn from the *inside* of the prehistoric samples, and the detected lipid composition should therefore reflect the compounds stored *within* the vessel and not the fingerprints left on the surface. Naturally, the cleaning of the vessels between meals could possibly introduce fingerprints within the vessel, leaving this to be a methodologically interesting dilemma in need of further investigation. It should be mentioned that further indications of modern contaminations is the presence of absorbed modern compounds within the ceramic matrix. These modern compounds were discovered in this study as well.

Since the samples contained squalene it was easy to see that they were contaminated, especially in combination with the unsaturated fatty acids and the plasticizers. However, the second and third sample did not absorb the same amount of different compounds as the
outer millimetre. This was indeed not surprising, however, since the outer millimetre is removed when analysing prehistoric samples it is important to investigate how the inner samples were interpreted. These samples displayed detectable amounts of squalene and unsaturated fatty acids, as well as sterols and plasticizers. Since the total amount of absorbed compounds is lower in these samples and squalene and the unsaturated fatty acids are easily degradable, the investigations of these samples show that they can be interpreted as traces of prehistoric vessel use if stored in an undesirable way.

Of further interest for this particular study is the fact that not one of the samples from Stensborg were interpreted as being contaminated even though they were subjected to modern contamination and stored outside a freezer. Notable in this discussion are the empty sherds, i.e. samples that do not display any or very low lipid compositions. These results provide yet another dilemma in need of further investigation, as the amount of contamination of the sherds appears to be dependent on the extent of “human handling” as indicated by the samples drawn from block FPC in this study as well.

The blocks that were sampled in this study is currently being stored in room temperature, and they will be subjected to degradation experiments in order to mimic the degradation of prehistoric samples. The investigations of the degradative processes could possibly elucidate the situation further. However, the results of this pilot study clearly show that modern contamination is a definite problem within food lipid residue analyses that is in need of further investigation.

8. Summary
When focusing on the subsistence patterns of the Funnel Beaker Culture (FBC) and the Pitted Ware Culture (PWC) the differential use of resources is noticeable, and this duality gives rise to a number of theories explaining this phenomenon. This particular study argues that food acts as a social binder, and stresses the importance of studying the flow of food signals as an integral part of archaeology as it directly contributes to a more nuanced understanding of the past groups of people. Osteological analyses of recovered human and animal bone assemblages as well as stable isotope analyses of human bones, provides important information about the dietary practices. However, in order to comprehend the true nature of the Neolithic food cultures, one must investigate the entire spectrum of ancient eating habits. This study has approached pottery and vessel use through identification of absorbed fatty acids in the ceramic walls via food lipid residue analyses, elucidating aspects of the once existing food practices that are left out through traditional archaeological, osteological, and scientific interpretations.

The two Neolithic ceramic assemblages from one FBC site (Stensborg) and one PWC site (Korsnäs) in Södermanland has been investigated due to their supposed deviating subsistence economies. A total of eight sherds have been analysed from Stensborg and totally 33 sherds have been analysed from Korsnäs, where 24 sherds displayed prehistoric vessel use and were thus included in this study. Moreover, the samples from Korsnäs were sampled based on their contexts, as possible indicators of spatial organisation within the site. A total 13 samples represent the general vessel use in area C and 6 samples represent the general vessel use in area D. In addition to this, two base fragments, one mini vessel, and one clay disc were analysed from area D as well. The Korsnäs site has also been investigated through a food cultural approach aiming to combine the results of the previously performed osteological and stable isotope analyses from the site. This approach was chosen in order to procure a more nuanced picture of the food culture at Korsnäs.

The results show that there is a difference in vessel use between Stensborg and Korsnäs, where the samples from Stensborg displayed a varied vessel use dominated by mixtures of terrestrial animal products and vegetables, however there is a slight presence of aquatic
products in some of the vessels as well. On the other hand, the samples from Korsnäs displayed a preponderance of aquatic animal products. In contrast to the well established marine food culture present at Korsnäs, Stensborg is distinguished in this study as the representative of a deviant vessel use. Since these analyses reflect what is cooked and/or stored in the vessels and not the general diet, it is difficult to say anything about the prevailing food culture at Stensborg, however in contrast to Korsnäs there is a definite domination of terrestrial animal products that have been processed or stored in the vessels.

The results from the studies of the spatial organisation at Korsnäs reveal tendencies that could be indicative of a difference in vessel use between the two investigated areas C and D, where area C displays a dominance of aquatic animal products in the vessels. The vessel use at area D on the other hand is dominated by terrestrial animal products and vegetables. Interestingly enough, the two base fragments found at a howe north of area D contained solely aquatic products, displaying an important difference in spatial organization at the site. The previous interpretations concerning deposited base fragments focus on the ritual sphere of the PWC, why the lipid contents in combination with the context is especially interesting. Furthermore, the combined food cultural approach, previously unattempted, shows that the food culture at Korsnäs was indeed dominated by aquatic resources, as seen in the osteological material, the isotopic data and now the food lipid residue analyses. Results that further accentuate the notion of the seal-hunting PWC, at least at Korsnäs.

These results clearly exhibit the advantages of applying a food cultural approach when investigating prehistoric groups, providing a currently undisputed view of the food culture at Korsnäs that is beneficial in the comparison with other PWC groups and/or deviating food cultures as Stensborg.

In addition to the food cultural studies, a series of investigative analyses have been performed aiming at the understanding of modern contaminants and to what extent they absorb into the ceramic matrix of prehistoric samples. Four different ceramic blocks were constructed for this purpose and exposed to varying amounts of contamination. The blocks were sampled in three sequences representing the first, second and third millimetre of each block. The results show a gradual absorption from the surface sample towards the inner sample. The blocks that have been subjected to the highest rate of contamination displayed high levels of squalene, cholesterol and unsaturated fatty acids.
9. References


Personal Comments
<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Amount (µg/g)</th>
<th>Neut. lipids</th>
<th>Intact trisacylglycerols</th>
<th>Cholesterol</th>
<th>Fatty acids</th>
<th>Sterol</th>
<th>Wax-residue</th>
<th>Long chain ketones</th>
<th>Y(0,12)</th>
<th>6-12</th>
<th>4,8,12-Thiod</th>
<th>6-10,1</th>
<th>4-Thiod</th>
<th>3,7,11,15-Thiadi</th>
<th>Terpenoids</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHP-10</td>
<td>0.31</td>
<td>0.8</td>
<td>CONC.</td>
<td>CONC.</td>
<td>CONC.</td>
<td>CONC.</td>
<td>CONC.</td>
<td>CONC.</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Empty</td>
<td>T/Y</td>
</tr>
<tr>
<td>CHP-20</td>
<td>0.63</td>
<td>0.2</td>
<td>CONC.</td>
<td>CONC.</td>
<td>CONC.</td>
<td>CONC.</td>
<td>CONC.</td>
<td>CONC.</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Empty</td>
<td>T/Y</td>
</tr>
<tr>
<td>CHP-30</td>
<td>0.28</td>
<td>0.2</td>
<td>CONC.</td>
<td>CONC.</td>
<td>CONC.</td>
<td>CONC.</td>
<td>CONC.</td>
<td>CONC.</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Empty</td>
<td>T/Y</td>
</tr>
<tr>
<td>CHP-40</td>
<td>0.76</td>
<td>0.5</td>
<td>CONC.</td>
<td>CONC.</td>
<td>CONC.</td>
<td>CONC.</td>
<td>CONC.</td>
<td>CONC.</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Empty</td>
<td>T/Y</td>
</tr>
<tr>
<td>CHP-50</td>
<td>0.67</td>
<td>0.7</td>
<td>CONC.</td>
<td>CONC.</td>
<td>CONC.</td>
<td>CONC.</td>
<td>CONC.</td>
<td>CONC.</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Empty</td>
<td>T/Y</td>
</tr>
<tr>
<td>CHP-60</td>
<td>0.57</td>
<td>0.6</td>
<td>CONC.</td>
<td>CONC.</td>
<td>CONC.</td>
<td>CONC.</td>
<td>CONC.</td>
<td>CONC.</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Empty</td>
<td>T/Y</td>
</tr>
<tr>
<td>CHP-70</td>
<td>0.71</td>
<td>0.2</td>
<td>CONC.</td>
<td>CONC.</td>
<td>CONC.</td>
<td>CONC.</td>
<td>CONC.</td>
<td>CONC.</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Empty</td>
<td>T/Y</td>
</tr>
<tr>
<td>CHP-80</td>
<td>0.49</td>
<td>0.4</td>
<td>CONC.</td>
<td>CONC.</td>
<td>CONC.</td>
<td>CONC.</td>
<td>CONC.</td>
<td>CONC.</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Empty</td>
<td>T/Y</td>
</tr>
<tr>
<td>CHP-90</td>
<td>0.52</td>
<td>0.6</td>
<td>CONC.</td>
<td>CONC.</td>
<td>CONC.</td>
<td>CONC.</td>
<td>CONC.</td>
<td>CONC.</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Empty</td>
<td>T/Y</td>
</tr>
<tr>
<td>CHP-100</td>
<td>0.51</td>
<td>0.7</td>
<td>CONC.</td>
<td>CONC.</td>
<td>CONC.</td>
<td>CONC.</td>
<td>CONC.</td>
<td>CONC.</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Empty</td>
<td>T/Y</td>
</tr>
</tbody>
</table>

*Note: X indicates a presence of the compound, and S indicates traces of the specific compound.*
Appendix 2
Detailed Interpretations of the Food Lipid Residue Analyses

Stensborg

SB1
The sample contains high amounts of lipids: 9315µg lipids/g ceramic powder. The C₁₈₀/C₁₆₀ ratio is rather high: 244. The presence of waxes and the long-chain ketones as well as the traces of the isoprenoid phytanic acid give rise to the interpretation that the vessel contained a mixture of terrestrial animal products, and vegetables that has been heated. T/(V).

SB2
The sample contains relatively high amounts of lipids: 450µg lipids/g ceramic powder. The C₁₈₀/C₁₆₀ ratio is high, 3.25 and the C₁₇₈/C₁₈₀ ratio is low, 0.017. The narrow distribution of TAG (48-50) and the traces of cholesterol imply that the vessel contained terrestrial animal products. In addition to this, there are traces of waxes, the TMTD isoprenoid acid, and 16- and 18-o-(o-alkylphenyl) fatty acids. This signal is interpreted as a mixture of terrestrial and marine animal products, as well as vegetable products. T/A/V.

SB3
The sample contains very low amounts of lipids, 0.80µg lipids/g ceramic powder, and there are no further detectable signals present in the sample. However the internal standard (n-hexatriacontan) was detectable, indicating that the sample is empty. E.

SB5
The sample contains very low amounts of lipids, 0.36µg lipids/g ceramic powder, and there are no further detectable signals present in the sample. However the internal standard (n-hexatriacontan) was detectable, indicating that the sample is empty. E.

SB6
The sample contains high amounts of lipids: 1452µg lipids/g ceramic powder, and the C₁₈₀/C₁₆₀ ratio is rather high, 3.79. There are traces of waxes, the TMTD and TMPD isoprenoid fatty acids, and higher amounts of the TMHD, phytic acid. There are definable amounts of C₁₈₀ 16- and 18-o-(o-alkylphenyl) fatty acids. The signal is interpreted as T/A/V.

SB7
The sample contains high amounts of lipids: 149µg lipids/g ceramic powder, and the C₁₈₀/C₁₆₀ ratio is relatively high as well, 2.33.

The sample contains wax residues, and TMHD (phytic acid) isoprenoid acids, and traces of C₃₀ and definable amounts of C₁₆ and C₁₈ of the 16- and 18-o-(o-alkylphenyl) fatty acids. Signs that are interpreted as terrestrial-, and marine animal products as well as vegetable products. Furthermore, there are long chain ketones and triterpenoids present, indicating heating. T/V/ (A).

SB8
The sample contains 1.56µg lipids/g ceramic powder, and the overall signals are very low. There are however phytosterols present in the sample and the original vessel is interpreted as containing vegetable products. V.

SB9
The sample contains high amounts of lipids, 392µg lipids/g ceramic powder. The C₁₈₀/C₁₆₀ ratio is high, 8.89. There is a rather narrow distribution of TAG (46-50) and traces of cholesterols that indicate terrestrial animal products. There is also a presence of phytosterols and wax residues. Furthermore, there are traces of the isoprenoid, TMPD acid and a definable abundance of the TMHD, phytic acid. Something that could indicate a vegetable and marine animal content. Moreover, there are traces of the C₁₈₀ 16- and 18-o-(o-alkylphenyl) fatty acids acid, something that further indicate a marine animal presence. The long-chain-ketones present in the sample indicate that the vessel has been heated. T/A/V.

Korsnäs

CKP10
The sample contains rather low levels of lipids 5.77µg lipids/g ceramic powder. The C₁₈₀/C₁₆₀ ratio display low levels as well at 0.12. The sample is considered to be contaminated by modern products since there are a lot of unsaturated fatty acids present in the sample, which is a good indication of modern contaminations. Contaminated.

CKP18
The sample displayed relatively high amounts of lipids, 13µg lipids/g ceramic powder. The C₁₈₀/C₁₆₀ ratio at 0.74, indicate adipose fatty acids from terrestrial animal products. The phytosterols indicate that vegetable products
were processed in the vessel. The triterpenoids indicate traces of soot or smoke, something that could indicate that the vessel has been handled near fire. T/V.

**CKP28**
The sample display high amounts of lipids: 803µg lipids/g ceramic powder. The C\textsubscript{18:0}/C\textsubscript{16:0} ratio was however rather low, 0.22, thus indicating marine or vegetable contents. The sample displayed a narrow distribution of TAG (46-52). The cholesterol indicates traces of animal products, and the phytosterols vegetable residues. The presence of the isoprenoid acids, TMTD, TMPD and TMHD indicate marine contributions as well as possible oxidation of chlorophyll. The sample also contains traces of C\textsubscript{16}, C\textsubscript{22} and a definable amount of the C\textsubscript{18} and C\textsubscript{20} ω-(o-alkylphenyl) fatty acids, thus further indicating marine contributions as well as vegetable origin. This complex signal is interpreted as a mixture of marine (possibly lean fish), and vegetable products. A/V.

**CKP30**
The sample contained rather low levels of lipids: 3.65µg lipids/g ceramic powder. The high C\textsubscript{18:0}/C\textsubscript{16:0} ratio at 0.98 suggests terrestrial animal products. The sample contains both cholesterol and phytosterols implying both animal and vegetable contents. The sample contain both of the diterpenoid acids, and triterpenoid acids conveying traces of tar, soot and/or smoke, something that could reveal exposure to fire. T/V.

**CKP32**
The sample display high levels of lipids, 49.7µg lipids/g ceramic powder. The C\textsubscript{18:0}/C\textsubscript{16:0} ratio at 0.06, is to low in order to be indicative of terrestrial animal products. The sample further contains phytosterols and all of the isoprenoid fatty acids; an indication of marine animal products and vegetables. A (V).

**CKP35**
The sample contains high amounts of lipids, 1082µg lipids/g ceramic powder, and it was subjected to three reruns due to the abundance of lipids, and to some complications during the derivatisation process, e.g. small amounts of water in the vial. As a result of this, the sample was finally diluted with 1 ml n-hexane. The C\textsubscript{18:0}/C\textsubscript{16:0} ratio is 0.23. Waxes are present in the sample, together with all of the isoprenoid fatty acids. Furthermore, there are definable amounts of C\textsubscript{18} ω-(o-alkylphenyl) fatty acids in the sample, thus indicating a vegetable origin. This combined signal is interpreted as a result of marine animal products and traces of vegetable products. A/N.

**CKP36**
The sample displayed high amounts of lipids, 104µg lipids/g ceramic powder. The C\textsubscript{18:0}/C\textsubscript{16:0} ratio is also relatively high at, 0.97, as well as the C\textsubscript{17:0}/C\textsubscript{18:0} at 0.12. The sample is considered to be contaminated by modern products, and is thus excluded from the final interpretation. **Contaminated.**

**CKP37**
The sample contains 0.51µg lipids/g ceramic powder, and the C\textsubscript{18:0}/C\textsubscript{16:0} is rather low at 0.20, thus indicating marine/vegetable contents. There are traces of cholesterol and definable amounts of phytosterols. The sample and the original vessel are interpreted as containing marine/vegetable products. A/V.

**CKP44**
The sample contains relatively high amounts of lipids 151µg lipids/g ceramic powder, as well as the C\textsubscript{18:0}/C\textsubscript{16:0} ratio at 0.94. The C\textsubscript{17:0}/C\textsubscript{18:0} ratio display levels at 0.05 thus presenting a possible presence of ruminant animal products. The cholesterol and phytosterols present in the sample indicate animal and vegetable products. The vegetable presence is further confirmed by waxes. Definable amounts of all of the isoprenoid fatty acids indicate marine animal products; the combination with the traces of C\textsubscript{16} and C\textsubscript{22} and definable amounts of C\textsubscript{18} and C\textsubscript{20} ω-(o-alkylphenyl) fatty acids, contribute to the marine animal signals as they become more evident. T/A/V.

**CKP45**
The sample display low amounts of lipids, 0.41µg lipids/g ceramic powder. The C\textsubscript{18:0}/C\textsubscript{16:0} ratio is low as well, 0.32. There are traces of phytosterols in the sample, however in addition to this there are no other detectable signals present in the sample. V.

**CKP15**
The sample contains 42.3µg lipids/g ceramic powder. The C\textsubscript{18:0}/C\textsubscript{16:0} ratio is relatively low at, 0.13, thus indicating a content of marine animal, and/or vegetable products. There are traces of TAG present in the sample. The present phytosterols and the phytanic (TMHD) isoprenoid acid are interpreted as signals deriving from vegetable products. Traces of TMPD and definable amounts of TMTD as well as traces of C\textsubscript{18} and definable amounts of the C\textsubscript{18} ω-(o-alkylphenyl) fatty acid are interpreted as indicators of marine animal content in the vessel. Furthermore, there are traces of the diterpenoid, dehydroabietic acid in the sample. These traces suggest a vessel use close to, or
directly in fires, possibly as a cooking vessel.

**CKP20**
The sample contains low amounts of lipids, 3.7µg lipids/g ceramic powder, and the C\(_{18:0}/\)C\(_{16:0}\) ratio is relatively low as well at 0.18. There are TAG present, however they display a rather narrow distribution (46-50). There are traces of TMTD and TMDP and definable amounts of TMHD, indicators of marine animal products. The TMHD, phytanic acid is also a possible product of oxidized chlorophyll, and in combination with the phytosterols this is an indication of vegetable products. The final interpretation suggests a marine animal and vegetable content. A/V.

**CKP38**
The sample contains 2.6µg lipids/g ceramic powder, and display a C\(_{18:0}/\)C\(_{16:0}\) ratio of 0.43 possibly indicating marine and vegetable products. The TAG distribution is rather narrow (44-52). The presence of cholesterol indicate animal products, and in this case probably lean fish. The phytosterols and waxes suggests vegetable products. The interpretation of the past vessel use is therefore marine animal products and vegetable products. A/V.

**CKP41**
The sample contains high amounts of lipids, 1608µg lipids/g ceramic powder. The C\(_{18:0}/\)C\(_{16:0}\) ratio is low: 0.19, and the TAG distribution is narrow (44-48), thus indicating a marine/vegetable content. The presence of cholesterol and the TMHD isoprenoid fatty acids confirm a marine animal presence, possibly lean fish. A.

**CKP49:1**
The sample contains 4.35µg lipids/g ceramic powder. The C\(_{18:0}/\)C\(_{16:0}\) ratio is low: 0.15. The TAG distribution is narrow (44-50). In addition to this there are phytosterols present in the sample, indicating vegetable contents. The sample and the original vessel are interpreted as containing lipids of vegetable origin. V.

**CKP49:2**
The sample contain 2.09µg lipids/g ceramic powder lipids. The C\(_{18:0}/\)C\(_{16:0}\) ratio is low: 0.86. The presence of both cholesterol and phytosterols is interpreted as traces of terrestrial animal and vegetable contents. T/V.

**KPD7**
The sample contains 0.88µg lipids/g ceramic powder, and the C\(_{18:0}/\)C\(_{16:0}\) ratio is also rather low 0.66. The sample display high amounts of unsaturated fatty acids, and since they are fragile over archaeological time these fatty acids are interpreted as modern contaminations, and the sample is thus excluded from the study. **Contaminated.**

**KPD17**
The sample contains 2.69µg lipids/g ceramic powder. The C\(_{18:0}/\)C\(_{16:0}\) ratio is high: 0.73. The TAG distribution is narrow (48-50). There are both phytosterols and waxes present in the sample. T/V.

**KPD26**
The sample contains very low amounts of lipids, 0.04µg lipids/g ceramic powder. No other signals were detected in the sample except for phytosterols. The interpretation of the original vessel use is connected to vegetable products. V.

**KPD36**
The sample contains rather high amounts of lipids: 14.13µg lipids/g ceramic powder. The C\(_{18:0}/\)C\(_{16:0}\) ratio is high as well, 0.66. However, there are large amounts of unsaturated fatty acids present in the sample as well, thus indicating modern contaminations. The sample is excluded from the study. **Contaminated.**

**KPD58**
The sample contains 1.76µg lipids/g ceramic powder. The C\(_{18:0}/\)C\(_{16:0}\) ratio is high, 1.04, indicating terrestrial animal products, something that is confirmed by the presence of cholesterol. The plant sterols are also present in the sample, and the sample is interpreted as containing terrestrial animal products as well as vegetable products. T/V.

**KPD201**
The sample displays very low amounts of lipids: 0.07µg lipids/g ceramic powder. There are no detectable amounts of any biomarkers found in the sample, however the internal standard (n-hexatriacontan C\(_{36}\)) has been detected and the vessel is thus interpreted as being empty. E.

**KPD203**
The sample contains low amounts of lipids: 0.58µg lipids/g ceramic powder. The C\(_{18:0}/\)C\(_{16:0}\) ratio is rather high however, 1.68. The presence of phytosterols and traces of waxes together with the C\(_{18:0}/\)C\(_{16:0}\) ratio is interpreted as the traces of terrestrial animal and vegetable contents. T/V.

**KPD206**
The sample contains low amounts of lipids: 0.26µg lipids/g ceramic powder. The C\(_{18:0}/\)C\(_{16:0}\) ratio is high: 1. The high ratio together with the presence of cholesterol entails the sample to be interpreted as containing terrestrial animal
products. Furthermore, there are phytosterols and waxes present in the sample as well, and the sample is thus interpreted as containing vegetable lipids and terrestrial animal products.

**T/V.**

**KPD207**
The sample contains very low amounts of lipids, 0.06µg lipids/g ceramic powder. There are no detectable amounts of any biomarkers and the vessel, however the internal standard (n-hexatriacontan C36) is detected in the sample, and it is therefore interpreted as being empty. **E.**

**KPD209**
The sample contains high amounts of lipids: 174µg lipids/g ceramic powder, the C18:0/C16:0 ratio is high as well: 0.53. The sample contains high amounts of unsaturated fatty acids and is thus interpreted as contaminated by modern compounds, and is thus excluded from the study. **Contaminated.**

**KPD56**
The sample display very low amounts of lipids: 0.14µg lipids/g ceramic powder. Phytosterols are the only detectable biomarkers found in the sample and the original vessel is thus interpreted as containing vegetable products. **V.**

**KPD70**
The sample contains high amounts of lipids: 30µg lipids/g ceramic powder. The C18:0/C16:0 ratio is high as well: 0.6. There are high amounts of unsaturated fatty acids, and the sample is therefore interpreted as being contaminated by modern compounds and is thus excluded from the study. **Contaminated.**

**KPD40:1**
The sample contains 2.5µg lipids/g ceramic powder. The C18:0/C16:0 ratio is high, 1.4, thus indicative of the presence of terrestrial animal products in the sample. The presence of phytosterols further indicate vegetable contents as well. **T/V.**

**KPD40:2**
The sample contains 0.99µg lipids /g ceramic powder. The C18:0/C16:0 ratio is high displaying amounts at: 1.6. The presence of phytosterols together with the C18:0/C16:0 ratio entails the interpretation that the sample and original vessel contained vegetable and terrestrial animal products. **T/V.**

**KPD39**
The sample contains high amounts of lipids: 165µg lipids /g ceramic powder. The sample is interpreted as being contaminated by modern compounds and it is thus excluded from the study. **Contaminated.**

**FD220**
The sample contains high amounts of lipids: 27µg lipids /g ceramic powder. The C18:0/C16:0 ratio is rather low: 0.44. The TAG distribution is narrow (44-48). The presence of cholesterol and traces of the THTD together with definable amounts of TMHD isoprenoid fatty acids entails that the final interpretation is marine animal products. **A.**

**FD228**
The sample contains very high amounts of lipids: 461µg lipids/g ceramic powder. The C18:0/C16:0 ratio is low, 0.36. The C17:0/C18:0 ratio is however rather high, 0.03. Cholesterol is present in the sample, thus indicating animal products. All isoprenoid fatty acids are present together with the C16 α-(ω-alkylphenyl) fatty acids, thus indicating marine animal products in the sample. Furthermore, there are traces of long-chain ketones in the sample as well, indications of heating. **A.**

**FD136**
The sample is interpreted as being contaminated. **Contaminated.**
Appendix 3

Table displaying total amount of absorbed lipids, the lipid distribution in each sample, as well as the interpretation.

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Amount (ng/g)</th>
<th>Neutral lipids</th>
<th>intact triacylglycerols</th>
<th>cholesterol</th>
<th>free sterol</th>
<th>free sterol</th>
<th>wax residue</th>
<th>Isoprenoid fatty acids</th>
<th>w-(O-alkyl)-fatty acid terpenoids</th>
<th>Interpr.</th>
</tr>
</thead>
<tbody>
<tr>
<td>FPA1</td>
<td>1.8</td>
<td>C18:0/C16:0 (0.48)</td>
<td>cont-</td>
<td>cont-</td>
<td>cont-</td>
<td>cont-</td>
<td>cont-</td>
<td>cont-</td>
<td>cont-</td>
<td>cont-</td>
</tr>
<tr>
<td>FPA2</td>
<td>1.3</td>
<td>C17:0/C18:0 (0.02)</td>
<td>cont-</td>
<td>cont-</td>
<td>cont-</td>
<td>cont-</td>
<td>cont-</td>
<td>cont-</td>
<td>cont-</td>
<td>cont-</td>
</tr>
<tr>
<td>FPA3</td>
<td>2.9</td>
<td>cont-</td>
<td>cont-</td>
<td>cont-</td>
<td>cont-</td>
<td>cont-</td>
<td>cont-</td>
<td>cont-</td>
<td>cont-</td>
<td>cont-</td>
</tr>
<tr>
<td>FPA5</td>
<td>5.2</td>
<td>no C18:0</td>
<td>no C18:0/C17:0</td>
<td>cont-</td>
<td>cont-</td>
<td>cont-</td>
<td>cont-</td>
<td>cont-</td>
<td>cont-</td>
<td>cont-</td>
</tr>
<tr>
<td>FPA6</td>
<td>5.9</td>
<td>no C18:0/C16:0</td>
<td>cont-</td>
<td>cont-</td>
<td>cont-</td>
<td>cont-</td>
<td>cont-</td>
<td>cont-</td>
<td>cont-</td>
<td>cont-</td>
</tr>
<tr>
<td>FPA7</td>
<td>1.6</td>
<td>no C18:0/C16:0</td>
<td>cont-</td>
<td>cont-</td>
<td>cont-</td>
<td>cont-</td>
<td>cont-</td>
<td>cont-</td>
<td>cont-</td>
<td>cont-</td>
</tr>
<tr>
<td>FPA8</td>
<td>1.0</td>
<td>no C18:0/C16:0</td>
<td>cont-</td>
<td>cont-</td>
<td>cont-</td>
<td>cont-</td>
<td>cont-</td>
<td>cont-</td>
<td>cont-</td>
<td>cont-</td>
</tr>
<tr>
<td>FPA9</td>
<td>2.4</td>
<td>no C18:0/C16:0</td>
<td>cont-</td>
<td>cont-</td>
<td>cont-</td>
<td>cont-</td>
<td>cont-</td>
<td>cont-</td>
<td>cont-</td>
<td>cont-</td>
</tr>
<tr>
<td>FPA10</td>
<td>20.7</td>
<td>empty</td>
<td>empty</td>
<td>empty</td>
<td>empty</td>
<td>empty</td>
<td>empty</td>
<td>empty</td>
<td>empty</td>
<td>empty</td>
</tr>
<tr>
<td>FPA11</td>
<td>5.7</td>
<td>0.1</td>
<td>empty</td>
<td>empty</td>
<td>empty</td>
<td>empty</td>
<td>empty</td>
<td>empty</td>
<td>empty</td>
<td>empty</td>
</tr>
<tr>
<td>FPA12</td>
<td>105.3</td>
<td>0.36</td>
<td>empty</td>
<td>empty</td>
<td>empty</td>
<td>empty</td>
<td>empty</td>
<td>empty</td>
<td>empty</td>
<td>empty</td>
</tr>
</tbody>
</table>

AV= Aquatic animal/Vegetable, E= Empty, and Cont.= Contaminated. The X's indicate a presence of the compound, and an S indicates traces of the specific compound.