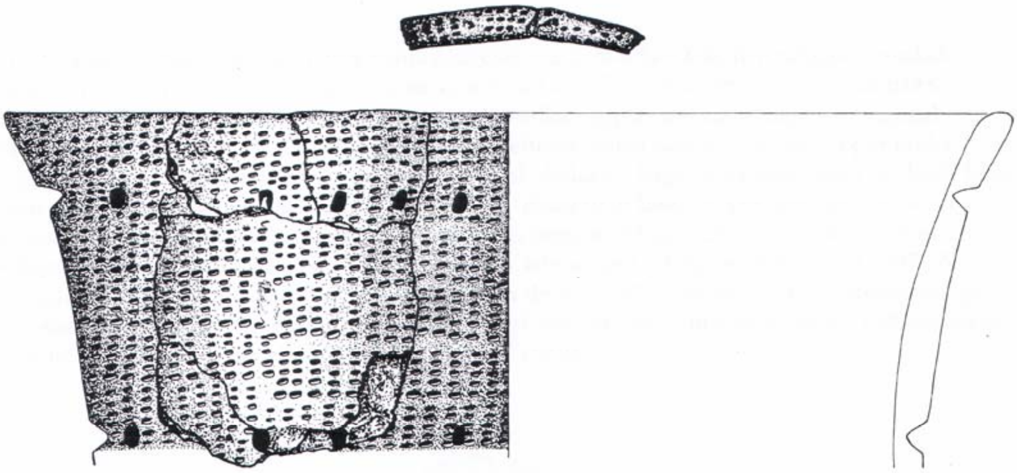
Distinguished by Culture

A study of lipid residue content in Neolithic potsherds from Trössla and Överåda in the parish of Trosa-Vagnhärad, Södermanland, Sweden.



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Abstract

The thesis is concerned with pottery and vessel use during the Neolithic (c. 4000 -2500 cal BC). Pottery from Funnel Beaker culture (in Swedish “trattbägarkultur”) and Pitted Ware culture (in Swedish “gropkeramisk kultur”) have been analysed for lipid residue content. The material comes from two sites, Trössla and Överåda in the parish of Trosa-Vagnhärad, in eastern central Sweden. Vessel use can show if food or other products were processed or stored in them. The lipid residue content in Neolithic pottery from this area has not been studied earlier. The results will contribute with new knowledge on vessel use in the Funnel Beaker and Pitted Ware culture at Trössla and Överåda.

Keywords: *Funnel Beaker culture, Pitted Ware culture, Neolithic, Trosa-Vagnhärad parish, lipid residue content, vessel use.*

Cover illustration of a reconstruction of a funnel beaker from Trössla by Gunnel Graner (Hallgren 2004a:29). This vessel has been analysed and has identity T15.

Contents

1. Introduction

The introduction of ceramic technology has been considered to be an important cultural step and the question why some cultures started to make pottery and other groups did not has been debated for a long time. The presence or lack of pottery has been connected to ideology and cultural identity. In the end, a group of people could see themselves as pottery makers and see the advantages of using ceramic vessels. The use of pottery can be seen as a practical decision to adopt a new kind of equipment that could make life easier. Potsherds are often found in large amounts at excavations of Neolithic settlements. According to shape and décor different Neolithic styles have been established and connected to a specific culture. Therefore, the pottery has been used to both from the perspectives to date Neolithic sites and to recognize a cultural identity.

In eastern central Sweden pottery was introduced during early Neolithic (3900-3300 cal. BC) and related to the Funnel Beaker Culture (TRB). It is also argued that this group of people chose a settled farming life (Hallgren 2004a:123f).There seem to be a relationship between the start of farming and the manufacturing of pottery (Gill 2003:43). The shape of the vessels have given name to this culture. The type of TRB pottery found in eastern central Sweden is often called Vrå pottery (in Swedish “Vrå-keramik”) after the Neolithic site at Vrå, Södermanland. The TRB sites have been found both in inland parts and close to the seashore. Around 3300 cal. BC a different type of ceramic emerged with the Pitted Ware Culture. The pottery is named pitted ware after the decoration of pits (in Swedish “gropkeramik”).This study will discuss the outcome of analyses of possible lipid residues in potsherds from two Neolithic sites in Trosa-Vagnhärad parish representing both TRB and PWC. One interesting aspect is that bones from cattle found at Trössla have been radiocarbon dated to c. 3900 BC. So the TRB pottery from Trössla can be assumed to be much older than the PWC pottery. A map over the area and the location of the sites can be seen in Figure 1.

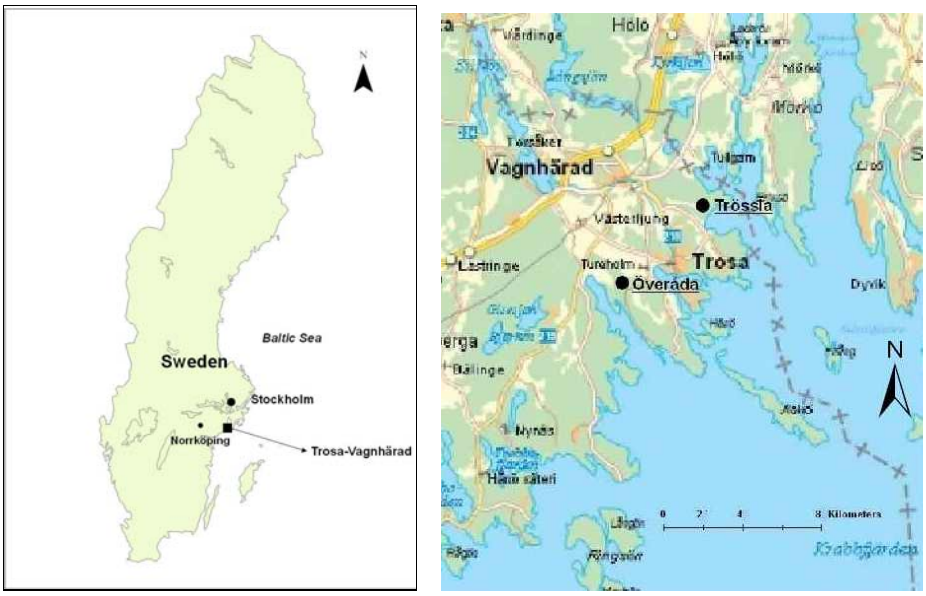


Figure 1. Map with the area around Trosa-Vagnhärad parish and the Neolithic sites Överåda and Trössla marked. Maps from the websites of Lantmäteriverket and Trosa, modified by the author.

The lipid residue content can show what has been stored or processed in a specific vessel. As there are many ways to process food without pottery this approach can not be used to determine the whole range of food that was consumed. In dietary studies analyses of stable carbon, nitrogen and sulphur isotopes of in bone materials are performed.

1.1 A theoretical approach to archaeological science

According to the Finnish Oxford philosopher Georg Henrik von Wright (1916-2003) there are two separate main traditions in the philosophy of scientific methods. These two scientific activities could be termed *descriptive* and *theoretical* science (von Wright 1981:1). The difference between *Erklären* (explain), linked to natural science, and *Verstehen* (understand), linked to human science, is of fundamental importance. This concept was presented by the German historian Johann Gustav Droysen (1808-1884) and further developed by his countryman the philosopher Wilhelm Dilthey (1833-1911). In everyday language, one does not make a sharp distinction between the words "explain" and "understand". According to von Wright "understanding" has a psychological ring but "explanation" has not. von Wright refers to the German philosopher Georg Simmel (1858-1918) who regarded understanding as a form of empathy (in German *Einfühlung*) or re-creation. In the mind of the scholar were thoughts, feelings and motivations for the studied object (von Wright 1981:4 ff). Returning to the two traditions in Western philosophy as described and defined by von Wright, one is named the "Continental tradition" and the other "Galilean tradition". The "Continental tradition" goes back to Aristotle and Giambattista Vico. Later in the 20th century, these thoughts were developed into hermeneutics. This rather diffuse term covers a wide range of scholars for example neo-Heglians as Benedetto Croce (1860-1952) and R G Collingwood (1989-1943) as well as non-Heglians as Dilthey, Simmer and Hans-Georg Gadamer (1949-1968). The other "Galilean" (natural scientific) tradition goes back to Galiieo, Bacon and to logical positivism (Saari 1984:15; von Wright 1981:1ff).

To study archaeological artefacts with chemical methods can be seen as a challenging mix of human-hermeneutic and scientific methods. In this field, I regard R. G. Collingwood as a good example. Collingwood was a British philosopher and historian but also an archaeologist. Two philosophers with very different views influenced him. The Italian philosopher Benedetto Croce (1866-1952) represented a hermeneutic approach and the British philosopher Francis Bacon (1561-1626) had a strict scientific view. Bacon wanted to understand nature by asking questions to nature. In the same way, Collingwood saw a way to investigate prehistoric times with specific questions and getting answers (Collingwood 1994:269; 2002:124; van der Dussen 1994:xxxi). In the hermeneutic line, Collingwood developed a special attitude in approaching the past: *re-enacting*. To try to "re-perform" the past seems to me to have much in common with Simmel´s empathy or *Einfühlung* (Collingwood 1994: 282 ff; Saari 1984).

From a very humble view, my ambition is to put questions to the Neolithic on vessel use. Hopefully I can get answers from my own and others analyses of potsherds to come closer to people living in the past.

1.2 Aim

The timeframe of interest is Early Neolithic (4200-3300 BC) and Middle Neolithic (3300-2350) in the region of Trosa-Vagnhärad parish. The aim of this work is to study Neolithic pottery from Trössla and Överåda representing two different cultures, the Funnel Beaker Culture (TRB) and the Pitted Ware Culture (PWC), existing at different periods of time. TRB is supposed to belong to the period of Early Neolithic and PWC to Middle Neolithic. PWC replaced TRB in eastern central Sweden around 3300 BC (Carlsson 1998:38, 41, 48; Malmer 2002:50; 127; Larsson 2008:83). Another opinion is that PWC developed parallel with TRB (Åkerlund 2000:18). As there are no findings from the Battle Axe Culture (BAC) in the studied area, I will not discuss pottery from that culture.

The concept of culture often refers to artistic activities or life-styles. The ceramic characteristics and design of pottery found at archaeological excavations have been used to identify different cultures, economies and chronology. From Överåda potsherds from PWC is analysed and from Trössla both TRB and PWC. The relationship between these cultures has been a subject of controversy for a long time. Different models have been used to visualize the time periods of these cultures and if they existed at the same time or not. These cultures used the same area in the landscape so often pottery from both cultures can be found at the same place. The TRB and PWC pottery can be classified in different styles representing different time periods.

The focus on the archaeological material will be on the interpretation of the lipid residue content in potsherds and vessel use and not so much on style and craft tradition. No attempts to discuss the stone materials will be done. Regarding the classification of the studied material to pottery in TRB and PWC I totally rely on the statement from experts. When scientific analyses on archaeological artefacts are used for interpretation of a specific question, it is important to discuss possibilities and limitations of the method. The lipid residue content in prehistoric pottery can be chemically analysed after extraction and derivatization. With this method, it is possible to distinguish between lipids originating from vegetable, terrestrial or marine animal or mixed origin (Isaksson 2000; Charters et al 1993; Craig et al 2007). Earlier investigations have shown a change in vessel-use around 3000 cal BC resulting in a decrease in lipid residues. This could mean that cooking was to a larger extent performed with other methods than using pottery as roasted on embers or in a cooking-pit (Brorsson et al 2007:431).

The chemical method used for the determination of lipid residues in pottery is an important part of this work and will be discussed in terms of selectivity, accuracy, precision and recovery. The issue of a chronological period for TRB and PWC are discussed from available radiocarbon dating. So the approach is based on a hermeneutic understanding of published data in the field together with new experiments. The determination of the origin of the lipid residues in archaeological ceramics can add information on the question if they were farmers or hunters. My hypothesis is that the lipid analyses will give evidence that the vessel use was different between the TRB and PWC societies in this geographical area and time-period. Earlier investigations have not included analysis of the lipid residue content of Neolithic potsherds from Trössla and Överåda so these analyses will contribute with new knowledge. This is also the first attempt to compare the pottery-use of two adjacent sites in eastern central Sweden connected to the TRB and PWC cultures respectively.

The questions asked can be summarised in the following points:

- What are the possibilities and limitations of the chemical methods used for lipid residue analyses?
- Can the results of the lipid residue analysis of these potsherds show if TRB and PWC had different "life-styles" and vessel use?

2. The Funnel Beaker Culture and the Pitted Ware Culture

2.1 About Neolithic ceramics and cultures

A crucial feature when TRB and PWC are discussed is the style of their pottery. This has been one important characteristic used to assign a site to a specific culture. I have adopted the traditional view to use TRB and PWC as cultures connected with a specific pottery and assume that TRB is older than PWC in eastern central Sweden. J. Strange also used by Orton et al can illustrate the aspect of identity and pottery with this quotation.

"It (a pot) may mean that I, as the ancient owner of this vessel, belong to *this* group, and believe *these* things, that I have *this* level of wealth, and *this* much status. I am also of a specific sex, and perform *these* labours defined to my sex, and this vessel correlates with *this* sex and *these* labours" (Orton et al 1993:227f).

First, some thoughts about the ceramic tradition and the use of pottery in different societies will be discussed. The handicraft needed to produce ceramic artefacts is clay and temper together with the knowledge of heating the object to a lasting piece. When vessels are produced, different hand-built techniques have been used as coil building and modelling (Stilborg 2002:17ff).

During late Mesolithic (5400-3900 cal BC) people living in eastern Sweden, Mälardalen, had not adopted ceramic technology in contrast to other people around the Baltic. Hunter-gatherers from Germany in the south to northern Finland in north started to manufacture and use pottery around 5000 cal. BC (Hallgren 2004a:125; 2008:58). The introduction of pottery has been considered to be part of a domesticated economy with farming, agriculture and a settled life. The adoption of pottery can be seen as a choice based on shaping an identity and not just a technological choice. One example against the relationship between pottery and domestication is that seal-hunters on Åland did not take up agriculture but used pottery (Hallgren 2008:35; 57). Their pottery was made of clay not available on the island. So either the vessels or the clay was transported to Åland from Finland (Hallgren 2004a:126). The reason for not choosing to adopt the ceramic tradition or agriculture can be that the people did not see themselves as pottery makers or farmers (Hallgren 2008:70). Therefore, I believe that when ceramic became part of the society it was because they had mentally changed their cultural identity. The transformation of clay to pots can be seen as a process of sharing the handicraft in the group. Another hypothesis for the delay and than the rapid spread of Neolithic process is that an opposition against the traditional way of living resulted in a conflict leading to the sudden acceptance of pottery and farming (Malmer 2002:18f). Based on available radiocarbon dating the Neolithic process in present Sweden took about 100-200 years to spread from Scania up to Uppland (Malmer 2002:25).

As already mentioned the early Neolithic TRB period in Mälardalen started around 3900 cal BC and was replaced by PWC around 3300 cal BC (Larsson 2008:83; Malmer 2002:127). There are some disagreements on the relationship between TRB and PWC. The questions if these cultures were contemporary or not and if PWC was a continuation or an aspect of TRB have been argued for a long time. Another opinion has been that PWC partly developed parallel with TRB in eastern central Sweden (Åkerlund 2000:18). The co-existence of TRB and PWC populations on Öland has been demonstrated. Bones and teeth from human individuals have been investigated with different techniques as radiocarbon dating, carbon and nitrogen isotope analyses and DNA technology (Linderholm 2008; Eriksson et al 2008:520ff).

Why pottery? The thermal processing of food could take place in pit hearths or a cooking pit. The most important issue for cooking the food is that it increases the nutrient density and enhances the flavour of the food. Other advantages with pottery have been pointed out as the fact that ceramic vessels can be heated to higher temperatures than vessels of skin or birch-bark. Then microbes will not survive and inedible roots and vegetables will be detoxified (Craig 2007:148f). Pots could be used for storage of marine and terrestrial resources (Welinder 1976:28; Åkerlund 1996a:93). The use of ceramic vessels for storage could also hinder animals from eating the content (Stilborg 2002:14). I have not found many references to finds of ceramic lids as artefacts so perhaps the vessels were closed with some organic material. Pieces of clay discs have been found but their function is not fully understood. They could have been used as heaters (Hulthén&Welinder 1981:127) or for baking (Malmer 2002:29).

Regarding the size and weight of one pot it is not a far-reaching assumption that pottery was associated with dwelling sites. To make pottery you needed raw material as clay, temper and firing. This procedure takes many days and needs skill to form, decorate and dry the vessels to avoid cracks. The procedure to fire the goods also needed skill. An attempt to estimate the amount of pottery needed and the lifetime of it can be based on the potsherds found at a site. The diameters of the vessels vary from 4 to more than 40 cm. The miniature vessels have not been used for cooking but could be a part of burial ceremony. From ethnographic studies, the following vessel life expectancy and use have been estimated. The volumes of cooking vessels are from 3-20 litres and for vessels for storage up to 40 litres. Small vessels, bowls and cups, have a capacity of 1-2 litres. The median age in years is 2.5 for vessels up to 10 litres and more than 10 years for the largest pots. Pots with daily contact to fire and regularly moved has the shortest life span. Other factors are the basic strength of the vessels. Animals damaged many vessels. It was observed that pots were handled with more care in places where no production of pottery took place (Orton et al 1993:207ff).

The amount of pots needed at a site can only be estimated in a rough outline. Other materials as skin or birch-bark have not been preserved over time so artefacts of stone and ceramic are what can be found in the archaeological material. At Överåda about 300 kg of potsherds were found at an excavation in 1969. Stig Welinder estimated that this assemblage originated from 150 vessels based on the amount of different rim sherds and a weight of one complete Pitted Ware pot to 0.5 – 5 kg. According to calculations made by Hultén and Welinder a production of 25-30 vessels of normal size could be fired at the same time (Hultén &Welinder 1981:118). Welinder has also approximated the number of a household in the Neolithic to 6-7 persons (Welinder 1998:201).If four households lived together I think that they needed 8-10 pots. If a vessel holds for 2-3 years, the production of pottery was not a task performed frequently. Also vessels probably broke in the firing step of the manufacturing and this could lead to a miscalculation of the size of the ceramic assemblage and would also result in potsherds without traces of lipids.

One interesting vessel has been found at Skogsmossen, Västmanland, deposited in a sacrificial fen. From this vessel ^{14}C dating from a foodcrust and a grain found enclosed in the clay gave evidence that the vessel had been used for a long time before the deposition. This vessel was also one of the most beautiful vessels found at the site. An interpretation is that it was kept as an heirloom and then finally deposited (Hallgren 2008:88).

The use of the décor of the vessel to give a chronological sequencing of the pottery is based on the idea that pottery with the same décor is contemporary. Welinder has questioned this concept for a long period among others. His point is that differences in the decoration can depend on local variations (Welinder 1987:104). One explanation of the fact that the same or very similar decoration can be found in areas far from each other at the same time is that the handicraft was taught and spread rapidly over a large area. Nevertheless, other factors as material, temper and polish of the surface are important, as undecorated pottery is common. Many decoration elements are the same for TRB and GRK pottery (Welinder 1987:114; Hallgren 2008:139; 153). In my opinion, the thought that certain patterns and also the shape of the vessel are associated with their content is interesting. Some elements as pit impressions could have a practical function as well as decorative. Sherds have also been decorated on the inside, interior surface, of the vessel and this decoration has been hidden. The reason for this action can have a symbolic significance and might have been related to the intended use of the vessel. In this case the decoration consists of comb stamps (Papmehl-Dufay 2006:146 and given references). In my samples from Överåda, some sherds are decorated on both the exterior and interior surface. One was covered with comb stamps on both sides of the vessel (Sample Ö3).

The occurrence of single sherds of deviating design in the assemblages from different sites can have a possible explanation if not only vessels but also sherds were circulated and exchanged between the sites and group of people as part of a network (Stenbäck 2003:199).

Large-scale area investigations in different parts of Sweden due to infrastructural ventures have given new information on the location of Neolithic sites and settlements. The E4 Highway-project in Uppland revealed earlier unknown Neolithic sites. The pottery from this excavation and from earlier known settlements in the vicinity was studied for changes in vessel ware, shape, temper and decorative elements over time. Radiocarbon dating of foodcrusts from sherds from different levels above the seashore was used to relate the styles to a chronology. This method showed that there were some overlaps between the styles due to inaccuracy of the ^{14}C method. The result of this investigation was that a new typology and chronology for Neolithic pottery in eastern Sweden could be proposed (Ytterberg 2007:369ff).

2.2 The Funnel Beaker Culture

The typology of TRB for this region was prepared by Florin and is called Vrå pottery after the Vrå site (Florin 1958:81ff). The material has a hard and dense structure and crushed granite as temper (Florin 1958:85f; 122). It was technically of high class with a variety of vessel shapes (Malmer 2002:28). The vessels had different shapes as funnel-necked beakers and collared flasks. The pots had a sparse decoration at the rim of cord impression, lines and pit incisions (Florin 1958:80ff). In addition, impressions of grains and grape seeds have been found (Florin 1958:88). It has later been disputed if the impression of grape seed was a correct interpretation (Bagge 1950:253).

In the material from Trössla potsherds with these typical features have been found. Funnel-necked beakers, collared flask and decorated sherds with cord impression and pit incisions have been identified. Sherds with sparse decoration from the north side have been classified as Vrå I. These sherds are supposed to be older than the more decorated ones found at the south side and classified as Vrå II (Hallgren 2004b:25).

The TRB sites in Mälardalen can be found both in inland and at the coast. Inland sites are often situated in wooded ground that has not been used since Neolithic. Coastal sites have often been used over a long time and artefacts from a long period can be found. Due to frost heaving the vertical position of artefacts in the soil was disturbed. Ground frost also has a negative influence on the stability of the pottery (Hallgren 2008:76).

2.3 The Pitted Ware Culture

The PWC sites are situated along the shoreline of the coast often on a steep slope in the direction of southwest to south in shelter of a hill. The sites can have an area up from 500 to 90000 m^2 (Edenmo et al 1997:173; Olsson 1996:44).

The traditional typologies of PWC pottery styles for eastern Sweden have been established using the chronology from excavations at the Neolithic sites at Säter and Fagervik near Bråviken. The different stages are grouped mainly according to the form, surface-covering ornaments and form of the vessels. These styles have resulted in a chronological classification scheme named Säter II-IV and Fagervik II-IV. The Fagervik styles were based on shore displacements and topographical conditions (Bagge 1951).

Very often large quantities of sherds of pottery have been found at excavations of PWC sites. The amount of potsherds from Överåda found at the excavation has already been mentioned and was estimated to originate from 150 different pots (Welinder 1971:26).This large amount can be interpreted in different terms. If the sites were non-permanent and only used occasionally for hunting and fishing pottery could have been left behind (Carlsson 1987:233f). The deposition of fragmented pottery at the edge of the shore can come from processing marine products or from ritual activities related to fishing. It can also be seen as an alternative to monument construction (Åkerlund 2000:18).

As mentioned earlier the different ceramic styles can be defined in different ways. The PWC styles have been named after an excavated site where different styles have been found. Today most PWC pottery is often grouped in styles defined from the settlement site of Fagervik (Krokek parish), Östergötland. A very large assemblage of 170000 potsherds was found at this place. The position of the potsherds was registered for every half metre vertically between 31 to 21 m a.s.l. Based on the decoration and the assumption that earliest artefacts were found at a higher level than the later ones a typology of FagervikI-IV was defined (Malmer 2002:77ff).

In addition, radiocarbon dating of foodcrusts has been used to establish a chronology for sherds. It is not necessarily that the foodcrusts in the vessels come from heating on fire but could be the result of fermenting porridge (Arrhenius 1981: 7ff).The chemical pre-treatment of the foodcrust is crucial as the sample for radiocarbon dating must be free of contaminants. Otherwise, this can give a false dating. A refined method was established by Segerberg et al and applied on foodcrusts from sherds representing Säter II and III. The result from this study was that the sherds from Säter II gave expected data and the sherds from Säter III were somewhat older than expected. The $\delta^{13}C$ values suggested a terrestrial origin of the foodcrust. Therefore, reservoir effects did not affect the radiocarbon dates (Segerberg et al 1991:83ff). The results from another study also using carbon dating of sherds from PWC sites to classify pottery in terms of Fagervik styles are presented in Table 1 (Edenmo et al 1997:184).

Table 1. Radiocarbon dating of sherds from PWC sites presented in terms of Fagervik styles. Data from Edenmo et al 1997:184. Translated to English by the author.

Style	**^{14}C age BP (1σ)**	**Cal BC (1σ)**	**Number of sherds**	**Archaeological period**
Fagervik I	5030-4480	3890-3110	5	TN I-MN A
Fagervik II	4765-4100	3620-2610	13	TN II-MN B
Fagervik III	4860-4220	3650-2790	18	TN II-MNA
Fagervik IV	4450-4060	3090-2580	4	MN A-MN B

The same concept has also been used at another PWC site at Sittesta, Södermanland. The results from this investigation gave a chronology that is presented in Table 2 (Kihlstedt et al 2007:52).

Table 2. Radiocarbon dating of foodcrusts from PWC-sherds from Sittesta, Södermanland, presented in terms of Fagervik styles. Data from Kihlstedt et al 2007:52.Translated to English by the author.

Style	**^{14}C age BP**	**Cal BC (1σ)**
Fagervik I	4535 ±35, 4510 ±40, 4450 ±40	3360–3020 BC
Fagervik II	4430 ±40	3310–2930 BC.
Fagervik III	4470 ±40, 4360 ±40, 4300 ±40, 4260 ±40	3330–2770 BC.
Fagervik IV	4230 ±40, 4110 ±40	2910–2580 BC.

The results from Fagervik and Sittersta show some overlap and also a difference in dating perhaps due to the fact that the styles developed locally. My conclusion is that the transition from one style to another did not follow a strict pattern and that the adoption of a new décor and change in clay and temper developed locally. The same applies for TRB pottery as many elements in the décor are found in the PWC pottery. Therefore, I will leave this subject to experts and concentrate on the chemical analyses of lipid residue contents in potsherd.

2.4 Neolithic sites in the neighbourhood of Trosa-Vagnhärad parish.

There are ten known Neolithic sites in the parishes of Trosa-Vagnhärad and Västerljung. Pottery from the Pitted Ware Culture and Funnel Beaker pottery has been found. These sites have in common that they were situated close to the Neolithic seashore, today at about 30 metres altitude above the sea level (m a.s.l.). The Neolithic sites are marked in the map with the coastline at 30 m a.s.l. corresponding to c. 3000 B.C. in Figure 2. Some of the sites have been partly excavated as Överåda, Trössla, Djupvik and Sköttedal. During the last years two new Neolithic sites have been found (Klacka and Nora). They are not yet registered in the Register of Swedish National Heritage Board (Fornsök). The ceramic from all sites have been identified as PWC pottery and at Trössla and Sköttedal also a small amount of TRB pottery.

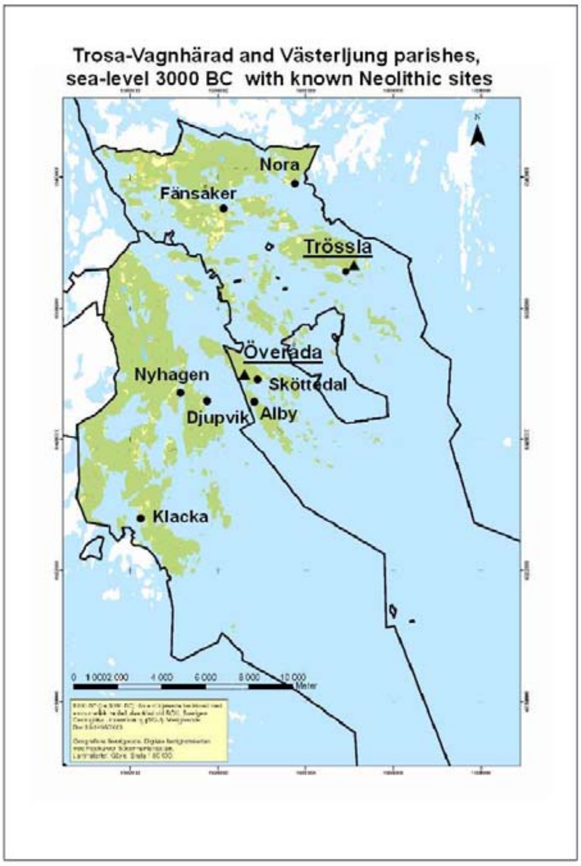


Figure 2. Map over the parishes of Trosa-Vagnhärad and Västerljung with sea level as it was 3000 BC. Known Neolithic sites marked with dots and Trössla and Överåda marked with triangles. Map from Patrik Gustafsson, Sörmlands museum and modified by the author.

2.4.1 Trössla

The eastern side of the gravel-pit at Trössla has been known as a Neolithic sites for a long time and is registered as RAM 270, Trosa-Vagnhärads parish. Artefacts of PWC and TRB such as pottery, separate bones, stone tools and fire-cracked stones have been found at this place (FMIS). Close to Trössla is another site RAM 233 situated with PWC pottery. During

Neolithic these sites at Trössla were situated on a small island. TRB settlements have been situated in the landscape in inland parts and in coastal locations. On sea facing sites, finds of bones of seal and fish have been found and on land facing sites bones from cattle and sheep or goat. It was more the activities related to a settlement than the actual location in the landscape that was of importance for this classification. With this view the north side of Trössla could be regarded as a land facing site based on the finds of bones from cattle and sheep and goat despite its location at the seashore (Hallgren 2008:92). In 2002 Boris Wredenmark, who earlier worked with national survey of ancient monument, discovered an earlier unknown area in the gravel-pit with pottery and stone tools (Henlert 2002). This discovery initiated an excavation in 2003 led by Fredrik Hallgren and reported in SAU Rapport 2004:7(Hallgren 2004b). A map with the gravel-pit is presented in Figure 3. The marked area to the right is the earlier known area of RAM 270 and the hatched area on the left side is shows the area of the new investigation. The distance between the north and south side is 150 meters.

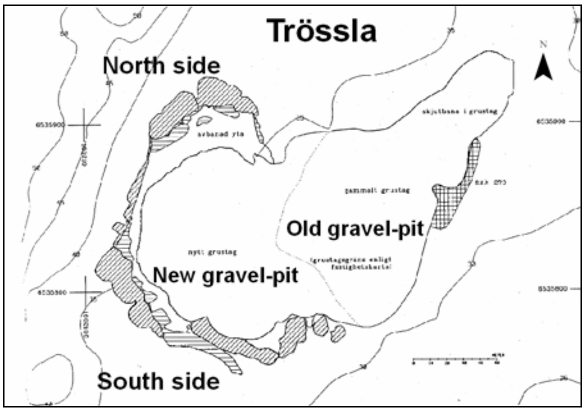


Figure 3. Map over the area at Trössla modified by the author. The hatched area on the left side of the gravel-pit was investigated in 2004. The distance between the north and south side is 150 metre. (Hallgren 2004b:9)

The pottery found consisted of 3.4 kg mostly from TRB. Some sherds of PWC were also found in mounds of dumped sand and gravel. Other findings were tools of flint and quartz and burned bones from cattle, goat/sheep, fish and seal.

The northern side in the investigated area can be dated to the beginning of Early Neolithic based on ^{14}C-dating of two burned bones from cattle. This is one of the oldest findings of cattle in Scandinavia. However, there are problems with radiocarbon dating of burned bones due to the fact that collagen disappears during burning. Bones that have been exposed to temperatures less than 600°C can give a too young radiocarbon date. At temperatures above 600°C the hydroxyapatite is more robust and the bones can give a reliable carbon age if no reservoir effect is expected (Blücher 2009).

From the south side of the gravel-pit a foodcrust has given a ^{14}C-dating to 3400 cal BC. From the δ^{13}C value, the origin of the foodcrust could be of terrestrial origin. The dated foodcrusts have δ^{13}C value of –25.9 ‰ that are normally considered as indicative of a terrestrial origin of the organic remain in question (Hallgren 2004:22). This limit was used to interpret two sherds from site in Tunaberg parish, Södermanland. The δ^{13}C values were in the range of -22.9 to -25.8 which suggests a terrestrial origin (Åkerlund 1996a:93f). Organic crusts from other sites have been analyzed to check the typological grouping of pottery with radiocarbon dating. The δ^{13}C measurement is however a very blunt tool to evaluate the origin of the foodcrust (Hallgren 2008:82ff; Craig et al 2007:135ff; Fischer et al 2003:449ff; Papmehl-Dufay

2006:152). The impact of a marine reservoir effect on the ^{14}C-samples, as a result of a possible marine content in the foodcrust, will at most be in the magnitude of c. 300 years in the Littorina stage of the Baltic (Lindqvist & Possnert 1997: 73), or possibly much less, 70±40 years (Eriksson 2003:21). The results from samples of shells from hazelnuts and a piece of charcoal were disappointing and represented later events than the dated potsherds. These samples will therefore not be discussed further. ^{14}C-datings from Trössla relevant for this paper are summarized in Table 3 (Hallgren 2004b:23). The uncalibrated radiocarbon dates have been calibrated by the author using OxCal v. 4.1 and are given in Table 3, column 7. No correction for the reservoir effect has been made.

Table 3. Table with ^{14}C-datings of samples of burned bones from cattle and a foodcrust from Trössla. Data from Hallgren in columns 1-5 (Hallgren 2004b:23) and in column 6 are calibrated radiocarbon data (OxCal v. 4.1) calculated by the author. No correction for the reservoir effect has been made.

Lab No	**Location**	**Context**	**Species**	**δ^{13}C (‰)**	**Radiocarbon age BP**	**Calibrated date (2σ)**
Ua-22408	North side	A3188, R1051	Bos taurus (Cattle)	-27.5	4955 ± 45	3930–3650 cal BC
Ua-22409	North side	R1054	Bos taurus (Cattle)	-27.1	5105 ± 45	3980–3790 cal BC
Ua-22411	South side	R1068	Foodcrust	-25.9	4690 ± 45	3630–3370 cal BC

The dating of samples from both the north and south side of the area to Early Neolithic is in good agreement with the typology of the pottery found. The north side is situated higher in the landscape and can be set to the beginning of EN and the south side to the end of this period. The conclusion was that the settlement was situated at the seashore and followed the receding shoreline as the land continued to rise (Hallgren 2004b:23). The pottery came from trenches on the north and south side and stray finds from mounds of dumped sand and gravel removed from the south side. The style and type of the pottery differed in these places. On the north side the pottery was sparse decorated TRB (4% décor based on weight) and made with N-technique and a coarse temper of crushed rock. Sherds from four funnel-necked beakers and one collared flask were identified. The pottery was more decorated TRB (33% décor) at the south side. A large part of the decorated sherds originated from two vessels. In the dumped sand and gravel, both TRB and PWC were found (Hallgren 2004b:25).

The bone material from the site was examined and classified in species and quantity. The material was highly fragmented and an overrepresentation of bones from seal can be assumed. The structure of seal bones is more compact and better preserved than other species found. The material from the north side with a weight of 17.06 g and fragments from cattle, goat/sheep, seal, fish, bird and small terrestrial animals could be identified. The weight of the material from the south side was 56.3 g contained fragments from seal, cattle, fish, bird and terrestrial animals. The conclusion of the report was that area investigated and the materials were both small and could not give an answer to the activities on the site. It seemed that hunting of seal could have been concentrated to the south side (Hallgren 2004b:53ff). The material of plant macrofossils was very small. The most interesting finding was a possible impression of a grain of unknown origin on a potsherd (Hallgren 2004b:35).

2.4.2 Överåda

During Middle Neolithic period, the site Överåda was situated on an island about 7 km in length and 0.5-1 km in width. Today this place is situated about 30 m a.s.l. on a slope of a glacifluvial ridge (Welinder 1971:5). The Neolithic site has number RAM 263, Trosa-Vagnhärad parish. Today the gravel-pit is covered with sand and a plantation of pine trees as can be seen in Figure 4.

Figure 4. The gravel-pit at Överåda is now covered with sand and pine trees. (Photo: B. Ohlberger 2008)

In 1966 potsherds were found when the place was exploited as a gravel-pit. A test-excavation took place in 1967 followed by an excavation conducted by Welinder in the summer of 1969 (Welinder 1973b). Three trenches and test-pits were dug at around the gravel-pit revealing post-holes, hearths and pits. It was concluded that a large part of the dwelling-site had vanished owing to the gravel-pit. Two stone-covered graves with skeletons and one with traces from a skeleton were found. The material results from this excavation were about 300 kg of potsherds, 2.8 kg bones, stone finds, one amber-bead (axe-shaped) and four clay figurines. Among the artefacts of stone were grindstones and two stones with boreholes. The post-holes were arranged in a half-circle with a diameter of about 2 metres. One post-hole was situated in the centre of the circle. This construction of cottages has been found on PWC sites and on comb-ornamented pottery sites (Welinder 1971:14;78). The hearths found were very simple and were made of irregular heaps of fire-cracked stones, burned stones and soot. The number of pits was higher than usually found at other PWC sites in central Sweden and varied in size. In one area of 8x10 metres, twelve pits were situated. An interpretation of the pits was not obvious but all large pits contained refuse. Other possibilities were that the pits were used as cooking-pits or fire-stoves (Welinder 1971:78f). In the area examined in 2002 large quantities of burned stones and fire-cracked stones were found in the cultural layer. It is unusual to find this large amount of fire-cracked stones at PWC sites south of the lake Mälaren (Olsson et al 2003:13; Edenmo et al 1997:175).

Close to Överåda at about 500 metres distance is another Neolithic site situated named Sköttedal (RAM 254). At Sköttedal pottery from both TRB and PWC has been found. In1945 a fragment from a collared flask was found (Åkerlund 1996b:4)

During the first investigation in 1966-67 phosphate analyses of soil-samples were performed to enable an estimation of the area of the site. Later more investigations have been carried out during 1990 and 2002. A new study of the phosphate content was performed on samples from the east side of the gravel-pit. A map over Överåda with data from the phosphate analyses are in Figure 5. The high concentrations indicate that there might be remains of the settlement to the east of the gravel-pit. The area of the original settlement has been estimated to 30 000 m^2 (Olson&Vinberg 2002:14f)

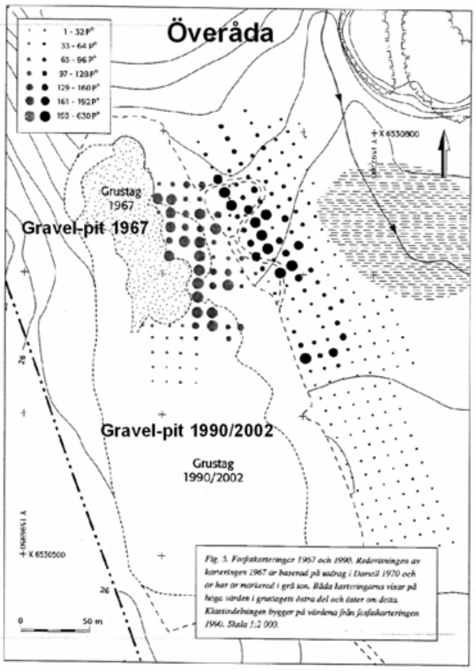


Figure 5. Map over Överåda showing the phosphate content from investigations in 1967 and 1990. Content and distribution are given as proportioned symbols representing data magnitudes (Olson&Vinberg 2002:29).

^{14}C-daterings from Överåda have been performed on bones from one human and four seals. The results were published by Welinder in 1973. He discussed the sources of errors that must be considered and the problems to date bones from seal. These data have also been discussed and published by Löfstrand. However, the radiocarbon data from Överåda was analysed with a method not used today and calculated with a half-life of 5730 years for ^{14}C (Welinder 1973a:109; Löfstrand 1974:106). The conclusion Welinder made of the radiocarbon data was a most uncertain absolute age of 2700 ± 400 B.C.

In my opinion, these radiocarbon data are difficult to interpret and they are not calibrated. I have chosen to present the "calculated" data as years in BC to point out that they are not calibrated. I have used a calibration program, Oxcal 4.1, to calibrate the radiocarbon data from Överåda. No correction for the reservoir effect has been made. An estimation of the marine reservoir effect for Neolithic PWC on Gotland is established to 70 ±40 years (Eriksson 2004:150). This correction has been applied on samples from Korsnäs, Södermanland, in eastern central Sweden (Fornander et al 2008:292). The results are given in Table 4.

Table 4. An attempt to calibrate the radiocarbon data from Överåda from Welinder (Welinder 1973a:109) and Löfstrand (Löfstrand 1974:106) with Oxcal 4.1 (column 4.).

Sample nr	**Species**	**Radiocarbon age BP**	**Calibrated date (2σ)**
St-3422	Seal	4155±100	3000-2470 calBC
St-3427	Seal	4155±120	3080-2350 calBC
St-3428	Seal	4035±105	2880-2300 calBC
St-3429	Seal	4200±100	3070-2490 calBC
St-2953	Human	3790±120	2570-1900 calBC

In the end, my conclusion is that it is difficult to evaluate radiocarbon data produced 40 years ago. So the most correct age of the Neolithic site at Överåda can be established from the pottery styles.

The assemblage of 300 kg potsherds from Överåda was investigated and style-grouped in three chronological stages. The results of the classification of the pottery have been published (SHM 30097; ATA, dnr 4619/73; Welinder 1971). The potsherds were decorated with groups, incised lines, whipped cord impressions, cross-hatching, comb and line stamps. As already mentioned they were classified to Säter groups II-IV or Fagervik II-IV. The principles for this classification were based on form, surface- and rim ornaments, technique (measured as density) and the positions where the sherds were found within the site (Welinder 1971:27ff). The three types Överåda I-III show similarities with Säter/Fagervik II-IV (Welinder 1971:83). Överåda style I and Säter II have the same decorations with impressions and drawn lines and pot profile as pottery from the Funnel Beaker Culture. A very short description of the characteristic decors of the pottery styles from Överåda and Säter are presented in Table 5 (Welinder 1971:89f).

Table 5. A short description of the pottery styles from Överåda (Welinder 1971:89f).

Style	Décor
Överåda I, Säter II	Drawn lines together with strokes in combination with pits
Överåda II, Säter III:	Strokes and crosses in horizontal rows or in zig-zag pattern. Comb-impression and pits are used.
ÖverådaIII, Säter IV	Comb-impression covering large surfaces but pits are less frequent

The density of the pottery is lower, more porous, for sherds in the younger styles (Welinder 1971:82f). In terms of the Fagervik chronology most of the pottery belongs to Fagervik II and III (Malmer 2002:99). In the ceramic assemblage from the excavation in 1969, also 30 – 50 miniature vessels were found. A miniature vessel has a rim diameter less than 10 cm (Welinder 1971:26ff). The number of fragments from miniature vessels found at Överåda is large, approximately 100. Artefacts from the excavation of Överåda in 1969 are kept at the Museum of National Antiquities (SHM). The inventory list (SHM 30097). gives 62 hits in a search for miniature vessels. Each hit can contain of many fragments. Miniature vessels could have a ritual place in burial ceremonies. If they were placed in a grave, my guess is that no one ever drank from them and that rim sherds in this case are not a good sampling strategy.

The bone material consisted of 2.8 kg, was divided among 142 find-numbers, and was classified according to quantity. Seal was identified in 90 find-numbers. In 42 find-numbers fish were found and in three find-numbers birds. Two fragments of “domestic” pig and one fragment from moose, hare, deer and marten were identified. In 40 find-numbers, the bones were more or less burnt so no species-classification could be performed (Welinder 1971:74). The characterisation of the pig bones as "domestic" must be questioned. There is no reference to the method giving this result. The standard procedure to distinguish wild and domestic ones is the difference in length in their third molar. Results from analyses of stable isotopes in human skeletal material originating from a Pitted Ware site at Korsnäs, Södermanland gave evidence for a marine diet where pork was not an essential part. Also data from pig bones showed that they did not relay on garbage from human activities but had a terrestrial herbivorous diet. The conclusion of this study is that the pigs were wild boars (Fornanader 2008:286ff). As two-thirds of the animal bones were from harp seals living in deep water and about a third from saltwater fish the site can be used for hunting and fishing (Malmer 2002:99f).

Sculptures of clay were also found and have been interpreted as miniatures of animals (SHM 30097). Red-ochre was found in two graves and in two herths under clay plates. Red-ochre in hearths could have a magical function in people’s thought-world. The use of red-ochre has been connected to magical-religious conception around the antithesis of life and death (Welinder 1971:88). In the inventory list for SHM 30097 a search for red colour gives ten hits and in eight together with miniature vessels.

2.4.3 Concluding reflections

Even if the radiocarbon dates from especially Överåda are not exact it can in my opinion be concluded that the TRB period at Trössla is older the PWC period at Överåda and Trössla. A rough estimation could be that at Trössla the earlier stage of TRB on the north side was established around 3900 BC and the later stage on the south side about 500 years later. The radiocarbon dating from Överåda has been related to the period of Säter II-III. In terms of the Fagervik chronology the greater part of the pottery was belonging to Fagervik II and III (Malmer 2002:99). Welinder reported one sherd with a “megalithic” pattern from Överåda (Welinder 1971:48). This type is referred to Fagervik II. A Fagervik chronology has been proposed for eastern central Sweden using radiocarbon dating (Edenmo et al 1997:184; Kihlstedt et al 2007:52). These data can only suggest the different stages in the chronology. With these results in mind the PWC pottery from Överåda are younger than the TRB pottery.

Faunal refuse from these sites indicate an exploitation of marine resources as seal and fish but also traces of cattle on the north side of Trössla. One bone from cattle was also found on the south side. Welinder has presented a suggested time schedule for activities at TRB sites over the year with farming and hunting-gathering activities. He assumes that the marine resources were also exploited at TRB sites situated close to the sea (Welinder 1982:157). The most important difference between Trössla and Överåda is the findings of bones from cattle and sheep/goat.

3. Investigating archaeological ceramics: Materials and methods

3.1 Materials

To my disposal, I have from Trössla 3.4 kg of potsherds consisting of 2029 pieces. The majority of the sherds are very small and fragmented. The findings of pottery are given in Appendix 6 in SAU Rapport 2004:7 (Hallgren 2004b). Most part of the sherds from Trössla came from the excavation in 2004 but also from Boris Wredenmark.

The material from Överåda consists of 10 kg of potsherds, most of them collected in 1977-88 by Boris Wredenmark. These potsherds have never been classified or analyzed earlier. I have made an approximation that they represent about 6000 sherds. About 25% of the sherds are decorated with the ornaments already mentioned but there are some sherds with a different appearance. In addition, four pieces from miniature vessels were identified. Except vessel fragments, an oblong piece of pottery was also found. It was identified as a clay bead by Fredrik Hallgren and the shape gives association to half an axe. All sherds are stray finds and lack exact location but have been found at the gravel-pit of Överåda.

The sampling strategy has been to choose rim sherds when possible to avoid analysis from the same vessel. From Trössla all sherds available have been analysed and from Överåda matching number were chosen to test my hypothesis that vessel use differed between funnel beaker and pitted ware pottery. The sherds were given an identity but some were omitted because they could come from the same vessel as another sherd. The Trössla samples included both funnel beaker and pitted ware pottery and the sherds from Överåda were all pitted ware pottery. The sample from Trössla consisted of 24 potsherds, 15 sherds from TRB and 9 from PWC. From Överåda 22 sherds were analysed including two rim sherds from miniature vessels: These two sherds are reported separately.

The handlings of the sherds were unknown and they had been stored in plastic bags. Therefore, the occurrence of contaminations was likely to be detected in the analyses. Some sherds were sooty but no traces of visible surface residues were seen in microscope. All pottery was registered, weighed and photographed. A rough description of the sherds was made with these criteria: ordinary/poriferous ware decorated/undecorated and rim sherds. The diameter of the vessels was also estimated and recorded when possible. Some of the decorated sherds could be classified in styles. Sherds from the excavation at Trössla have their location in terms of find number (Number) and context reported as they are given in Appendix 6 in SAU Rapport 2004:7 (Hallgren 2004b). The classification of the TRB pottery is given as Vrå 1 or 2. All sherds from Överåda are stray findings within the site. The samples from Trössla are listed in Appendix 1 and the samples from Överåda in Appendix 2.

3.2 Methods

3.2.1 Morphological analyses

The potsherds were studied with a microscope looking for visible residues as foodcrusts and soot. The sherds were weighed and photographed. The rim diameter was measured for rim sherds or estimated when possible for the rest. Most of the rim sherds from TRB vessels had a smaller diameter than the PWC vessels.

3.2.2 Lipid residue analysis

Lipids are fats, waxes and resins from living organisms built of fatty acids and their derivatives, containing a high number of carbon atoms, usually >14. Lipids are highly hydrophobic and more or less insoluble in water and this property has been important for their ability to survive in potsherds for thousands of years.

Various classes of lipids display a variety in their chemical and structural functions. Simple lipids are esters of fatty acids and alcohols. Triacylglycerols (TAG) are esters of glycerol with three hydroxyl groups and common in fat. The degradation pathway for TAG are the formation of diacylglycerols (DAG) and monoacylglycerols (MAG) and free fatty acids. Lipids lacking an ester group are sterols and fatty acids. Sterols are composed of four fused rings and a side chain and examples are cholesterol and phytosterols. Most natural fatty acids have an even number of carbon atoms because they are biosynthesised from acetylcoenzyme A with two-carbon acetyl groups. The range of these fatty acids usually varies from C_4 to C_{36} but C_{16} and C_{18} are dominant (Fessenden&Fessenden 1987:933ff; Pollard et al. 2007:22ff; 149ff). Fatty acids are carboxylic acids with a saturated hydrocarbon chain or unsaturated (with double bounds). Unsaturated fatty acids are more exposed to bacterial degradation. Also long-chain ketones may be formed when lipids are heated. Ketones with a number of 31 and 35 carbon atoms from $C_{16}{:}_0$ and $C_{18}{:}_0$ fatty acids give evidence that vessel has been heated and used for cooking (Evershed et al 2002:662f). But it must be stressed that the absence of long-chain ketones in a vessel still makes it possible that the vessel was used for cooking. Dicarboxylic fatty acids are also a result from degradation formed through oxidation of lipids.

Different analytical techniques have been used to determine the lipid content in unglazed potsherds. Lipids can be found in a solvent-soluble lipid fraction (TLE=total lipid extract) and in an “insoluble” or recalcitrant fraction when lipids are bound in the ceramic matrix. The analyses can give information on the structure and distribution of lipids in the vessel. The origin of lipids can be evaluated by biomarkers, which are unique compounds and have been identified from natural origin. In addition, the distribution of different fatty acids gives a "fingerprint" that can be used to trace the origin. Archaeological biomarkers that can give information to human activities in the past are among others sterols, isoprenoid fatty acids, ω-(*o*-alkylphenyl)alkanoic acids and terpenoids. Biomarkers will be discussed further.

In unglazed ceramics, the fired clay acts as a matrix to absorb lipids from the content that has been in the specific vessel. The residue can be visible as a charred foodcrust on the surface or be invisible and absorbed in the ceramic wall of the vessel (Evershed 2008c:897). Absorbed lipid residues on potsherds can be analysed with chemical methods. Analysis can provide this information and thus the practical use of a specific vessel can be evaluated. This procedure has been used in archaeological studies in Sweden (Isaksson 2000:37ff; Papmehl-Dufay 2006:163).

The property of the fabric depends among other factors on the choice of temper and clay. Porosity can depend on the use of limestone or bone temper. This can occur when the vessel was used and after burial (Orton et al 1993:215). A porous fabric allows liquids to seep through the wall from one surface to another. This is good for keeping water cool as water can evaporate and hence cool the content. However, in vessels for cooking seepage of liquid through the wall of the pot will reduce heating efficiency and prolong the heating process. One boiling experiment in a new replica jar showed that it took c.1 h 50 min for water to boil but after one single cooking of cabbage the time was reduced to c. 30 min (Charters et al 1997:4). This demonstrates that when lipids and other substances have been absorbed to the ceramic matrix the cooking time will decrease dramatically. The possibility that fat was applied to pots as a post-firing treatment to speed up the time for cooking water has been discussed. To use fat as a sealant can have an effect on the lipid residue content if the pot was used only for a short period (Pollard et al 2007:150; Charters 1993:218; 1997:2; Malainey 1999:99; Orton et al 1993:224f). Treatment of one or both sides of the vessel will reduce the permeability but not the porosity of the fabric (Orton et al 1993:221).

Heron et al has observed that sherd-absorbed lipids did not match the surrounding soil in composition or quantity (Heron et al 1991:665ff). Isaksson has also sampled soil together with potsherds at excavations and has come to the same conclusion (Isaksson personal communication). For potsherds found in seawater the possibility that also marine sediment can be attached to the ceramic must be considered (Craig et al 2007:137).

Experimental studies have been performed to study the spatial distribution of lipids in new produced replica vessels and in archaeological vessels. The materials from these studies have sometimes been used to study the decomposition of lipids in an environment with high temperature and under oxic or anoxic conditions. Degradation studies have also been performed on ceramic blocks that have been soaked in solutions containing fat.

Experiments have shown that lipid accumulation vary depending on the form, size and use of a specific vessel. Samples of unglazed pottery sherds representing rim, body and base from vessels with different shape and size were analyzed for lipid residue content. The result was a wide distribution of the lipid content within the vessels. Rim sherds with high lipid content have been interpreted as originating from a cooking vessel. Fat from food has been concentrated to the surface of the liquid in the vessel. Cooking could yield low values in bottom sherds as the heat in the bottom of the vessel could reach a very high temperature. On the other hand, high values in the bottom sherd could indicate that the food had been roasted (Charters et al 1993: 211ff).

A study of the concentration gradients of fatty acids across potsherds has been performed on amphoraes used for transportation of vegetable oils. Multiple samples were taken through the wall of the vessels in separate 2 mm thick layers from the inner to the outer surface. Different extraction protocols followed with GC-MS for the quantification and identification confirmed a concentration gradient in oil fabric sherds. The result was that the highest yield was found in the inner 2 mm layer close to the inner surface of the sherd. One factor that must be considered is the permeability of the clay fabric, which can have an effect on absorption of lipids (Stern et al 2000:399f).

Analyses of an unglazed vessel used on single occasion for 40 years to prepare pork stew showed the highest value of lipid residues near the rim, c. 5.4 mg/g. The lipid content was high in the lid, 3.7 mg/g, and the handle of the vessel, 1.3 mg/g, due to the permeability of the fabric. Experiments with replica vessels and repeated boiling of lamb meat and cabbage (*Brassica* leaves) gave the highest accumulation in rim position, followed by body and base. It was also noticed that the lipid concentration where c. 150 times higher when lamb was processed than cabbage. Lamb gave 21.8 mg/g and cabbage 0.26 mg/g in the analyzed rim sherds. So the content of lipids in different foodstuffs has an impact on the accumulation of lipids in the pottery (Evershed 2008a:28; 35). Sherds from rim are a good choice when sampling potsherds. The probability is high that this part represents the highest concentration in the vessel and you can control that only one sherd per vessel is sampled. The same result was found in another study with boiling cabbage showed that lipids were accumulating faster in the rim and body region than in the bottom. This was explained with the high temperature in the bottom of the vessel could reach a temperature of 800 °C (Charters 1997:2).

We do not know the function of a vessel during its life. Therefore, we must consider the possibility that it could be used for cooking a range of food at the same time or separately. Alternatively, used for something completely different not related to food at all. Organic residues from all of them could have been absorbed into the ceramic matrix. When it comes to the distribution of lipid within the vessel wall the big issue is whether lipids from the last or all uses of the vessel are preserved in the ceramic matrix. This question has been debated and Craig et al have concluded that the lipid residues can be derived from the last or the last few usages of the vessels (Craig et al 2004:632). Experiments with repeated boiling of cabbage and then lamb once showed an admixture of cabbage and lamb. Before and after boiling lamb the lipids were quantified and the result was that lamb fat did not replace vegetable wax. The concentration of wax was maintained and fat from the lamb was added as an integrated signal (Evershed 2008a:35). In my opinion, it would have been interesting to boil cabbage once in the vessel used for lamb to see if the vegetable wax could be detected.

A study with replica vessels used to prepare different meals with different foodstuffs gave very interesting results. The exact amount of the ingredients and cooking times are not available. Unfortunately, the vessels cracked after being used five times. From each vessel, three sherds were sampled from rim and bottom. In addition, a decay experiment was performed with rim sherds stored at 37 °C for 30 days. Determination of the total lipid extract (TLE) gave the following result with mean values presented in Table 6.

Table 6. Experimental cooking of different meals in two replica vessels. Results of total lipid extract (TLE) in potsherds when the experiment was completed and after a decay study. Abbreviations. A: Terrestrial animal, V: vegetable, FM: fish/marine, I: ruminant, milk (Karlsson 2007:35f).

Vessel 1	Meal	Meat	Vegetable	Fish	Dairy	Interpretation
1:1	Pea-soup and pork	**X**	**X**			
1:2	Vegetable stew		**X**		**X**	
1:3	Barley porridge		**X**		**X**	
1:4	Fish-soup (salmon)		**X**	**X**		
Assay	**3 mg/g**					**FMIV**
Degraded	**0.3 mg/g**					**AV**
Vessel n2	**Meal**	**Meat**	**Vegetable**	**Fish**	**Dairy**	**Interpretation**
2:1	Pork casserole	**X**	**X**		**X**	
2:2	Pork casserole	**X**	**X**			
2:3	Pork casserole	**X**	**X**			
2:4	Boiled pike-perch		**X**	**X**		
2:5	Vegetables		**X**			
Assay	**20 mg/g**					**FMIV**
Degraded	**1.0 mg/g**					**FMV**

The fact that a lean fish like pikeperch has transferred lipids to the ceramic in the latest use of the vessel is important. Fish has left detectable traces in the potsherds after the processing of pork three times. Noteworthy is also the interpretation of vessel 1 after degradation when the lipid signal from salmon has disappeared. The interpretation was mainly based on an increase of the ratio of $C_{18:0}$/ $C_{16:0}$ which might come from the degradation of TAG and DAG (Karlsson 2007:23ff).

In my opinion, this study pinpoints some of the problems with lipid residue studies. To start with we do not know what ingredients and how cooking times varied during the lifetime of the archaeological vessels. When analyzing and evaluating archaeological samples we can just search for biomarkers, stable isotopes and lipid content. In the earlier mentioned experiments to boil lamb a content of c 22 mg/g were found which is very close to the amount in vessel 2. In another decay experiment, meat broth of lamb, pork and fish was used to dose pottery with lipids. The initial amounts of lipids for lamb and pork were c. 20 mg/g and for fat fish 0.3 mg/g (Olsson 2004:19ff). It also is of the same magnitude, c. 20 mg/g, as published results of the practical capacity of fired ceramics to absorb lipids. A reasonable value is on the other hand given as 10 mg/g. The highest amount found in an archaeological potsherd is 17.8 mg/g (Evershed 2008a:28; 35).

The mentioned degradation study by Olsson used bouillon prepared from 5-10 g of food in 150 ml water and boiled for 15-20 minutes. A ceramic block was heated in an oven at 500°C for 30 min to remove possible contaminations. Pieces of the ceramic block were soaked in the bouillon and then dried at room temperature. Each block was divided in two pieces. One part was analysed directly with two different methods namely a quantitative method for TLE and a qualitative method with alkaline hydrolysis. The other part was stored for 30 days in soil under humid and oxic conditions in an oven at 37°C and then analysed for TLE. The results are given in Table 7.

Table 7. A decay study of different foodstuffs in ceramic block. Storage for 30 days in soil under humid and oxic conditions in an oven at 37°C (Olsson 2004:23)

Food	Assay µg/g	Assay after degradation µg/g	Decrease %
Herring	267	95	65
Beef	1899	79	95
Lamb	21469	2897	87
Pork	19048	2081	89

Also a lean fish as pikeperch and perch were used in this study but the results are omitted because the lipid content was low and not measurable after degradation. The results from the hydrolysis were used for interpretation of the origin of the foodstuff. The rapid decay was assumed to be the result of microbiological β-oxidation (Olsson 2004:23).

One very important aspect in the interpretation of organic residue analysis has been raised by Evershed who asked this question: ”Is the presence of a constituent of a residue based on an observed biomarker consistent with the archaeology and palaeoecology of the settlement, region and/or period from which it is derived?” The difficulty to elucidate the origin of unknown residues in potsherds was shown in an interlaboratory test with dosed sherds without archaeological contextual information and a defined research question. None of the participating laboratories could identify the unknown sample as camel’s milk (Evershed 2008c:899). With this in mind, I will start with a brief discussion of which lipids that might be found in my samples.

The bone material from Trössla and Överåda has been classified according to species representing cattle, goat/sheep, pig, seal, fish, bird and terrestrial animals as elk, hare, deer and marten (Hallgren 2004b:53ff; Welinder 1971:74). The plant macrofossils listed was restricted to charred shells of hazelnut and from Trössla a sherd with a possible mark of a grain of unknown origin (Hallgren 2004b:35). The conclusion is that there is no need to look for residues from camel but to concentrate on vegetable wax, marine, ruminant and non-ruminant fat. The categories to look for are ruminants (cow, goat/sheep, elk and deer), non-ruminants (pig), marine animal (seal), fish and vegetables. Some sherds are sooted so biomarkers from firewood as dehydroabeitic acid (from coniferous resin) and betulin (from birch bark) might be detected.

Fat from terrestrial animals has a higher amount of the saturated fatty acids n-octadecanoic acid ($C_{18:0}$) compared with n-hexadecanoic acid ($C_{16:0}$) and a high ratio of $C_{18:0}$/ $C_{16:0}$ is an indication of fat from terrestrial animals and a low ratio fat from marine animals /fish and vegetables as shown in Figure 6 (Olsson 2004:24).

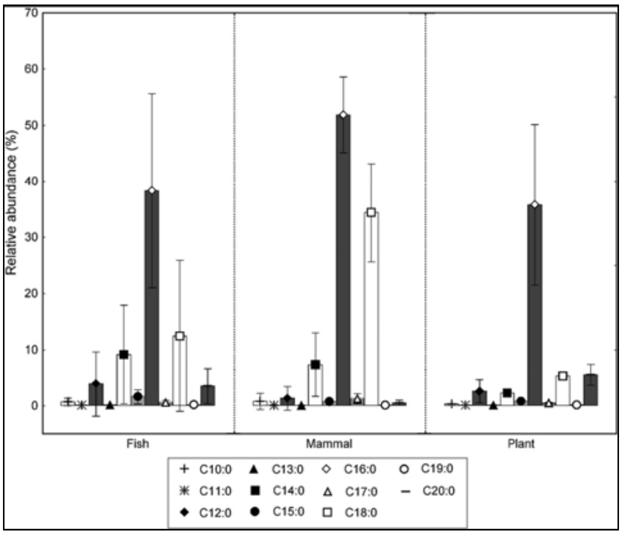


Figure 6. The distribution of n-alkanoic acids in experimentally decomposed lipids of various origins. Multivariate analyses of variance show that the distributions are statistically significant different between lipid residues from fish and mammals (Wilks' L = 0.054, Rao's R = 12.63, df = 8, p = 0.00068), and between lipid residues from mammals and plants (Wilks' L = 0.013, Rao's R = 35.62, df = 5, p = 0.00050). The difference between fish and plants was not statistically significant (From Olsson 2004:24).

The composition of fatty acids from marine animals/fish has a high degree of unsaturated acids, which are degraded rapidly. When heated over 300 °C ω-(*o*-alkylphenyl)alkanoic acids with 16-20 carbon atoms are formed from unsaturated acids with 16-20 carbon atoms and they are more stable and can be detected (Copley et al 2004:281; Evershed 2008c:901). The formation of these acids might be formed by alkali isomerization catalysed by the ceramic surface (Hansel et al 2004: 300). These assumption has been questioned by Craig et al who could demonstrate that ω-(*o*-alkylphenyl)alkanoic acids may be formed without direct contact with the ceramic matrix (Craig et al 2007:147). Decomposition experiments have shown a possibility to distinguish between lipid residues of fish from those of terrestrial animals based on the distribution of saturated n-alkanoic acids. On the other hand, this distribution was not enough to separate fish from plant lipid because both are dominated strongly by the $C_{16:0}$ acid (Figure 6). Therefore, the presence of the biomarkers cholesterol for fish and phytosterols for plant or their corresponding decomposition products can be used to distinguish them. Experimental decomposition studies for thirty days have also given evidence that the isoprenoid alkanoic acids 4,8,12-trimethyltetradecanoic acid (4,8,12-TMTD) and 3,7,11,15-tetramethylhexadecanoic acid (3,7,11,15-TMHD) or phytanic acid can be derived from marine animals/fish. The result was also that lean fish gave a low initial lipid content and very little was left and hardly detectable after storage. For the identification of possible fish residues two criteria was defined:

(1) the value of the ratio of $C_{18:0}$/ $C_{16:0}$ should be <0.48 derived from experimental data (Isaksson, 2000; Olsson, 2004) together with the presence of cholesterol;

and/or

(2) two acyclic isoprenoid alkanoic acids (4,8,12-TMTD and 3,7,11,15-TMHD) and the complete set of C_{16}, C_{18} and C_{20} ω-(*o*-alkylphenyl)alkanoic acids should be present.

The peak-area ratio was calculated through integration of the total ion-chromatogram and other components were detected by their characteristic ion-fragments (Olsson&Isaksson 2008:777).

A degradation experiments with different fatty acids, rape seed oil, horse adipose fat and cod liver oil gave evidence that ω-(*o*-alkylphenyl)octadecanoic acids are formed when potsherds are heated. The following criteria for evidence of processing marine fats in potter are:

(1) ω-(*o*-alkylphenyl)alkanoic acids of C_{18} and C_{20} should be present and C_{22} should be detected

(2) at least one of the free isoprenoid alkanoic acids (4,8,12-TMTD, pristianic acid and 3,7,11,15-TMHD) should be observed (Evershed et al 2008b:110f).

These studies have come to close criteria for the presence of marine fat in archaeological pottery. But the two isoprenoid acids 4,8,12-TMTD and 3,7,11,15-TMHD are also found in geolipid record and their presence is not specific to marine remains (Brassell et al 1983:575ff). The ω-(*o*-alkylphenyl)alkanoic acids with 16 and 18 carbons can be found in vegetable oil so the presence of C_{20} ω-(*o*-alkylphenyl)alkanoic acid can indicate marine residues but .The amount of $C_{20:3}$ acid is very low in lean fish and hence difficult to detect in degraded archaeological samples (Olsson&Isaksson 2008:777). It is also formed in terrestrial mammal liver (Estévez et al. 2004:457).

Patrick et al have studied the distribution of fatty acid in modern seals in South Africa and the ratio of $C_{16:0}/C_{18:0}$. The result was that no polyunsaturated fatty acids were detected and the ratio of $C_{16:0}/C_{18:0}$ was 4.94 (mean value of n=2) giving a value of $C_{16:0}/C_{18:0}$. to 0.2. The $C_{24:1}$ acid, nervonic acid, was also present. The ratio of oleic acid ($C_{18:1}$ ω9) and vaccenic acid ($C_{18:1}$ ω7) were studied in fresh and degraded tissue from modern seals compared with archaeological samples. The ratio of oleic and vaccenic acids indicated that seal was a probable origin in the lipid residues from the potsherds (Patrick et al 1985:232ff). Copley et al have analyzed pottery vessels from South Africa and for evidence for the processing of marine products. In this study phytanic acid was detected in some potsherds but 4,8,12-TMTD was not present at all. This can be due to the lower content of 4,8,12-TMTD compared to phytanic acid. Also ω-(*o*-alkylphenyl)alkanoic acids were found and the interpretation was that either marine products had been heated in the vessels or the vessels had been heated after they had come in contact with marine products (Copley et al 2004: 280ff).

As already mentioned an indication of fat from terrestrial animals is a high ratio of $C_{18:0}/ C_{16:0}$ (Olsson 2004:24).Terrestrial animals as ruminant and non-ruminant animals are not so easy to distinguish in ancient pottery as the degradation of biomarkers for ruminants are high and often not detectable. With GC-IRMS the $\delta^{13}C$ values of individual fatty acids can give a hint. Isomers of monounsaturated octadecenoic acids with double bonds in 9-, 11-, 13-, 14-, 15- and 16-position are found in ruminant animals but in monogastric animals as pigs only one isomer is found, Z-9-octadecenoic acid (Evershed et al 2002:664)

Methods to analyse and elucidate the structure of extract from lipids in archaeological artefacts consist of several steps. A short description of the methods used is that an internal standard is added to a pulverised sample of the potsherd and followed by an extraction with organic solvent and ultrasonification. The extract is derivatized prior to analysis with GC-MS. There are different methods for the pre-treatment of the samples before the extraction depending on the nature of lipids in the ceramic matrix. To start with the potsherds ceramic was ground off from the inside using a low-speed pottery grinder. The first millimetre was discarded to avoid any contamination from soil. The powdered ceramic was transferred quantitatively (0.5 g) into an extraction vessel and an internal standard was added (hexatriacontane, C36). Three ml of a mixture of chloroform and methanol (2:1, v:v) was added and the lipid residues were extracted through ultrasonification (2 x 15 min). The samples were then centrifuged (3000 rpm, 30 min). The clear extracts were transferred to vials and the solvent evaporated under a gentle stream of nitrogen. The lipid residues were treated with bis(trimethylsilyl)trifluoracetamide containing 10% (v) chlorotrimethylsilane at

70 °C for 15 min to produce trimethylsilyl derivatives, which were then dried under nitrogen. The derivatized extracts were re-dissolved in n-hexane and analysed by GC-MS. Only solvents p.a. (pro analysi) grade were used.

Then the extracts were analysed with a HP 6890 Gas Chromatograph equipped with a SGE BPX5 capillary column (15 m x 220 mm x 0.25 mm). The injection was done by pulsed splitless (pulse pressure 17.6 Psi) technique at 325 °C through a Merlin Microseal High Pressure Septum using an Agilent 7683B Autoinjector. The oven was temperature programmed with an initial isothermal of 2 min at 50 °C, followed by an increase of the temperature with 10 °C per minute to 350 °C, followed by a final isothermal at this temperature of 15 min. Helium was used as carrier gas and held at a constant flow of 2.0 ml per minutes throughout the analysis. The gas chromatograph was connected to a HP 5973 Mass Selective Detector via an interface with a constant temperature of 350 °C. The fragmentation of separated compounds was performed by electronic ionisation (EI) at 70 eV. The temperature at the ion-source was 230 °C. The mass filter was set to scan between m/z 50 and 700, providing 2.29 scans per second. The temperature of the mass filter was 150 °C. The data was processed using the HP Chemstation software (Olsson&Isaksson 2008:778).

The first step is to integrate relevant peaks in the produced chromatograms omitting peaks from contaminations. Then the assay of the total lipid extractable residue (TLE) is calculated by comparison with the peak of the internal standard with known assay. The next step is to investigate the presence of different biomarkers as cholestrerol, phytosterols and vegetable wax residues according to a standard protocol given in Appendix 1-2. The interpretation of sherds with low lipid content is based on a judgement that the presence of biomarkers really represents the presence of "old" lipids.

3.2.3 Hydrolysis of the insoluble fraction

To investigate if acidic or base treatment could release more lipids from the analysed samples after the solvent extraction some samples were selected for this study. Treatment with alkali (saponification) and a methylating step has been used by to demonstrate release of oxidation products from the insoluble residues (Regert et al 1998:2027ff; Craig et al 2004:613ff; Copley et al 2004:280ff; Craig et al 2007:135ff). The presence of degraded components as diacids and hydroxyl acids showed that oxidation of lipids start during food preparation. These compounds have only been detected in samples from arid settlement in Egypt with good preservation conditions. In addition, more saturated and unsaturated acids were released with base treatment. The use of methanol and acid to release ester bound carboxylic acids was also tested (Stern 2000:403ff).

Sherds analysed in duplicates were selected together with samples with different content and origin. Many sherds had not given any lipid residue content and/or had been contaminated but were included in case they might release oxidation products from the insoluble residues. The two miniature vessels were included and the only vessels with fish/marine origin, sherds T15 and Ö3. In total 21 samples were further investigated, 7 with base treatment and 14 with acidic treatment.

For the hydrolysed samples no assay were calculated and only biomarkers were evaluated. Protocols are presented in Appendix 3-4.

Treatment with base

To the residue was added 1 ml of 5 % NaOH in methanol (w/v). After ultrasonification (15 min) the mixture was heated for 3 hours at 70° C. After cooling the saponified mixture was neutralised with HCl and extracted with n-hexane (3x1 ml). The combined n-hexane extracts were evaporated under a stream of nitrogen gas. The extracts were treated with14 % boron trifluoride-methanol and heated for one hour at 70° C to prepare methyl ester derivates. After extraction with n-hexane (3x1 ml) and centrifugation (5 min 3000 rpm) the combined hexane extracts were evaporated under a stream of nitrogen gas. The extracts were re-dissolved in hexane and analysed by GC-MS.

Treatment with acid

To the residue was added 1 ml of methanol. After ultrasonification (15 min) sulphuric acid was added and the mixture was heated for 3 hour at 70° C. Ester bound carboxylic acids are released and all acids are methylated. After cooling the mixture was extracted with n-hexane (3x1 ml). The combined hexane extracts were evaporated under a stream of nitrogen gas. The extracts were treated with bis(trimethylsilyl)trifluoracetamide containing 10% (v) chlorotrimethylsilane at 70 °C for 20 min to produce trimethylsilyl derivatives of sterols and alcohols and then dried under nitrogen. The derivatized extracts were re-dissolved in n-hexane and analysed by GC-MS. Only solvents of p.a. (pro analysi) grade were used.

3.2.4 Possibilities and limitations of the method

Methods for the determination and evaluation of the lipid residue content in potsherds should be able to extract, separate and determine degraded lipids in very small quantities. Usually analytical methods are validated regarding accuracy, precision, recovery and the detection limit of the substances determined. The accuracy of an analytical method describes the closeness of mean test results to the "true" value. The precision describes the closeness of individual measurements when the same sample is analysed several times and is usually expressed as the standard deviation of the analytical method. The recovery gives the extraction efficiency of the method (Pollard et al 2007:313ff).

The questions we hope to answer with this method are: "How much lipid residue is in the potsherd?" and "When is a potsherd empty?" Therefore in my opinion errors from weighing and pipetting that can be calculated from the criteria for accuracy, precision and recovery are not the most important issues. As has already been stated samples from the same vessel can give different values depending on which part they have been taken. Another issue that must be stressed is a proper handling of the potsherds from excavation to the analysis to avoid contaminations from hands and plastics. In this case the sample can limit the outcome of the analysis. The detection limit is of interest as it gives the lowest amount of lipids that can be quantitatively determined and shows the ability of the chromatographic system and the detector to distinguish desired peaks from background noise. Many authors have set the detection limit to 0.005 mg/g (Dudd et al 1999:1476; Evershed 2008a:28) and I have come to the same conclusion. You can sometimes still see signals from biomarkers even when there is less than 5 µg/g lipid left in the sherd so the question to decide when a pot is empty can be subtle. Also the upper limit of quantification is of interest as an internal standard is used for the evaluation. The span of the total amount of lipids assayed varies from 0. 1 to 20 mg/g but the same amount of the internal standard is used, 0.02 mg, so the error in the determination is higher with a high lipid content. When an internal standard is added it is possible to estimate the recovery of the extraction step. The integration step can be tricky to evaluate when the sample gives a large number of signals from degraded lipids and contaminations.

To sum up the assay of lipid residues in potsherds can give an approximate assay of the lipid content in a specific vessel and an interpretation of the origin of the biomarkers. As GC-IRMS technique is not available, the possibility to distinguish lipids from ruminant animals to other terrestrial animals is limited. The content will be given in mg with one decimal with the exception for values close to the detection limit, which has been set to 0.005 mg/g. When the lipid content is less than 0.005 mg/g and biomarkers are identified the content is given as traces.

4. Results

The protocols from the total lipid extractable residue analyses (TLE) of potsherds from Trössla and Överåda are given in Appendix 1 and 2. Sherds that have been further investigated for the insoluble lipid fraction are presented in Appendix 3 and 4. Samples treated with acid have an "A" added to the sample number and samples treated with base have a "B" added. Sherds from Trössla with a known find-place are given as Trössla north side or Trössla south side. Samples T1-T15 have been classified as TRB and samples T16-T18 and T22-T27 as PWC. The results of the solvent extractable lipid residue content (TLE) are presented and discussed. The content is given in mg/g sherd contents larger or equal to 0.005 mg/g that is considered the lowest amount to be detected. Samples with traces of fatty acids and distinct signals from biomarkers are considered to have been used in the past and marked as "traces". Potsherds with traces of fatty acids but without identified biomarkers are considered empty. Some samples have been difficult to integrate and assay due contaminants from plastics.

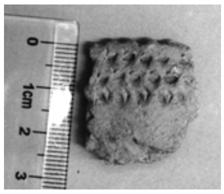
The interpretation of the origin is based on findings of biomarkers. The following abbreviations are used: FM for fish or marine animals, A for terrestrial animals, V for vegetables, E for empty and Tr for traces of lipids. Comments are made for traces of terpenes as DHA (dehydroabietic acid) and contaminations. The ratio of C_{17br} (C17 branched) and $C_{18:0}$ was calculated in some sherds with a high ratio of $C_{18:0}/C_{16:0}$. A value of $C_{17br0}/C_{18:0}$ >c. 0.02 could indicate traces of lipids from ruminant or milk (Hjulström et al 2008:68).

4.1 Vessel classification: Samples from Trössla.

Sample T1, Trössla north side. The lipid content was 0.005 mg/g and the ratio of $C_{18:0}/C_{16:0}$ could not be calculated due to low peaks in the chromatogram. The presence of cholesterol and wax residues gave a vessel classification of terrestrial animal and vegetables.
T1A was treated with acid also traces of cholesterol and presence of isoprenoidic acids 4,8,12-TMTD and 3,7,11,15 TMHD together with ω-(alkyl-phenyl)alcanoic acids (C_{16}?, C_{18} and C_{20}) could be detected. Long-chained hydroxy acids (C_{20}, C_{22}, C_{24}) were detected. A new interpretation gave a vessel classification of fish/marine and vegetables.

Samples T2 and T3, Trössla north side. The vessels were classified as empty.

Sample T4, Trössla north side. (See photo).The lipid content was 0.005 mg/g and the ratio of $C_{18:0}/C_{16:0}$ could not be calculated due to low peaks in the chromatogram. The presence of cholesterol and wax-residues gave a vessel classification of terrestrial animal and vegetables.



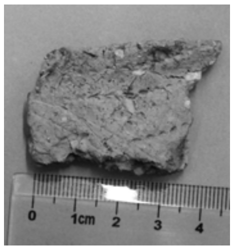
Sample T501 and T502, Trössla north side. Duplicates from the same sherd. The vessel was classified as empty.
T501A was treated with acid and resulted in the presence of hydroxy acids and cholesterol. The ratio of $C_{18:0}/C_{16:0}$ was 0.42. This could indicate residues from fish/marine.
T502B was treated with base and resulted in the presence of fatty acids. The sample was contaminated. No cholesterol could be detected. The ratio of $C_{18:0}/C_{16:0}$ was c. 0.6 and vessel was classified as empty.

Sample T601 and T602, Trössla north side. Duplicates from the same sherd. The vessel was classified as empty.
T601A was treated with acid and resulted in the presence of wax residues. No cholesterol could be detected. The ratio of $C_{18:0}/C_{16:0}$ was c. 0.4 and could indicate vegetables.
T602B was treated with base but the chromatogram was bad and could not be interpreted.

Sample T7, Trössla north side. The lipid content was 0.005 mg/g and the ratio of $C_{18:0}/C_{16:0}$ could not be calculated due to low peaks in the chromatogram. The presence of cholesterol and wax residues gave a vessel classification of terrestrial animal and vegetables.

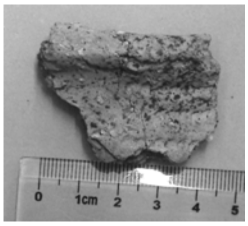
Samples T801 and T802, Trössla north side. Duplicates from the same sherd. The vessel was classified as empty.

Samples T9 and T10, Trössla north side. The vessels were classified as empty.



Sample T11, Trössla south side. (See photo). The lipid content was 0.2 mg/g and the ratio of $C_{18:0}/C_{16:0}$ was 0,34. This could indicate fish/marine or vegetables. The presence of cholesterol, phytosterols, wax residues, isoprenoidic acids 4,8,12-TMTD and 3,7,11,15 TMHD together with ω-(alkyl-phenyl)alcanoic acids (C_{16}, C_{18} and C_{20}) gave a vessel classification of fish/marine and vegetables.
T11A was treated with acid and traces of cholesterols and the presence of wax residues and 4,8,12-TMTD hydroxyl acids were detected. This could indicate residues from fish/marine and vegetables. No change in classification.

Sample T12, Trössla south side. (See photo). The lipid content was 0.2 mg/g and the ratio of $C_{18:0}/C_{16:0}$ was 0,2. This could indicate fish/marine or vegetables. The presence of cholesterol, phytosterols, wax residues, isoprenoidic acids 4,8,12-TMTD and 3,7,11,15 TMHD together with ω-(alkyl-phenyl)alcanoic acids (C_{16}?, C_{18} and C_{20}) gave a vessel classification of fish/marine and vegetables. Dehydroabietic acid (DHA) was detected and can indicate that the vessel had been heated. This vessel had a foodcrust that have been radiocarbon dated to 3400 cal BC and has been supposed to be of terrestrial origin.



T12B was treated with base and the ratio of $C_{18:0}/C_{16:0}$ was 0.30. The presence of wax residues, isoprenoidic acids 4,8,12-TMTD and 3,7,11,15 TMHD together with ω-(alkyl-phenyl)alcanoic acids (C_{16}?, C_{18} and C_{20}) gave a vessel classification of fish/marine and vegetables. This vessel had a diameter of 40 cm and the detection of DHA together with the foodcrust give evidence that it has been used for cooking.

Sample T13, Trössla south side. The lipid content was less than 0.005 mg/g and the ratio of $C_{18:0}/C_{16:0}$ could not be calculated due to low peaks in the chromatogram. The presence of cholesterol, phytosterols and traces of ω-(alkyl-phenyl)alcanoic acids (C_{20}) gave a vessel classification of terrestrial animal and vegetables.

Sample T14. Trössla south side. The lipid content was less than 0.005 mg/g and the ratio of $C_{18:0}/C_{16:0}$ could not be calculated due to low peaks in the chromatogram. The presence of cholesterol and wax residues gave a vessel classification of terrestrial animal and vegetables.

Sample T15, Trössla south side. The sample comes from the vessel that can be seen on the cover illustration. The lipid content was 0.03 mg/g and the ratio of $C_{18:0}/C_{16:0}$ was 0.01 and indicated fish/marine or vegetables. The presence of cholesterol and the absence of phytosterols and wax residues gave a vessel classification of fish/marine, probably lean fish.
T15A was treated with acid and resulted in the presence of cholesterol, phytosterols, wax residues, isoprenoidic acids 4,8,12-TMTD and 3,7,11,15 TMHD and DHA. The ratio of $C_{18:0}/C_{16:0}$ was 0.83 and could indicate a terrestrial origin. The ratio of $C_{17br}/C_{18:0}$ was 0,06 and could indicate traces of lipids from ruminant or milk from earlier use of the vessel.

Samples T16 and T17. The vessels were classified as empty.

Sample T18. Traces of phytosterols gave a vessel classification of vegetables.
T18A was treated with acid and resulted in the presence of phytosterols, wax residues and DHA. The vessel classification was vegetables.

Sample T22. The vessel was classified as empty.
T22A was treated with acid and resulted in the presence of phytosterols, traces of wax residues and DHA. The ratio of $C_{18:0}/C_{16:0}$ was 0.3 and could indicate fish/marine or vegetables. The vessel classification was vegetables.

Sample T23. The lipid content was less than 0.005 mg/g and the ratio of $C_{18:0}/C_{16:0}$ could not be calculated due to low peaks in the chromatogram. The peak from $C_{16:0}$ was visible. The presence of cholesterol and wax residues gave a vessel classification of fish/marine and vegetables.

Sample T24. The sample was contaminated with plasticizer. The vessel was classified as empty.
T24A was treated with acid. DHA was now detected. As the vessel was classified as empty DHA could originate from the firing step in the manufacturing of this vessel.

Sample T25. The lipid content was 0.3 mg/g and the ratio of $C_{18:0}/C_{16:0}$ was very low and indicated an origin of fish/marine or vegetables. This is the only sample with traces of diacylglycerols (DAG) and monoacylglycerols (MAG). The presence of cholesterol, phytosterols and traces of wax residues gave a vessel classification of fish/marine and vegetables.

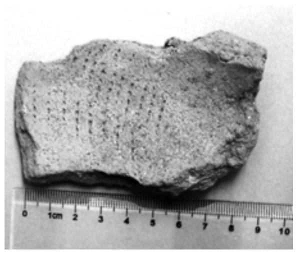
Samples T26 and T27. The vessels were classified as empty.

4.2 Vessel classification: Samples from Överåda.

Samples Ö1. The vessel was classified as empty.

Sample Ö201 and Ö202. Duplicates from the same sherd. **Ö201** gave a chromatogram that was overloaded and difficult to evaluate. **Ö202** This sherd had the highest amount of lipid residue content of all sherds namely 1.2 mg/g. The ratio of $C_{18:0}/C_{16:0}$ was 0.25 and indicated a fish/marine or vegetable origin. The presence of cholesterol, wax residues and isoprenoidic acids 4,8,12-TMTD and 3,7,11,15 TMHD together with traces of ω-(alkyl-phenyl)alcanoic acids (C_{16}, C_{18} and C_{20}) gave a vessel classification of fish/marine and vegetables.
Ö201A was treated with acid and gave the same result as Ö201. The ratio of $C_{18:0}/C_{16:0}$ was 0.22 and could indicate fish/marine or vegetables. No change in vessel classification.
Ö202B was treated with base and gave bad chromatogram but the vessel classification was still fish/marine and vegetables.

Sample Ö3. (See photo). The lipid content was less than 0.005 mg/g and the ratio of $C_{18:0}/C_{16:0}$ could not be calculated due to low peaks in the chromatogram. The presence of cholesterol and the absence of phytosterols and wax residues gave a vessel classification of fish/marine. Probably lean fish.



Ö3A was treated with acid and the ratio of $C_{18:0}/C_{16:0}$ was 0.59 and could indicate a terrestrial origin. The ratio of $C_{17br}/C_{18:0}$ did not indicate traces of lipids from ruminant or milk. Traces of wax residue but no cholesterol were detected. A new vessel classification could be vegetables and terrestrial animals. An explanation could be that the insoluble fraction originated from an earlier use. The diameter of this vessel was estimated to 12 cm and probably a drinking vessel. If beverages from a variety of foodstuffs have been filled in this cup, it can explain the different biomarkers. This vessel was decorated on both the exterior and interior surface with comb stamps.

Sample Ö401 and Ö402. Duplicates from the same sherd. The vessel was classified as empty.

Samples Ö5. The vessel was classified as empty.

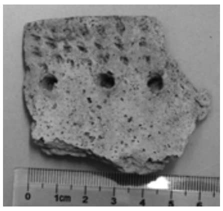
Sample Ö6. The lipid content was 0.4 mg/g and the ratio of $C_{18:0}/C_{16:0}$ was 0.31 and indicated fish/marine or vegetables. The presence of wax residues and 3,7,11,15 TMHD and the absence of cholesterol gave a vessel classification of vegetables.

Sample Ö7. The lipid was 0.5 mg/g. The ratio of $C_{18:0}/C_{16:0}$ was 0.35 and could indicate fish/marine or vegetables. Traces of cholesterol and the presence of wax residues and isoprenoidic acids 4,8,12-TMTD and 3,7,11,15 TMHD together with traces of ω-(alkyl-phenyl)alcanoic acids (C_{16}, C_{18} and C_{20}) gave a vessel classification of fish/marine and vegetables. Also terpenoids were detected and could indicate that the vessel had been heated.

Samples Ö8. The vessel was classified as empty.

Sample Ö9. The lipid content was less than 0.005 mg/g and the ratio of $C_{18:0}/C_{16:0}$ could not be calculated due to low peaks in the chromatogram. The presence of wax residues and the absence of cholesterol gave a vessel classification of vegetables.

Sample Ö11. (See photo). The lipid content was 0.005 mg/g and the ratio of $C_{18:0}/C_{16:0}$ could not be calculated due to low peaks in the chromatogram. Traces of wax residues and ω-(alkyl-phenyl)alcanoic acid (C_{20}) and the absence of cholesterol gave a vessel classification of vegetables.
Ö11A was treated with acid and the ratio of $C_{18:0}/C_{16:0}$ was 0.18. The presence of cholesterol, phytosterols and wax residues gave a new vessel classification of fish/marine and vegetables.



Samples Ö12. The vessel was classified as empty.

Samples Ö13 and Ö14. These samples were from two miniature vessels and contaminated with plasticizer. The vessels were classified as empty.

Samples Ö15. The vessel was classified as empty.

Samples Ö16. The vessel had traces of lipids but no biomarkers were identified. The vessel was classified as empty.

Sample Ö17. The lipid content was 0.1 mg/g and the ratio of $C_{18:0}/C_{16:0}$ could not be calculated due to the very low peak of stearic acid ($C_{18:0}$) in the chromatogram. Traces of wax residues and ω-(alkyl-phenyl)alcanoic acids (C_{20}) and the presence of cholesterol and phytosterols gave a vessel classification of fish/marine and vegetables.

Sample Ö18. The lipid content was less than 0.005 mg/g and the ratio of $C_{18:0}/C_{16:0}$ could not be calculated due to low peaks in the chromatogram. The presence of phytosterols and the absence of cholesterol gave a vessel classification of vegetables.

Samples Ö19. The vessel had traces of lipids but no biomarkers were identified. The vessel was classified as empty.

Sample Ö20. The lipid content was less than 0.005 mg/g and the ratio of $C_{18:0}/C_{16:0}$ could not be calculated due to low peaks in the chromatogram. Traces of phytosterols and the absence of cholesterol gave a vessel classification of vegetables.

Samples Ö21. The vessel was classified as empty.

Sample Ö22. The lipid was 0.2 mg/g. The ratio of $C_{18:0}/C_{16:0}$ was 0.22 and could indicate fish/marine or vegetables. The presence of phytosterols and isoprenoidic acid 3,7,11,15 TMHD together with traces of ω-(alkyl-phenyl)alcanoic acids (C_{20}) gave a vessel classification of fish/marine and vegetables. Also terpenoids were detected and could indicate that the vessel had been heated.

Samples Ö23. The vessel had traces of phytosterols. The vessel was classified as empty.
Ö23B was treated with base. Traces of fatty acids but the classification is still empty.

Sample T12 is interesting as it comes from a vessel with foodcrust which has carbon dated (Ua-22411). As already mentioned the sample was considered to have a terrestrial origin and a carbon age without reservoir effect (Hallgren 2004b:22f). My result was that the lipid residue came from a fish/marine and vegetable source. The problems with δ^{13}-values for mixed contents have been discussed by Fischer (Fischer et al 2003:449ff) and Isaksson. In a case study from western Norway early dates with radiocarbon dating of foodcrusts from pottery were obtained together with indications of a terrestrial origin based on δ^{13}C values. A theoretical approach to calculate δ^{13}C from mixtures of terrestrial vegetables and marine fish showed a span of δ^{13}C values from -26 (100% vegetables) to -15.1 (100% marine fish) (Isaksson in press). This might be applied to the result from Trössla as well and in my opinion the carbon date of this foodcrust should be investigated further.

A summery of the data from the studied potsherds is listed regarding interpretation, site and culture in the Table 8. The two miniature vessels are not included.

Table 8. The distributions of vessel use between TRB and PWC at Trössla and Överåda.

Site	Culture	E	FM	FMV	V	AV	Number
Trössla	TRB	7	1	2	0	5	15
Trössla	PWC	6	0	2	1	0	9
Överåda	PWC	10	1	4	5	0	20
	Number	23	2	8	6	5	44

The distribution of vessel use are presented in terms of vessel use between cultures (Figure 7) and between the sites and cultures and between TRB at the north side (TRBN) and south side (TRBS) side at Trössla (Figure 8) .

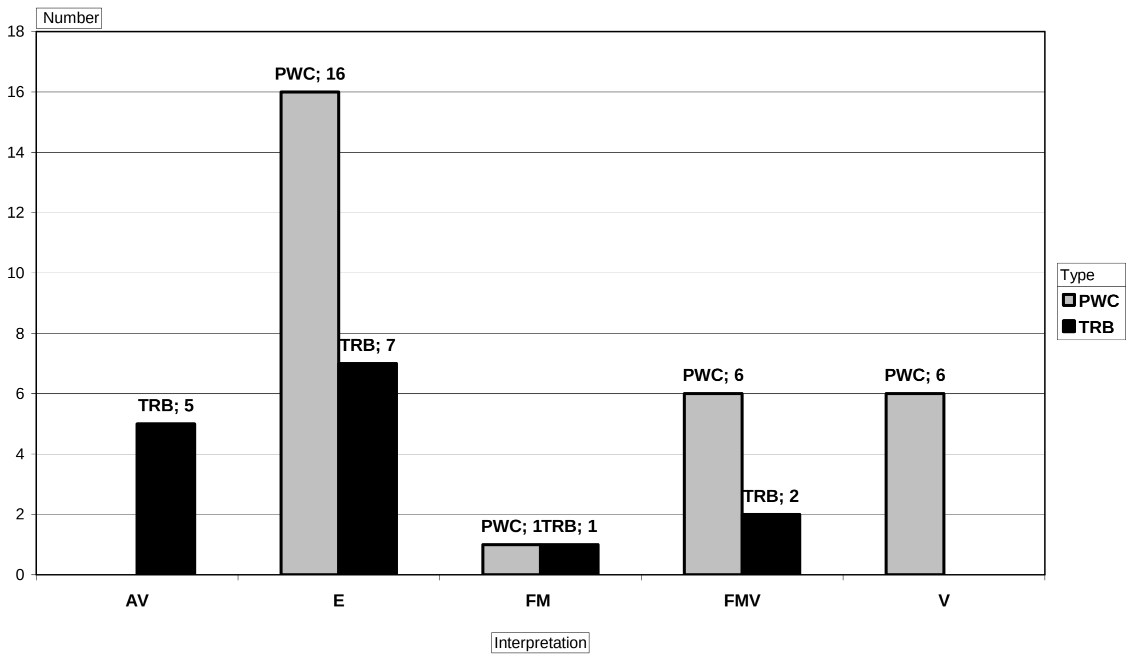


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Figure 7. Bar charts representing the distribution of vessel use between TRB and PWC. A= Terrestrial animal; V= Vegetables; FM= Fish/marine; E= Empty.

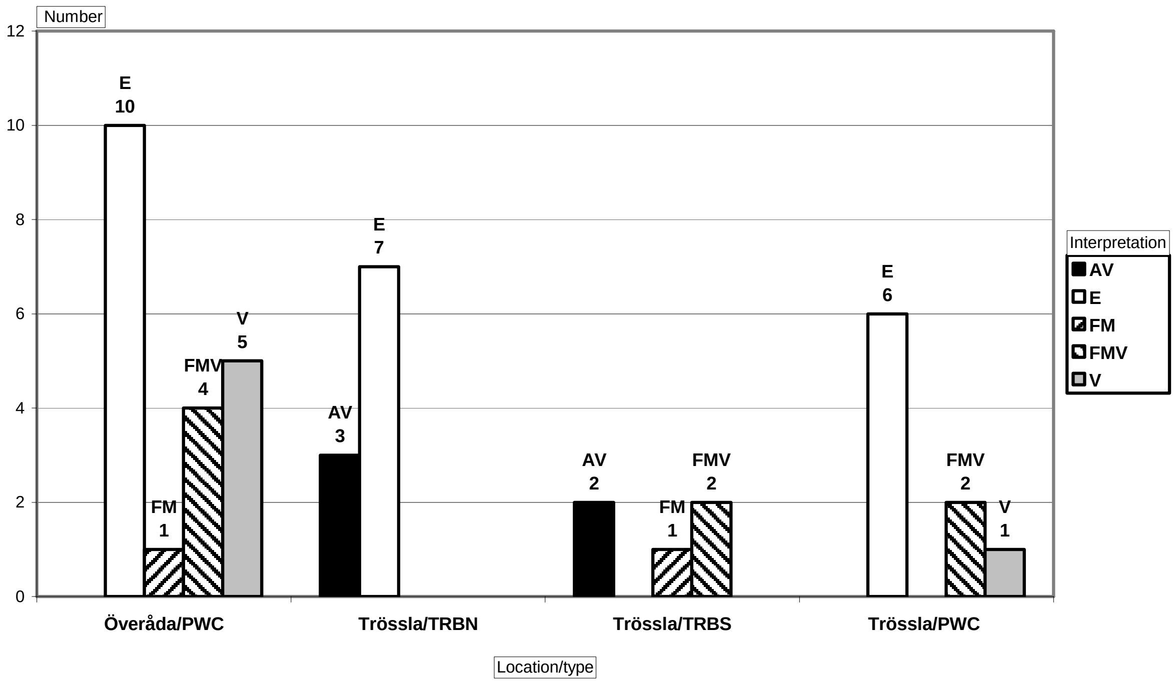

Figure 8. Bar charts representing the distribution of vessel use at Överåda and Trössla (south,TRBS, and north, TRBN, side) between PWC and TRB. A= Terrestrial animal; V= Vegetables; FM= Fish/marine; E= Empty.

Statistical calculations have been made using Statistica ver.5. With a χ^2-test between these distributions (χ^2=11.39, df=4, p=0.023) a significant difference can be shown. To evaluate what kind of lipid origin that can explain these results calculations were performed for the number of empty vessels, vessels with vegetables as ingredient and terrestrial animals.

1) Empty vessels gave no significant difference in frequency in TRB and PWC.

2) More vessels with vegetables as ingredient for PWC than TRB:-Significant difference with χ^2-test (χ^2=4.31, df=1, p=0.0138), but only close to significant with the more discriminating Fischer´s exact two-tailed p=0.0765.

3) Vessels with terrestrial animals were only found in TRB at Trössla and this difference can be shown to be statistically significant both with χ^2-test (χ^2=10.91, df=1, p=0.001) and Fischer´s exact two-tailed p=0.003.

Qualitative differences in vessel use between Trössla and Överåda expressed as Euclidian distances have been calculated giving the following results:

1) The Euclidian distance between PWC pottery from Trössla and Överåda is 0,23.

2) The Euclidian distance between PWC and TRB pottery from Trössla is 0,42.

A large Euclidian distance indicates large difference in vessel use. The conclusion is that the vessel use for PWC pottery at Trössla and Överåda has more similarities than between PWC and TRB at Trössla.

A calculation of the mean value for the TLE content for TRB and PWC gave the following results. For TRB a mean value of 0.03 mg/g was calculated with a standard deviation of 74%. For PWC the mean value was 0.1mg/g and a standard deviation of 250%. This means that the span between the content in the sherds were very large. The distribution of the content is visualised in Figure 9 and sherds with traces of lipids have been given a content of 0.001 mg/g. The diagram illustrates the differences between the PWC potsherds with a higher mean value and standard deviation than the TRB potsherds.

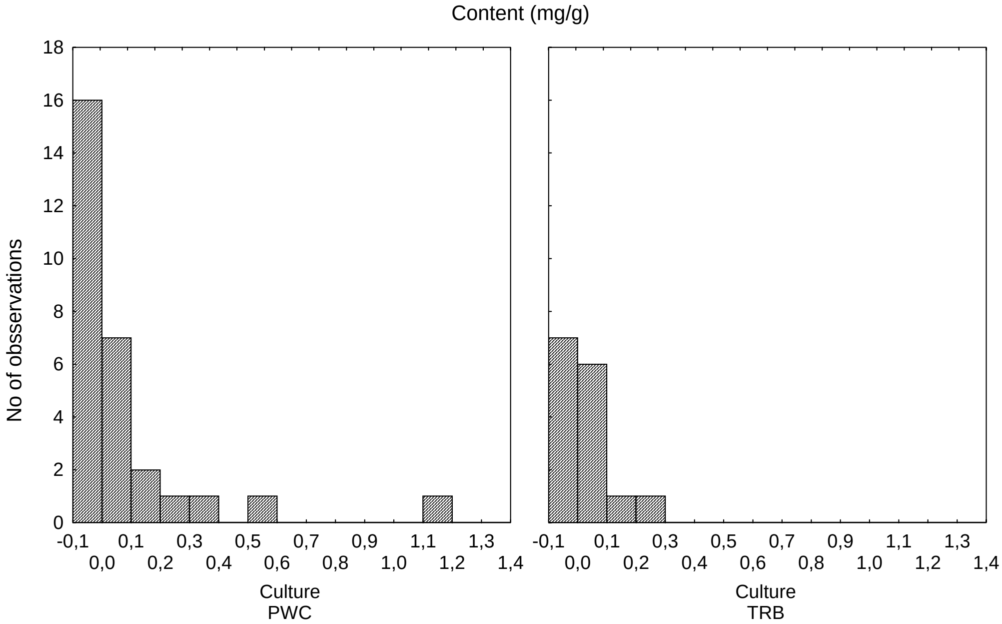

Figure 9. The diagram shows the distribution of the lipid residue content between potsherds from TRB and PWC at Trössla and Överåda.

The two sherds from the miniature vessels were contaminated with plasticizer and no lipid residue was detected. Miniature vessels could have a ritual place in burial ceremonies (Welinder 1971:88). If they were placed in a grave as grave goods, my guess is that no one ever drank from them and that rim sherds in this case are not a good sampling strategy. It is interesting to compare the result from a miniature vessel from Sittesta, Södermanland that had a TLE content of 0.1 mg/g and was interpreted to have contained a mixture of fish/marine animal and vegetables and also showed traces of long-chained ketones. It is highly improbable that it was used as a cooking vessel so explanation is that it had been heated intentional or unintentional after the vessel had absorbed lipids (Isaksson 2008:4ff).

When the soluble and insoluble fractions have been analysed they have often given a similar distribution of fatty acids and have been interpreted in the same way (Craig et al 2004:614f). The formation of the insoluble fraction of degraded lipids in pottery can be through chemical bonding or possibly via ester linkages (Regert et al 1998:2029).

The result of this investigation was that seven sherds gave indications that other biomarkers were released from the insoluble fraction. This gave an alternative interpretation of the origin of the content. Samples of T12, T18 and Ö2 (two samples) gave the same interpretation after treatment with acid or base. In some sherds DHA were released and biomarkers for fish/marine and vegetables. Degraded fatty acids as hydroxyl acids were detected in several samples. As the number of sherds was small it is not possible to establish if acidic or base treatment is best suited to release fatty acids and sterols from the insoluble fraction in the pottery. Some sherds gave a new interpretation as new biomarkers were released. The interpretation of the solvent lipid residue in sherd T1 was "AV", terrestrial animal and vegetable, based on presence of cholesterol and wax residues. Now the isoprenoidic acids 4,8, 12-TMTD and 3,7,11,15-TMHD had been released and possible also an ω-(alkyl-phenyl)alcanoic acid (C20) so the interpretation changed to fish/marine and vegetable. The sherd T15 changed from fish/marine and vegetable to terrestrial animal, ruminant or milk, and vegetable based on the ratio of C_{17br} /$C_{18:0}$ and the presence of and phytosterols and wax esters. Sherds with low lipid residue content can be difficult to interpret. As the solvent extraction gives an indication of the last or latest vessel uses my interpretation is that the vessel has been used for different foodstuffs and that the oldest preparations of foodstuff can be linked to the insoluble fraction.

5. Discussion

As has been already emphasised the result from the lipid residue contents in pottery does not reflect the diet but only the vessel use. The interpretation of lipid residues is based on the presence of biomarkers. Due to preservation conditions, signals from foodstuff can have vanished. This applies for example for unsaturated fatty acids. Also many potsherds have been located close the surface of the ground means that they have been exposed to weather conditions and also forest fire.

Analyses of TRB and PWC pottery from three Neolithic sites at Öland have given different results. The number of empty sherds in the assemblages was small and the content was significantly higher in the TRB potsherds. Terrestrial animals and marine animals were also detected in both the TRB and PWC pottery (Papmehl-Dufay 2006:217ff; Palomäki 2006:26ff). For comparison of vessel use a number of other PWC sites in eastern Sweden with data from lipid residue contents have been listed in Table 9. Data from other TRB sites have only a few results and will therefore not be discussed.

Table 9. PWC sites with data from lipid residue contents for comparison with Trössla and Överåda.

Site	Culture	E	FM	FMV	V	AV	Number
Trössla, Södermanland	PWC FII-IV	6	0	2	1	0	9
Överåda, Södermanland	PWC FII-III	10	1	4	5	0	20
Högmossen, Uppland	PWC FII?	2	2	5	7	0	16
Brännpussen, Uppland	PWC FIII-IV	9	0	3	4	3	18
Sittesta, Södermanland	PWC FIII	7	0	1	2	0	10

All sites have a large number of "empty" vessels with one exception. At Högmossen the number of "empty" sherds is small (2/16). This site is considered one of the oldest PWC sites in Uppland (Brorsson et al 2007:420). The data shows a similar vessel use at Brännpussen (Brorsson et al 2007:424) and Överåda. They have also in common that red-ochre, sculptures and beads of clay have been found at excavations (Welinder 1971:88; Nilsson 2006:41; 66).

This study has investigated Neolithic pottery from Trössla and Överåda with chemical analyses. The possibilities and limitations of the methods have been discussed. The hypothesis that vessel use differed between TRB and PWC has also been corroborated. To study if more lipids could be released with treatment of acid or base after the extraction of total lipid residues some sherds were selected for further investigation. More lipids from the insoluble fraction bound in the ceramic matrix were released and in some cases and also other biomarkers were detected. One explanation could be that the extraction with organic solvents only gives indications of last or the last few usages of the vessel and that the insoluble fraction contains lipids from earlier usages.

A foodcrust from sample T12 has been carbon dated (Ua-22411) and considered to have a terrestrial origin (Hallgren 2004b:22f). My result gave a different vessel use and indicated that the lipid residue came from a fish/marine and vegetable source.

The TRB settlement at Trössla was situated in a coastal location with findings of bones from seal and fish together with bones from cattle and sheep or goat. The radiocarbon dating suggests that the north side was populated as early as c. 3900 BC. This radiocarbon dating can be questioned as the analyses were performed on burned bones. If the bones had been exposed to temperatures less than 600°C it can result in a too young radiocarbon date. On the other hand a reservoir effect can give a too old radiocarbon date.

A difference in vessel use between TRB and PWC at Trössla and Överåda has been demonstrated. More vessels with vegetables as ingredient were found in PWC than TRB. Vessels with terrestrial animals were only found in TRB. Also vessel use for PWC pottery at Trössla and Överåda has more similarities than between PWC and TRB from Trössla.

Trössla can be regarded as both a land facing and a sea facing site during the TRB period regarding the finds of bones. Bones from cattle and sheep or goat can indicate a land facing site and finds of bones of seal and fish a sea facing site (Hallgren 2008:92).
At Överåda the finds of bones from seal are frequent and indicates that hunting of seal was important. Vessels with the highest lipid residue content had biomarkers for fish or marine animals and vegetables. My assumption is that the marine biomarkers originates from seal as meat from seal has high fat content

The vessel use betweenTRB and PWC can indicate different lifestyles. The TRB pottery has been used to process terrestrial animals and to a minor degree for vegetables and marine resources. The PWC pottery was used to process marine resources and vegetables. So the hunting for seal was important for people from TRB at sea facing sites and to people from PWC.

To return to my ambition to put questions to the Neolithic on vessel use I have come a bit forward. The analyses of potsherds have given me some answers on the content of the vessels. I have not been able to evaluate the identity of the lipid residues from terrestrial animals so new questions have been generated. The potsherds have also brought me closer to the people living at Trössla and Överåda. When I can see and feel marks from their fingers left in the clay it seems to me that they are still present.

What about the future for lipid residue analysis? In my opinion, a better understanding of the nature of the absorption of lipids into the ceramic matrix is important. The technique used by Stern et al to study the concentration gradients of fatty acids across the wall of the vessel could be one way to study this and the creation of the insoluble fraction (Stern et al 2000:399f). The extraction step is crucial when it comes to the release of organic residues in the ceramic matrix. An evaluation could be performed with different methods for extraction with multiple analyses of the same samples. More experimental cooking should be performed with different foodstuffs and followed with degradation studies. However, even with new technology and better extraction methods there is one very important thing that are often neglected and that is the handling of potsherds at excavations. When the potsherds are contaminated with fat from hands and plasticizers the results from the lipid residues can be difficult to interpret.

6. Summery

The aim of this study was to investigate vessel use at two Neolithic sites, Överåda and Trössla, with lipid residue analyses. These sites are situated in the parish of Trosa-Vagnhärad in Södermanland, Sweden. Both sites have been excavated and potsherds from two Neolithic cultures, TRB and PWC, have been found. Trössla is considered one of the oldest sites in Scandinavia with a ^{14}C-dating of burned bones from cattle to c 3.900 cal BC. This place has been interpreted as a farmstead with domesticates of cattle. The excavations at Överåda have shown a site based on an ideology representing the Pitted Ware culture and an economy based on hunting and gathering.

From TRössla both pottery from TRB and PWC has been analysed and from Överåda sherds of PWC. With chemical methods, the lipid residue content the origin of the residue has been evaluated. The chemical methods used have been discussed from aspects of possibilities and limitations. The hypothesis that vessel use differed between TRB and PWC has been demonstrated. This difference is based on the presence of terrestrial animals in TRB pottery. With the equipment available and the low lipid residue content, it has not been possible to distinguish lipids of ruminant origin. It has also been demonstrated that the vessel use for PWC pottery at Trössla and Överåda have more similarities than between PWC and TRB pottery at Trössla.

Vessels with the highest lipid content had biomarkers for fish or marine animals and vegetables. The assumption that the marine origin comes from seal is not farfetched as bones from seal have been found at both sites and that meat from seal has high fat content. Hunting for seal was important for people from TRB and PWC.

A study of the insoluble fraction of lipids bound in the ceramic matrix gave some interesting result. The lipid residue content is supposed to come from the last or the last few usages of the vessel. Therefore, when different biomarkers are found in the insoluble fraction it could come from earlier usages of the vessel. A foodcrust from a sample had been carbon dated and considered to have a terrestrial origin. My result gave a different vessel use and indicated that the lipid residue came from a fish/marine and vegetable source. So new questions have come up and they need to be investigated further.

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8. List of appendices

Appendix 1. List of analysed samples from Trössla.

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Appendix 3. Protocol from the total lipid residue analysis (TLE) of potsherds from Trössla.

Appendix 4. Protocol from the total lipid residue analysis (TLE) of potsherds from Överåda.

Appendix 5. Protocol from acidic and alkaline treatment of potsherds from Trössla.

Appendix 6. Protocol from acidic and alkaline treatment of potsherds from Överåda.

The results of the total lipid analyses are given in terms of amount of extractable residues and the presence or absence of a number of biomarkers. “x” indicates presence, 2-2 indicates absence and Tr indicates traces. The samples were checked for long-chain ketones but not found and are not included in the protocol.

Abbreviations used for the interpretations:

A: Terrestrial animal
V: Vegetable
FM: Fish/marin
R: Ruminant, milk
E: Empty
DHA: Dehydroabeitic acid

Appendix 1.

Samples from Trössla with laboratory identity and location according to SAU report 2004:7 (Hallgren 2004b). The TRB pottery are classified as Vrå 1 or 2 and the PWC pottery in Fagervik styles, when possible.

Identity	Location	Number	Context	Weight (g)	Rim sherd	Diameter (cm)	Comments	Classifi--cation
T1 N	North side	1064	R2103	11.0	-	c.12	Ordinary, decorated	Vrå I
T2 N	North side	1112	R1056	28.5	-	c.28	Ordinary, undecorated	Vrå I
T3 N	North side	1117	R1058	8.8	-	-	Ordinary, undecorated	Vrå I
T4 N	North side	1004	F7	4.7	X	16	Ordinary, decorated	Vrå I
T5 N	North side	1110	R1055	11.5	-	-	Ordinary, undecorated	Vrå I
T6 N	North side	1106	R1054	9.5	-	-	Ordinary, undecorated, collared bottle	Vrå I
T7 N	North side	1002	F5	15.6	X	18	Ordinary, undecorated	Vrå I
T8 N	North side	1036	F2023	15.6	-	-	Ordinary, undecorated	Vrå I
T9 N	North side	1028	F2011	9.5	-	-	Ordinary, undecorated	Vrå I
T10 N	North side	1105	R1054	16.9	-	-	Ordinary, undecorated	Vrå I
T11 S	South side	1551	-	12.1	X	32	Ordinary, decorated	Vrå II
T12 S	South side	1423	R1068	19.4	X	40	Ordinary, decorated	Vrå II
T13 S	South side	1551	-	21.2	X	28	Ordinary, decorated	Vrå II
T14 S	South side	1430	R1070	10.0	-	-	Ordinary, decorated	Vrå II
T15 S	South side	1410	R1068	118	X	14	Ordinary, decorated	Vrå II
T16	South side	1551	-	9.1	-	-	Ordinary, decorated	Fagervik III
T17	South side	1551	-	12.7	-	-	Ordinary, decorated	Fagervik II
T18	-	-	-	25	-	c.18	Ordinary, decorated	Fagervik II
T22	-	-	-	8.5	-	-	Ordinary, decorated	PWC
T23	-	-	-	12.3	X	24	Ordinary, decorated	Fagervik II
T24	-	-	-	17.4	-	-	Ordinary, undecorated	PWC
T25	-	-	-	10.5	-	-	Ordinary, decorated	PWC
T26	-	-	-	14.2	-	-	Ordinary, decorated	Fagervik II
T27	-	-	-	27.6	-	-	Ordinary, undecorated	PWC

Appendix 2.

Samples from Överåda with PWC pottery. When possible the classification is given in Fagervik styles when possible. All sherds are stray finds.

Location	Identity	Weight (g)	Rim sherd	Diameter (cm)	Comments	Classification
Överåda	Ö1	27.8	X	38	Ordinary, decorated	PWC
Överåda	Ö2	20.8	X	34	Ordinary, undecorated	PWC
Överåda	Ö3	103.2		12	Porous, decorated on both sides , comb	Fagervik III -IV
Överåda	Ö4	52.8		28	Ordinary, decorated	PWC
Överåda	Ö5	26.0		28	Porous, pits	Fagervik III
Överåda	Ö6	26.7		40?	Ordinary, decorated	PWC
Överåda	Ö7	89.6		22	Ordinary, decorated	PWC
Överåda	Ö8	34.6	X	30	Porous, decorated on both sides	PWC
Överåda	Ö9	25.8		40	Porous, decorated	Fagervik III
Överåda	Ö11	25.7	X	40	Porous, decorated	Fagervik III
Överåda	Ö12	40.8	X	28	Ordinary, decorated	PWC
Överåda	Ö13	1.7	X	4	Ordinary, decorated miniature vessel	PWC
Överåda	Ö14	2.6	X	4	Ordinary, decorated miniature vessel	PWC
Överåda	Ö15	7.7	X	32	Ordinary, decorated	PWC
Överåda	Ö16	17.6	X	40	Porous, decorated	Fagervik III
Överåda	Ö17	21.	X	40	Porous, decorated	Fagervik III
Överåda	Ö18	10.0		40?	Ordinary, undecorated	PWC
Överåda	Ö19	43.3	X	38	Ordinary, decorated	Fagervik II
Överåda	Ö20	13.9	X	40	Ordinary, decorated	PWC
Överåda	Ö21	15.8	X	40	Ordinary, decorated	Fagervik II
Överåda	Ö22	6.2	X	40	Ordinary, decorated	PWC, Fagervik III
Överåda	Ö23	13.9			Ordinary, decorated	PWC, Fagervik III

Appendix 3.

Appendix 3

Samples from Trössla with total lipid residue content and interpretation.
Abbreviations used for the interpretation are listed in page 40.

Sample	Content	Neutral lipids				Isoprenoidic alcanoic acids		ω-(alkyl-phenyl) alcanoic acids			Terpenoids	Interpretation
	mg/g	C18:0/C16:0 (0.48)	Cholesterol	Phytosterols	Wax residues	4, 8, 12- TMTD	3 7,11 15- TMHD	C16	C18	C20		
T101	**0.005**	-	+	-	+	-	-	-	-	-	-	**AV**
T201	-	-	-	-	-	-	-	-	-	-	-	**E**
T301	-	-	-	-	-	-	-	-	-	-	-	**E**
T401	**0.005**	-	+	+	-	-	-	-	-	-	-	**AV**
T501	-	-	-	-	-	-	-	-	-	-	-	**E**
T502	-		-	-	-	-	-	-	-	-	-	**E**
T601	-	-	-	--	-	-	-	-	-	-	-	**E.**
T602	-	-	-	-	-	-	-	-	-	-	-	**E**
T701	**Tr**		+	-	**Tr?**	-	-	-	-	-	-	**AV**
T801	-	-	-	-	-	-	-	-	-	-	-	**E..**
T802	-	-	-	-	-	-	-	-	-	-	-	**E**
T901	-		-	-	-	-	-	-	-	-	-	**E**
T1001	-		-	-	-	-	-	-	-	-	-	**E**
T1101	**0.2**	**0,34**	+	**Tr**	**Tr**	+	+	+	+	+	**?**	**FMV**
T1201	**0.2**	**0,33**	+	+	+	+	+	**?**	+	**+**	**DHA**	**FMV. Heated?**
T1301	**Tr**	-	+	+	-	-	-	**?**	**?**	**Tr?**	-	**AV**
T1401	**Tr**	-	+	-	+	-	-	-	-	-	-	**AV**
T1501	**0.03**	**0,01**	**Tr**	-	-	-	-	-	-	-	-	**FM**
T1601	-	-	-	-	-	-	-	-	-	-	-	**E**
T1701	-	-	-	-	-	-	-	-	-	-		**E**
T1801	-	-	-	**Tr**	-	-	-	-	-	-	-	**V**
T22	-	-										**E**
T23	**Tr**	-	**Tr**	-	+							**FMV**
T24	-	-	-	-	-	-	-	-	-	-	-	**E**
T25	**0.3**	**Low**	+	+	**Tr**	-	-	-	-	-	**?**	**FMV**
T26	-	-	-	-	-	-	-	-	-	-	-	**E**
T27	-	-	-	-	-	-	-	-	-	-	-	**E**

Appendix 4

Samples from Överåda with total lipid residue content and interpretation.
Abbreviations used for the interpretation are listed in page 40.

Sample	Content	Neutral lipids				Isoprenoidic alcanoic acids		ω-(alkyl-phenyl) alcanoic acids			Terpenoids	Interpretation
	mg/g	C18:0/C16:0 (0.48)	Cholesterol	Phytosterols	Wax-residues	4, 8, 12- TMTD	3 7,11 15- TMHD	C16	C18	C20		
Ö101	-	-	-	-	-	-	-	-	-	-	-	E
Ö201	> 0.2		+	-	Tr	-	+	-	-	-	-	FMV
Ö202	1.2	0,25	+	-	+	+	+	+?	Tr	+?	-	FMV
Ö301	Tr		+	-	-	-	-	-	-	-	-	FM
Ö401	-											E
Ö402	-		-	-	-	-	-	-	-	-	-	E
Ö501	-		-	-	-	-	-	-	-	-	-	E
Ö601	0.4	0,31	-	-	+	-	+	-	-	-	-	V
Ö701	0.5	0,35	Tr	-	+	+	+	Tr	+	+	+	FMV
Ö801	-	-	-	-	-	-	-	-	-	-	-	E
Ö901	Tr	-	-	-	Tr	-	-	-	-	-	-	V
Ö1101	0.005		-	-	Tr	-	-	-	-	+	-	V
Ö1201	-		-	-	-	-	-	-	-	-	-	E
Ö1301	-		-	-	-	-	-	-	-	-	-	E; Miniature.
Ö1401	-		-	-	-	-	-	-	?	-	-	E; Miniature.
Ö1501	-		-	-	-	-	-	-	-	-	-	E
Ö1601	Tr											E
Ö1701	0.1	Low	+	+	-	-	-	-	-	-		FMV
Ö1801	Tr		-	+	-	-	-	-	-	-	-	V
Ö1901	Tr		-	-	-	-	-	-	-	-	+	E
Ö2001	Tr		-	Tr	-	-	-	-	-	-	-	V
Ö2101	-		-	-	-	-	-	-	-	-	-	E
Ö2201	0.2	0,22	-	+	-	-	+	-	-	Tr	+	FMV
Ö2301	Tr	-	-	Tr	-	-	-	-	-	-	-	E

Appendix 5.

Appendix 5

Samples from Trössla. Protocols from the treatment with acid (A) and base (B). Abbreviations used for the interpretation are listed in page 40.

Sample	Content	Neutral lipids				Isoprenoidic alcanoic acids		ω-(alkyl-phenyl) alcanoic acids			Terpenoids	Interpretation
	mg/g	C18:0/C16:0 (0.48)	Cholesterol	Phytosterols	Wax-residues	4, 8, 12-TMTD	3 7,11 15-TMHD	C16	C18	C20		
T101	**0.005**		+	-	+	-	-	-	-	-	-	**AV**
T101A		**0,35**	+	+	**Tr**	+	+	?	+	+	-	**FMV**
T501	-	-	-	-	-	-	-	-	-	-	-	**E**
T501A	-	**0,42**	+	-	-	-	-	-	-	-	-	**FM**
T502	-		-	-	-	-	-	-	-	-	-	**E**
T502B	-	**~0,6**	-	-	-	-	-	-	-	-	-	**E.**
T601	-	-	-	-	-	-	-	-	-	-	-	**E.**
T601B	**Tr**	**~0,4**	-	-	**Tr**	-	-	-	-	-	-	**V**
T1101	**0.2**	**0,34**	+	**Tr**	**Tr**	+	+	+	+	+	**?**	**FMV**
T11A		**0,33**	**Tr**	-	+	+	-	-	-	-	-	**FMV**
T1201	**0.2**	**0,33**	+	+	+	+	+	?	+	+	**DHA**	**FMV**
T12B	-	**0,30**	-	-	+	-		+	+	+	**DHA**	**FMV**
T1501	**0.03**	**0,01**	**Tr**	-	-	-	-	-	-	-	-	**FM**
T15A	-	**~0,8**	**0,06**	+	+	+	+	-	-	-	**DHA**	**RV**
T18	**Tr**	-	-	**Tr**	-	-	-	-	-	-	-	**V**
T18A	-	-	-	+	-	-	-	-	-	-	**DHA**	**V**
T22	-	-	-	-	-	-	-	-	-	-	-	**E**
T22A	-	**0,3**	-	+	**Tr**	-	-	-	-	-	**DHA**	**V**
T24	-	-	-	-	-	-	-	-	-	-	-	**E.**
T24A	-	-	-	-	-	-	-	-	-	-	**DHA**	**E. Heated?**

Appendix 6.

Appendix 6

Samples from Överåda. Protocols from the treatment with acid and base. Abbreviations used for the interpretation are listed in page 40.

Sample	Content	Neutral lipids				Isoprenoidic alcanoic acids		ω-(alkyl-phenyl) alcanoic acids			Terpenoids	Interpretation
	mg/g	C18:0/C16:0 (0.48)	Cholesterol	Phytosterols	Wax-residues	4, 8, 12- TMTD	3 7,11 15- TMHD	C16	C18	C20		
Ö201	**>0.2**	**Low**	+	-	**Tr**	-	+	-	-	-	-	**FMV**
Ö201A	**-**	**0,22**	+	-	**Tr**	-	+	-	-	-	-	**FMV**
Ö202	**1.2**	**0,25**	+	-	+	+	+	+?	**Tr**	+?	-	**FMV**
Ö202B	**-**	**-**	**Tr**	-	**Tr**	+	-	-	**Tr**	-	-	**FMV**
Ö301	**Tr**		+	-	-	-	-	-	-	-	-	**FM**
Ö301A	**Tr**	**0.59**	-	-	**Tr**	-	-	-	-	-	-	**A? V?**
Ö1101	**O.005**		-	-	-	-	-	-	-	**Tr**	-	**V**
Ö11A	**Tr**	**0,26**	+	+	**Tr**	-	-	-	-	-		**FM**
Ö2301	**Tr**	**-**	-	**Tr**	-	-	-	-	-	-	-	**E**
Ö23B	**Tr**		-	**Tr**	-	-	-	-	-	-	-	**E. Tr?**