6. Results

6.1. Introduction.

Three questions were proposed in the chapter 2 that could help us produce a meaningful dataset of plant microfossils from Mesolithic and Early Neolithic surface deposits. These were;

1. whether plant microfossils survived in association with ceramics,
2. whether these microfossils could be accorded an origin related to the role of the vessel rather than contamination,
3. and finally, whether the microfossils could be identified to a plant food.

The answers to these questions will be presented here, on a site by site basis. Following these primary data, pertinent evidence from the results of organic-geochemical analyses will be combined, as will evidence of ceramic features, in order to expose patterns of ceramic use and food combinations. Descriptions and illustration of modern reference material for starches and phytoliths is given in Appendix V. A compendium of the raw archaeological data per sherd is given in Appendix VII, including images of starches and phytoliths, and organic-geochemistry findings.

6.2. Neustadt.

6.2.1. Do indicators of foods (including phytoliths and starches) survive in association with the vessels?

6.2.1.1. Macroremains.

Low-powered microscopy was most useful at Neustadt for recovering animal products that may have been cooked. Most frequently this meant fish products, evinced by carbonised fish scales, or scales embedded in the deposit. The recovery of these remains cannot be confidently said to be representative of the extent of past aquatic resource use, as the remains are very fragmentary and clearly at risk of destruction and/or erosion from the deposit; the largest scale fragment was c. 1mm.

More features were found in the Ertebølle (EBK) residues than from the Funnel Beaker (TRB) vessels. Of the 17 EBK deposits, 10 had visible features such as fish scales, possible leaf matter and possible bone fragments. This contrasts with an absence of any features in the 20 TRB residues observed, and a general amorphous appearance at low magnification.

Examples of possible fish scales were examined by Dr. Jen Harland of York University. Only three samples contained examples preserved enough to give a cautionary identification. A fragment from sample N_3148_F exhibited a concentric 'fingerprint' type circuli pattern, displayed in figure 6.1. This is consistent with the scales of the Salmonid family, and occurred also in N_2648_F and N_1025_S.

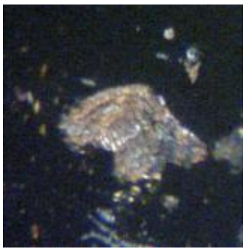


Figure 6. 1. The light brown feature in this image is a portion of fish scale with concentric circuli consistent with a member of the Salmonid family, x20.

Limited success was also achieved at the identification of plant remains from the EBK residues at low magnification. In a number of cases it was possible to suggest leaf matter or plant stalk, but not to confirm identification, as for example with N_3304_F (figure 6.2 a and b). More success was had with sample N_3201_S where it was possible to observe lenticels in the initial periderm of bark (figure 6.2c), small blistered arrangements of cells involved in gaseous exchange. The adherence of a shiny 'tar-like' substance to the sample suggests perhaps birch bark. However, the lenticels of birch (*Betula* sp.) are transverse, and those on the sample appear to be longitudinal.

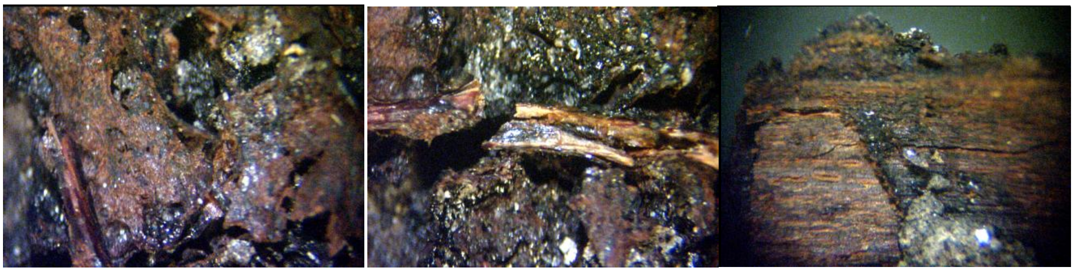
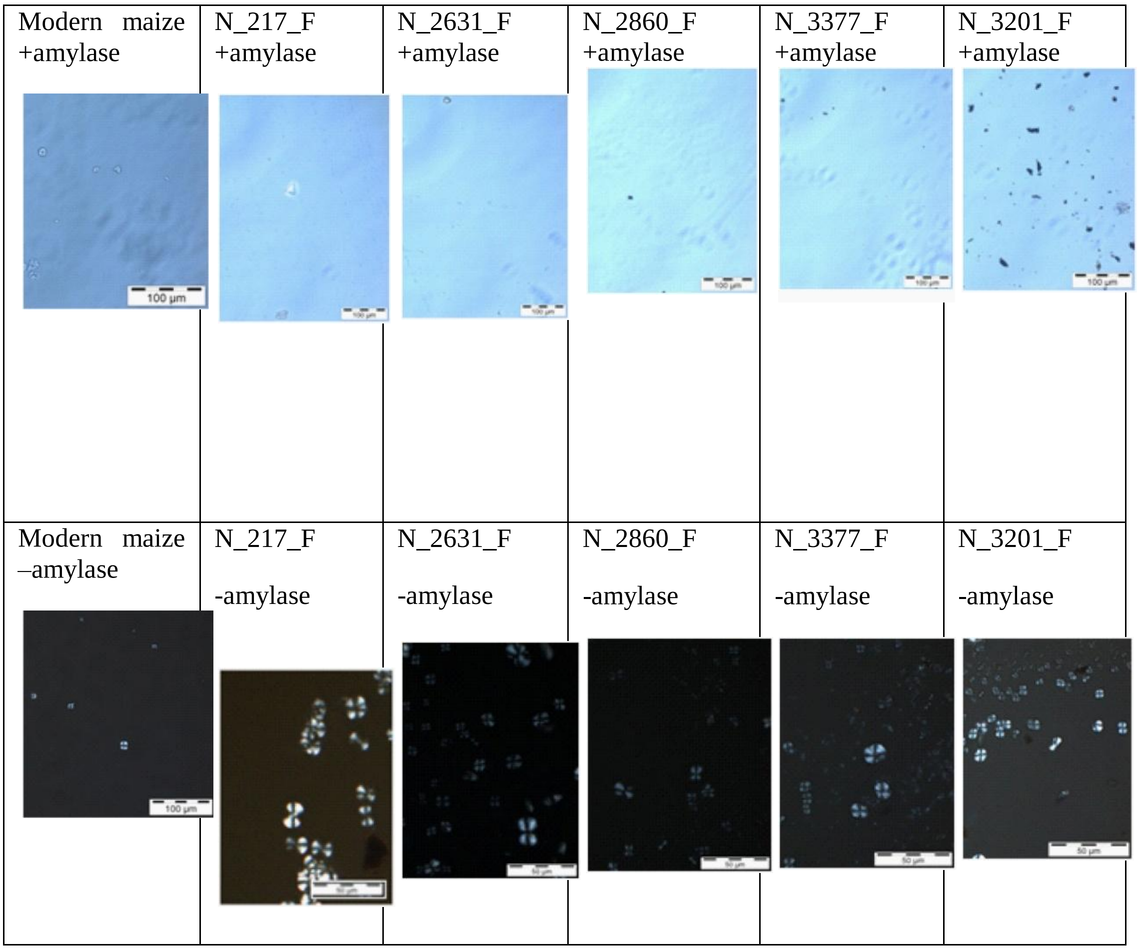


Figure 6. 2. a) possible leaf matter x30, b) a possible plant stalk embedded in the charred matrix x30, c) bark periderm showing lenticels, x20.

6.2.1.2. Starch grains.

Using confocal microscopy up to magnifications of x600 it was possible to recover plant microfossils from the Neustadt residues. Starches were present in varying conditions of preservation, some seemingly undamaged, and some with greater degrees of heat alteration such as swelling and retrogradation. Birefringent artefacts were confirmed as starches by degradation with α-amylase (figure 6.3). In all five archaeological samples and the modern control, the addition of amylase degraded the starch. Granules were present in all of the negative samples, including the negative modern control. At Neustadt it was possible to capture time-lapsed images of this degradation process (figure 6.4).



Modern maize +amylase | N_217_F +amylase | N_2631_F +amylase | N_2860_F +amylase | N_3377_F +amylase | N_3201_F +amylase

Modern maize –amylase | N_217_F -amylase | N_2631_F -amylase | N_2860_F -amylase | N_3377_F -amylase | N_3201_F -amylase

Figure 6. 3. The amylase degradation of starches from a sub-group of Neustadt foodcrusts, showing also the positive presence of starches in the polarised negative controls and modern negative controls. All samples were viewed in both polarised and brightfield light. Polarised images were taken if starches were present because the extinction cross better demonstrates their occurrence.

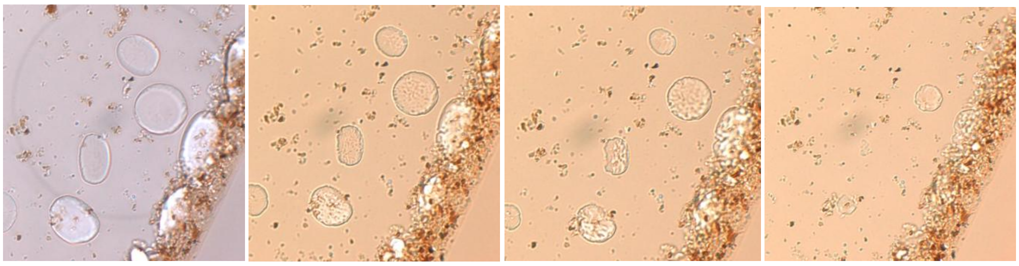


Figure 6. 4. A time-lapsed capture of starch degradation with amylase from N_2756_F. The sequence from left to right documents intervals at 0 min, 3 min, 6 min, 12 min, x600. The method of capture and degradation in this instance follows Hardy *et al.* (2009).

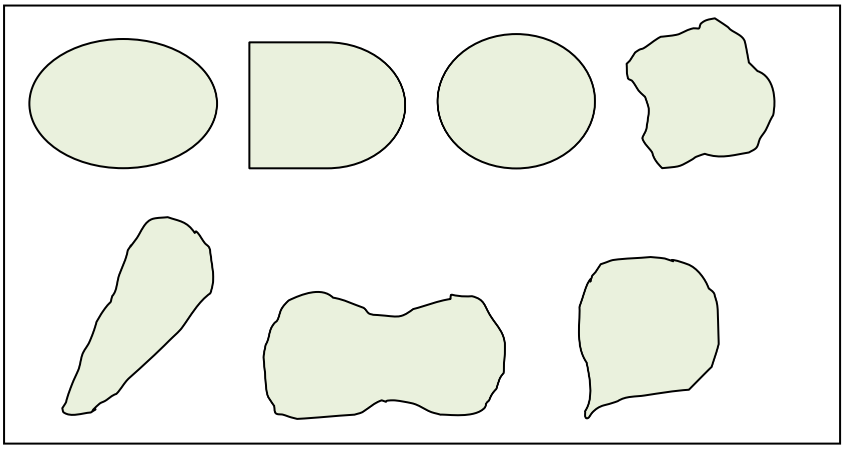


Figure 6. 5. The morphological classes that were confirmed as starch by amylase degradation.

The morphological classes depicted in figure 6.5 were confirmed as starches. At Neustadt granules showed various forms of alteration from heat taphonomy. Some granules appeared to be unaltered, or only mildly so compared to modern correlates, consistent with the observation by Barton and Torrence (2006, 45) that heat alteration of granules in water occurs over a range of temperatures, rather than as a single homogenous event. The situation is well illustrated by the 'bean-shaped' granules shown in figure 6.6. In an unaltered state this granule is small, averaging only a few microns in length. The small size is correlated with its hydration (Alsberg, 1938; Barton and Torrence, 2006). Through heating in water the extinction cross becomes progressively more visible and the granule swells, particularly at the distal ends. One degradation pathway results in the rupture and gelatinisation of the granule, which is beginning in figure 6.6c. The second taphonomic pathway evidenced by many of the granules is retrogradation, as for example those granules in figure 6.6d. In these instances swelling is slow enough that catastrophic structural changes do not take place. The partial loss of amylose renders the granules more brittle, and cracking can occur, usually along expanded lamellae.

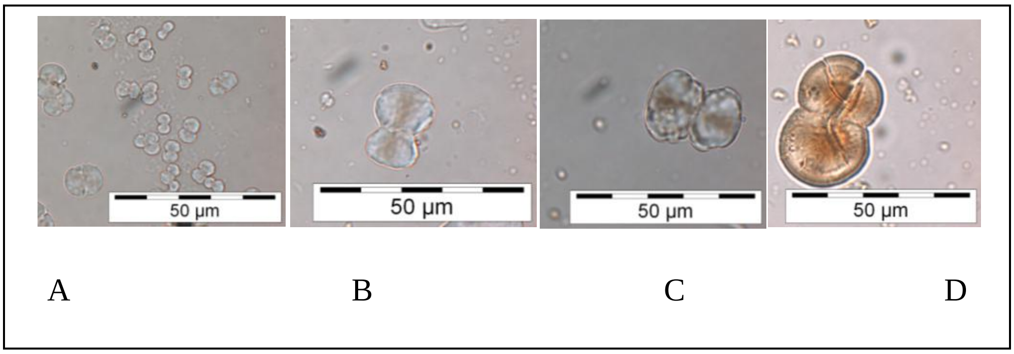


Figure 6. 6. Under the influence of heat bean-shaped starches swell (a-b), and may either begin to rupture as the gelatinisation point is reached (c), or they crack along lamellae (d).

The length and width measurements of a sample of one hundred 'bean-shaped' granules, give an indication of the extent of heat alteration in a randomly chosen sample from Neustadt (figure 6.7). The range of sizes is quite evenly spread between the very small c.6 x 2µm up to larger examples c.10 x 3-4 µm, with some even larger examples nearly 12 µm long. In general there is a tendency for a greater increase in length than in width, as a feature of the swelling.

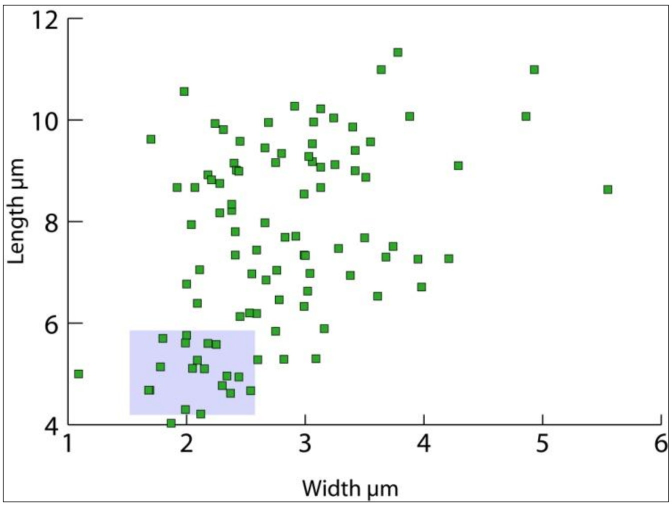


Figure 6. 7. In a sample of 50 starches from a single 'bean-shaped' class at Neustadt, heat-induced swelling is in evidence. The shaded region illustrates the size range for modern unheated examples (N=50) of this class type. Outside this range, the granules began to show visible evidence of heat-alteration such as cracking.

6.2.1.3. Phytoliths.

The possibility for the preservation of phytoliths is much less in question, because of the thermal stability of silica. Silica bodies were indeed recovered from the Neustadt archaeological residues. Their siliceous nature was established based on their properties in polarised light; they are non-crystalline and so are non-iridescent.

6.2.2. Are these indicators related to the vessel use or are they derived from the burial environment?

6.2.2.1. Starch granules.

Normalised starch granule counts (mg^{-1} of surface deposit) show two apparent clusters (figure 6.8) separating low (green bars) and high (orange bars) starch representation. Generally interior deposits (F) exhibit higher counts than exterior ‘sooty’ crusts (S). Twenty out of thirty-three of the interior deposits have over 200 granules mg^{-1}, compared to none of the five exterior deposits exceeding 100 granules.

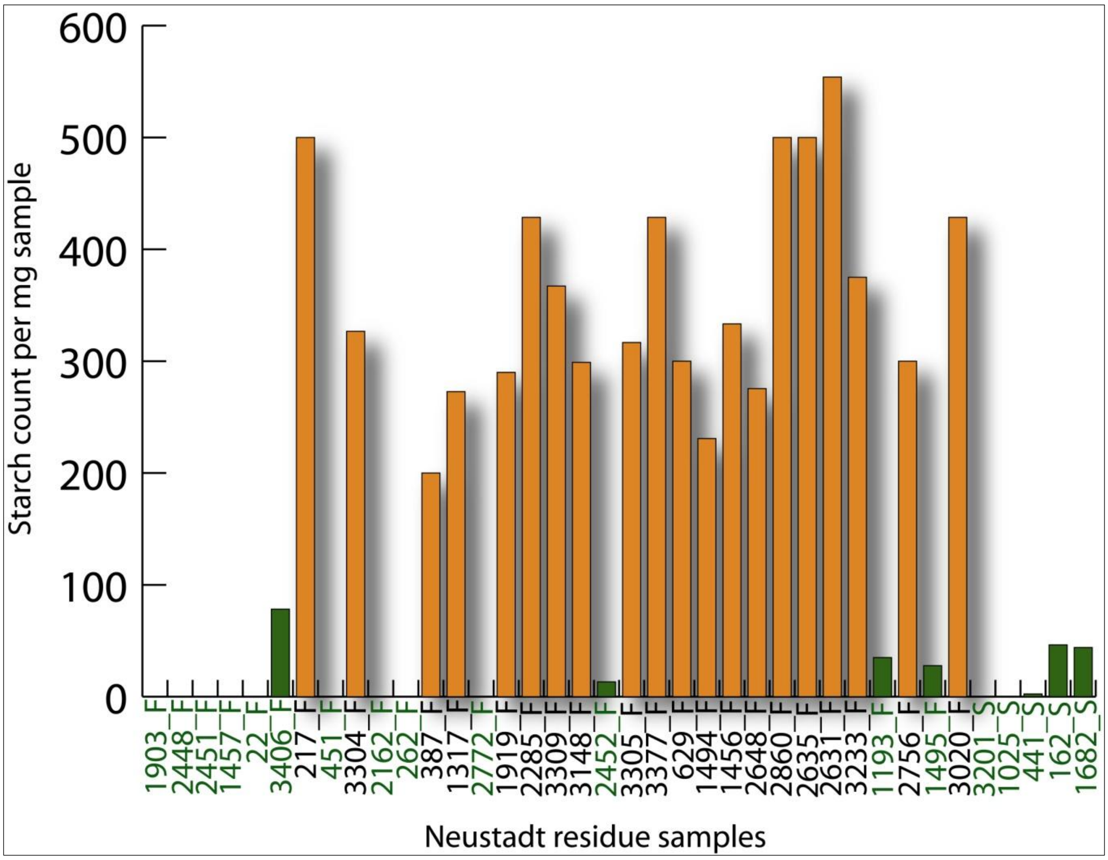


Figure 6. 8. Starch counts from the Neustadt foodcrusts (mg^{-1}). There is a nominal distinction between high and low counts, indicated by orange and green bars respectively.

A t-test shows the difference between interior (F, N=33) and exterior (S, N=5) counts to be significant ($p = 9.85^{-07}$ (<0.01), t= 2.03). This is consistent with a deliberate packing of the interior of the vessels with starchy plant foods. The complete absence of any granules in 11 instances supports the notion that the carbonised matrix is dense and non-porous enough to effectively minimise contaminant starches from the burial environment.

Thirteen of the interior residues fall into the low count per milligram cluster. Their values are similar to the ‘sooty’ exterior deposits suggesting they represent vessels that have not been used to process starchy plant foods, rather than vessels exhibiting differential degradation of starches. Samples in this low cluster were removed from subsequent species identifications. Soil samples yielded similar low starch counts to the sooty exteriors (average 0.013 granules mg^{-1}, 0.01 to 0.02 granules mg^{-1}) showing an insubstantial migration between the carbonised ‘food-crust’ and surrounding sediment. Were a foodcrust to *be* more porous in composition therefore, it is still unlikely that the crust would uptake contaminant starches against the concentration gradient of these microfossils from sediment to ceramic deposit.

6.2.2.2. Phytoliths.

Normalised silica body counts (mg^{-1}) from Neustadt also display nominal clustering into high and low counts, though less pronounced than for the starches. There is a significant difference between interior (F) and exterior (S) deposits though ($p = 0.004$ (<0.01), t= 2.03, N=33 (F), N=5 (S)). Of the thirty-three interior deposits there were some clear examples where counts were very low, such as N_2631_F and N_1317_F. A conservative threshold of fifty phytoliths $mg^{-1}$was adopted to filter low from high counts.

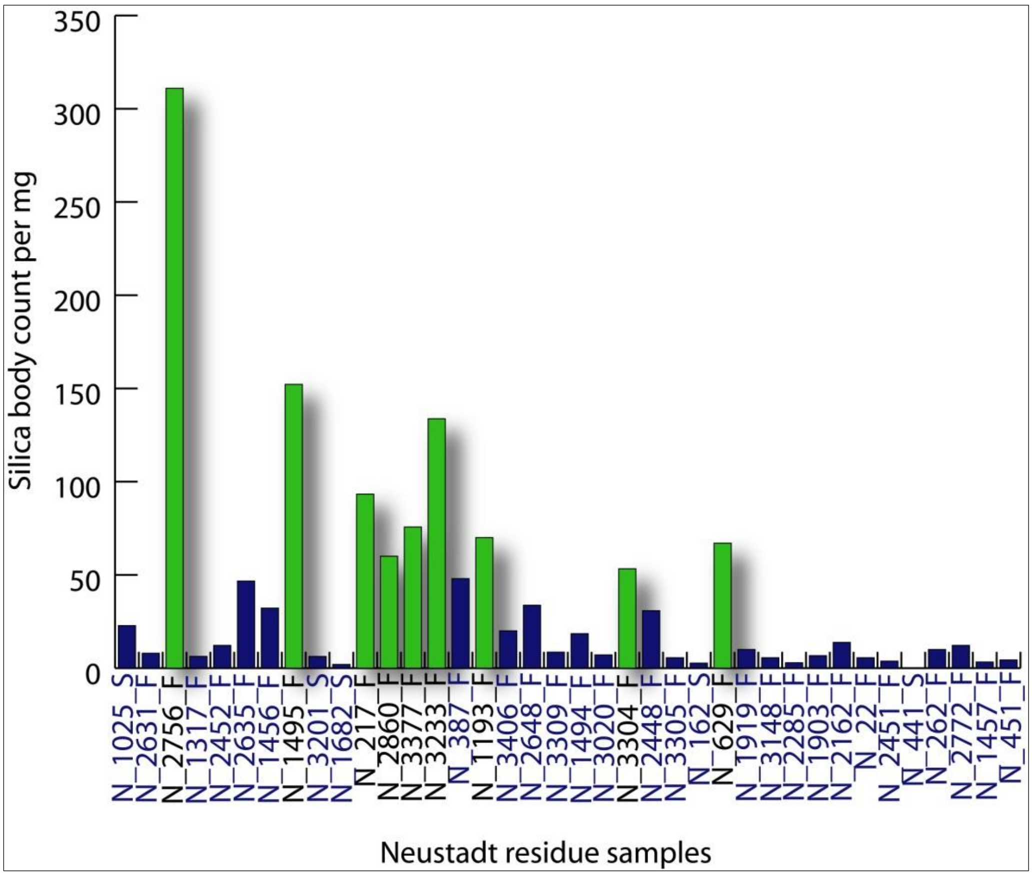


Figure 6.9. Silica body counts for Neustadt foodcrusts (mg^{-1}). Those bars indicated in green are statistically higher counts than those indicated by a blue bar.

Those samples that have low counts are indicated by a blue column in figure 6.9, those designated high counts have a green column. Nine samples were accepted for further phytolith analysis. Of note are those samples such as N_441_S that have a complete absence of silica bodies, supporting the notion that the residue matrix is preventing the contaminant incorporation of silica from the burial environment, suggesting the low interior (F) counts do indeed represent pots that have *not* been used for the processing of silica rich plant material.

6.2.3. Can the microfossils be identified to a plant food origin?

6.2.3.1. Starch granule classification: Neustadt.

The automated classification outcomes for each image taken were combined to give a sample result. Figure 6.10 shows the percentage of granules identified as each species, with a final column showing the most likely class for that sample, if we were to assume a single species is present in the deposit. Thirteen have considerable proportions classified as acorns (*Quercus* sp.), and 11 of those have been classified as primarily acorn type grains. These findings correspond strongly with manual observations of the distinctive acorn type granules, suggesting that a primary role for these vessels was the processing of acorns.

Sample	#granules	*Acorus calamus*	*Arum maculatum*	*Cyperus longus*	*Armoracia rusticana*	*Triticum monococcum*	*Pteridium* sp.	*Filipendula ulmaria*	*Quercus* sp.	*Typha latifolia*	*Fagus* sp.	*Sparganium erectum*	*Corylus avellana*	**Most likely species**
N1317	45	0	0	0	0	0	0	29	67	0	0	4	0	*Quercus* sp.
N1456	23	22	9	30	9	9	4	9	9	0	0	0	0	*Cyperus longus*
N1919	1	0	0	0	0	0	0	0	100	0	0	0	0	*Quercus* sp.
N217	46	74	0	15	0	2	4	0	2	0	0	0	2	*Acorus calamus*
N2285	19	32	0	0	0	0	0	16	5	0	5	0	42	*Corylus avellana*
N2631	43	0	2	0	0	0	12	5	79	0	0	2	0	*Quercus* sp.
N2635	70	3	0	0	0	0	3	34	51	0	1	7	0	*Quercus* sp.
N2648	66	32	0	0	9	0	0	30	27	0	0	0	2	*Acorus calamus*
N2756	5	0	20	20	0	20	0	0	40	0	0	0	0	*Quercus* sp.
N2860	60	0	5	2	0	2	12	2	75	0	0	3	0	*Quercus* sp.
N3148	29	0	3	0	0	0	14	0	76	0	0	7	0	*Quercus* sp.
N3233	24	38	0	0	25	0	8	13	0	0	0	17	0	*Acorus calamus*
N3304	23	0	0	0	0	0	4	4	61	0	4	26	0	*Quercus* sp.
N3305	14	0	7	0	0	7	43	14	29	0	0	0	0	*Pteridium* sp.
N3309	27	0	0	0	0	0	4	11	85	0	0	0	0	*Quercus* sp.
N3377	30	0	3	0	0	0	27	3	50	0	3	13	0	*Quercus* sp.
N629	19	0	5	11	0	0	11	0	68	0	0	5	0	*Quercus* sp.
N1494	2	0	0	100	0	0	0	0	0	0	0	0	0	*Cyperus longus*
N3020	60	52	0	0	0	0	0	0	22	0	24	0	1	*Acorus calamus*
N387	303	43	0	0	20	0	0	2	11	0	1	0	22	*Acorus calamus*

Figure 6. 10. The automated classification of starch granules from Neustadt foodcrusts, showing the number of granules analysed for each sample with the percentage of granules allocated to each species class.

Other samples show equally high proportions of some of the other species that generated highly identifiable criteria during testing of the automated classification. For example *Acorus calamus*, a type of edible freshwater reed is classified by the programme in seven of the samples as well as classifications of other edible reeds such as *Cyperus longus* (n=3), with *Corylus avellana* (n=2), *Filipendula ulmaria* (n=2) and *Armoracia rusticana* (n=1). Evidence for a use of cereals is virtually absent; the only sample with moderate percentages is represented by a low granule count, and comes from an Ertebølle vessel.

Although it has been established using multivariate statistical analysis that the modern starch classes are separable using the 26 morphological variables employed in the classification programme, it must be remembered that any archaeological granules that do *not* conform to the size and shape ranges established for the modern references will still be classified to the closest comparison. In other words they will be assigned a class of closest ‘fit’, which leaves open the possibility that species’ *not* included in the reference collection are being incorrectly classified. In the long term continued additions of modern references to the automated classification training with incrementally alleviate this problem. This primary reference collection *is* composed of those species frequently recorded from plant macrofossils on southern Scandinavian sites however, including the sites in this study set.

6.2.3.2. Phytolith classification.

The phytoliths at Neustadt form five classes (figure 6.11). None are known from the literature, and so all have been named according to the International Committee on Phytolith Nomenclature criteria. Commonly present in four of the samples are the ‘globular sinuate’ type (figure 6.11a), which are near spherical bodies with surfaces characterised by irregular concavities, giving a near facetate appearance optically but without the surfaces being truly flat. They average 6-11µm (figure 6.12).

The third descriptor variable notes anatomical origin which cannot be accurately given. However, the features of this phytolith type compare most consistently with the type found in the seed casings of *Alliaria petiolata* (garlic mustard). This identification was confirmed by Marco Madella (*pers. comm.*). These modern globular sinuate phytoliths have a similar range of 4.8-11.2µm and mean of 6.98 µm (figure 6.12). This would narrow down the likely tissue origin to a silicified testa (seed coat), or endosperm tissue. In order to better verify this identification the phytolith content of fennel (*Foeniculum vulgare*), salsify (*Tragopogon porrifolius*), chamomile (*Matricaria discoidea*), and borage (*Borago officinalis*) were analysed, and found not to silicify their seed tissues.

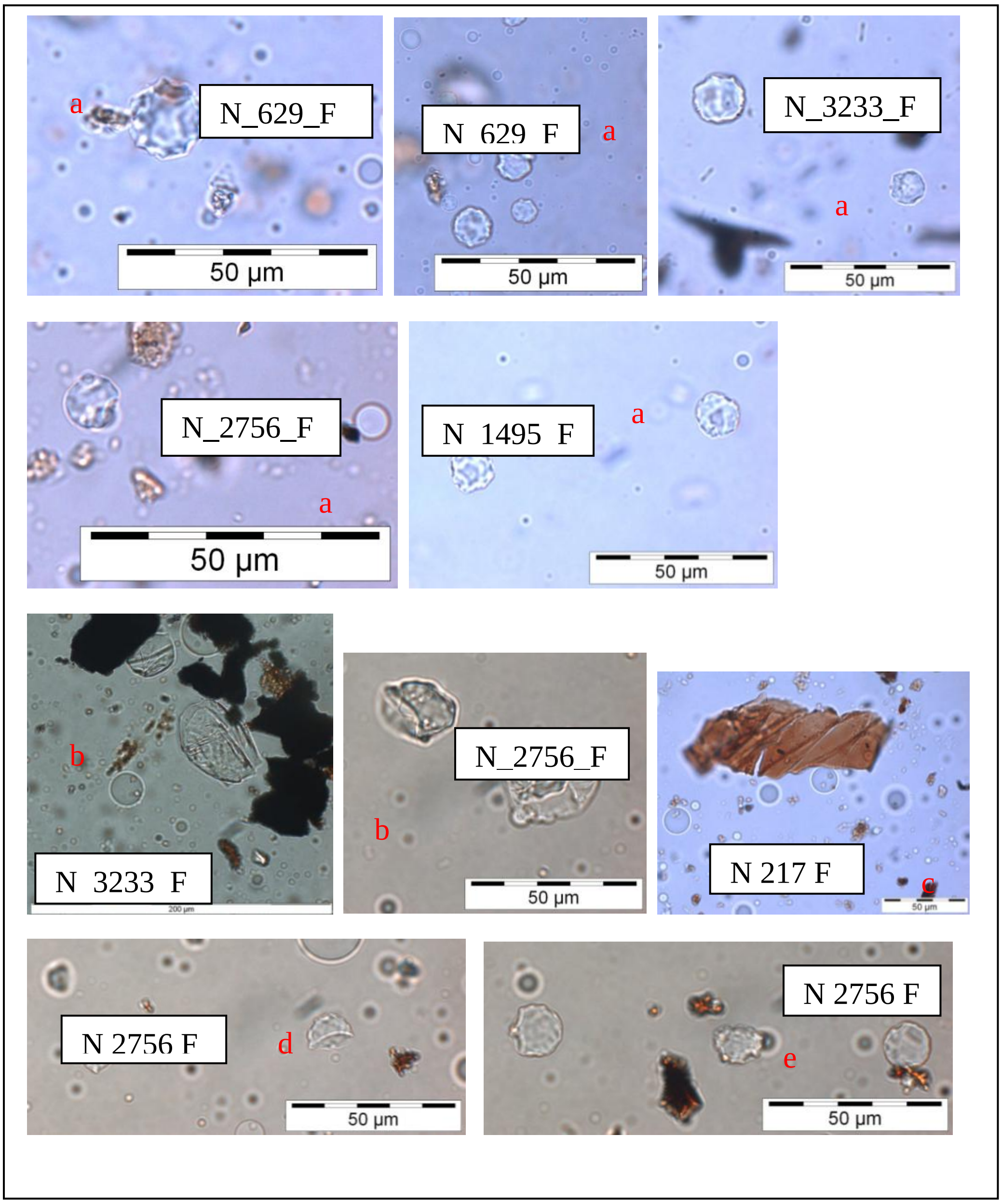


Figure 6. 11. Phytolith forms found in the Neustadt foodcrusts.

Sample code	Sample number	Mean size (µm)	Max size (µm)	Min size (µm)
Neustadt 1025_S	3	10.49	12.48	8.5
Neustadt 2756_F	31	7.24	10.5	4.3
Neustadt	33	7.8	13.4	3.7

1495_F				
Neustadt 3233_F	30	10.27	15.4	6.8
Neustadt 387_F	32	8.11	12.0	5.5
Neustadt 1193_F	30	6.43	9.2	3.6
Neustadt 629_F	30	8.48	16.3	5.0
Modern *Alliaria petiolata*	50	6.98	11.2	4.8

Figure 6. 12. The minimum, maximum and average size of globular sinuate phytoliths from archaeological samples, with modern *Alliaria petiolata* sizes for comparison.

Using Scanning Electron Microscopy is was possible to isolate and image a possible example of the globular sinuate phytolith from *Alliaria petiolata*. This is shown in figure 6.13, and is c. 8μm diam., within the range of modern referents (4.8-11.2μm). The larger example on the right may be next to a smaller example that is at the very small end of the size range.

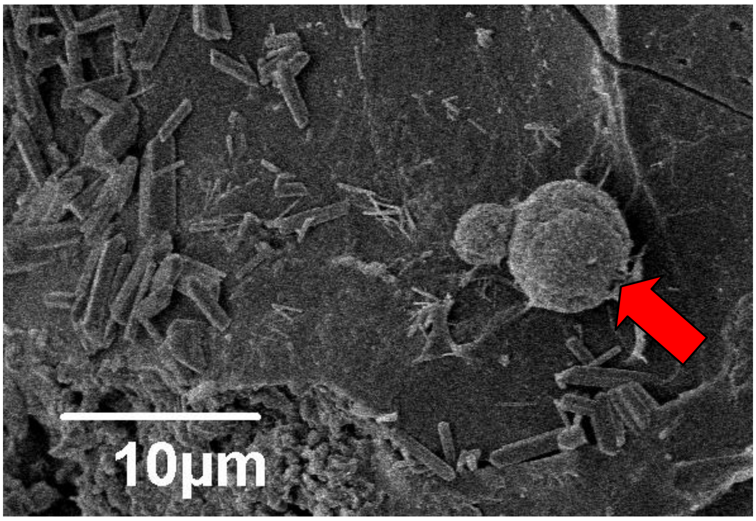


Figure 6. 13. An SEM image of a probable globular sinuate phytolith from Neustadt (N_2756_F) indicated by the arrow.

The second type (figure 6.11b) is an ‘oblong irregular rugulate’ in the case of N_3233_F where the raised striations run parallel to the long axis of the silica body. This class may sub-divide into two however, as the descriptor best suited to N_2756_F for this class is ‘oblong irregular sinuate’, as the raised surface architecture is less linearly arranged. These were grouped as one class, however because of the broad shape similarity, and the similar size ranges (max 69µm, min 17µm, mean 36.7µm).

The third type (figure 6.11c) are epidermal silica skeletons and are common in all of the samples with significant counts mg^{-1}. They are diagnostic only to the degree that they discriminate between monocotyledonous and dicotyledonous plants. The example from N_217_F illustrates a monocotyledon contribution to the contents of the residue; cells are elongated and parallel-sided.

Figure 6.11d shows an unusual ‘semi-globular verrucate’. These are very rare and only found in sample N_2756_F. The convex side displays irregular small bulbous protrusions, whilst posterior to this, what appears as a planar margin is slightly concave with a smoother surface. Their length along the planar edge is recorded as 12.7µm and 12.6µm, from these two examples. There are no recorded correlates in the modern reference collection to suggest a taxonomic origin for this type, and so neither can an anatomical origin be assigned.

The final type (figure 6.11e) has a similar size range (max 18.2µm, min 13.5µm, mean 15.8µm) to the ‘globular sinuate’ but differs in terms of the surface architecture. These are ‘irregular globular facetate’ bodies; whilst being predominantly spherical in many cases they display marked concavities that make sharp depressions in the shape. The majority of the surface however, is organised into shallow facets, giving the appearance of greater smoothness than the ‘globular sinuate’ type. There are no recorded correlates for this type in the modern reference material, making it impossible to assign a taxonomic or anatomical origin. It is possible that this type represents a damaged form of the *Alliaria petiolata* phytoliths, worn smoother, and with portions missing, although this does not explain the facets.

6.2.4. Comparison of plant microfossil data with bulk isotope and lipid residue analyses.

On their own bulk isotopes give an imprecise description of the composition of residues, because there is no way to know the relative isotopic contributions from different foodstuffs. By overlaying and comparing plant microfossil data, bulk isotope data of experimentally cooked foods and more specific isotopic and structural characterisation of lipids, we can disaggregate the bulk isotope patterning and give a more precise description of the vessels’ former contents. Figure 6.14

shows the bulk isotope ratios of those Neustadt samples that were also studied for plant microfossils, alongside a graphical representation of the number of starches mg^{-1} correlated with the δ^{15}N value.

Overall the wide ranging bulk isotope ranges for Neustadt may indicate use-related variation, perhaps brought about by considerable isotopic differences in the contributory foods, with their respective carbon and nitrogen contents. Agglomerative cluster analysis identifies three groupings in the bulk isotope data (figure 6.14) (Appendix VIII, for dendrogram). Cluster A is a group with the most enriched carbon-13 and nitrogen-15 values. Cluster B classifies the majority of the samples with relatively enriched δ^{15}N signatures and δ^{13}C values that span a range from c.-20‰ to -26‰. Cluster C incorporates those samples most depleted in nitrogen-15 as well as five samples most depleted in carbon-13. Within this cluster, at a lower degree of dissimilarity is a sub-cluster D which describes a group of TRB samples with the most depleted δ^{15}N values. From the associated graph of plant microfossil evidence we can see there is a trend for low starch counts in the group with depleted nitrogen isotope values. The δ^{15}N values from this cluster D are statistically lower than the remaining TRB samples (t-test, p=0.0002 (<0.05), t= 2.13, (<c.6‰) N=7, (>c.6‰) N=11).

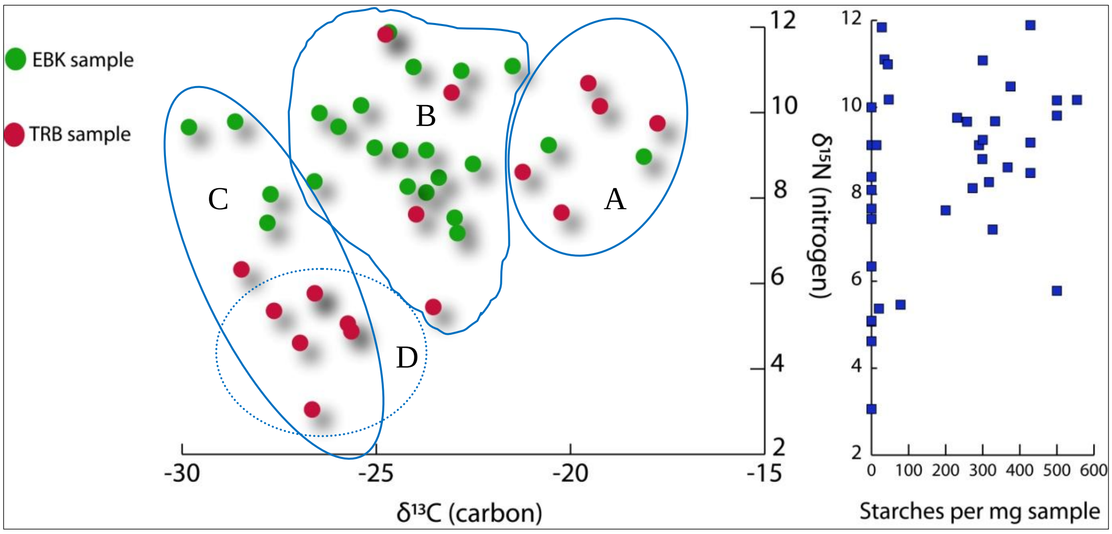


Figure 6. 14. The bulk isotope values of the Neustadt foodcrusts showing EBK and TRB samples, arranged next to a graph with the same y-axis showing the number of starch granules mg^{-1}.Clusters are outlined.

6.2.4.1. Milk.

The $\delta^{15}N$ and $\delta^{13}C$ values of our modern fresh and experimentally cooked reference foods suggest what the vessels making up these patterns may have held (figure 6.15). The milk and plant food sources plot as relatively low $\delta^{15}N$ values, in the region of 4‰ to 6‰. Cluster D is weighted towards the more depleted $\delta^{13}C$ values of the milk and plant.

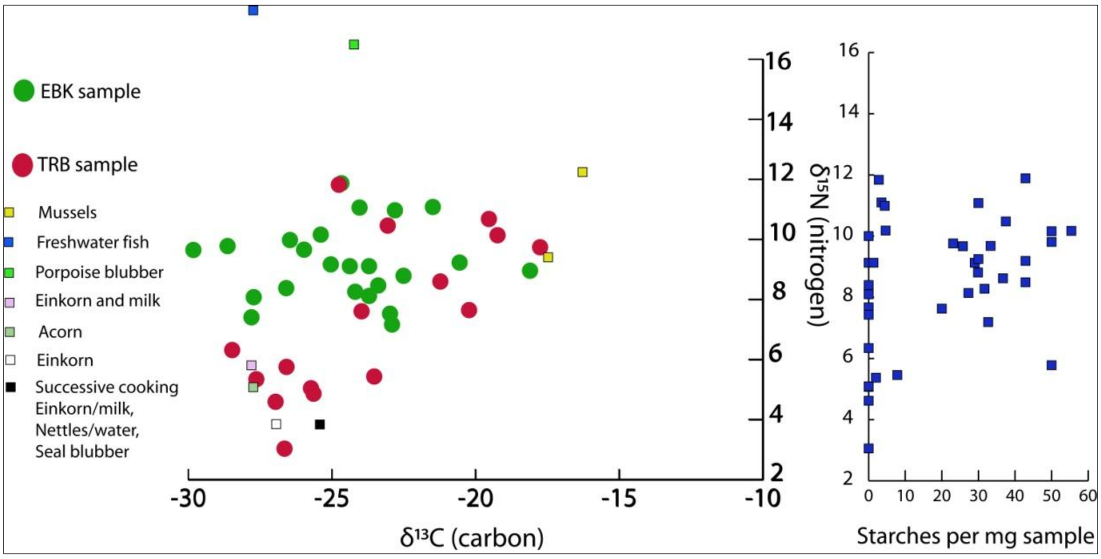


Figure 6. 15. The bulk isotope ratios of archaeological samples plotted against modern experimentally cooked reference foods. This graph again compares the $\delta^{15}N$ values to the starch counts mg^{-1}.

The absorbed residues for a number of sampes in cluster D also have carbon isotope values of individual $C_{16:0}$ and $C_{18:0}$ fatty acids that are consistent with established ranges for ruminant dairy (Dudd *et al*. 1999; figure 6.16) These include sherds N_22, N_441, N_1457, and N_2451. Figure 6.16 shows these $\delta^{13}C$ values on the $C_{16:0}$ and $C_{18:0}$ compounds, with a close up of those samples corresponding to Cluster D. All display $C_{18:0}$ fatty acids depleted in ^{13}C, as a result of routing of dietary $C_{18:0}$ to the mammary gland during lactation. Although it is possible that the accumulation of other reference fats could overlap these relatively discrete isotope ranges in the future, based on established criteria for identifying dairy signatures there is clear evidence here that dairy foods also occur in pointed-based Ertebølle vessels at Neustadt, the earliest evidence of domesticated foods at the site.

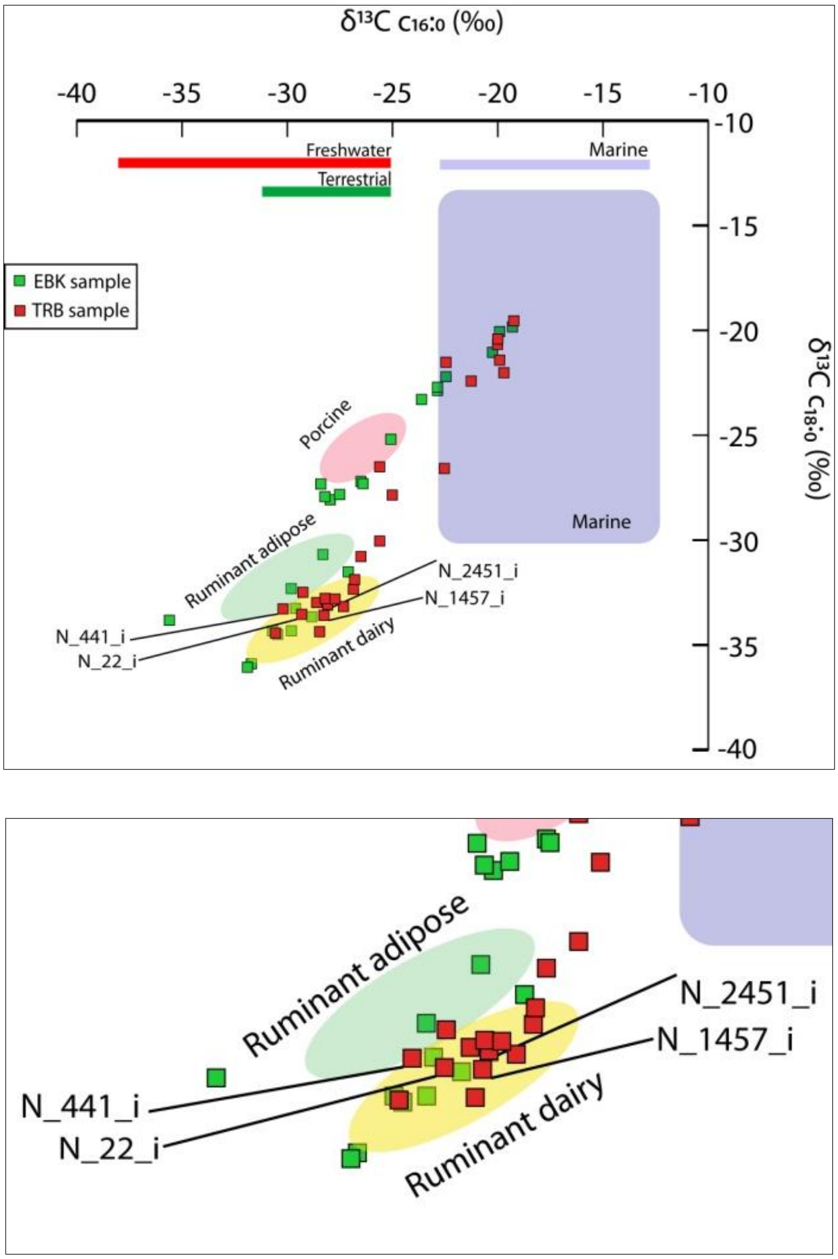


Figure 6. 16. Above, a graph plotting the single compound carbon isotope ratios on the C18:0 and C16:0 fatty acids. Below, a close-up on the ranges for ruminant adipose and dairy foods, with those samples in cluster A noted. Ranges were generated using authentic marine and freshwater reference fats from Danish coastal, river and lake waters. Terrestrial data are a combination of published references (Dudd and Evershed, 1998), with northern German wild boar and cow milk, and are plotted with 95% confidence intervals.

Starches and phytoliths are also absent in the samples in Cluster D, indicating a possibly *specialised* use of these vessels for dairy products during the Funnel Beaker period. Below (figure 6.17) are the bulk isotope values of surface residues overlaid with those samples that have significant quantities of starches (figure 6.17, below) and phytoliths (figure 6.17, above). With the exception of sample N_217, which has identical values to N_22 and so occupies the same graphical position, Cluster D shows no plant remains, whereas those samples more enriched in ^{13}C and ^{15}N show greater mixture of foods.

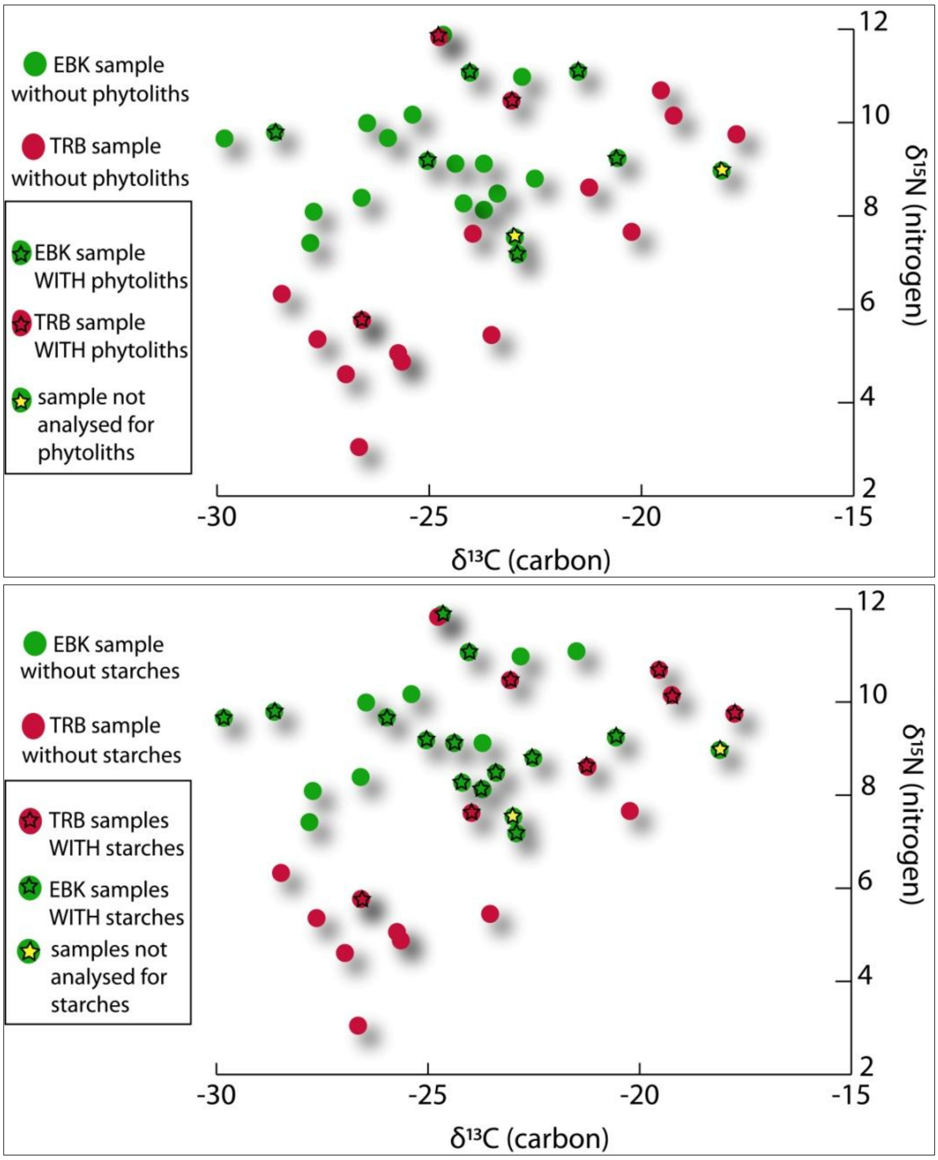


Figure 6. 17. Above, a graph showing the bulk isotope values for the Neustadt foodcrusts, overlaid with symbols that indicate whether significant quantities of silica bodies were associated with those samples. Below, the same plot of bulk isotope values, with symbols indicating whether there were significant starches associated with the sample.

Single compound isotope analysis of the dominant $C_{16:0}$ and $C_{18:0}$ fatty acids provide greater identification precision than bulk isotope ratios but there is not always enough lipid present in surface deposits to generate these results, or surface deposits were absent. Each of the surface deposits has associated absorbed lipid GC-C-IRMS results however, and these were overlaid on the bulk isotope plot to identify patterning in the region with higher δ13C and δ15N values than Cluster D (figure 6.18). The results confirm that Cluster D is dominated (4 out of 6) by dairy signatures, but includes N_2448, that contained lupenone, betulin and hopanol diagnostic of birch bark tar.

6.2.4.2. Aquatic foods.

Many of the vessels from both the Ertebølle and Funnel Beaker periods are relatively enriched in ^{13}C and ^{15}N, which suggests a substantial contribution from marine sources. However, this is only indicative and cannot be used to *securely* identify marine from terrestrial because the surface deposits are heterogeneous mixtures, and bulk isotope measurements are performed on the collective constituents despite the δ^{13}C values of different biomolecules varying. Residues high in lipid would be relatively depleted in carbon-13 compared to a protein-rich residue. By implication, a residue high in marine *lipid* might have a δ^{13}C value comparable to a sample that is dominated by terrestrial *protein* (Craig *et al.* 2007). Nevertheless, considering these caveats, here bulk isotope data indicates continuity in the δ^{13}C values across the transition, with both EBK and TRB samples occupying similar isotopic ranges on the graph (EBK n=23, TRB n=17) evidencing the continued use of aquatic resources (t-test, p=0.61 (>0.05), t= 2.04). Overlaid with the single compound isotope classification, this is further confirmed. Though samples N_1009, N_2635 and N_2631 have insubstantial amounts of lipid for isotopic characterisation of C16:0 and C18:0 fatty acids, lipid characterisation revealed aquatic biomarkers 4,8,12-trimethyltridecanoic acid (TMTD), phytanic acid and C18-alkylphenyls pointing to a marine resource. Additionally, one or more of these biomarkers were identified in all the other vessels with the marine isotopic signatures indicated in figure 6.18 with the exception of N_2162, lending further credibility to this identification. In N_1494 all three biomarkers were identified: C18, C20 and C22 alkylphenyls, TMTD and phytanic acid. At Neustadt, consumption of marine foods such as fish continued into the Neolithic.

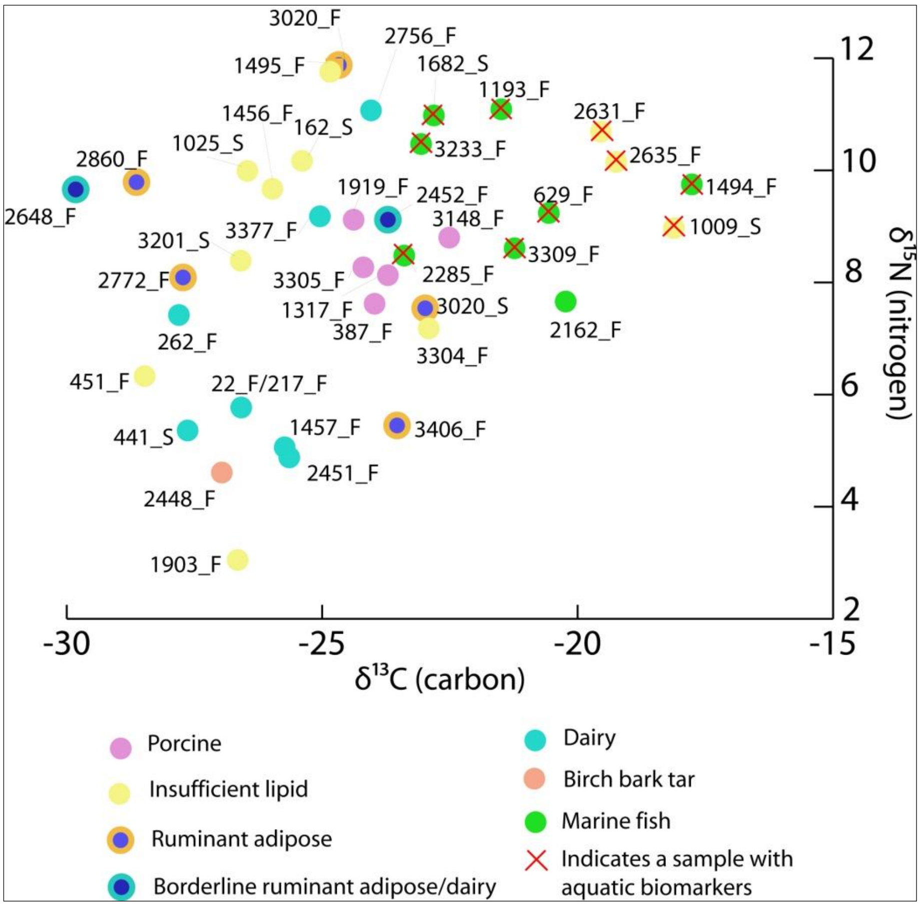


Figure 6. 18. A plot of the bulk isotope ratios of the Neustadt foodcrusts. The datum points are overlaid with symbols representing the food class result of the sample acquired by GC-C-IRMS.

Seventy percent (8 out of 11) of vessels used to process marine resources also have a significant starch component. Whether this is a feature of mixing or successive cooking episodes is unclear, but we can be certain that prescribed use of vessels for either plant processing *or* marine resources is not in evidence. Based on the presence *within* surface deposits themselves of C18, C16 and C20 alkylphenyls (N_1494, N_3233, N_3309, N_1193), phytanic acid (N_1682, N_629) and TMTD (N_1009) it likely that these plants *were* mixed with marine resources.

As to the identity of those marine resources, bulk isotope values of experimentally cooked porpoise and seal blubbers are more enriched in carbon-13 and nitrogen-15 than our archaeological samples (figure 6.15). Seal plot in the region of -12 to -14‰ (δ^{15}N) and -16 to -17‰ (δ^{13}C), very isotopically marine, whereas the migratory patterns of porpoise lend it an intermediate freshwater/marine δ^{13}C value of -25‰. This suggests the marine resources being cooked are more likely to be crustacean and/or fish products rather than sea mammals. In addition, during experimental cooking it was observed that marine oils do not form a surface deposit, and in fact tend to reach such high temperatures that they begin to sear off former deposits from previous meals. Thus it seems unlikely that the well-preserved ‘foodcrusts’ we possess come from a sea mammal origin. In this instance, clarifying a sea mammal origin using single compound isotope analyses is not accurate because marine oils do not contain much C18:0, so if they are mixed with more saturated terrestrial fats the $\delta^{13}C_{18:0}$ of the sample will be disproportionately weighted towards the terrestrial animal fats.

There is one possible use of a vessel to process freshwater fish. Sample N_2860 is dominated by fatty acids with a ruminant adipose outlier $\delta^{13}C$ signature. This places it in a broader range of freshwater aquatic foods. The co-presence of aquatic biomarkers TMTD, phytanic acid, C18 and C20-alkylphenyl biomarkers may represent a pure freshwater fish product rather than a ruminant adipose/aquatic mixture.

6.2.4.3. Porcine products.

Returning to figure 6.18, porcine products were identified by isotopic characterisation of the C16:0 and C18:0 fatty acids in 5 of the vessels that cluster within a range of only around 2‰ on both the $\delta^{13}C$ and $\delta^{15}N$ axes. All contain significant quantities of starchy plants, but none contain preserved phytoliths. Both Ertebølle and Funnel Beaker vessels show porcine residues, although our sampling suggests that the practice was perhaps reduced during the Early Neolithic, with proportions falling from 28% of the total EBK assemblage to only 4% of the TRB ceramics. The mixture of these samples with plant material may have depleted their bulk nitrogen isotope values causing them to plot closer to Cluster D than if they had been single products.

6.2.4.4. Ruminant products.

Ruminant meat makes up only 6% of the contents of vessels, compared to 44% content of ruminant dairy, based on carbon-13 isotope values of the dominant fatty acids (figure 6.16). N_3020, N_2860, N_3406 exhibit ruminant adipose signatures, as does sample N_217 (occupying the same position as N_22) which returns a borderline ruminant adipose/dairy single compound isotope signature. All display possible evidence of mixing or reuse. In the case of N_217 I would lean towards it being evidence of the *mixing* of ruminant products with aquatic, because single compound measurements taken on the ‘foodcrust’- a preservation of the later history of use- are contradicted by mass spectra of the same substrate which show two aquatic biomarkers. The same applies to N_2860 which has all three aquatic biomarkers in the same surface deposit that registered isotopically as a ruminant outlier. Where N_3406 and N_3020 are concerned both absorbed residues evidence aquatic biomarkers (phytanic acid, C18-alkylphenyls and phytanic acid respectively), whilst also returning ruminant single compound isotope signatures, making it difficult to suggest mixing and/or reuse. We can be certain that ruminant meats were not processed exclusively in vessels, at Neustadt they occur as combinations with fish in all cases.

6.2.4.5. Plant products.

The presence and absence of significant plant remains in residues has been mentioned in relation to patterns of animal foods. Lipid residue analysis revealed that all samples with significant plant microfossils also contained compounds consistent, though not diagnostic, of plant including alkane series’ (20-35), long chain alcohols (C26), polyunsaturated fatty acids $C_{18:2}$ and $C_{20:2}$. Sample N_629 also yielded nonacosane, found in *Brassica* sp. leaf-wax but was missing the other markers needed for secure identification such as β-sitosterol (Charters *et al*. 1997).

The automated starch classification allows for greater detail about what plant species may have been cooked and combined in vessels also used for animal products. Figure 6.19 shows a plot of the surface deposit bulk isotopes overlaid with the proportions of starches identified to each species, for each sample. Patterns in the use of vessels are not obvious, and an extended use-life of the vessel must surely be a contributory factor in this. What this implies then, is that for the majority of the vessels there was not an exclusive use of them for the preparation of restricted food products.

One possible exception to this seems to be the group of TRB vessels named Cluster D. These do not show significant quantities of starch and phytolith remains. Example N_217 which has an isotopic dairy signal is the exception, containing high proportions classed as *Acorus calamus* root, a type of edible reed. Perhaps significantly, this sample does not register acorn in high quantities. This point will be expanded on in the interpretation (section 7.2.4.2), but suffice to say that the by-products of acorn processing can have a deleterious effect on dairy gastronomy.

Acorns (*Quercus* sp.) are found in 18 of the 20 samples, suggesting that intensive and temporally extensive processing of acorn took place at Neustadt. The exceptional preservation of this class of starch may be due to the low temperature heating of the acorn to leach toxic tannins. This act would soften the nut-meat and begin to release the amylose content resulting in a slow swelling of many of the starches. This evidence suggests that the role of hazelnut in the diet of hunter-gatherers may have been over-exaggerated to the detriment of other possible staples, like acorn. In a pottery context hazelnuts are only in two vessels in proportions >20%.

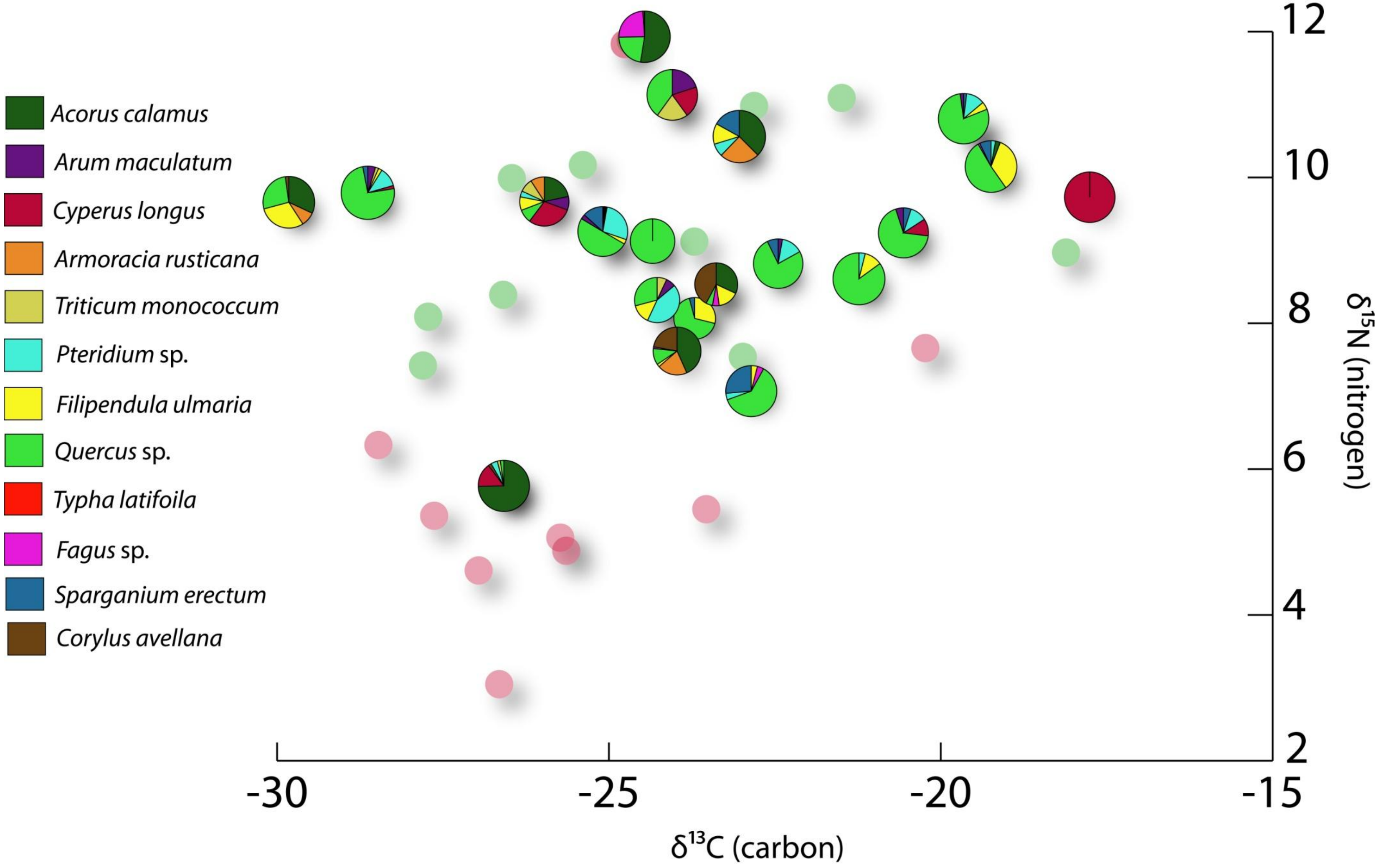
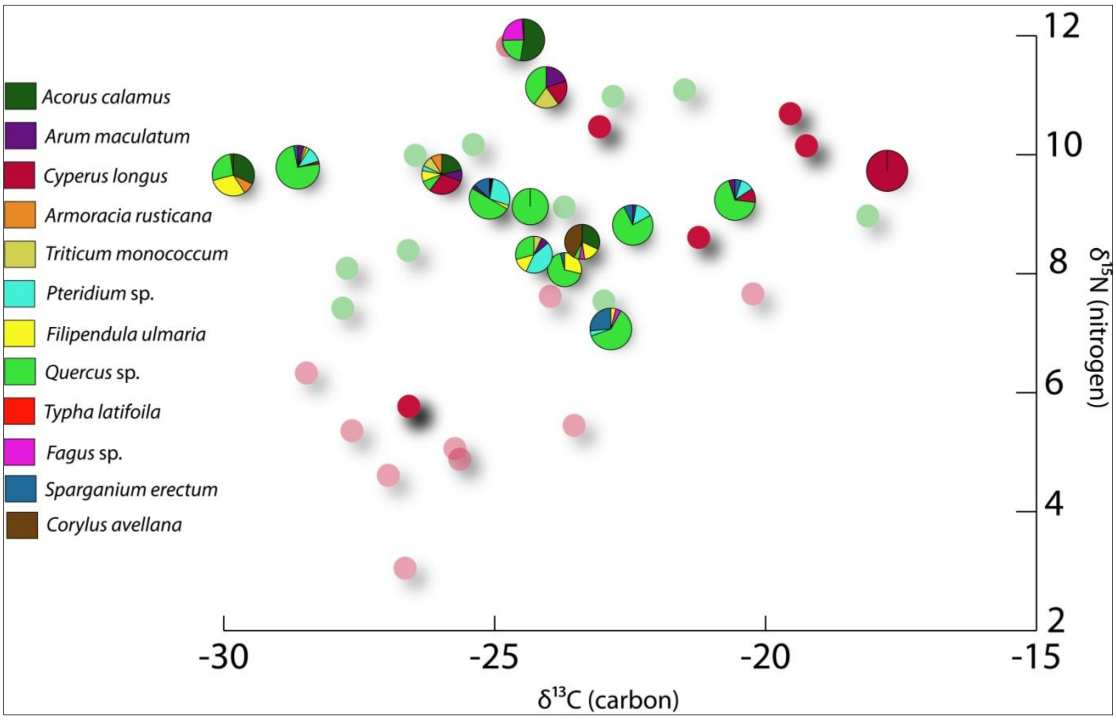


Figure 6. 19. The bulk isotope values of the Neustadt foodcrusts. Those samples with significant starch counts are represented by pie charts indicating the proportions of the different plant species identified using automated classification.

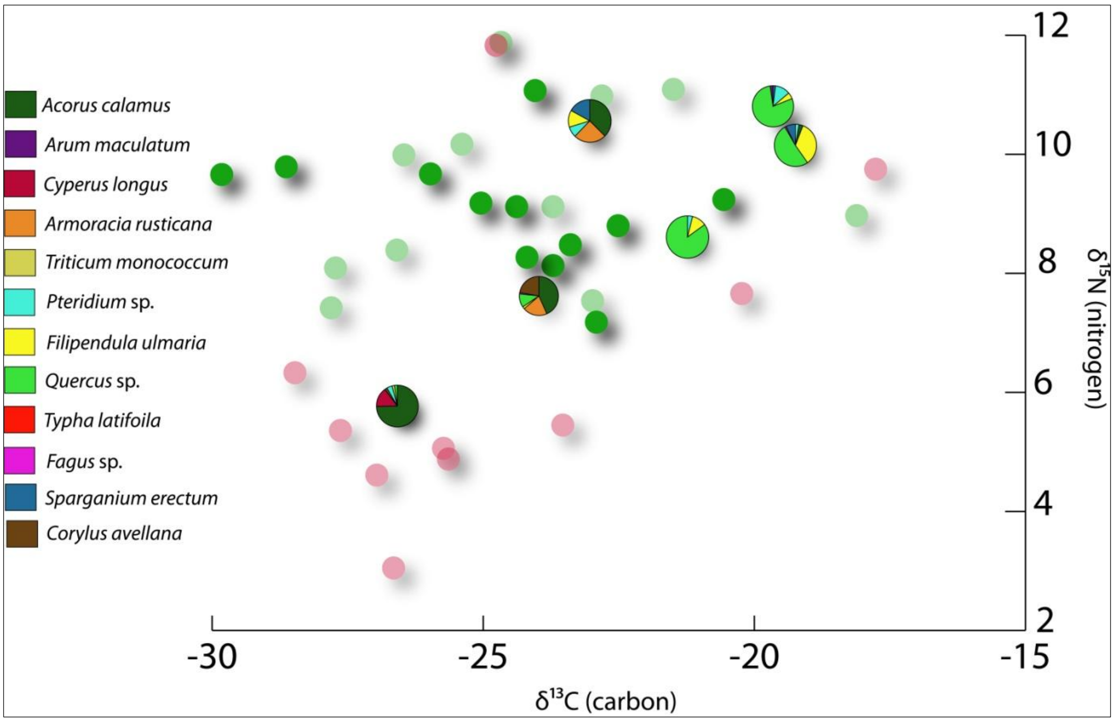
The extensive findings of acorn in both the Ertebølle *and* Funnel Beaker period evidence a much more gradual increase in the importance of domesticated plants than we have seen for domesticated animals products, like milk, which are present in the Ertebølle period. Wild plants massively outweigh the representation of domesticated plants in both periods, and acorn exemplifies this. Although there are findings of *Triticum monococcum* from samples N_2756 and N_1456 we must be cautious of their validity. N-2756 is 20% einkorn, but of a sample count of only 5 starches. Conversely, the sample count for N_1456 may be higher, but the proportion is only 9%, so whilst their identification as domesticated einkorn is possible, it is unlikely.

The most classified staple plant then is acorn *(Quercus* sp.), and from figure 6.18, samples that contain aquatic biomarkers/isotopic signals generally also contain high proportions of acorn type starch. This is further reinforced if we include sample N_2860 as the single example of freshwater fish. The evidence points to a possible association of aquatic foods like fish with acorns then. Sixty percent of samples with biomarker or isotopic values for fish also contain acorn (*Quercus* sp.) granule forms. Exceptions to this trend include N_1494 which is 100% *Cyperus longus* but from a small sample count, N_3233 which does not contain acorn starch, and N_1193 and N_1682 both of which contain no starches, the latter because it is an exterior surface deposit.

Dividing the Ertebølle plant remains from the Funnel Beaker produces some interesting temporal trends (figure 6.20 a and b). Although acorn is present in both periods it is represented in 9/23 (39%) of the respective EBK residues in proportions >20% of the pie charts, compared to only 3/17 (18%) of the Funnel Beaker samples suggesting its staple importance was beginning to decline in the Early Neolithic. To a certain extent the role played by acorn may have been supplemented by edible reeds like *Acorus calamus* during the Early Neolithic, as this starch type is classified in the remaining 3 samples (3/17, 18%) in proportions >20% (figure 6.20b). In the Late Mesolithic style vessels *Acorus calamus* type starch only reaches those proportions in 3/23 of the samples (13%) showing a marginal increase, and at least evidencing that edible reed use persisted rather than dropping off.



a



b

Figure 6. 20. The two graphs both show plots of the bulk isotope values for the Neustadt foodcrusts. In the above graph (a) EBK samples with significant starch are represented by a pie chart detailing the proportions of species represented. In the below graph (b) TRB samples with significant starch are represented by pie charts showing the proportions of plants cooked in them.

6.2.5. Comparison of identified food contents to vessel features.

Estimations of vessel size were made (Glykou *pers. comm.*) based on the diameter of the rim or body where available. Information is less forthcoming from pointed-based styles because the height:width ratio varies much more than with Funnel Beakers, and if only a fragment exists from near the base it is not possible to extrapolate how tall the vessel was, and how wide the mouth. However, figure 6.21 shows some interesting patterning related to the contents of the vessels. Although large vessels are not statistically related to low $\delta^{15}N$ values (t-test, p 0.21 (>0.05), t=2.26, (<6‰) N=6, (>6‰) N=14), Cluster D contains four large vessels, two of which correspond to known dairy residues suggesting an association. N_441 unfortunately has no available size information to support or refute this trend, but although N_1903 has too little lipid for a single compound isotope dairy corroboration, its bulk signature would seem to support a dairy interpretation and mass spectra yielded C16 and C18 fatty acids consistent with animal fats rather than its closest sample relative N_2448 which was lupenone and betulin rich from birch bark tar.

Two of the vessels from the Ertebølle period that show possible dairy signatures from single compound isotope measurements also occur in the only two large vessel examples we have lipid analysis information for. This further supports an association between large vessel size and dairy products. The exception to this is N_2756 which yields a dairy isotope signature and comes from a small vessel (figure 6.21), but contradictory results from 'foodcrust' and absorbed residue suggest this vessel was perhaps *sealed* or waterproofed with milk rather than being used to process/store it.

All those Funnel Beaker vessels that contain marine signatures from single compound isotope analyses are found in large vessels, or vessels that err on the large size of the medium range. Far from evidencing a taboo on the consumption of fish, this evidence suggests that large quantities may have been cooked in a single episode.

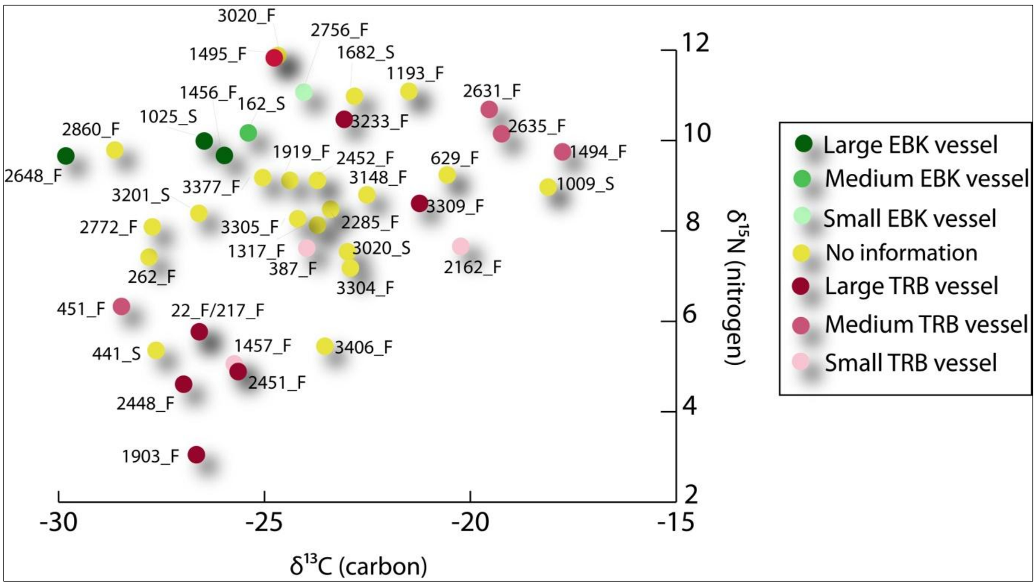


Figure 6. 21. A plot of the bulk isotope ratios of the Neustadt foodcrusts. Each datum point is represented by a symbol expressing the size of the vessel from which the sample was taken. Small= 5-15 cm, medium= 16-25 cm, large= 27-37 cm, extra large= >38cm.

The cluster of vessels with depleted nitrogen values is further marked by the variation in vessel *types* that compose the group (figure 6.22). The production of dairy products; butter, cheeses, yoghurt etc., are multi-stage processes that lends itself to the requirement of different forms of ceramic to fulfil specific functions. TRB styles that diverge from the funnel *beaker* form are significant to cluster D (t-test, $p = 0.008$ (<0.05), $t= 2.45$, (<6‰) N=7, (>6‰) N=11), these divergent forms *only* occur in this cluster. Of note is the presence of two vessels in this group that are jars or flasks, with narrowed necks suitable for the movement of liquid. Two others possess lugs for the looping of carrying cord. A form and function relationship is not a *necessity* for creating dairy products, but the evidence here (figure 6.22) does point to an increasingly specialised dairying economy in the Early Neolithic.

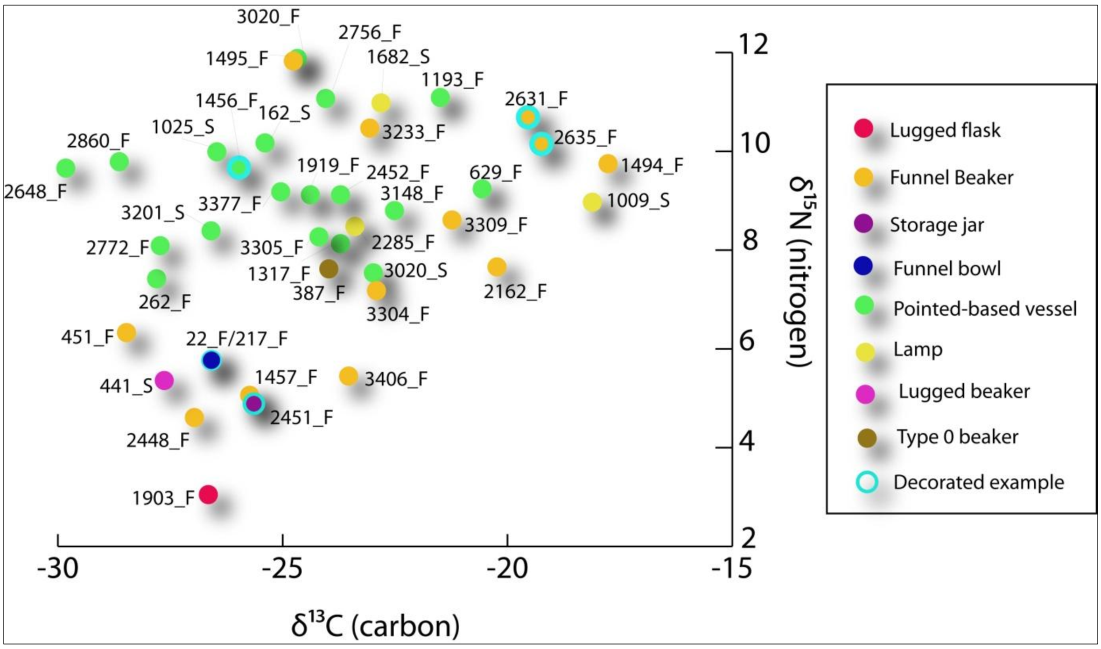


Figure 6. 22. A plot of the bulk istope values for the Neustadt foodcrusts. Each datum point is represented by a symbol that indicates the form type of the ceramic from which the sample derives.

Of particular interest is the occurrence of two vessels in cluster D decorated with an applied list of clay to the exterior of the rim. This characteristic ‘arcade rim’ is a feature found on Michelsburg style ceramics from farming groups further south in Germany. This would suggest that exchange with these agro-pastoral groups was occurring, spearheaded by dairy foods in the context of pottery. And these vessels, marked for use by their style and decoration were exclusive to their particular role. The small sample number does not lend these observations to statistical corroboration, but comparably depleted δ^{15}N values were made on Michelsberg pottery from the site of Doel ‘Deurganckdok’ in the region of 4‰ (Craig *et al.* 2007). Single compound analysis was inconclusive for ruminant dairy, but the fatty acids present were isotopically light consistent with a terrestrial food source (Craig *et al.* 2007), perhaps reinforcing the findings reported here.

6.2.6. Summary of the Neustadt results.

The Neustadt assemblage is composed of both EBK and TRB style ceramics. Continuity in the use of marine foods is evidenced by an insignificant alteration in bulk δ^{13}C isotope values across the transition to TRB wares. There is only one sherd with evidence for the cooking of freshwater fish. In 60% of the vessels used to cook fish significant quantities of acorn (*Quercus* sp.) type starch was also found, pointing to a possible mixture. All of the vessels with evidence for the processing of fish were in larger ceramics.

Porcine food was used in both EBK and TRB contexts. Only 6% of the total assemblage fall in the single compound $\delta^{13}C$ isotope range of ruminant adipose. However, 40% of the total assemblage analysed was used to process dairy foods. Milk is found in 28% of EBK vessels, making it the earliest domesticated food at Neustadt. During the TRB dairy activities seem to become more specialised. A cluster of samples significantly depleted in $\delta^{15}N$ corresponds to samples known to be dairy from single compound isotope analysis. This cluster is absent for plants remains and other food mixtures, and is made up of large sized vessels and vessel forms designed for the processing and carrying of milk.

There is no convincing evidence for the use of domesticated cereals in the context of pottery at Neustadt, although starches and phytoliths preserve well. Wild plant foods persist in importance as other domesticated foods like milk enter cuisine. Acorn (*Quercus* sp.) consistent granules are classified in 90% of samples used to process plants, from both EBK and TRB vessel styles. In contrast, hazelnut (*Corylus avellana*) is little in evidence in a pottery context. Phytolith evidence suggests the spicing of food with garlic mustard (*Alliaria petiolata*) occurred across the transition from EBK to TRB wares. Unidentified phytolith forms imply a greater utility for this technique with larger supporting modern reference materials.

6.3. Åkonge.

6.3.1. Do indicators of foods (including phytoliths and starches) survive in association with vessels?

6.3.1.1. Macroremains.

There was a complete absence of possible carbonised plant material, such as leaf matter at Åkonge, but there was excellent recovery of carbonised fish scales. Seven of the interior surface deposits contained examples of fish scales consistent with a Salmonid source (figure 6.23). The concentric circuli ‘ribs’ are clearly visible in all the examples, but their fragmentary nature precludes the reconstruction of the age of the fish at death.

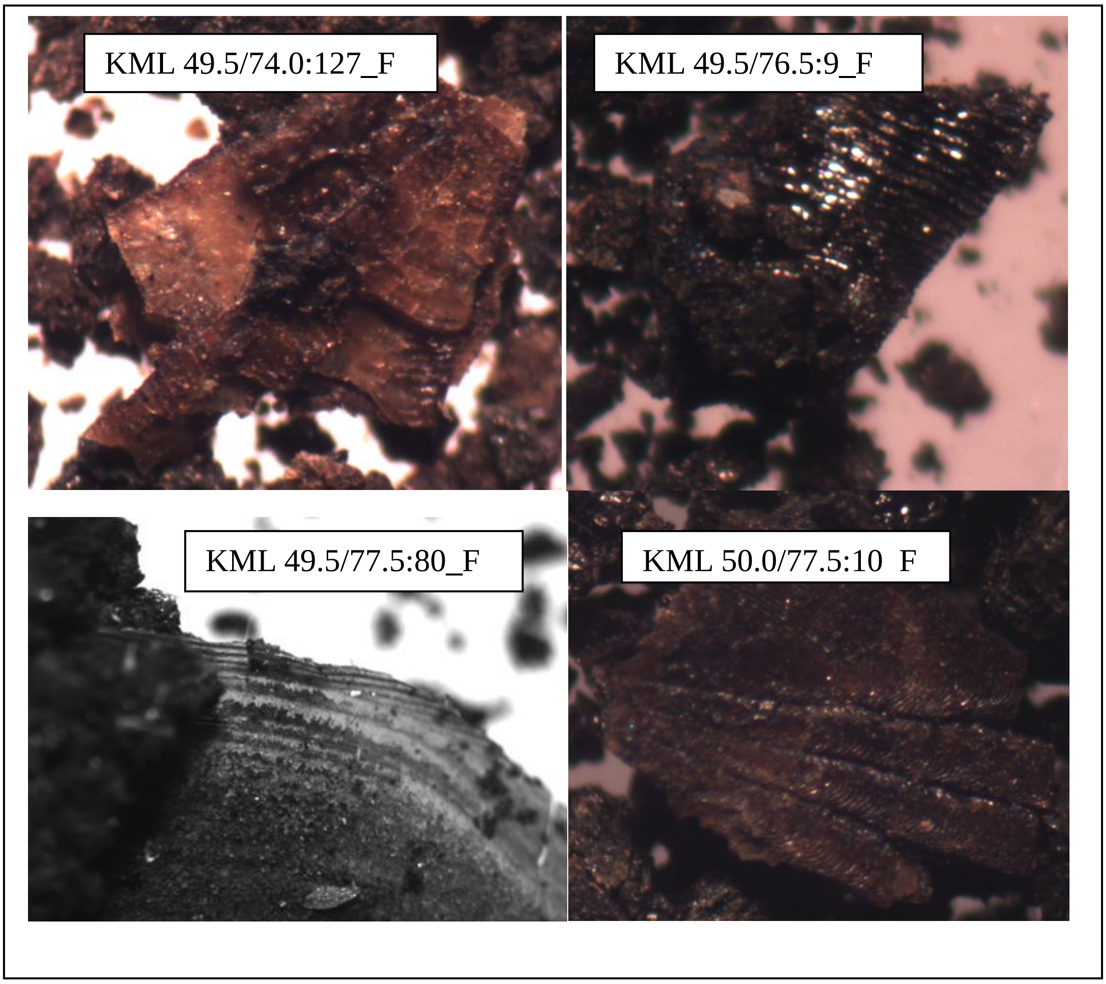


Figure 6. 23. Examples of fish scales found in the Akonge foodcrusts that have concentric circuli patterning consistent with members of the Salmonid family, x40.

In only one example (KML 49.5/77.5:80_F) was convincing evidence of eel discovered from a scale (figure 6.24). The surface appearance is granular, with raised keratin nodules clearly visible towards the bottom of the image. This occurred in a sample which also yielded Salmonid scales.

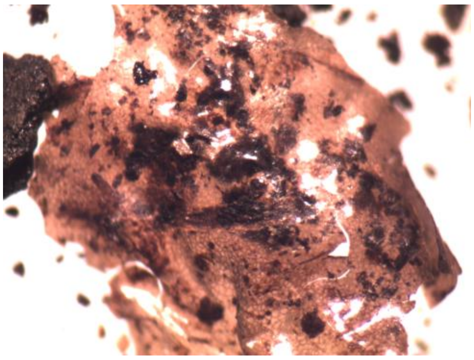


Figure 6. 24. A possible fragment of eel (*Anguilla anguilla*) scale recovered from Akonge foodcrust KML 49.5/77.5:80_F, x40.

6.3.1.2. Starch grains.

Starch preservation at Åkonge matched that of Neustadt in many respects, with eight of the residues exceeding 200 grains mg^{-1}. Similarly the grains varied from unaltered states, through swollen examples, to the gelatinised and retrograded forms. Figure 6.25 is compiled from a random sample of 100 'bean-shaped' granules. The trend is for more examples of smaller sizes showing that fewer of this grain type have been affected by swelling compared to Neustadt. However, the range in the sizes is the same, up to 12µm in length, suggesting a similar potential for the recovery of heat-altered examples. There does not seem to be an obvious difference in preservation between the underwater environment of Neustadt and the bog environment of Åkonge. All artefacts discovered were confirmed as starches by degradation with α-amylase (figure 6.26). Archaeological residues with added amylase showed an absence of starch granules, as did the modern maize with amylase. All samples without amylase displayed granule forms consistent with the types that were identified by automated classification.

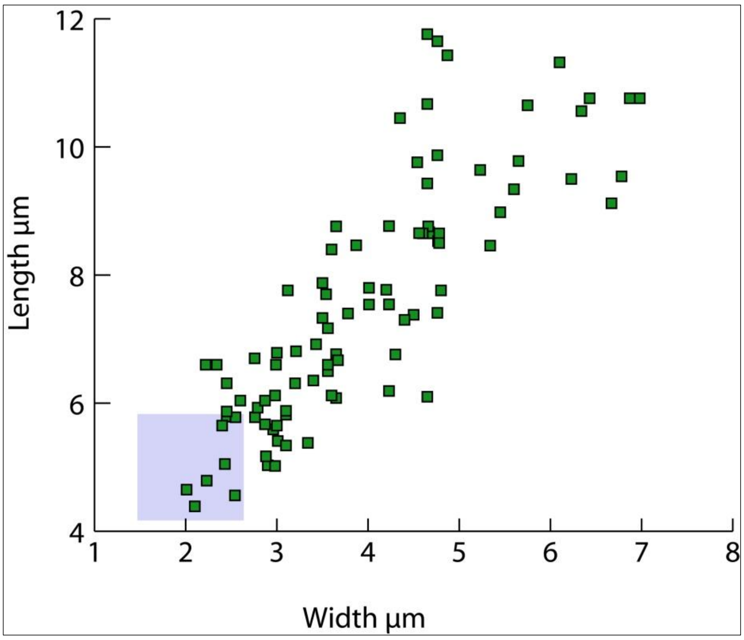
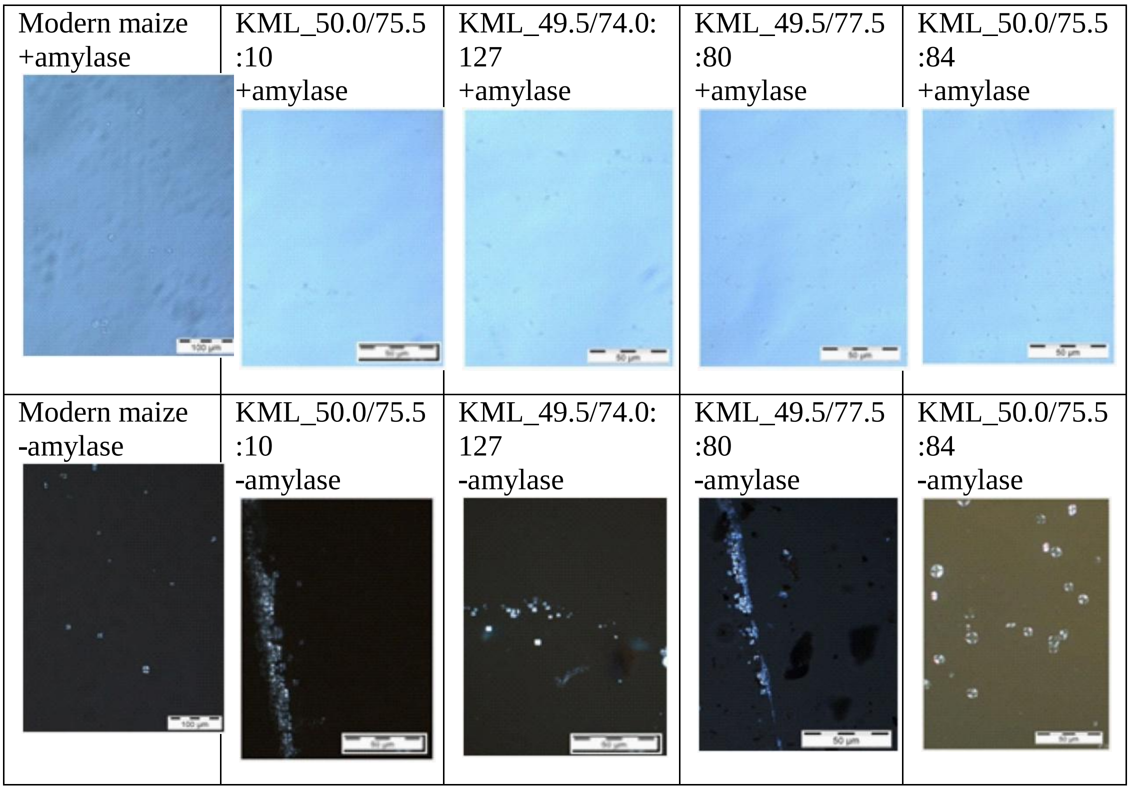


Figure 6. 25. The graph shows the length and width measurements taken of a random selection of a single class of 'bean-shaped' starch granules to suggest the degree of granule swelling caused by cooking at Åkonge. Modern size ranges for the same class (N=50) are indicated by the shaded region.



Modern maize +amylase	KML_50.0/75.5:10 +amylase	KML_49.5/74.0:127 +amylase	KML_49.5/77.5:80 +amylase	KML_50.0/75.5:84 +amylase
Modern maize -amylase	KML_50.0/75.5:10 -amylase	KML_49.5/74.0:127 -amylase	KML_49.5/77.5:80 -amylase	KML_50.0/75.5:84 -amylase

Figure 6. 26. Amylase degradation of starch granules from a sub-group of the Akonge foodcrusts, showing the presence of starch in samples with negative amylase, and the absence in samples positive for amylase.

6.3.2.2. Phytoliths.

Phytoliths were recovered in smaller quantities than at Neustadt, but their thermal durability means this is likely to be because phytolith producing plants were processed less at Åkonge rather than being attributable to preservation. The maximum number of silica bodies from Neustadt was over 300, and 4 of the samples reached over 100 artefacts. Only 1 sample at Åkonge exceeded 100 silica bodies.

6.3.2. Are these indicators related to the vessel use or are they derived from the burial environment?

6.3.2.1. Starch grains.

The graph in figure 6.27 shows the counts of starches mg^{-1}. There is a clear distinction between samples that contain few or no starch grains and a group where the counts exceed 150 mg^{-1}. There is not a statistical difference between the numbers of grains in samples that come from exterior (S) surfaces and interior (F) deposits (t-test, p= 0.34 (>0.05), t= 2.78, (F) N= 13, (S) N= 3), but it was only possible to analyse 3 exterior deposits so this sample group is too small to support the statistical test. Compounding this, KML 50.0/78.5:11_S came from an exterior deposit near a repair hole in the vessel conceivably making it a leak from the interior contents.

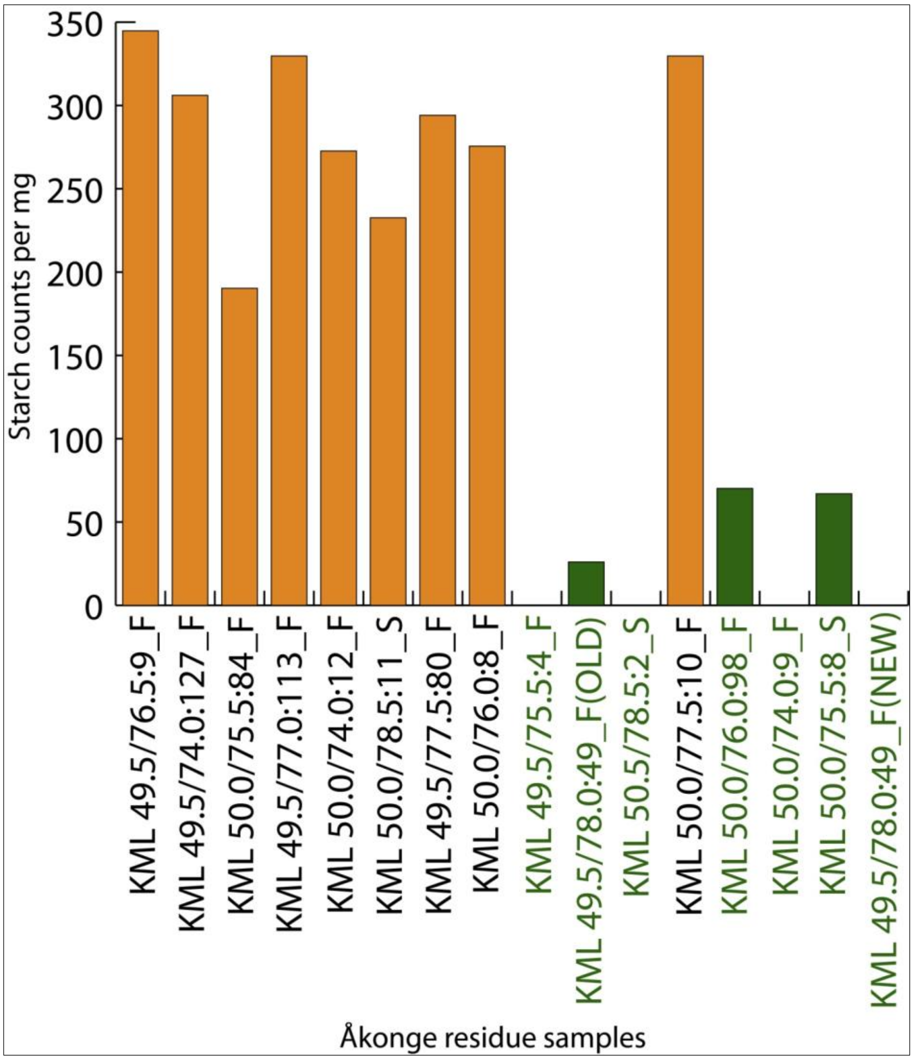


Figure 6. 27. A graph showing the normalised count of starches (mg^{1}) for each foodcrust sample from Åkonge. Those bars in orange indicate samples with high counts mg^{-1}, those with green bars are low counts mg^{-1}.

Taking the nominal cluster of samples marked in orange (figure 6.27) possessing counts of over 150 grains mg^{-1} as a group however, there is a statistical difference between these and samples with low counts marked in green (t-test, p= 4.48 $^{-09}$ (<0.05), t= 2.14, (>150/mg^{-1}) N=9, (<150/mg^{-1}) N=7) (figure 6.27). It is encouraging that there is such a marked difference between the two groups, as it suggests some vessels were deliberately excluded from the processing of plant material; the counts are not gradated as one would expect if they were just used *less*. It was not possible to compare the interior and exterior counts to soil samples at Åkonge because the site was excavated in the early 1980s. The proportion of interior (F) deposits representing significant plant material is 56% (9/16) at Åkonge, similar but slightly less than at Neustadt where 61% (20/33) of the interior residues contained high starch counts. This could be a factor caused by the range of sherds sampled or differential preservation, or it could imply that plant processing activities at Neustadt were slightly more intensive.

6.3.2.2. Phytoliths.

There is not such a clear distinction between high and low counts of silica bodies at Åkonge (figure 6.28). However, there is a statistical difference between interior (F) and exterior (S) deposits (t-test, p=0.03 (<0.05), t=2.18, (F) N=13, (S) N=3).

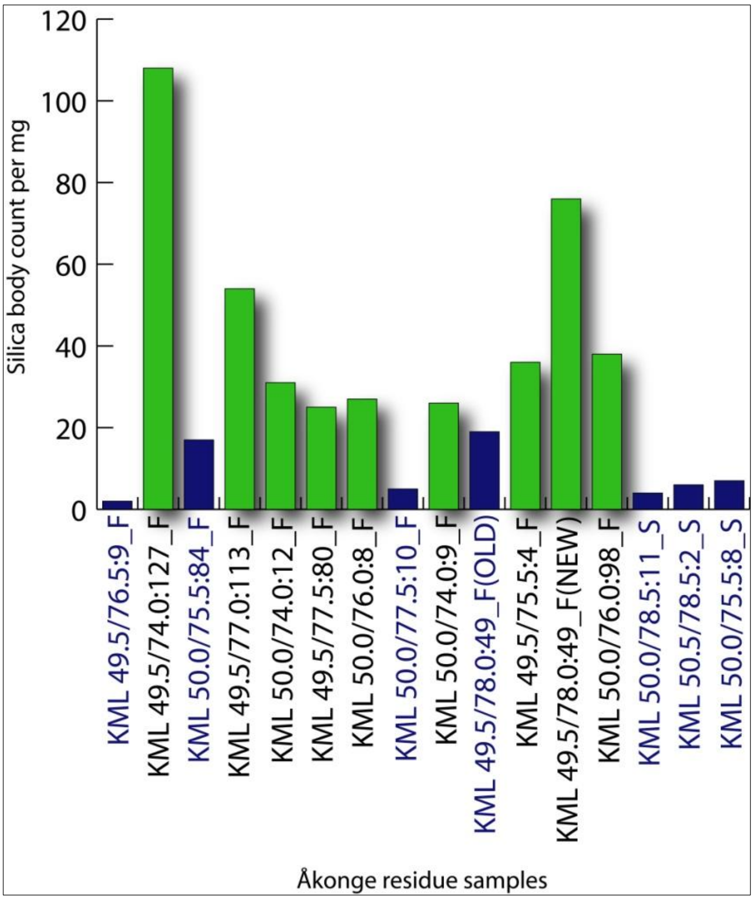


Figure 6. 28. A graph showing the number of silica bodies (mg^{-1}) for each of the Åkonge foodcrusts. Those with a green bar indicate samples with high counts mg^{-1}, whilst those with a blue bar indicate samples with low counts mg^{-1}.

A statistical difference between interior and exterior is consistent with the packing of the vessels with phytolith producing vegetation. Only one sample (KML 49.5/74.0:127_F) retained quantities of silica bodies comparable to the counts from Neustadt, which marks this vessel out as particularly intensively used for the processing of silica rich plant parts. Only those samples that exceeded 20 bodies mg^{-1} were accepted for further identification analysis.

6.3.3. Can the microfossils be identified to a plant origin?

6.3.3.1. Starch grain classification at Åkonge.

In only two instances was it not possible to define a substantial number of grains from the images during automated granule recognition. Fortunately in both cases (50.0/76.0:8 and 50.0/75.5:84) the distinctive acorn (*Quercus* sp.) type granules were present (figure 6.29), and we can be confident from the 100% correct classification from both the training and test sets of data that these are accurately representing a use of the vessel. We must perhaps treat the proportion results of other species identified in KML 50.0/75.5:84 with more caution when interpreting patterns of use with other vessels, as these are generated from only one or two granules respectively.

At Åkonge similar species emerge as important to those that are represented at Neustadt. Proportions classified as acorn (*Quercus* sp.) are high, followed by the edible reed species' such as *Acorus calamus* and *Sparganium erectum. Cyperus longus* type starches are less well-represented, as are those consistent with *Armoracia rustincana*, which appeared at Neustadt with the advent of funnel beakers. *Typha latifolia* type starches on the other hand are conspicuously absent from Åkonge, as it was at Neustadt.

Sample (KML)	**#granules**	***Acorus calamus***	***Arum maculatum***	***Cyperus longus***	***Armoracia rusticana***	***Triticum monococcum***	***Pteridium sp.***	***Filipendula ulmaria***	***Quercus sp.***	***Typha latifolia***	***Fagus sp.***	***Sparganium erectum***	***Corylus avellana.***	**Most likely species**
49.5/74.0:127	30	33	0	7	0	3	0	7	37	0	0	13	0	*Quercus* sp.
49.5/76.5:9	23	0	4	0	0	0	13	9	70	0	0	4	0	*Quercus* sp.
49.5/77.0:113	15	33	0	0	0	7	0	0	47	0	0	13	0	*Quercus* sp.

49.5/77.5:80	14	0	0	0	0	0	21	0	50	0	0	29	0	*Quercus* sp.
50.0/74.0:12	60	80	3	5	0	0	2	3	2	0	0	0	5	*Acorus calamus*
50.0/76.0:8	1	0	0	0	0	0	0	0	100	0	0	0	0	*Quercus* sp.
50.0/77.5:10	22	41	0	0	0	0	9	0	18	0	27	5	0	*Acorus calamus*
50.0/78.5:11	28	4	0	0	0	0	7	0	86	0	0	4	0	*Quercus* sp.
50.0/75.5:84	5	0	0	19	0	19	0	0	22	0	0	40	0	*Sparganium erectum*

Figure 6. 29. A table of the number of granules submitted for automated classification, with percentages of each species identified in the foodcrusts.

6.3.3.2. Phytolith classification.

Two of the samples from Åkonge contain ‘globular sinuate’ phytoliths consistent with *Alliaria petiolata* (garlic mustard) (figure 6.30a). Their diameters are 8.9µm and 8.5µm, within the range for modern garlic mustard at 4.8-11.2µm, average size 6.9µm. The bulk of the silica bodies are made up of single epidermis cells and silica skeletons, which are only diagnostic to monocotyledon or dicotyledon status (Madella *pers comm.*). The images in figure 6.30b show a dicot short cell on the left, and a dicot silica skeleton in the centre. All of the samples with significant quantities of silica bodies are predominantly composed of these dicotyledonous cells, with only a few instances of monocotyledonous silica skeletons such as that at the right of figure 6.30b. Dicotyledonous plants include many edible herbaceous species; such as those that have fractalised vascular tissue arrangements, rather than parallel vascular bundles as you would find in the grasses and sedges.

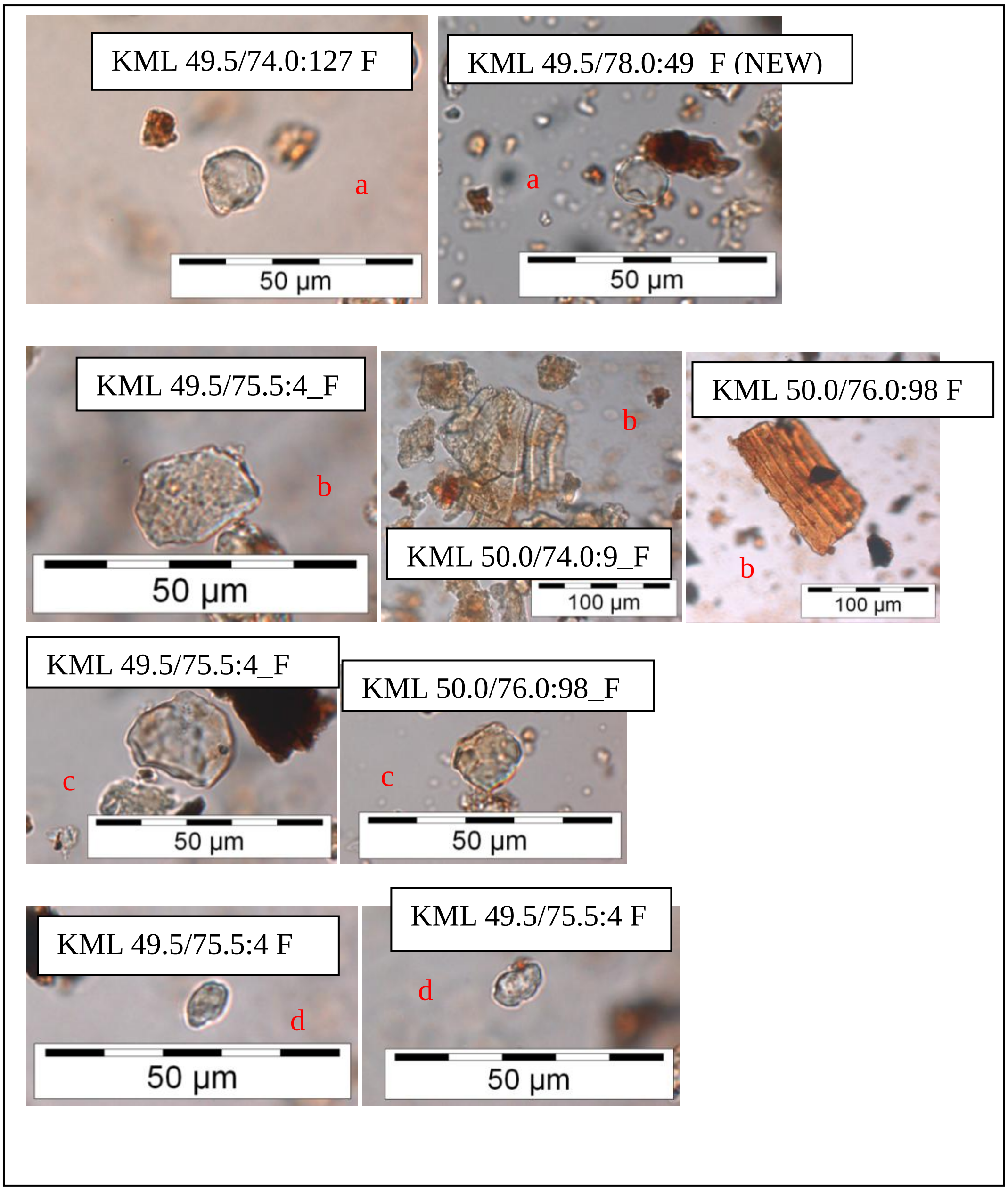


Figure 6. 30. The findings of phytolith types in the Åkonge foodcrusts.

The examples of silica bodies in figure 6.30c correspond to those identified as ‘oblong irregular sinuate’ varieties. They are not identifiable, as no referents exist. These examples do not have the parallel striations visible in some of the examples at Neustadt. The examples from Åkonge have diameters of 24.45µm and 15.4µm.

Finally, sample KML 49.5/75.5:4_F contained another possibly new type of phytolith, called an ‘oblong irregular psilate’ (figure 6.30d) based on phytolith nomenclature conventions (Madella *et al.* 2005). The oblong shape is generally smooth, with occasional irregular undulations. From the few examples in the sample, the length is quite consistently from 9.7µm to 10.1µm. There are no modern referents to identify this phytolith type, showing once again the limitations of phytolith research for identifying temperate European plant species in carbonised deposits, without modern reference research to back up discoveries.

6.3.4. Comparison of plant microfossil data with bulk isotope and lipid residue analyses.

The majority of the samples are depleted in ^{13}C, and when compared to bulk isotope values of experimentally cooked reference material (figure 6.31) compare well with the carbon and nitrogen isotope values of the cooked milk products, but with a 1-4‰ enrichment in ^{15}N. Both Ertebølle and Funnel Beaker samples occupy similar isotope ranges, suggesting that there is not a significant difference in the types of foods being eaten across the transition at this site. Carbon isotope values between EBK and TRB samples evidence continuity (t-test, p = 0.36 (>0.05), t= 2.16, (EBK) N=6, (TRB) N=9).

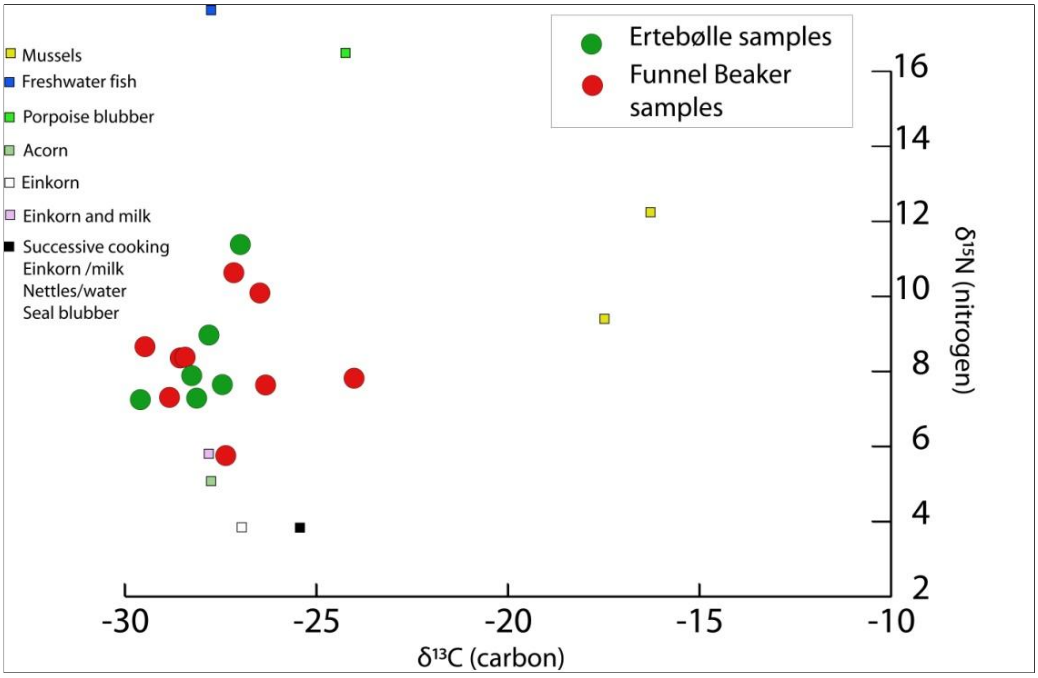


Figure 6. 31. A plot of the bulk carbon and nitrogen isotope values for the Åkonge foodcrusts, with isotope ratios for modern reference foods.

Overlaying those samples that contain significant quantities of starches and phytoliths (figure 6.32 a & b) does not offer any clustered patterning in the data.

Phytolith rich samples tend to be restricted to the δ^{13}C of -26‰ to -30‰ range, around δ^{15}N 7‰ to 9‰. The plant nitrogen contribution may be enriching these samples away from experimentally cooked milk products. Five outliers to this range do not contain significant silica bodies, and four of these are Funnel Beaker vessels. Starch rich residues are distributed over the entire range of bulk isotope values.

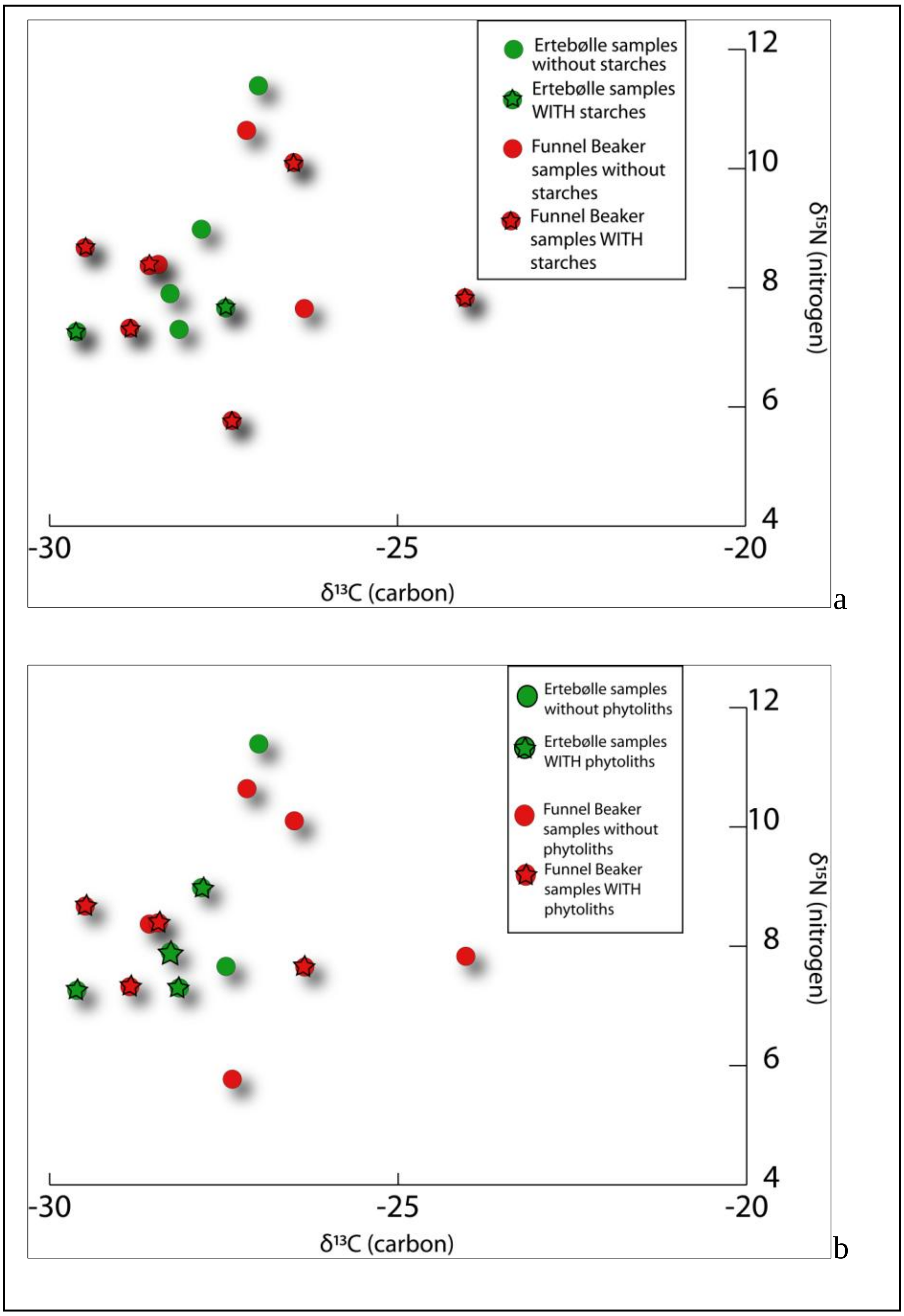


Figure 6.32. a) A plot of the bulk carbon and nitrogen isotope ratios of the Åkonge foodcrusts, with symbols indicating samples where the presence of starches was greater than 100 mg^{-1}, b) A plot of the bulk isotope ratios of the Åkonge foodcrusts with symbols indicating samples where silica body counts were greater than 20 mg^{-1}.

Greater clarity as to the identification of a content of the vessels is offered by single compound isotope results from absorbed lipid (figure 6.33). These identify the Åkonge samples as exclusively ruminant adipose or dairy in origin. There was not enough lipid in the 'foodcrusts' themselves, so these results illustrate the absorbed residues of the same sherds. This inland, lakeside site shows no evidence of freshwater fish from the any of the absorbed residues.

As well as 6 Funnel Beaker vessels with a dairy isotopic offset, there are also 2 Ertebølle vessels. Åkonge has been interpreted as a short-occupation phase site, covering the period around 3950 cal BC, so the EBK vessels may represent the very latest phase of pointed-based vessel use, which could have been temporally contiguous with the earliest use of flat-based vessels. Based on stratigraphy at the site this was certainly the case, but it does entrench the theme of very early domesticated foods being of dairy origin. The remaining samples all fall within the ruminant adipose isotope range.

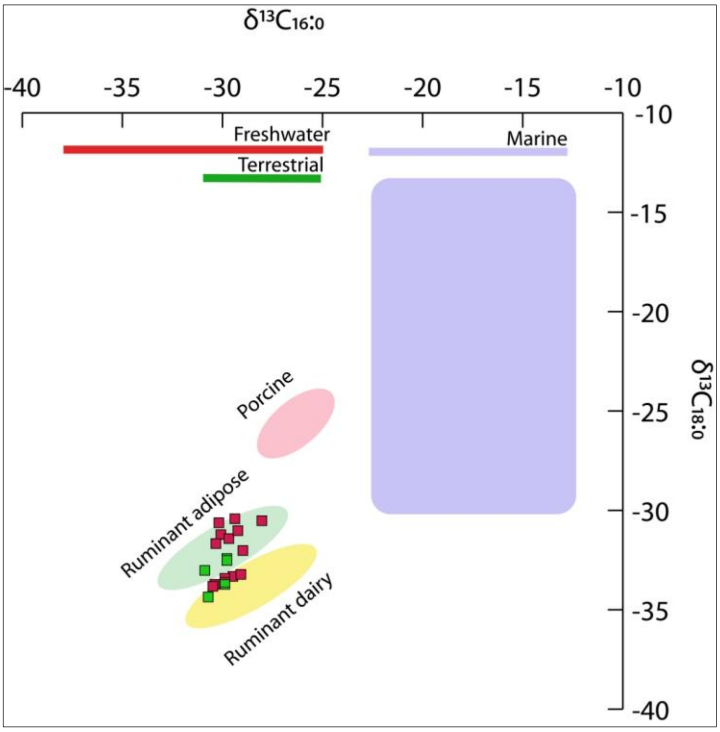


Figure 6. 33. The δ^{13}carbon isotope ratios of C16:0 and C18:0 fatty acids from the absorbed lipid component of the Åkonge ceramic samples. Mesolithic EBK samples are indicated with green symbols, Neolithic TRB samples are indicated with red symbols. Ranges were generated using authentic marine and freshwater reference fats from Danish waters. Terrestrial data are a combination of published references (Dudd and Evershed, 1998), with northern German wild boar and cow milk, and are plotted with 95% confidence intervals.

6.3.4.1. Milk.

Comparison of the single compound classifications with bulk isotope ranges (figure 6.34) show that the dominant $C_{18:0}$ and $C_{16:0}$ fatty acid contribution to vessel contents do not consistently account for the bulk isotopic signal on foodcrusts in many cases. KML 50.0/78.5:11 is the only example of a foodcrust bulk isotope value that complements the single compound signature for dairy, displaying a depleted $\delta^{15}N$ value. Although the surface deposit is taken from the exterior, it had collected around a repair hole that had seen twine holding two fractured pieces of pot together. It seems likely the contents had seeped into the hole and been absorbed by the twine, allowing them to dry and harden. Whilst this sample has significant numbers of starches- which also suggests it originated from the interior contents- lipid characterisation does not support any mixing or other use of the vessel for aquatic products.

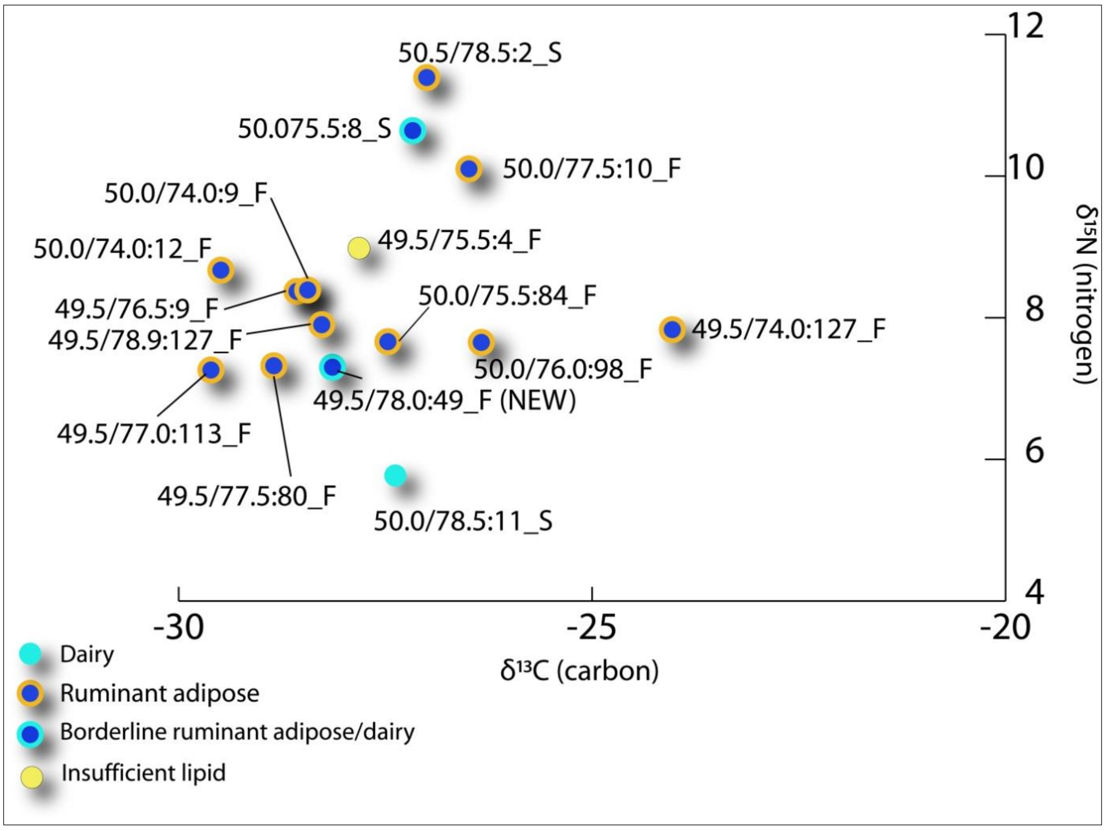


Figure 6.34. A plot of the bulk carbon and nitrogen isotope ratios of the Åkonge foodcrusts. Each datum point has been given a symbol indicating the food class defined by single compound isotope analysis for the absorbed lipid of the corresponding sherd.

6.3.4.2. Aquatic foods and ruminant adipose.

Of the thirteen ceramics classified as having a ruminant contribution to their contents, only three have markers suggesting they may have been mixed or reused for aquatic foods like fish. In the case of KML 50.5/78.5:2 and KML 50.0/77.5:10 both deposits contain phytanic acid, and C18 and C20 ω-(o-alkylphenyl)alkanoic acids, aquatic biomarkers strongly suggesting a use in this direction. In the latter sample positive identifications of Salmonid fish scales were also made. The bulk isotope values of these two ‘foodcrusts’ are inconclusively enriched in $\delta^{13}C$ to tentatively suggest that the aquatic contribution be of a freshwater or marine origin, although the inland location makes freshwater more likely.

Exactly the same aquatic biomarkers exist in the ‘foodcrust’ of KML 50.0/74.0:12, but it is relatively depleted in ^{13}C compared to the former examples. This may indicate a different source for the aquatic resources, or less of an overall contribution perhaps because the aquatic products were infrequently processed in the vessel. All other 10 examples of ruminant adipose exhibit no convincing contradictory findings between single compound isotope ratios and mass spectra results, and were seemingly used only for ruminants with respect to animal products. It therefore seems that Åkonge was strongly disposed towards the processing of ruminant animal foods.

6.3.4.3. Plant products.

At Neustadt, acorn (*Quercus* sp.) type starch was often classified in vessels used to process fish. There is more limited evidence of fish consumption at Åkonge though, and none of the three samples that contain aquatic biomarkers also contain high proportions of acorn (*Quercus* sp.) consistent grains (figure 6.35). Instead all of those samples classed as high in acorn starches (*n*5) (figure 6.35) come from vessels that have unadulterated ruminant adipose evidence. According to automated classification these vessels (*n*5) were also used for the processing of fern fiddleheads *Pteridium* sp., and *Sparganium erectum.* This latter reed is more highly represented at Åkonge, with 44% of the samples containing >10% starches from the reeds, compared to only 15% of the vessels at Neustadt. Of the fish and ruminant adipose (*n*3) mixes at Åkonge two contain plant foods, and this is predominantly classed as the edible reed rhizome of *Acorus calamus.* The selection of plants to complement fish products at this inland site seems to have been aquatic species that were attainable from the same place as the fishes themselves.

There is one example of a vessel used to contain dairy products, which also has high proportions of acorns consistent starch (KML 50.0/78.5:11). From the foodcrust evidence there is no indication that some pots were important solely for processing dairy products, like at Neustadt. However, ‘Peter’s Pot’ is a vessel that is clean of foodcrust and only shows evidence of a dairy content. Although only one vessel, ‘Peter’s Pot’ was so carefully disposed of intact in water away from the settlement that it seems the specialised use of this pot was invested with significance. Whereas specialised pots with dairy products were in *active* use at Neustadt, possibly even being transported between groups and certainly accumulating residues from processing activities; similar Åkonge vessels may have gained their significance by removal from participation in the sociality of settlement cuisine in the early Neolithic.

Cereals are again lacking in the context of pottery at Åkonge. One instance of high proportions comes from a small analysed sample number, and the vessel is an Ertebølle one. Wild plant foods persist in importance whilst other domesticated foods like milk become incorporated into cuisine at Åkonge. The process of adopted domesticated cereals is a slower one, and therefore may come about because of different culinary values and motivations than govern the adoption of the earliest domesticates.

There is no patterning in the occurrence of garlic mustard (*Alliaria petiolata*) consistent phytoliths. They are distributed between a sample containing ruminant adipose fat as well as high proportions of acorn (*Quercus* sp.) type starch and grains consistent with sweet-flag rhizome (*Acorus calamus*), and a sample that is borderline isotopically ruminant/dairy without starchy plant contributions.

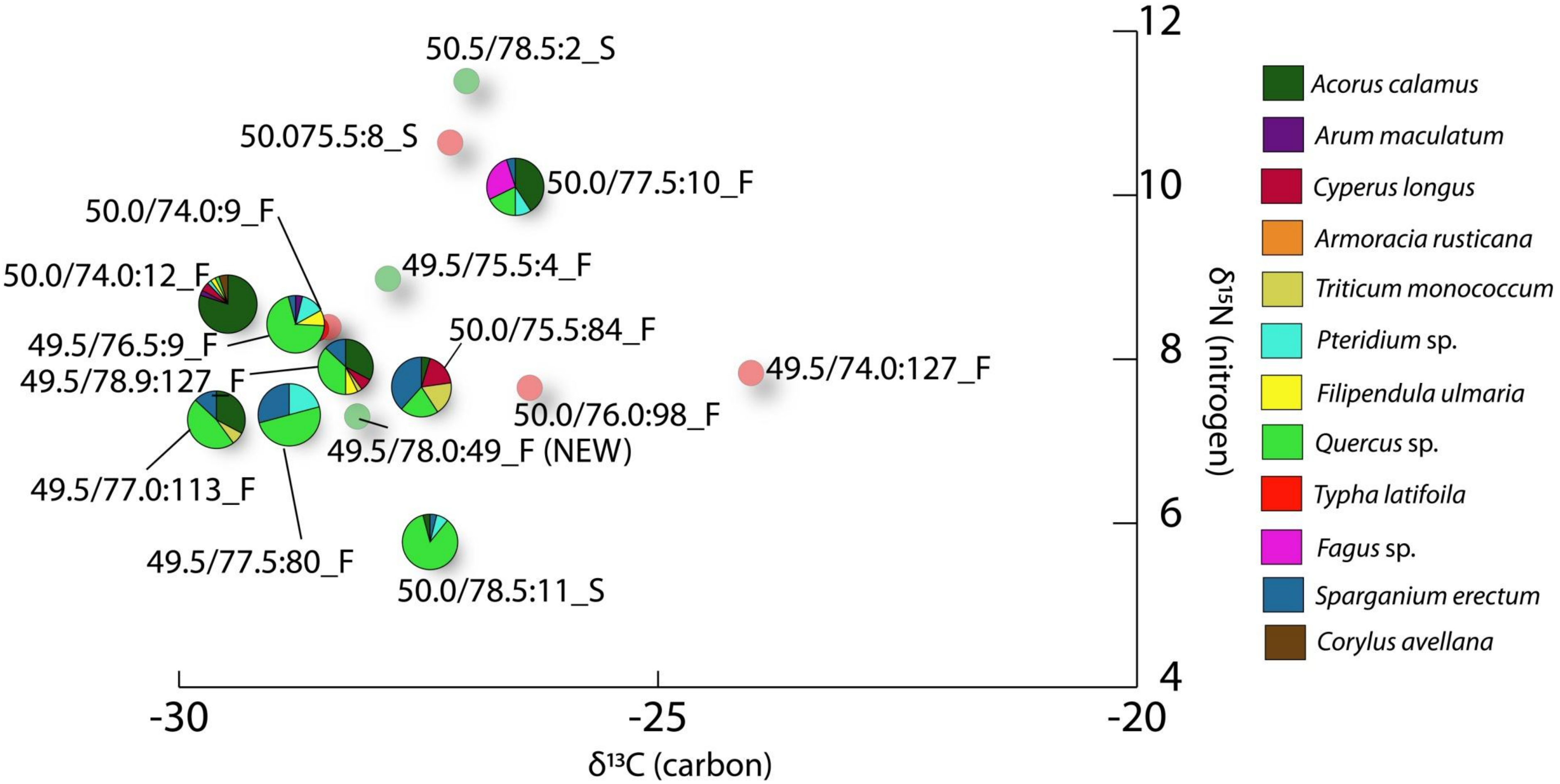
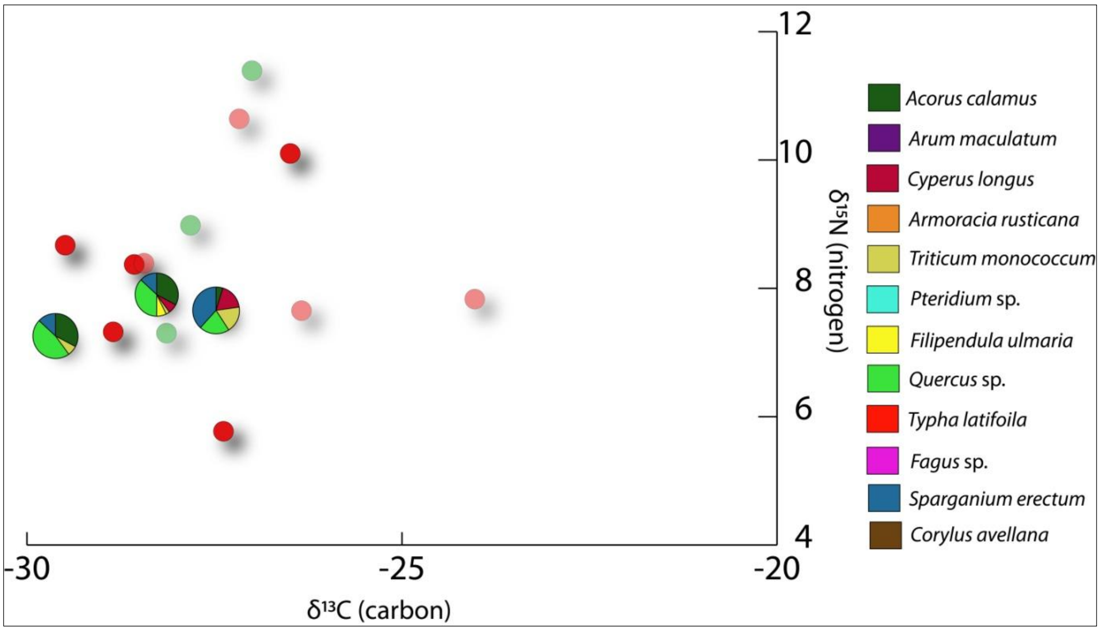


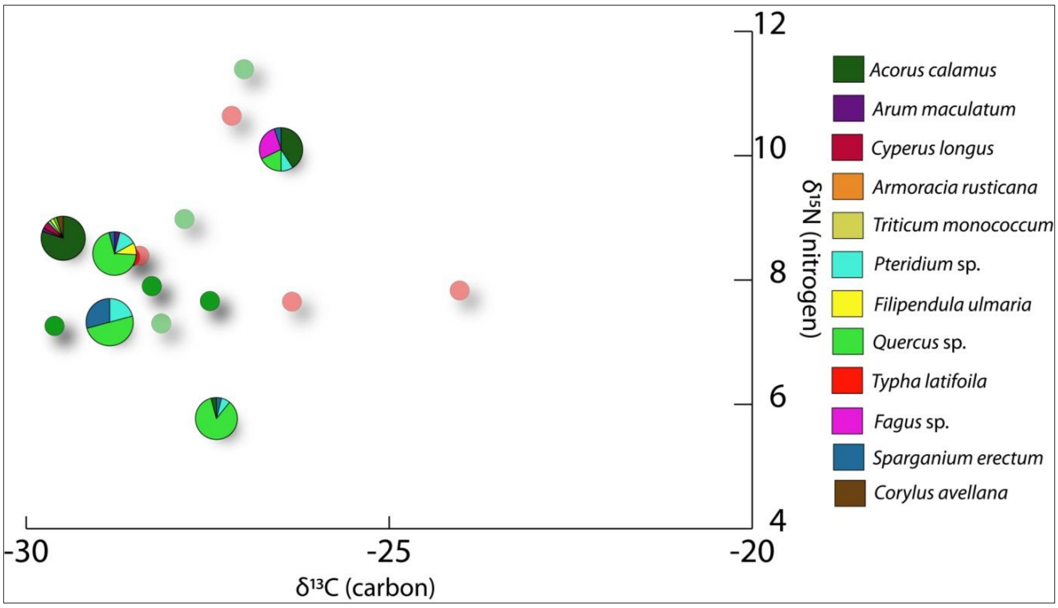
Figure 6.35. A graph plotting the bulk carbon and nitrogen isotope ratios of the Åkonge foodcrusts. Each datum point with significant starch counts is indicated with a pie chart illustrating the proportions of each plant type found as a result of automated classification of the starches.

Through time acorns (*Quercus* sp.) are persistly classified as important, and are present in 100% of the starch-rich EBK (figure 6.36a) foodcrusts in high proportions (*n*3), as well as 75% (*n*4) of starch-rich TRB deposits (figure 6.36b). This is in contrast to hazelnut (*Corylus avellana*) type starch which is classified as absent in both periods, showing its value to cuisine is restricted to an aceramic context.

Starches classified as *Acorus calamus* are supplemented by the burr-reed rhizome (*Sparganium erectum*) class in TRB pots (*n*2), but grains indicative of sweet flag (*Acorus calamus*) are especially prevalent in EBK cuisine at Åkonge. Certainly in the Ertebølle period we seem to be witnessing a wider range of starch classes, focused around those granules designated as edible reeds. Compared to Neustadt there seems to be an overall restriction in the types of foods represented, with a greatly reduced occurrence of phytoliths consistent with garlic mustard (*Alliaria petiolata*) as well as minor starch components such as horseradish (*Armoracia rusticana*) type grains which are absent at Åkonge.



a



b

Figure 6.36. a) The top graph is a plot of the bulk carbon and nitrogen isotope values for the Åkonge foodcrusts with EBK samples that contain significant starches indicated by pie charts showing the proportion of different plants in those samples., b) The same graph of bulk isotope data, but with TRB samples with significant starches indicated by pie charts showing the proportion of different plants.

6.3.5. Comparison of identified food contents to vessel features.

There are no distinctive patterns relating the contents of the vessels to the size of the pot (figure 6.37). Larger and smaller vessels exhibit no difference in either δ^{13}C values (t-test, p= 0.47 (>0.05), t= 2.18, N=7 (large), N=8 (small)), or the δ^{15}N values (t-test, p=0.85 (>0.05), t=2.16, N=7 (large), N=8 (small)). The three large examples do all have ruminant adipose contents from ^{13}C on the $C_{18:0}$ and $C_{16:0}$ fatty acids however. Of these there is no patterning in the relationship to plant material though; one sample is dominated by acorn (*Quercus* sp.) classified starch, another by burr-reed (*Sparganium erectum*), and another doesn't include plant food.

Ruminant adipose contents are distributed across the range of sizes. Likewise, plant material occurs in all size of vessel. However, the two samples that are also spiced with garlic mustard (*Alliaria petiolata*) consistent phytoliths are restricted to small vessels, perhaps nominally indicating that a concentrated flavour was desired. Unlike Neustadt, dairy foods are found in small (*n*2*)* and medium sized (*n*1) vessels.

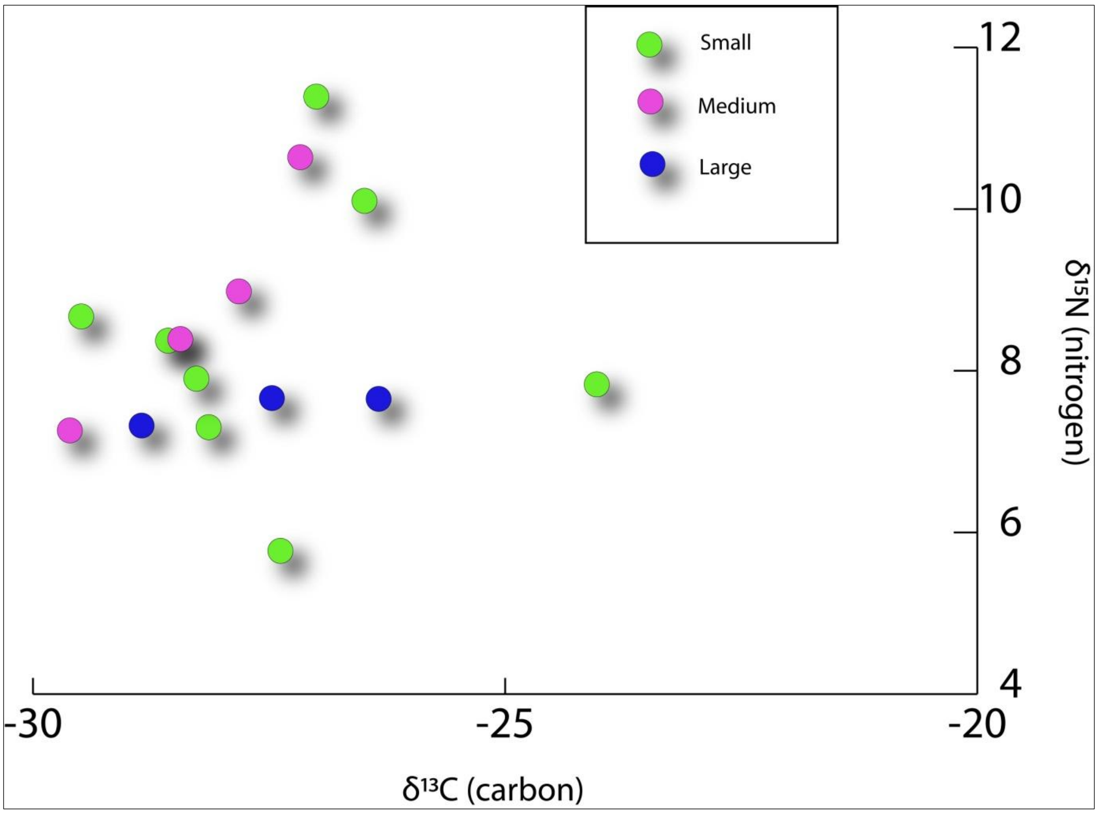


Figure 6.37. A graph showing the bulk carbon and nitrogen isotope values of the Åkonge foodcrusts with each datum point represented by a size of vessel classifier. Small= 5-15 cm, medium= 16-26 cm, large= 27-37 cm, extra large= >38 cm.

The ceramic assemblage at Åkonge is in smaller fragments than Neustadt, limiting the precision about what types the Funnel Beakers sub-divide into. It was possible to identify two Type 0 vessels though (figure 6.38), the earliest examples of the Funnel Beaker style. There are no patterns between vessel type and their contents; the Type 0 with a higher C:N ratio is indicated to contain ruminant adipose contents from corresponding single compound isotope analyses, whereas the Type 0 vessel depleted in ^{15}N contains lipid consistent with a dairy source. Perhaps significantly, 'Peter's Pot', the other known example of a pure dairy content without a foodcrust, also comes from a Type 0. There seems to be an association between this style and a use as dairy food containers at Åkonge.

The contents of the vessels have no bearing on the thickness of the vessels; there is no correlation (figure 6.39). One of the largest vessel sizes has one of the thinnest wall widths at 0.9 cm. Two of the vessels suggested to contain dairy foods (with a ^{13}C offset on the $C_{18:0}$ fatty acid) also have the thickest vessel walls at 1.3 cm. The other example of a possible dairy content, however, measures a vessel thickness of 1cm diffusing any correlation.

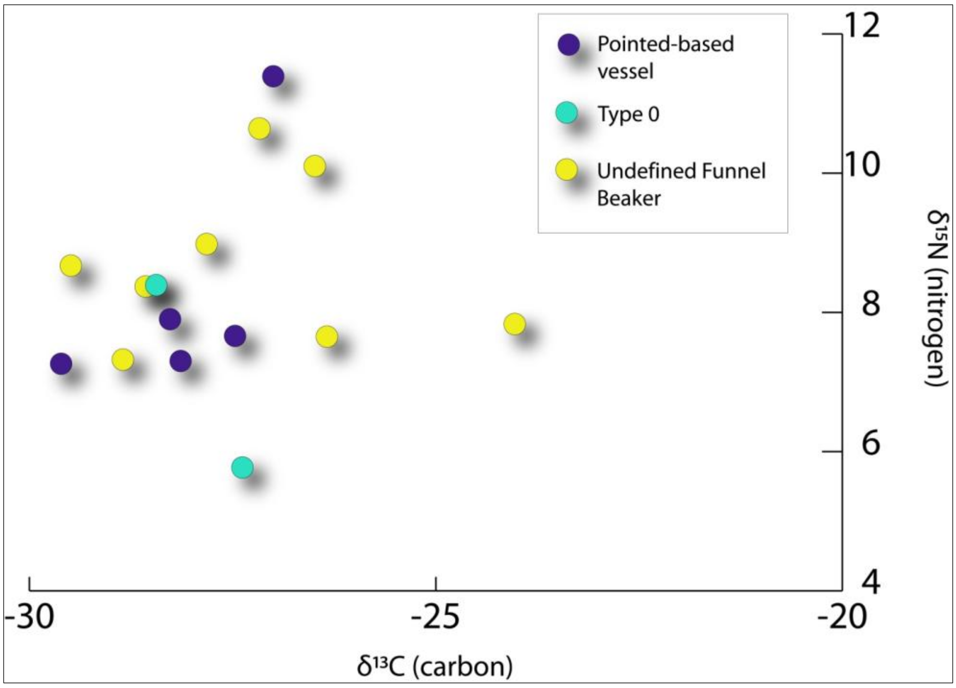


Figure 6.38. A graph plotting the bulk carbon and nitrogen isotope values of the Åkonge foodcrusts. Each datum point is represented by a symbol that defines the type of vessel the sample came from.

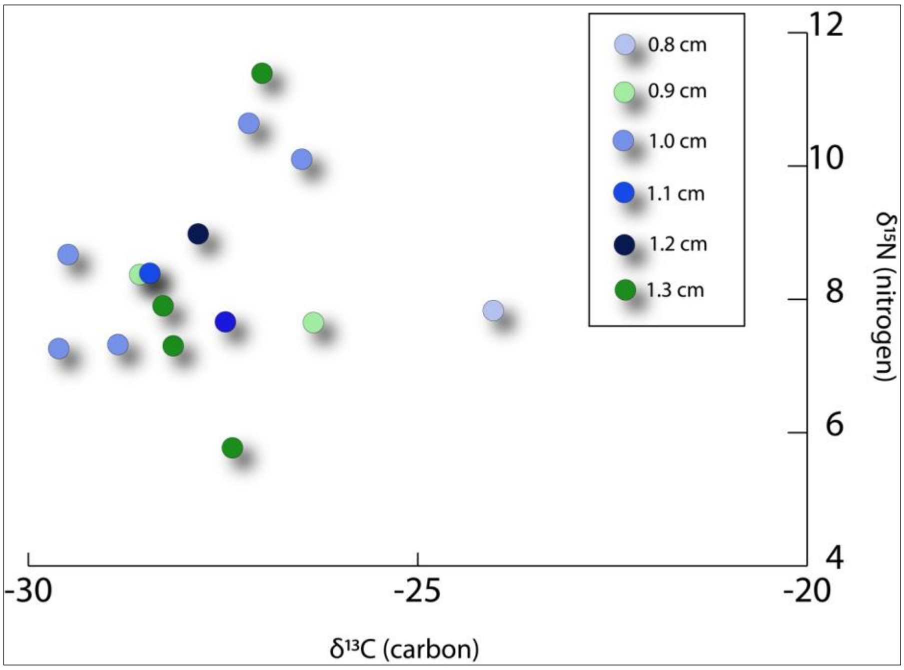


Figure 6.39. A graph plotting the bulk carbon and nitrogen isotope values of the Åkonge foodcrusts. Each datum point is represented by a symbol that indicates the width of the vessel wall that respective samples came from.

6.3.6. Summary of the Åkonge results.

Continuity in food practices across the transition from EBK to TRB vessel styles at Åkonge is suggested by the insignificant alteration in $\delta^{13}C$ between the two ceramic periods. Despite being a lakeside site there is no evidence of aquatic foods from single compound isotope results. Fish scales were present in five of the foodcrusts though, and 23% (3/13) of vessels that fell within ruminant adipose isotope ranges had aquatic biomarkers. Aquatic foods may have been rendered less visible in single compound isotope analysis if they were mixed with terrestrial animal fats because they are less rich in C18:0 saturated fatty acids, so their $\delta^{13}C_{18:0}$ isotope signature is susceptible to masking by the more abundant saturated fats in terrestrial foods. Aquatic foods become difficult to detect in such instances of mixing, because the signature is weighted towards terrestrial isotope ranges on the C18:0 axis.

The assemblage at Åkonge is focused on the processing of ruminant foods. Around 55% of the sampled assemblage falls in the single compound isotope range of ruminant adipose, whilst the remaining 45% falls in the range of dairy foods. Three vessels with EBK style features display evidence of a dairy food content, implying that milk was one of the earliest domesticated foods at Åkonge. Only one funnel beaker suggests a practice seen at Neustadt of exclusively retaining certain ceramics for dairy processing. ‘Peter’s pot’ was an exclusively dairy content, and its significance is further highlighted by its careful deposition at the edge of the settlement, in the water.

Unlike Neustadt, there is no association between fish and acorn type starch (*Quercus* sp.) at Åkonge. Instead, all five samples with high classified acorn proportions come from vessels used to process ruminant adipose fats. Wild plants again persist in importance as other domesticates are introduced, occurring in all EBK foodcrusts used to process starchy plants, and 75% of TRB examples. Hazelnut (*Corylus avellana*) starch forms are again absent from a pottery context, as is convincing evidence for the introduction of cereals. The spicing of food with seed phytoliths consistent with garlic mustard (*Alliaria petiolata*) is also suggested from Åkonge.

6.4. Wangels

6.4.1. Do indicators of foods (including phytoliths and starches) survive in association with vessels?

6.4.1.1. Macroremains.

There are no visible macroremains in the six surface deposits from Wangels. All of the samples appear highly carbonised and amorphous (figure 6.40). The degree of carbonisation is not necessarily a good indicator of how well-preserved we can expect the plant microfossils to be. The TRB foodcrusts from Neustadt were also highly carbonised and amorphous, but produced excellent microscopic plant remains.

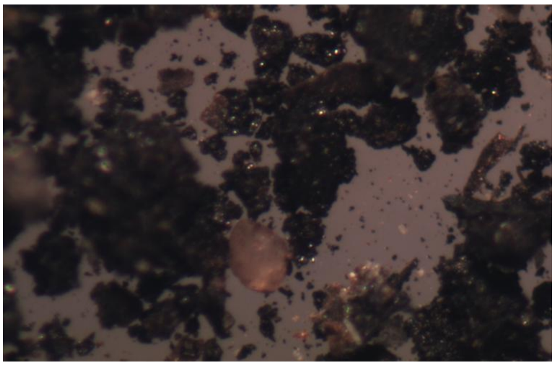


Figure 6.40. An image showing the characteristically amorphous, charred nature of the Wangels foodcrusts, x20.

6.4.1.2. Starches.

There was mixed recovery of starch grains from Wangels; one sample produced counts >400 mg^{-1} comparable to statistically significant foodcrust values from Åkonge and Neustadt. This would suggest that the *potential* for recovery is high and the underwater burial environment has not had a negative impact on preservation. Yet despite this there were few starches to be recovered from all five of the other samples.

It is possible that foodcrust survival has been compromised at Wangels, since it is on a seaward promontory and more exposed to wave action. Compared to nearby Neustadt there is a substantial decrease in the number of surface deposits available for analysis. Only 37% of the sherds at Wangels have associated visible residues, whereas at Neustadt it is 51%. If it were a simple case of the burial environment causing damage to starch preservation however, we would not expect instances where recovery reached the levels (>400 mg^{-1}) seen in sample KE_34_F. Therefore, whilst there may be an immeasurable loss in the *number* of foodcrusts, where they *are* available for study the microfossils recovered are representative of the frequency of starchy plant use. Starches were confirmed by degradation with α-amylase on sample KE_34_F, which was the only foodcrust to be provisionally accepted for automated starch classification (figure 6.41). The addition of amylase degraded the starches in the archaeological sample and the modern positive control. The negative controls retained their starch granules.

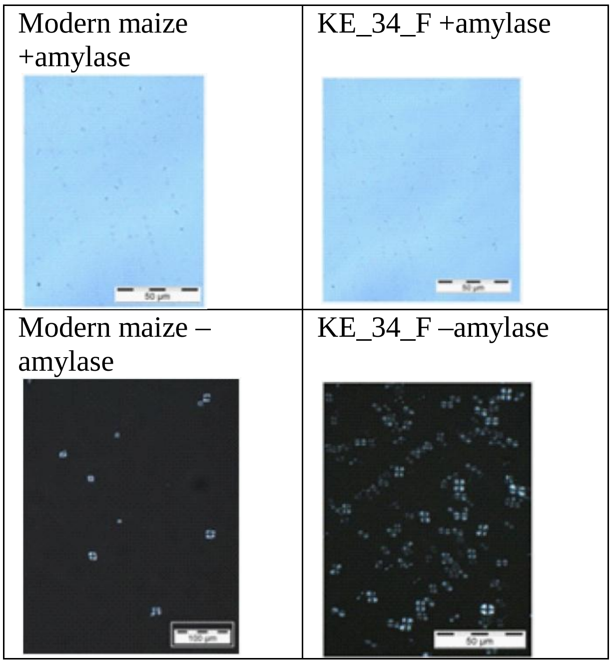

Modern maize +amylase
KE_34_F +amylase
Modern maize –amylase
KE_34_F –amylase

Figure 6.41. The amylase degradation of Wangels sample KE_34_F. With the negative addition of amylase starches are abundant in both the archaeological and modern control. When amylase was added degradation occurred in both the modern and archaeological samples.

6.4.1.3. Phytoliths.

There is likewise a poor recovery of phytoliths from the foodcrusts at Wangels. The greater durability of silica to high temperatures means that we can be confident this is because the pots were not being used to process silica rich vegetative matter. This also supports the starch results; overall a focus on plant processing and consumption is not evident at Wangels from either very taphonomically durable microfossils, or more vulnerable starches.

6.4.2. Are these indicators related to vessel use or are they derived from the burial environment?

6.4.2.1. Starch grains.

The graph of starch counts mg^{-1} (figure 6.42) reiterates the finding that there is a large variation in the numbers of grains recovered. A t-test is invalid to establish a statistical difference between interior (F) and exterior (S) deposits because the data are not normally distributed. KE_34_F was provisionally accepted for further analysis because the high starch count mg^{-1} was clearly greater than background levels of starch observed in the other samples. This sample also compares favourably to the quantities of starch granules mg^{-1} recovered from the Neustadt samples accepted for automated classification.

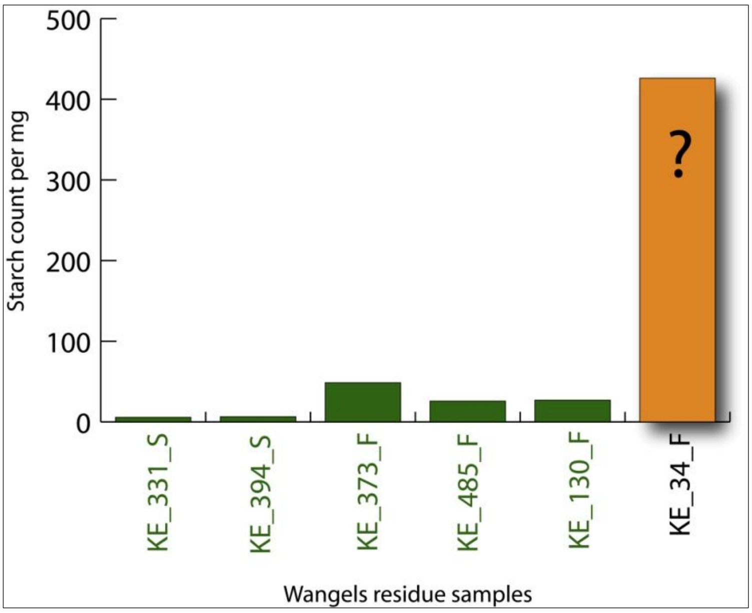


Figure 6.42. A graph showing the counts mg^{-1} of starches in the Wangels foodcrusts. Only sample KE_34_F measures high counts (orange bars), the other foodcrusts exhibit low granule counts (green bars).

6.4.2.2. Phytoliths.

There is no visible difference between the Wangels interior (F) and exterior (S) silica body counts mg^{-1} in figure 6.43. Neither is there an obvious split in the counts mg^{-1} to indicate a high and low count clusters. A two-tailed t-test does not support a significant difference between F and S deposits. A p-value of 0.76 ((>0.05), t= 4.30, (F) N=4, (S) N=2) supports the null hypothesis that there is no difference between interior and exterior residues. It is possible that both interior and exterior deposits have been contaminated by the burial sediment and counts mg^{-1} homogenised, and that silica rich plants were not utilised as much at Wangels than Neustadt, its nearest neighbour. Considering the comparability between the counts mg^{-1} at Wangels and the low counts at Neustadt, however, the latter suggestion seems more likely.

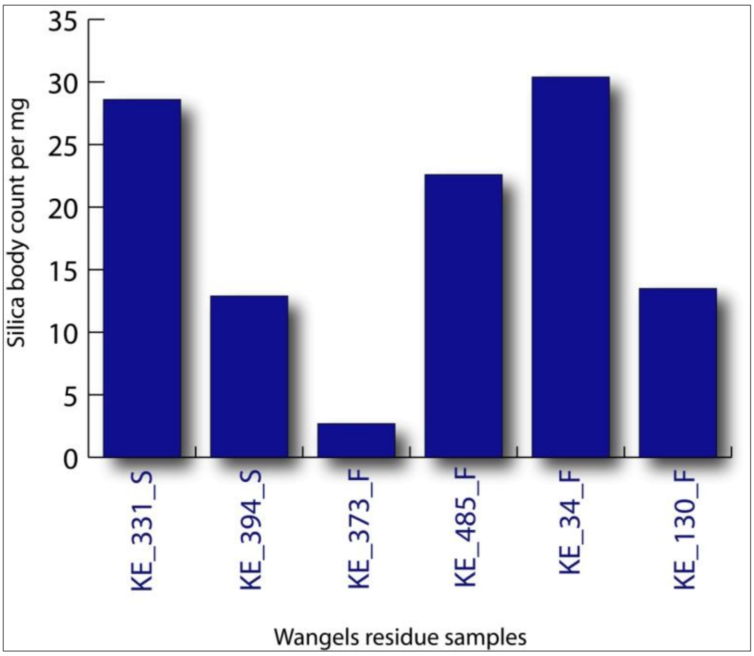


Figure 6.43. A graph showing the silica body counts mg^{-1} for the Wangels surface deposits. Blue bars indicate that all of the samples were low in phytoliths.

6.4.3. Can the microfossils be identified to a plant food origin?

6.4.3.1. Starch grain classification at Wangels.

The foodcrust from Wangels continues the classification emphasis on acorn (*Quercus* sp.) type grains as an important wild plant food right into the TRB period; with 52% of the starch assemblage belonging to this species (figure 6.44). Unlike Neustadt where reed mace (*Typha latifolia*) grains are absent from all samples, this rhizome is classified in moderate percentages (16%) in the Wangels residue. Proportions of *Acorus calamus* and *Sparganium erectum* are zero at Wangels, whereas they are both classified quite frequently (>10% grains mg^{-1}) in 44% of those residues that have significant starch counts at Åkonge. Neustadt also produced proportions consistent with *Acorus calamus* (>10%) in 35% of the residues found to have significant plant remains. At Wangels, edible reeds are represented by a high classification of *Cyperus longus* type starch, less popular at Neustadt and Åkonge.

Sample	#granules	*Acorus calamus*	*Arum maculatum*	*Cyperus longus*	*Armoracia rusticana*	*Triticum monococcum*	*Pteridium sp.*	*Filipendula ulmaria*	*Quercus sp.*	*Typha latifolia*	*Fagus sp.*	*Sparganium erectum*	*Corylus avellana*	**Most likely species**
KE_34	26	0	0	33	0	0	0	0	52	16	0	0	0	*Quercus* sp.

Figure 6.44. A table showing the automated classification of the Wangels foodcrust with a provisionally high count. The proportion of each plant present in the sample is indicated beneath the plant name.

6.4.4. Comparison of plant microfossil data with bulk isotope and lipid residue analyses.

Sample KE_34_F is the most enriched in both carbon-13 and nitrogen-15 (figure 6.46), and is the only foodcrust with high starch counts mg^{-1}. Those foodcrusts with a low δ^{15}N value and those that plot close to modern reference examples of milk and plant foods, including KE_373, KE_130, KE_485, and KE_394 are absent of substantial plant remains. All of the samples have bulk isotope values coarsely consistent with foods from a terrestrial origin, being relatively depleted in ^{13}C. This is despite Wangels being a coastal site.

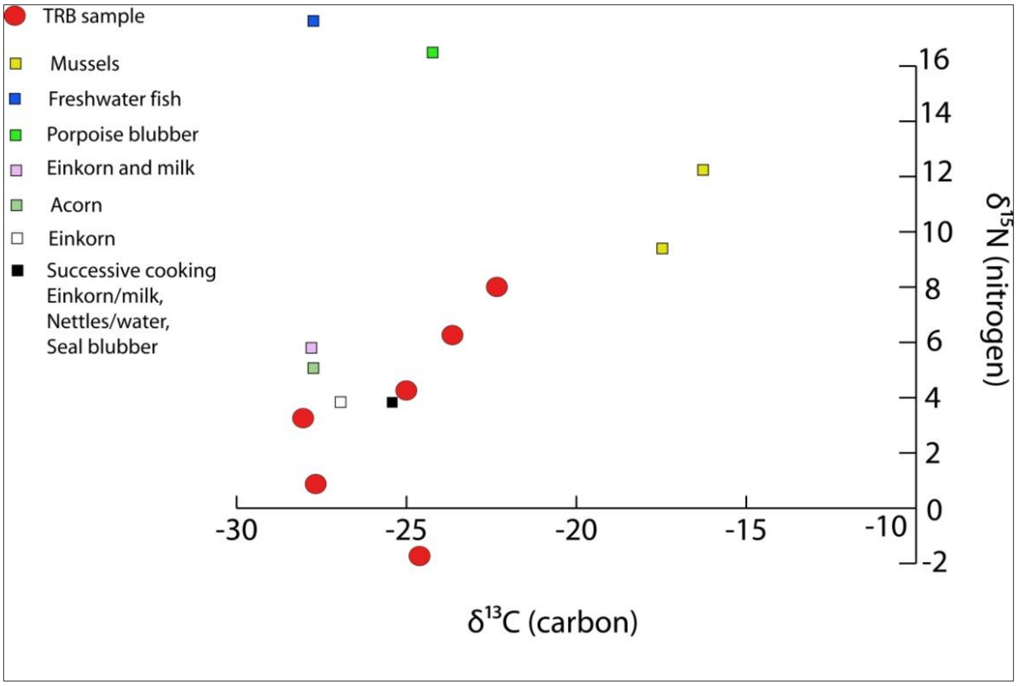


Figure 6.45. A graph of the bulk carbon and nitrogen isotope values of the Wangels foodcrusts, showing also the values for modern reference foods.

6.4.4.1. Aquatic foods.

The single compound isotope dataset of absorbed residues also show that marine resources are a minimum contribution to the foods that were processed in the pots (figure 6.46). Only two out of the sixteen vessels (12%) have *n*-alkanoic acids within the isotopic range for marine foods. Neither of these samples contains aquatic biomarkers however, one possibility being they were not heated to temperatures that would form the isoprenoid acids and ω-(*o*-alkylphenyl)alkanoic acids. There is no evidence from the lipid biomarker analysis that would suggest these vessels were used to cook mixtures with other foods. The reduction in the use of marine foods at Wangels is particularly significant given the coastal location and the proximity to Neustadt where three of the TRB samples had *n*-alkanoic isotope signatures that were marine, and another two with insufficient lipid for single compound isotope analyses had aquatic biomarkers to support enriched carbon-13 isotope values. Having said this, the actual *presence* of marine food in the early Neolithic vessels again points to a continuity of use across the transition to domesticated food use.

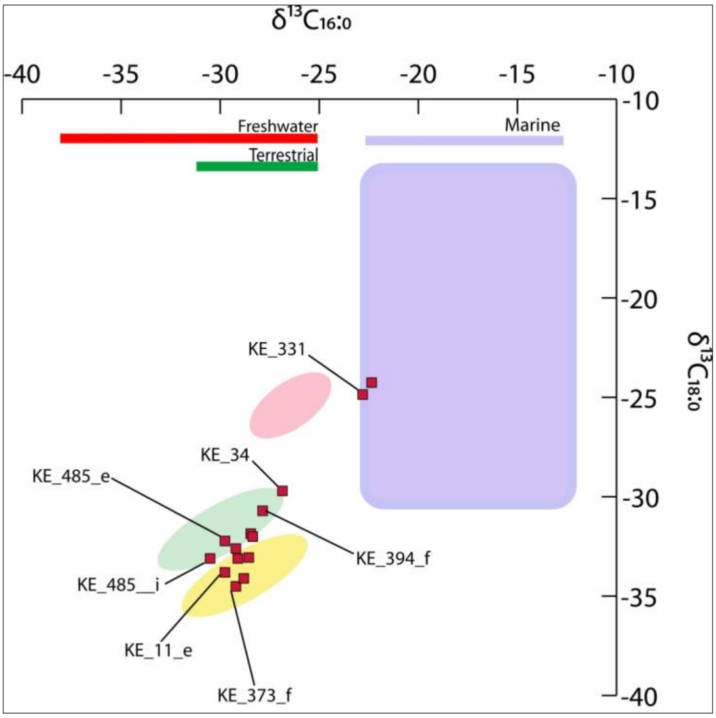


Figure 6.46. A graph plotting the δ^{13}C values of C16:0 and C18:0 compounds from absorbed lipid in the Wangels sherds. Those samples with corresponding foodcrusts are annotated. All the samples are from Funnel Beaker style vessels and so are indicated with a red symbol. Ranges were generated using authentic marine and freshwater reference fats from Danish coastal and lake waters. Terrestrial data are a combination of published references (Dudd and Evershed 1998), with northern German wild boar and cow milk, and are plotted with 95% confidence intervals.

6.4.4.2. Milk.

The rest of the sampled assemblage is split between ruminant adipose fats and dairy products, including most of the vessels with foodcrust adherences indicated by the labels in figure 6.46.The culinary emphasis at Wangels is targeted on a limited range of animals therefore. Given that the majority of the ruminant bone assemblage from the site was from domesticated cattle (cattle n=164, red deer n=65, auroch n=13) (Heinrich 1998) it seems likely that the site was indeed quite specialised towards cattle processing. The near equal numbers of samples in the ruminant adipose (*n*7) and dairy (*n*5) range, as well as the osteological evidence of cattle slaughter suggests that the supply of dairy products was assured enough for part of the herd to be relinquished to beef stock. In other words, that the herd was large enough to produce excess beasts for consumption, rather than being a limited to only a few animals conserved for secondary products. By implication what we may be seeing is a managed herd system, assuming the ruminant adipose is from domesticated cattle rather than auroch, or deer.

In the case of KE_394 it seems possible that the vessel was used to process multiple food types. It has a dairy related $C_{18:0}$ offset for ^{13}C on measurements taken of the interior absorbed residue. On the foodcrust single compound isotope measurements point to a ruminant source, suggesting that perhaps milk was used to seal the vessel before secondary use. Limited evidence in the form of phytanic acid may suggest a contribution from an aquatic food source such as fish, but only the single biomarker makes this difficult to state confidently.

However two of the five ceramics which show indications of a dairy use do not seem to have had mixtures of other foods in them. Absorbed lipid from KE_1 and KE_103 contains abundant C18:0 and C16:0 conducive with an animal origin, and are without convincing plant derived compounds or plant microfossil data. There is a case at Wangels for defining a select group of vessels as just for the processing of dairy products therefore. Added to this, the vessel types for these two samples are a funnel flask and a lugged beaker respectively. Both have stylistic adjustments making them suitable for transporting or containing liquid. The fact that neither has a foodcrust suggests that the processing involved did not involve heating.

6.4.4.3. Ruminant products.

In terms of the other seven samples with single isotope values consistent with ruminant adipose ranges, only one shows substantial evidence of a mixture with aquatic products such as fish. KE_34 contains a range of biomarkers including phytanic acid, TMTD, C18 ω-(*o*-alkylphenyl)alkanoic acids, and traces of C16 and C20 ω-(*o*-alkylphenyl)alkanoic acids. The relative enrichment in ^{13}C for this vessel, which we can see from an overlay of single compound isotope classifications on to bulk isotope values in figure 6.47, would suggest that this fish was from a marine source. The majority of the seven samples were exclusively used for the processing of ruminant flesh however.

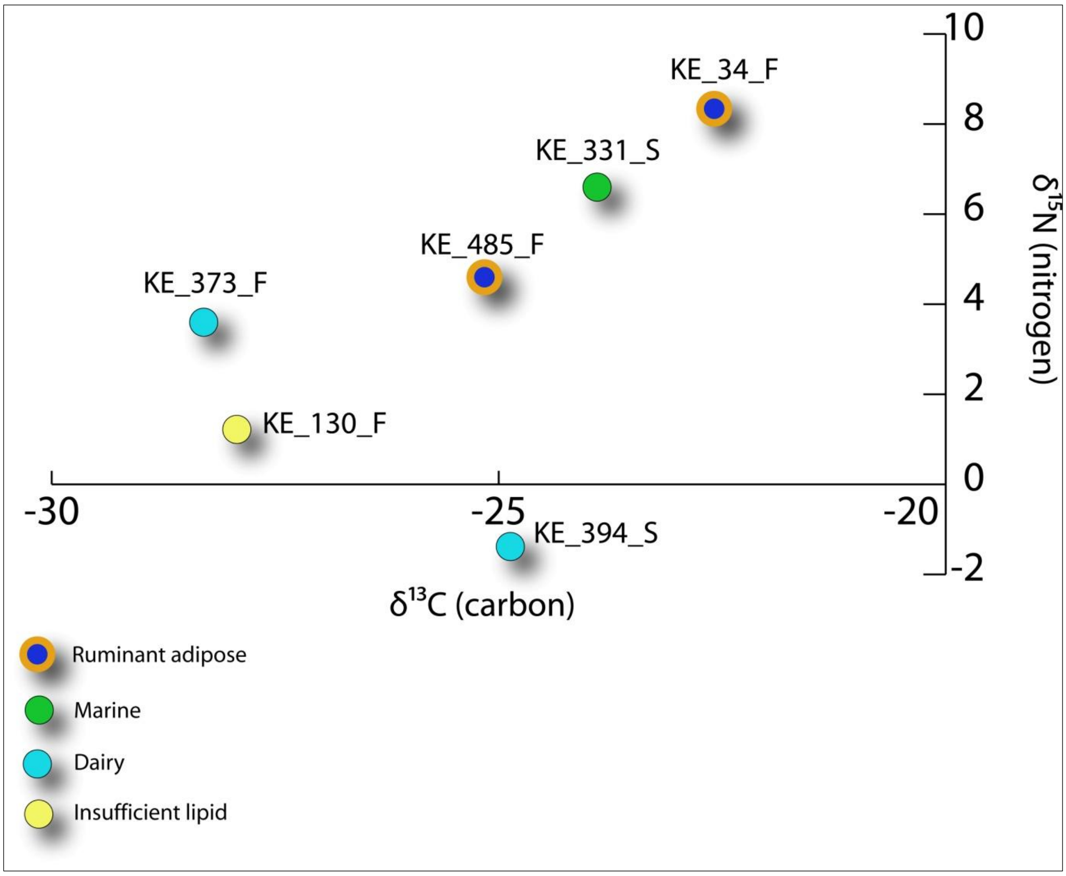


Figure 6.47. A graph plotting the bulk carbon and nitrogen isotope values for the Wangels foodcrusts. Each datum point is represented by a symbol that matches the class of food defined by single compound isotope analysis of the corresponding sherd fabric.

6.4.4.4. Plant products.

Vessel KE_34 has already been noted for its mixed processing history which includes ruminant adipose and marine products like fish. In addition to these, figure

6.48 graphically illustrates the proportions of different plants recovered. At Neustadt there was an association between marine foods and acorns (*Quercus* sp.) type starch, whereas at Åkonge it was ruminant adipose and acorn (*Quercus* sp.) consistent grains. The Wangels sample bears out both culinary traditions, with high proportions classified as *Quercus* sp., (52%) although just one sample radically reduces the confidence of this observation.

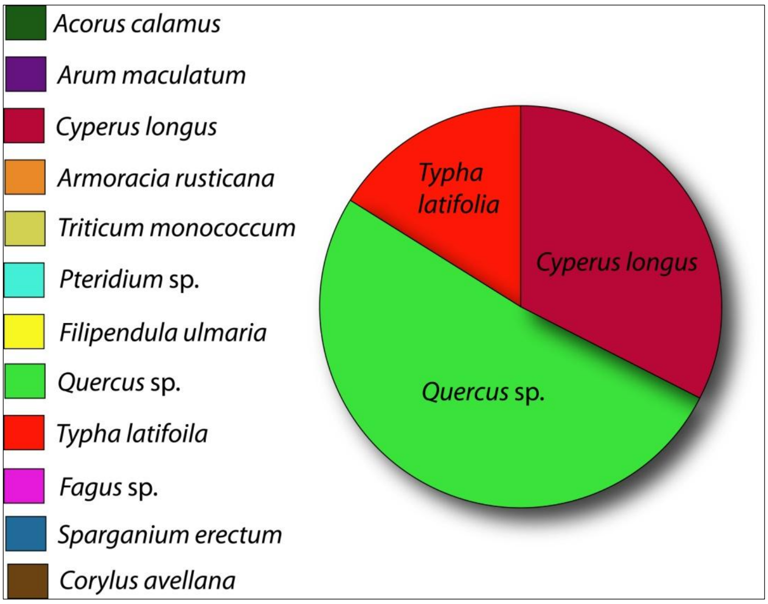


Figure 6.48. A pie chart illustrating the proportions of plants defined by automated starch classification for the only Wangels foodcrust with high starch counts mg^{-1}.

The greater proportion of vessels used to contain ruminant products show no evidence of plant remains, which must be considered deliberate if KE_34 is representative of the *potential* of starch recovery. The restricted types of food represented at Wangels suggest that in the context of pottery cuisine was much specialised with limited possibility for combinations. Only in rare instances (*n*3/16) are foods not related to ruminant animals included in the culinary repertoire.

By implication the extreme lack of plant food in diet suggests the site was occupied only for limited periods of time, and was part of a more spatially extensive network of settlement and craft sites during the early Neolithic. The only other vessel with plant compounds is KE_130 which displayed markers of birch bark tar; lupeone, lupeol and betulin. This suggests that the collecting of plant foods was a skill related task, as we are seeing for the processing of dairy products, perhaps assigned to a particular social denomination or gender group. Such specialised production of milk foods at Wangels may have been undertaken using restricted vessel types and to the exclusion of certain demographics that were not present at the site.

6.4.5. Comparison of identified food contents to vessel features.

The vessel which was most extensively used to contain multiple food types (KE_34) is an extremely large size with a rim diameter >38cm (figure 6.49). By inference, this vessel was one used to cook large quantities in one go, for group consumption as opposed to a craft specialised vessel. The extremely limited representation of ceramics at Wangels for the purpose of cooking multiple types of food marks this as a significant pot, as does its size, and emphasises an attitude where collective participation in specialised craft by a social sub-group was reinforced by communal eating, facilitated by ceramics.

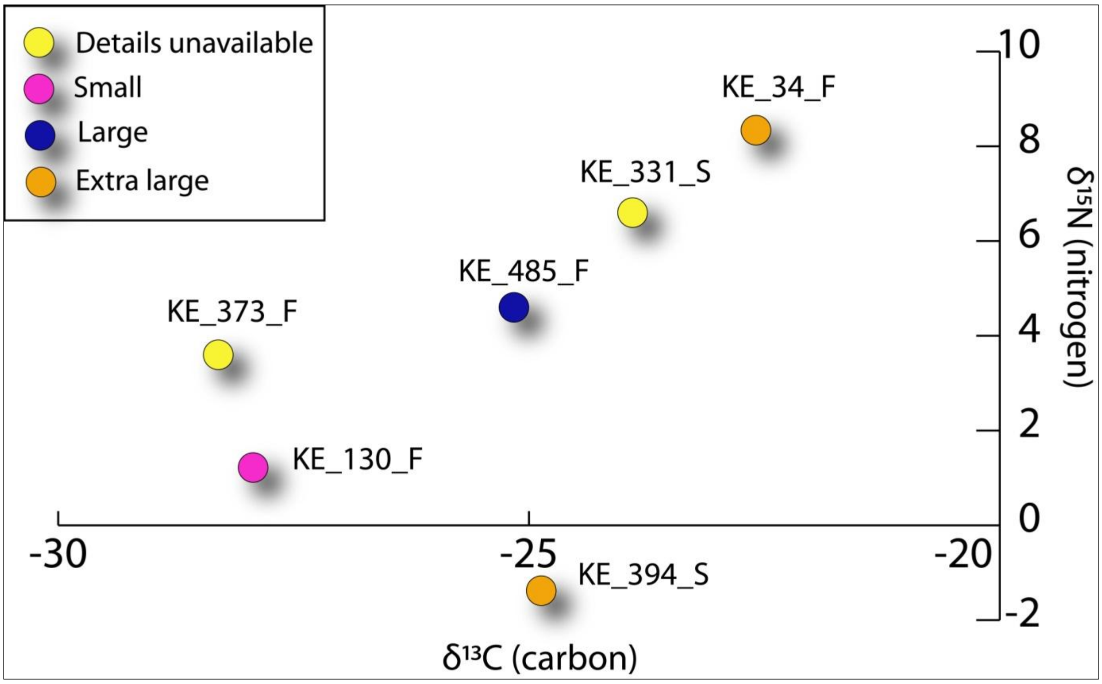


Figure 6.49. A graph plotting the bulk carbon and nitrogen isotope values of the Wangels foodcrusts. Each datum point is represented by a symbol detailing the size of the vessel from which the sample derives. Diameter sizes: small= 5-15 cm, medium= 16-26 cm, large= 27-37 cm, extra large= >38 cm.

The second most diverse range of foods occurs in vessel KE_394 which is also an extra large vessel. Combined evidence from interior and exterior absorbed residues, and associated surface deposits gives both a dairy and ruminant contribution from single compound isotopes, marine biomarkers from both the foodcrust and absorbed lipid, and long chain alkanes (C17-C33) indicative of a possible plant wax. This may be another example of a ceramic fulfilling a non-specialised craft activity, but an essential social role in group cohesion. KE_130 contains the birch bark tar markers; lupeone, lupeol and betulin, which explains its low lipid content and low $\delta^{15}N$ value.

KE_485 represents a vessel used for the exclusive used of processing ruminant adipose. This may have been for the collection of the fat from a roasted joint, or the rendering of it for storage and use in the preservation of other perishable foods. Although it is possible that ruminant animals were singly boiled in the vessels for food, it seems like a counterintuitive activity. Boiling beef alone draws out the flavour from the meat, preventing a Maillard reaction and diluting the umami taste, and since the purpose is clearly not to *add* flavour to plants for example, it seems counter-productive to prepare beef to be eaten in this way. Flavour enhancement is more effectively achieved by roasting.

It is possible however that the *act* of preparing foods in ceramics could be invested with significance that diminished the need for potent flavour, but considering the incorporation of spices, and innovative dairy sourness in Funnel Beaker cuisine this does not seem to be a pursuit. I would hazard to infer that these exclusively ruminant pots were for rendering or fat retrieval, which was destined for later incorporation with other foods. The large sized vessel would support this, allowing for the rendering of plentiful fat quantities in one go, which could be as much as 30-40% of a male adult cattle’s weight (estimations based on modern cattle and testimony of butcher). The use of KE_485 for the collection or rendering of ruminant fat is supported by the open funnel bowl for retrieving beef ‘dripping’ (figure 6.50). Similarly, although KE_114 does not have a foodcrust it is exclusive to ruminant product processing, and is also a funnel bowl. So far we have witnessed an association between dairy products and form diversity, seemingly for the specialist processing of milk foods, but at Wangels these specialist vessel forms are extended to include other ruminant products. If, as the faunal bone assemblage suggests, cattle were the main animal resource at the site the stimulation for innovating new pottery styles is still focused on the incorporation of cattle into cuisine, with the diverse culinary niches the animal occupies being reciprocated in the many ceramic distinctions accorded to it.

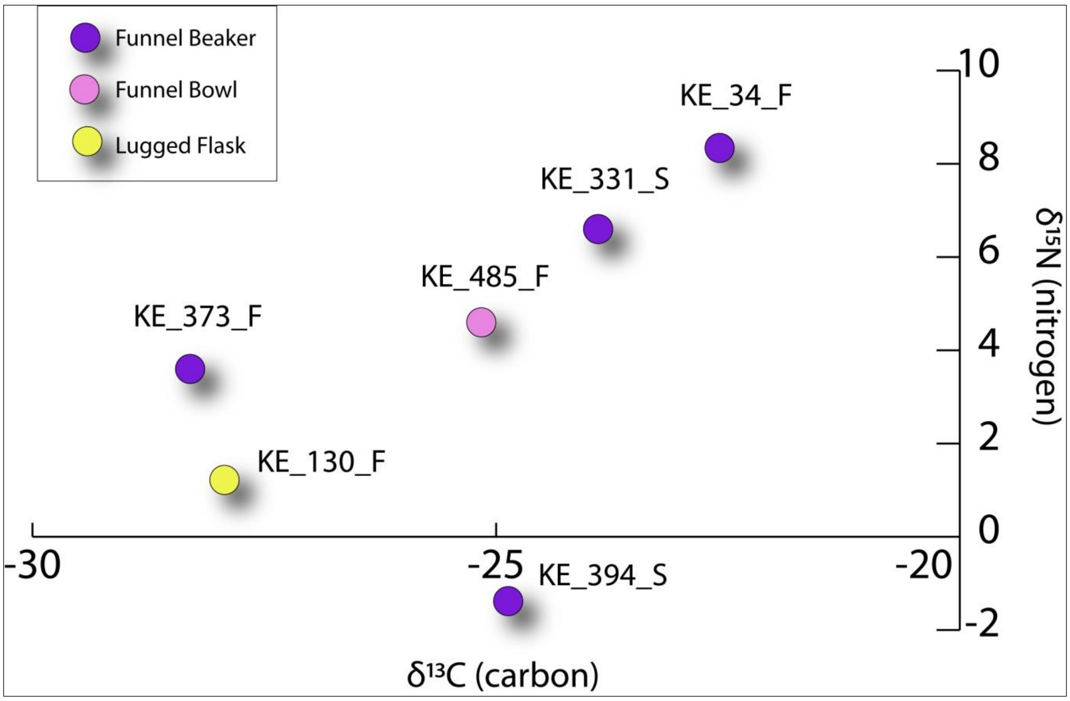


Figure 6.50. A graph plotting the bulk nitrogen and carbon isotope ratios for the Wangels foodcrusts. Each datum point is represented by a symbol indicating the type of funnel vessel the sample came from.

6.4.6. Summary of the Wangels results.

The culinary emphasis at Wangels is also focused on a limited range of foods, those related to ruminant animals. There is a near equal representation of ruminant adipose (n7) to dairy (n5) contents based on single compound isotope analysis of absorbed lipid. This suggests that cattle herding was practised on a scale large enough to relinquish animals for beef whilst maintaining a herd. It is possible that the fat from ruminants was being collected and rendered down in vessels; one example with an exclusively ruminant adipose content came from a funnel bowl suitable for collecting liquid. Dairy foods were also processed extensively at Wangels. Two out of five (40%) of ceramics were exclusively used for dairy processing, perhaps extending the trend observed in Neustadt and to a certain extent at Åkonge for the prescribed use of certain pots for dairy foods. These two vessels were variant forms suitable for liquid; a flask and a lugged beaker.

Wangels seems to be focused on specialist cattle-related food processing. Only two (16%) of the total number of ceramics studied contained marine aquatic foods, based on isotopic characterisation of the C16:0 and C18:0 fatty acids. Whilst this shows the continued use of fish into the early Neolithic seen at other sites, it also reinforces that activities at Wangels were focused on ruminants. A task-specific site interpretation is further implied by the lack of plant microfossils, except in one vessel. The two vessels used to process fish were both extra large ceramics, perhaps for collective consumption by members of the group carrying out the other specialised tasks. One of these vessels was also positive for significant starch, suggesting a mixture.

6.5. Tybrind Vig.

6.5.1. Do indicators of foods (including phytoliths and starches) survive in association with vessels?

6.5.1.1. Macro-remains.

Macro-remains were only identified in three of the Tybrind Vig samples, at low magnifications. In all cases they are the likely remains of fish. Figure 6.51a shows a possible eel scale fragment from sample TV_2033_BGU, in a carbonised state indicating cooking. The fragment displayed some evidence of the typical nodule projections found on modern eel scales. Figure 6.51b pictures an almost complete cycloid scale, common to many fish species and not very diagnostic. In figure 6.51c the fragment has longitudinal structuring reminiscent of bone, but clarification beyond this is not possible. Observations of the other foodcrusts from Tybrind Vig revealed a condition ranging from moderately to highly carbonised, which may explain the low recovery of macrofossils.

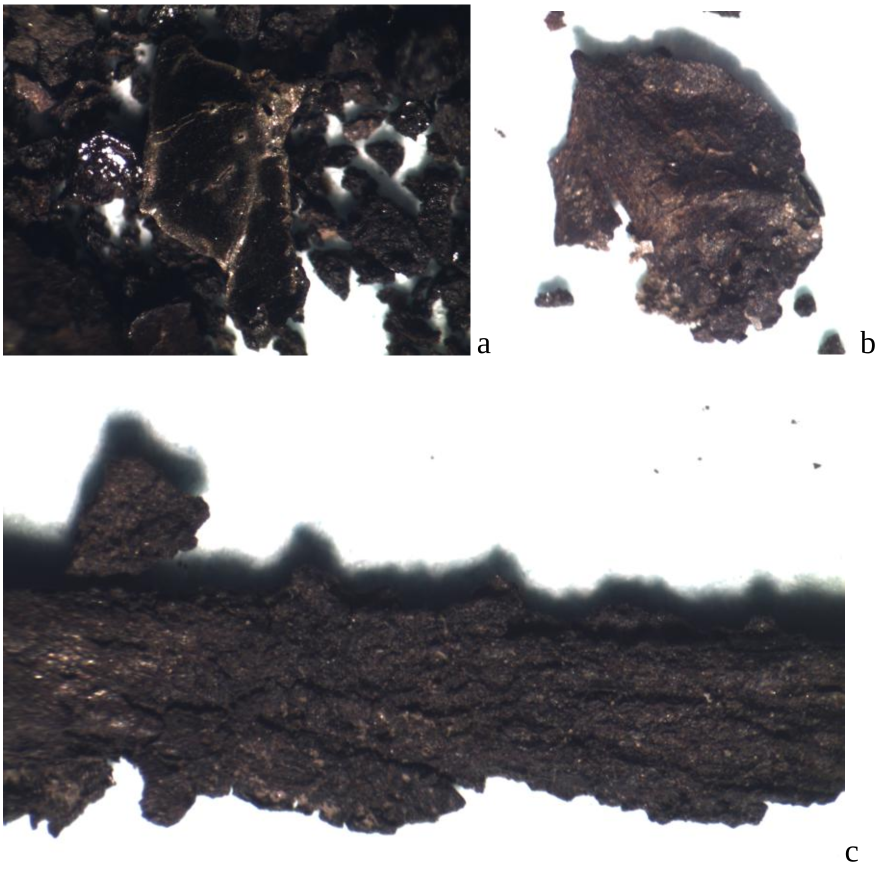


Figure 6.51. a) A possible fragment of eel scale, x30, b) a cycloid fish scale, almost complete, x10, c) a fragment of possible bone showing a longitudinal structure, x20.

6.5.1.2. Starch grains.

Although over half of the foodcrusts from Tybrind Vig did not preserve starches, there were several detailed below (section 6.5.2.1.) that produced high counts, leading to the conclusion that conditions were amenable to the preservation of grains. By inference the counts made at Tybrind Vig are representative of vessel use rather than significantly skewed by thermal-degradation and soil diagenesis. Compared to other sites under study, the preservation of starches at Tybrind Vig is of equivalent excellence. In a randomly selected sample of a hundred 'bean-shaped' starch granules (figure 6.52), the range of the length and width measurements is slightly in excess of those for Neustadt and Åkonge, reaching a maximum length >12μm which is slightly greater than the maximum length-alteration of the same granule type at the former two sites; at 11.4μm and 11.8μm respectively. Despite this marginal increase in heat-alteration to a few of the grains, the majority show only minor evidence of heat alteration, a large proportion being below 6x3μm.

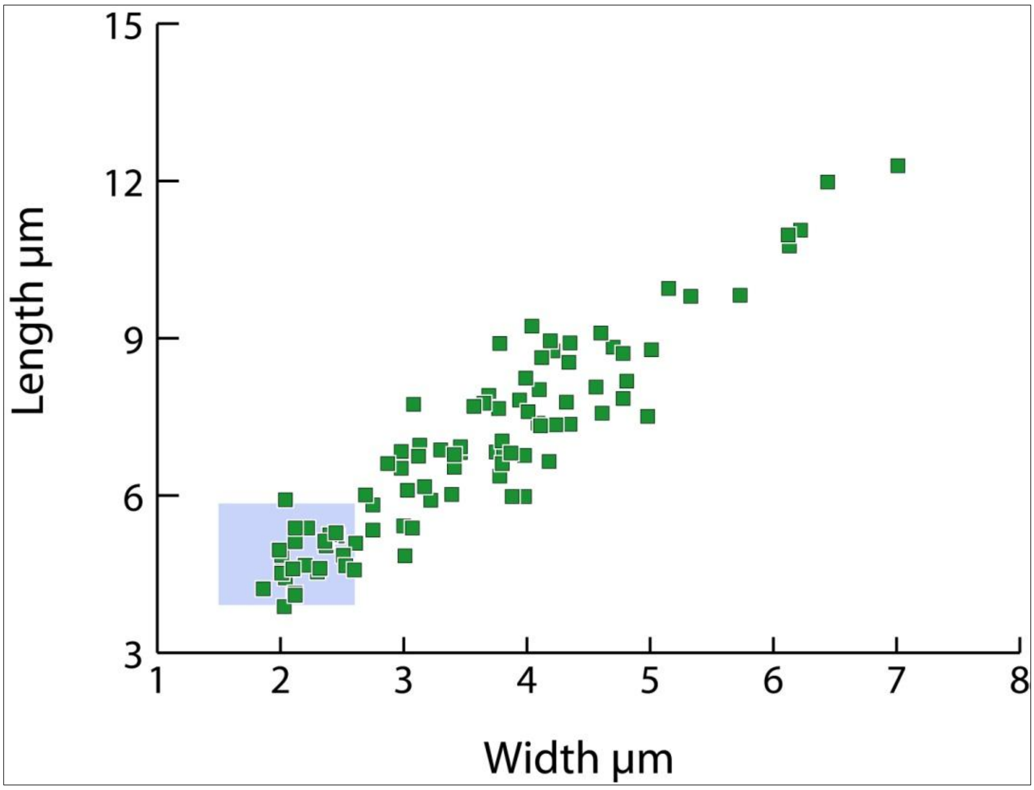


Figure 6.52. A graph showing the length and width measurements (µm) for 100 randomly chosen starch granules of the same 'bean-shaped' class, showing the swelling alteration caused by heat. The shaded region of the graph shows the size range for modern unheated granules of this class.

The granules were confirmed as starches in a subset of four Tybrind Vig deposits (figure 6.54) using α-amylase degradation. In those archaeological samples and the modern positive control with amylase added, starches were degraded in all cases. In the negative controls and modern negative control, however, starches were present of similar classes to those proposed for automated classification.

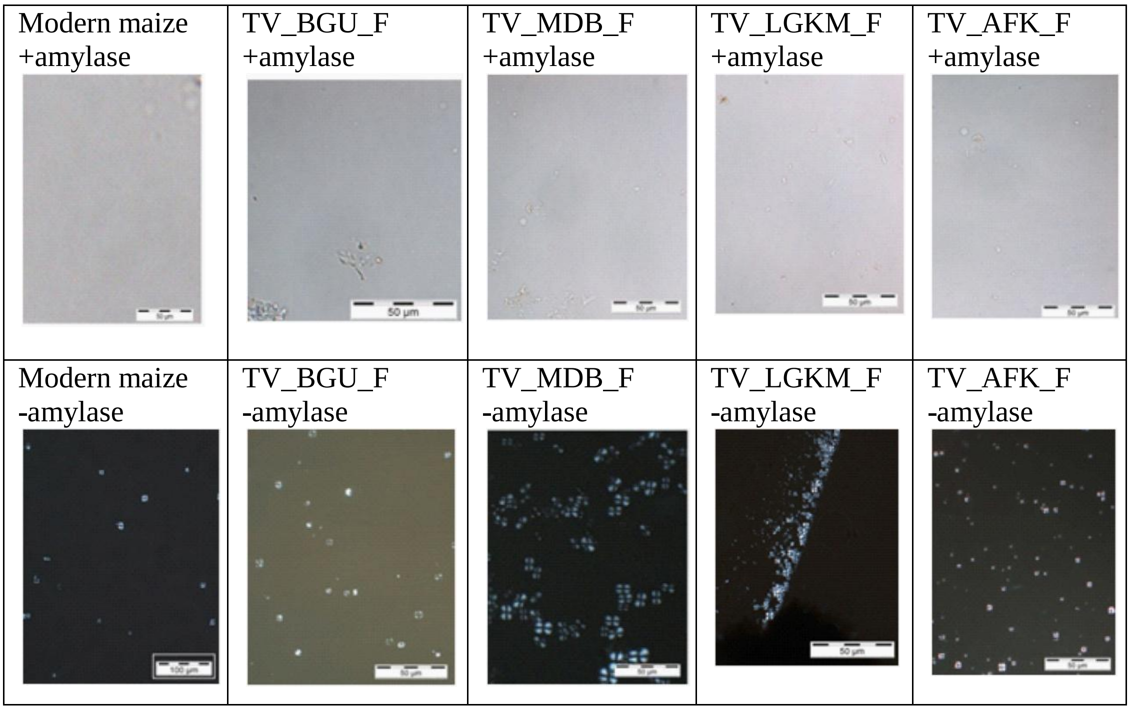

Modern maize +amylase
TV_BGU_F +amylase
TV_MDB_F +amylase
TV_LGKM_F +amylase
TV_AFK_F +amylase
Modern maize -amylase
TV_BGU_F -amylase
TV_MDB_F -amylase
TV_LGKM_F -amylase
TV_AFK_F -amylase

Figure 6.53. The α-amylase degradation of starches from four of the Tybrind Vig foodcrusts.

6.5.1.3. Phytoliths.

Phytoliths were preserved in the Tybrind Vig foodcrusts, but in overall numbers (mg^{-1}) that are much reduced compared to both Åkonge and Neustadt. In the latter two examples there are instances where counts exceed 100 and 300 per mg^{-1} respectively. At Tybrind Vig the largest count is <40 mg^{-1}. Results from Tybrind Vig are more akin to those of Wangels in total counts, with the caveat that there was no statistical difference between interior (F) and exterior (S) counts at Wangels meaning their presence as a result of contamination could not be ruled out. At Tybrind Vig however, clear differences between high and low counts (mg^{-1}) emerge at the observational level. So although overall phytolith presence is low, this points to a representative preservation and recovery.

6.5.2. Are these indicators related to vessel use or are they derived from the burial environment?

6.5.2.1. Starch grains.

Perhaps more than at any other site there is a clear difference between samples that have high counts (mg^{-1}) and samples that have low counts (mg^{-1}) of starches at Tybrind Vig (figure 6.54). This is important considering the residues being studied here are inherited from a previous project, leading to a lack of exterior (S) sooty adherences to investigate contamination as with the other sites being studied. In a two-tailed t-test a p-value of 9.92^{-05} (<0.05) ($t=2.36$, (>200 mg^{-1}) $N=8$, (<200 mg^{-1}) $N=16$) gives strong cause to reject the null hypothesis that there is no difference between observationally high and low 'background' counts however. Those samples indicated by an orange bar in figure 6.54 were accepted for further analysis with the automated classification system.

Were there contamination from the burial environment the graph would present a more homogenised series of counts. These findings are consistent with a deliberate inclusion of starchy plant foods in selected vessels, and exclusion from others. The marked distinction between high and low microfossil counts suggests that these behaviours were repetitive, and that perhaps these vessels were defined for use as plant processors or otherwise.

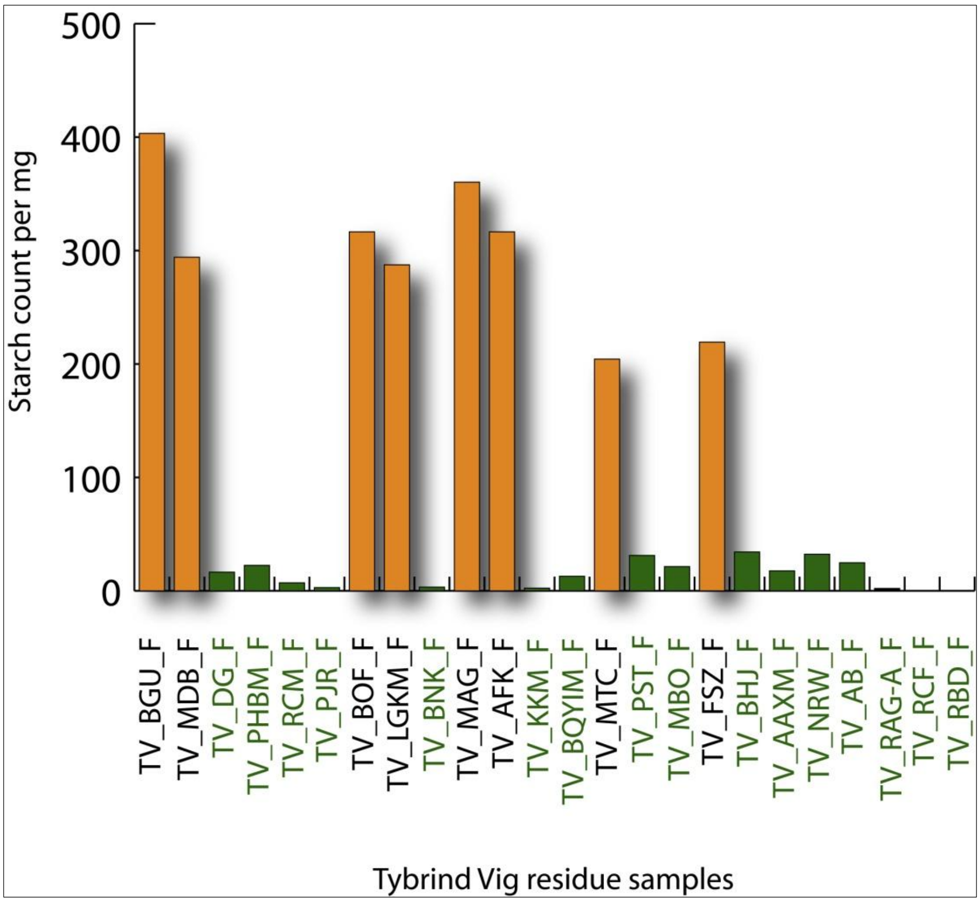


Figure 6.54. A graph of the starch counts mg^{-1} for the Tybrind Vig foodcrusts. High counts are indicated by samples with an orange bar, whilst low counts are indicated by a green bar.

6.5.2.2. Phytoliths.

Although the overall counts of silica bodies (mg^{-1}) are reduced at Tybrind Vig compared to similar underwater sites, there are still nominal differences between high phytolith numbers mg^{-1} and samples that represent background levels. There is a statistical difference between samples with >5 silica bodies mg^{-1} (N=9), and those samples <5 silica bodies mg^{-1} (N=15) (t-test, p=0.002 (<0.05), t=2.31) (figure 6.55). With a p-value <0.05 there is cause to reject the null hypothesis that there is no difference between the two groups. Those samples indicated by a green bar in figure 6.55 are considered to have been used for the processing of silica rich plants.

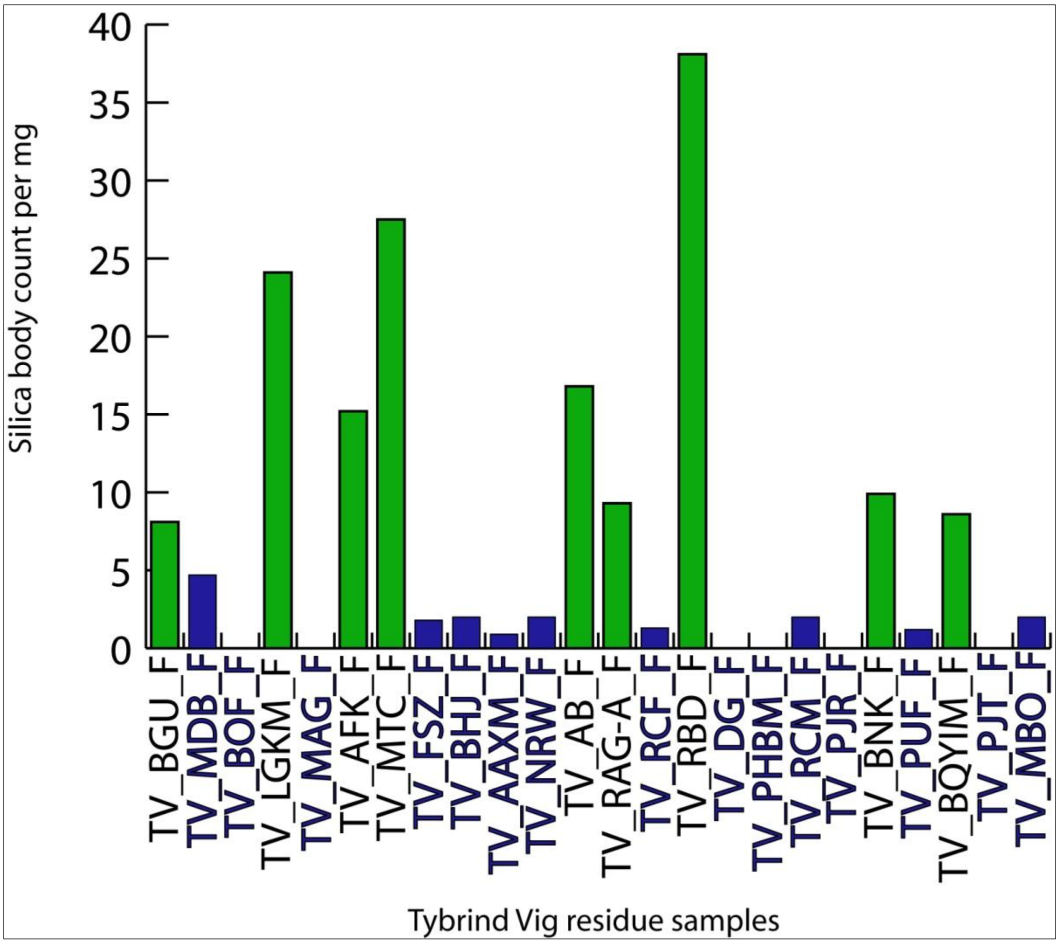


Figure 6.55. A graph of silica body counts mg^{-1} for the Tybrind Vig foodcrusts. Those samples with a green bar indicate samples that are considered to have been used to process silica rich plants.

6.5.3. Can the microfossils be identified to a plant food origin?

6.5.3.1. Starch grain classification.

Eight samples had grain counts acceptable for automated classification. It was possible to extract granules features from images for all of these eight, but for six samples the granule counts are high. Two samples (TV_MAG, TV_FSZ) have lower counts from which to retrieve granule information, resulting in less confident proportion ascriptions. The *identification* of the individual granules is unaffected by the granule count though, because it is still measured by the sensitivity of the classifier and the specificity of the granule type.

Tybrind Vig shows a great range in the plant foods being consumed (figure 6.56), more so than at Åkonge for example, although not as great as at Neustadt. At Tybrind Vig nine species are represented in proportions >10%, not as many as Neustadt where 11 plant species are represented across the samples in proportions >10%, but greater than Åkonge where only seven species are present as >10% of a sample grain assemblage. The larger overall sample number at Neustadt may be partly responsible, but Tybrind Vig has comparable and slightly reduced sample numbers than Åkonge and still displays a greater range of plant foods in the foodcrusts.

Sample	**#granules**	***Acorus calamus***	***Arum maculatum***	***Cyperus longus***	***Armoracia rusticana***	***Triticum monococcum***	***Pteridium sp.***	***Filipendula ulmaria***	***Quercus sp.***	***Typha latifolia***	***Fagus sp.***	***Sparganium erectum***	***Corylus avellana***	***Most likely species***
TV_AFK	87	19	0	0	1	0	0	0	21	4	15	4	35	*Corylus Avellana*
TV_BGU	12	0	0	84	0	8	0	0	0	0	0	8	27	*Cyperus Longus*
TV_BOF	77	9	0	1	0	0	13	3	21	1	25	25	1	*Fagus sp./ Sparganium erectum*
TV_FSZ	7	0	0	0	0	14	0	0	0	4	0	72	0	*Sparganium erectum*
TV_LGK	96	8	1	8	8	0	0	23	12	0	9	5	26	*Corylus Avellana*
TV_MAG	4	0	0	100	0	0	0	0	0	0	0	0	0	*Cyperus Longus*
TV_MDB	26	12	0	0	4	0	0	4	21	0	15	8	36	*Corylus*

														Avellana
TV_MTC	28	0	7	0	0	0	28	4	23	0	18	10	10	*Pteridium* sp.

Figure 6.56. A table of the automated starch classification results from Tybrind Vig. The proportion of each plant represented in the starch results is given beneath the respective species'.

Hazelnut (*Corylus avellana*) is classified in unprecedented numbers at Tybrind Vig, occurring in 63% of the samples (in proportions >10% of the pie chart), compared to an absence at Åkonge and only 10% of the samples suggesting hazelnut at Neustadt. At Tybrind Vig, hazelnut was slightly more important to cuisine in the context of pottery. As many samples contain high proportions of grains consistent with hazelnut in fact, as contain acorn (*Quercus* sp.) type starch at this site.

Compared to Neustadt (75%) and Åkonge (88%) the proportion of ceramics at Tybrind Vig with high classifications of acorns (*Quercus* sp.) is low at 63%, though still of considerable importance. It may be that the staple use of acorn evident at these two other sites and at Wangels, was offset by hazelnut (*Corylus* sp.) at Tybrind Vig. At Neustadt and Åkonge it was suggested that acorn was supplemented with edible reeds, and this classification trend bears out for Tybrind Vig; 25% of vessels contain high proportions of *Acorus calamus*, 25% *Cyperus longus*, and 38% *Sparganium erectum* type starch. So, what the automated classification points to is a reduction of acorn in favour of hazelnut, but with a persistent use of edible reeds. This does not include *Typha latifolia* however, which is consistently under-represented at all sites except the one sample from Wangels.

Proportions of einkorn (*Triticum monococcum*) starch forms are low as would be expected of this solely Ertebølle phase site. One vessel that has proportions of 14% einkorn comes from a low grain count (n=7), giving a low confidence to this proportion measure. In light of the late Mesolithic time period we are dealing with at Tybrind Vig, this confidence is further reduced.

6.5.3.2. Phytolith classification.

Of the nine samples to exhibit statistically high counts of silica bodies (mg^{-1}) only four showed phytoliths that may be of some taxonomic value. Three of the samples contained a type indicated 'a' in figure 6.57. According to phytolith nomenclature convention (Madella *et al.* 2005), these may be cuneiform bulliform cells, which originate from the epidermis of the grass leaf (Madella *et al.* 2005). They are regularly c. 20µm wide. In contravention of this is the curved apex on the proximal end shown clearly in the examples from TV_RBD and TV_MTC. This is unusual for cuneiform bulliform cells in the literature (Pearsall *et al.* 1995), and may be of taxonomic value, but does not occur in any of the modern reference material. It may be that these are modified cuneiform bulliforms that originate from an unknown Poaceae member, or the epidermis of a silica rich non-Poaceae plant.

One sample, TV_LGK produced a phytolith type (figure 6.57b) similar to two examples found at Åkonge (KML_49.5/75.5:4). These are described by nomenclature convention as ‘oblong irregular psilate’. They ranged from 9.7-10.1µm in length at Åkonge, and the example from Tybrind Vig is similarly sized at 10.2µm long, with the same moderate undulations on the surface. This type belongs to a class that has no known modern referent for anatomical or taxonomic assignation. Both figure 6.57c and d are examples of ‘oblong irregular sinuate’ phytoliths. In the case of figure 6.57c its size at 22.2µm registers parallels with examples from both Åkonge and Neustadt.

Figure 6.57e is a ‘semi-globular verrucate’ phytolith similar in shape to examples from Neustadt (N_2756) but much larger at 38.6µm and with its widest part being along its symmetrical axis, as opposed to a squatter semi-globule shape where the blunt edge is the longest as at Neustadt (N_2756). Finally, figure 6.57f is another example of a ‘globular sinuate’ phytolith of the kind consistent with *Alliaria petiolata*. However, this example is 14.2µm in diameter, exceeding the range of modern garlic mustard (*Alliaria petiolata*) which has a maximum length of 11.2µm based on a sample of 50 modern references. As at the other sites studied here, the range of phytoliths with potential taxonomic significance is unexpected, and the deficit in modern comparisons points to a substantial potential for this kind of plant food indicator.

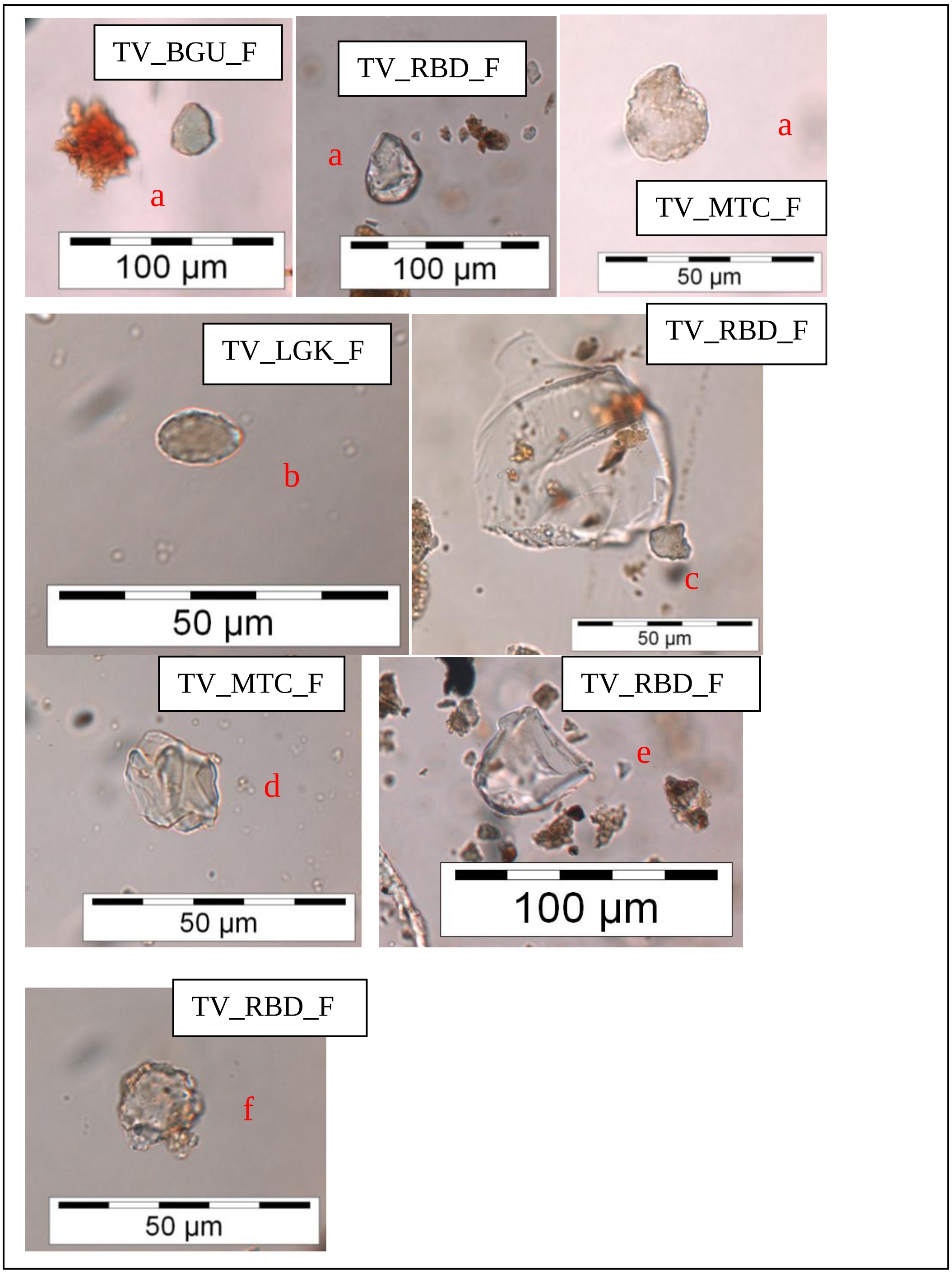


Figure 6.57. The types of phytoliths found in the Tybrind Vig foodcrusts.

6.5.4. Comparison of plant microfossil data with bulk isotope and lipid residue analyses.

As has been mentioned, the foodcrusts from Tybrind Vig were acquired from a previous project meaning some of the organic-geochemical analyses were not re-conducted. As a result, five of the foodcrusts that have plant microfossil analyses do not have corresponding bulk isotope values. The single compound isotope results for

Tybrind Vig likewise correspond poorly with those samples where there are also surface deposits, and only one vessel has values for analyses of plant microfossils, bulk isotopes and single compound isotopes. As a result the three lines of evidence are less amenable to integration than at the other sites studied. The primary publication of these findings is made in Craig *et al.* 2007.

The bulk isotope values of the Tybrind Vig residues are very discrete compared to other sites studied (figure 6.58). None of the δ^{15}N values are low enough to suggest an exclusively plant or milk content to the vessels, with the lowest ^{15}N value exceeding 6‰. The values plot in a region that is not isotopically distinctive enough to indicate a particular food source and this is probably compounded if mixtures of food are registering signals. In general there are two nominal clusters of samples (figure 6.58); the first is a group of five relatively depleted in ^{15}N and ^{13}C which can be said to have a carbon and nitrogen content with perhaps terrestrial contributors. The remaining samples are relatively enriched in carbon-13 suggesting a greater contribution of marine sources to their isotopic signatures.

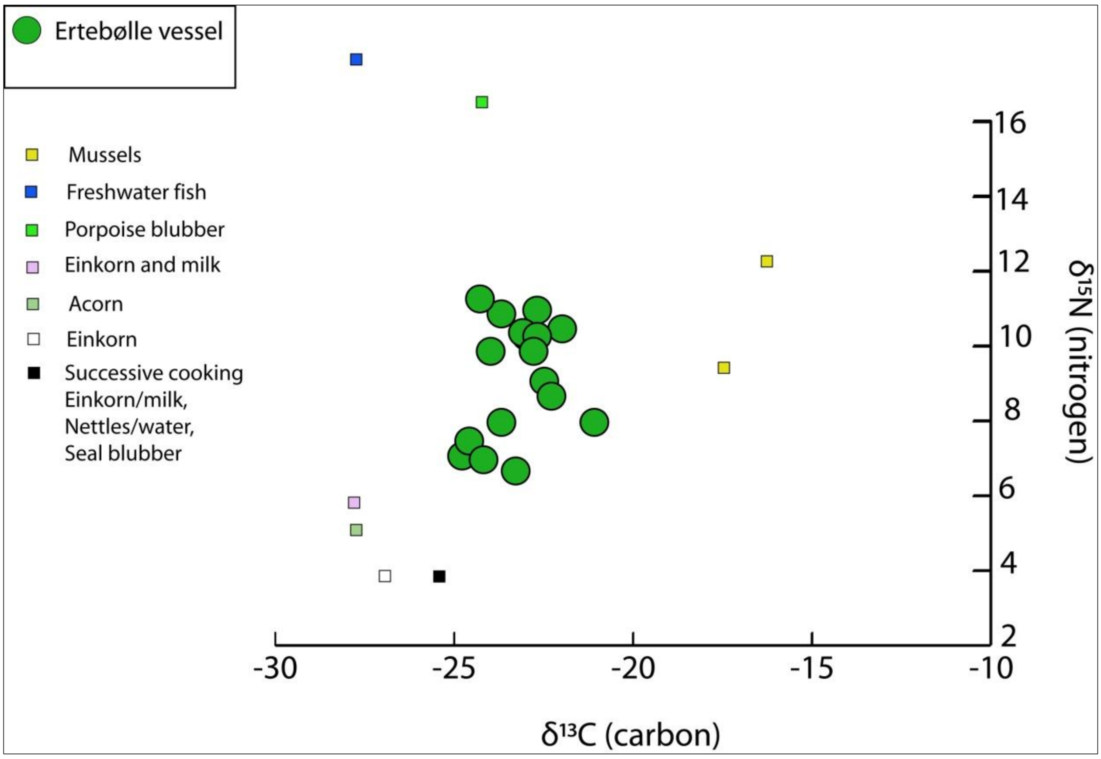


Figure 6.58. A graph plotting the bulk carbon and nitrogen isotope ratios of the Tybrind Vig foodcrusts, also showing the values for modern reference foods.

The dominant C16:0 and C18:0 fatty acid isotope values for the assemblage of residues from Tybrind Vig suggest that a mixture of terrestrial and aquatic foods is indeed the case. Of those samples with single compound results 38% fall within marine food ranges (figure 6.59), suggesting the larger number of samples measured for bulk isotopes (figure 6.58) do indeed represent marine foods. Since they are still relatively depleted in carbon and nitrogen compared to modern reference marine mammals, it seems likely these marine foods are lower tropic species like fish.

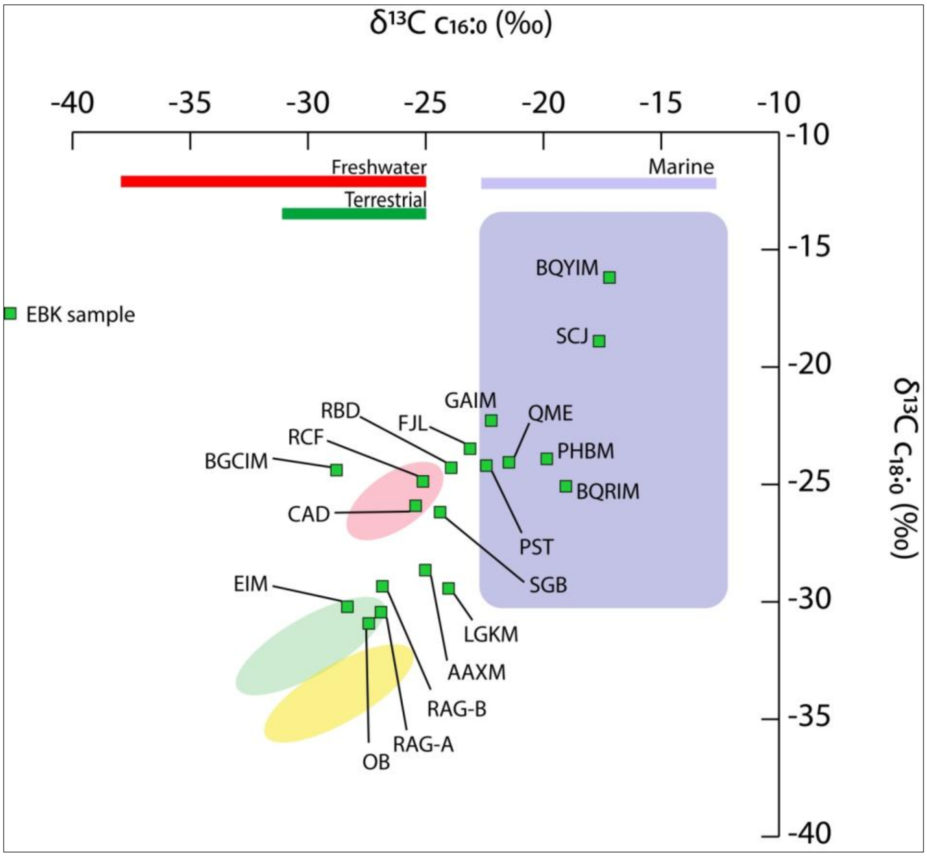


Figure 6.59. A graph plotting the δ^{13}C isotope values for C16:0 and C18:0 fatty acids from the lipid absorbed into the Tybrind Vig vessels. Ranges were generated using authentic marine and freshwater reference fats from Danish waters. Terrestrial data are a combination of published references (Dudd and Evershed 1998), with northern German wild boar and cow milk, and are plotted with 95% confidence intervals.

In figure 6.59 many of the remaining terrestrial foods fall outside the ranges of porcine and ruminant foods. None of them have C16:0 fatty acids depleted enough in ^{13}C to be considered freshwater fish which is consistent with Tybrind Vig being a coastal site, and suggests that only local resources were being utilised. Two samples very clearly fall in the porcine isotopic range, and two more can be considered a borderline monogastric food source. Meanwhile three samples clearly occupy the accepted isotope range for ruminant adipose tissue, and an extra one is a borderline addition. Clearly the foods being selected are quite diverse from this evidence; not only are fish, porcine foods like boar, and ruminant animals like deer being selected, but the samples that *don't* fall in these ranges may represent non-referenced species such as wildfowl, and small mammals.

6.5.4.1. Porcine products.

Of those samples registering single compound isotope values in figure 6.59, 22% are porcine or borderline porcine (*n*4). Of those, two have associated foodcrusts; TV_RCF and TV_RBD. The pork food in sample TV_RCF is not associated with any other foods, based on a lack of aquatic biomarkers or any plant microfossils. By contrast, TV_RBD is a vessel with a borderline porcine isotope value, and was also used to process aquatic products based on the presence of three aquatic biomarkers: C20:3, C18:3 and C16:3 ω-(*o*-alkylphenyl)alkanoic acids, phytanic acid and TMTDs. Foodcrust from this vessel also contained significant numbers of phytoliths. As well as a number of unidentified silica bodies, this pork and fish containing vessel also held the only candidate of garlic mustard (*Alliaria petiolata*) consistent phytolith found. Consumption of pork does not seem to adhere to prescribed patterns of vessel use at Tybrind Vig, mixtures or reuse of vessels is acceptable.

6.5.4.2. Ruminant products.

Of the three ruminant or borderline ruminant isotope signatures in figure 6.59, only one has foodcrust with a corresponding bulk isotope value and plant microfossil data. This sample is uncharacteristically enriched in ^{13}C (figure 6.60), which is explained by the presence of the suite of three aquatic biomarkers, making this a candidate for mixing activities as the results all come from foodcrust which evidences a later use of the vessel. This vessel was also used to process silica rich plant material, although none of the phytoliths can be identified to taxon.

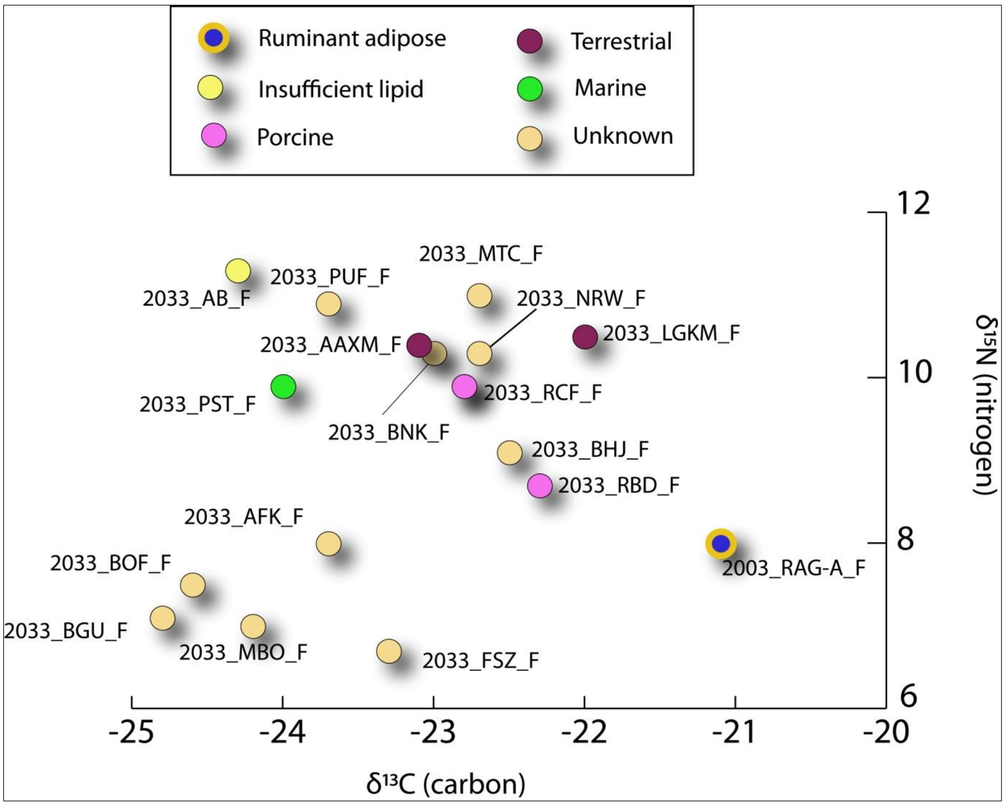


Figure 6.60. A graph plotting the bulk carbon and nitrogen isotope ratios of the Tybrind Vig foodcrusts. Each datum point is represented by a symbol indicating the food class defined by single compound isotope analysis of the corresponding sherd.

6.5.4.3. Aquatic products.

Of the 38% majority of samples that are isotopically marine fish (figure 6.59), only one bulk isotope value was available from the foodcrust making it difficult to explore patterning in association with other foodstuffs. Singly, this sample is not associated with starchy or silica rich plants. Taking the presence of aquatic biomarkers as further evidence of likely fish consumption (figure 6.61) there is not an exclusive use of vessels for either aquatic or terrestrial foods at the site. Although the two samples with a terrestrial isotope signature on the C16:0 and C18:0 fatty acids (figure 6.60), as well as the isotopically porcine TV_RCF have no aquatic biomarkers to indicate possible mixing, TV_RAG-A in the isotopic range for ruminant adipose, and TV_RBD with porcine isotope values *do* contain biomarkers.

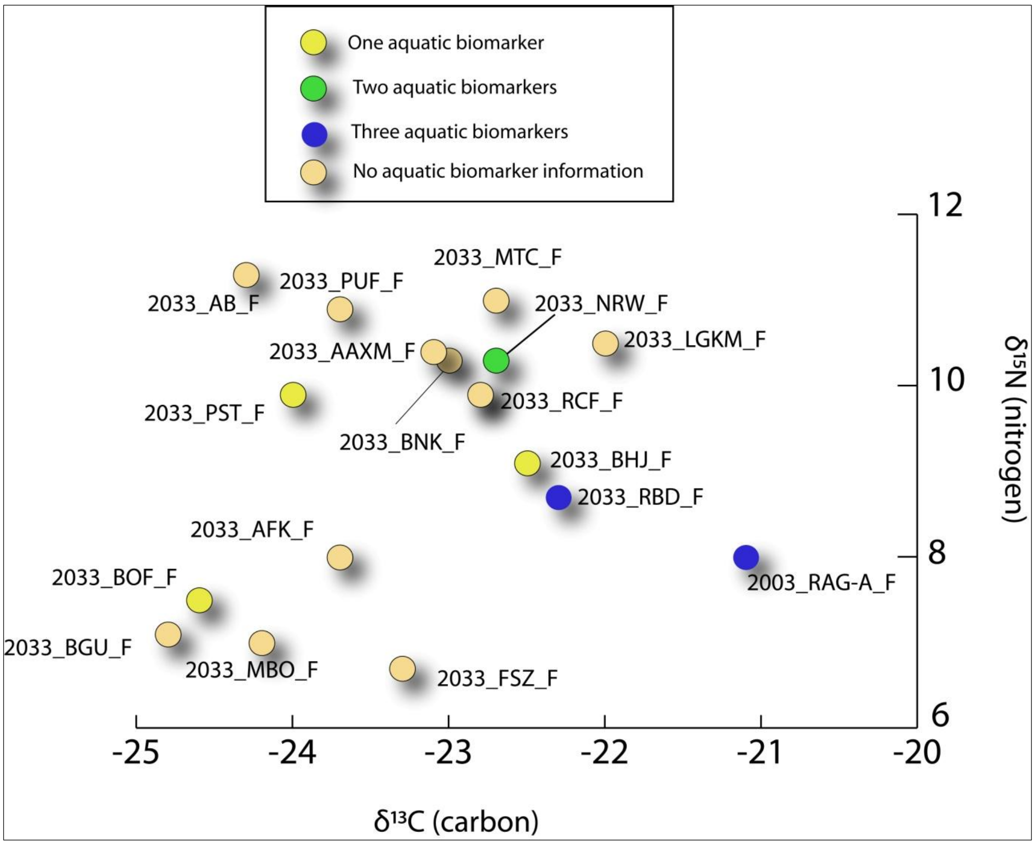


Figure 6.61. A graph plotting the bulk carbon and nitrogen isotope values for the Tybrind Vig foodcrusts. Each datum point is represented by a symbol that indicates the number of aquatic biomarkers present from absorbed and surface deposits, base on GC-MS results.

6.5.4.4. Plant products.

None of the vessels (*n*5) holding terrestrial foods such as the ruminant animals and pork are associated with starchy plant foods (figure 6.62). However, two of the four vessels that have aquatic biomarkers were also used to process acorns (*Quercus* sp.). Although not an extensive sample number by any means, this may be an extension of the patterning seen at both Neustadt and Wangels where there was an association of fish with acorn (*Quercus* sp.) type starch. Unfortunately the occurrence of grains indicative of hazelnut (*Corylus* sp.) in samples corresponds with foodcrusts where we have little evidence for other processing activities, making it impossible to explore their culinary context of use. Their spread in samples across the range of bulk isotope values suggests there may not have been restrictions on their mixture with other animal foods though.

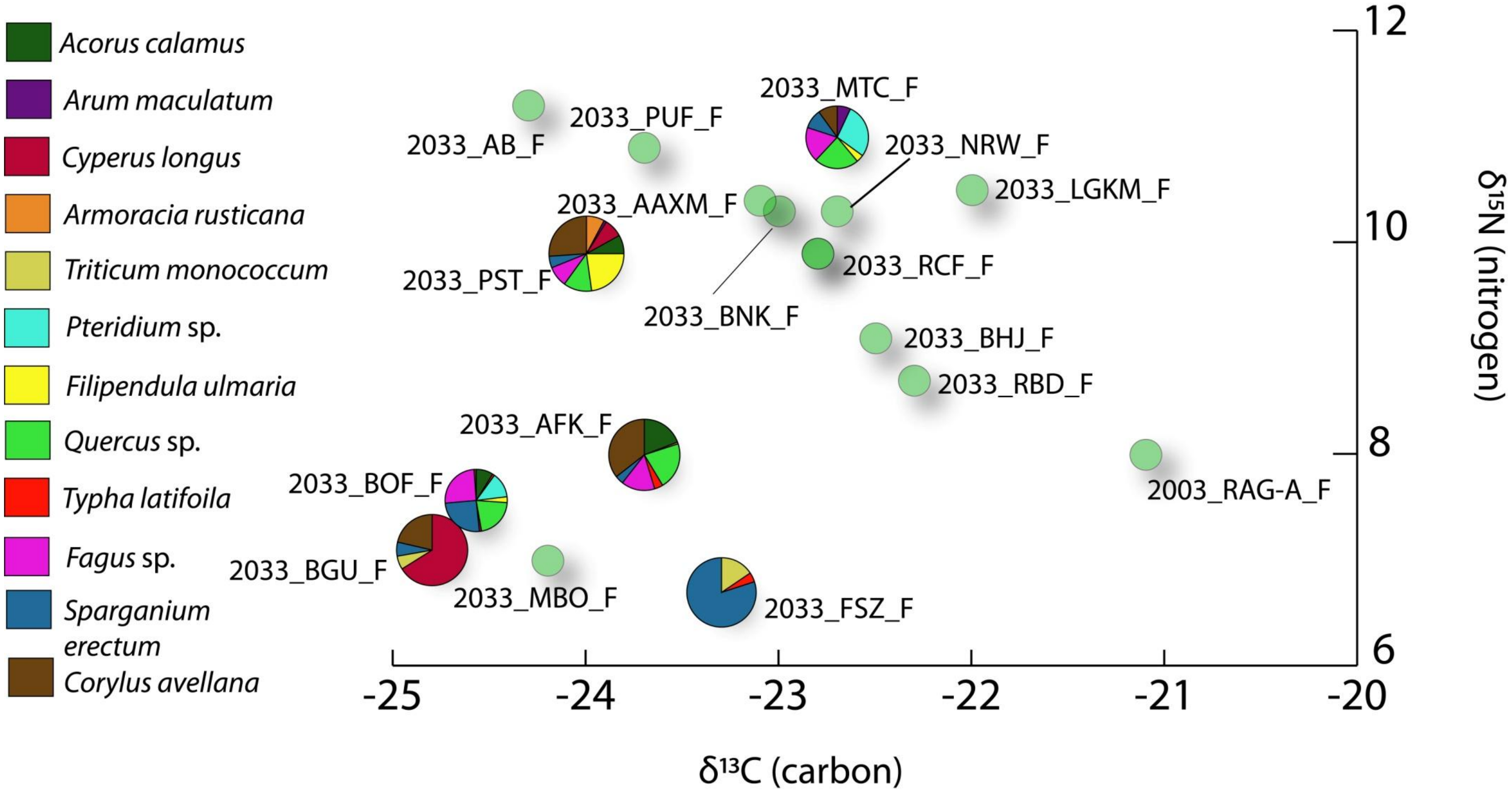


Figure 6.62. A graph plotting the bulk carbon and nitrogen isotope values of the Tybrind Vig foodcrusts. Those samples that have significant starch counts are represented by pie charts illustrating the proportions of different plants present based on automated starch classification.

6.5.5. Comparison of identified food contents to vessel features.

No information was available on features of the vessels such as thickness and size. All are pointed-based Ertebølle varieties. In terms of context, the vessels can be separated by layer, with the majority coming from the middle and upper strata (figure 6.63) corresponding with the terminal part of the Late Mesolithic. There are no clear patterns, both vessels with porcine isotope signatures on the C16:0 and C18:0 fatty acids are from the top layer, as are those with a terrestrial signature. However, there is also tentative evidence for fish foods from this very late Mesolithic layer, in the form of a single aquatic biomarker from TV_BOF, and all three aquatic biomarkers from TV_RBD. For the older middle layer, the only sample for which we have any information is TV_BHJ which contains a single aquatic biomarker.

It is also difficult to relate this layer information to plant microfossils for patterning because there are only four starch rich samples for which there is corresponding stratification detail. Considering that samples from the top stratum make up the majority of the sample set (*n*7) there are only two examples where starchy storage organs are present. In both these examples the role of the vessels is once again the processing of a storage organ like acorns (*Quercus* sp.), persisting with this notion of the importance of wild plant staples right up to the transition to the Funnel Beaker period. Hazelnut (*Corylus avellana*) is also classified in high proportions in one of these vessels from the upper stratum, marking its role as an additional culinary staple at Tybrind Vig.

There is only one sample from the lower stratum, and one out of a total of three from the middle stratum that held starchy plant foods. The vessel from the oldest layer had a diverse array of plants in it, with high proportions of *Quercus* sp. and *Pteridium* sp., type grains. The sample from the middle stratum was dominated by edible reed forms with smaller proportions of hazelnut (*Corylus avellana*) classified. In sum, there is insufficient reason to suspect that there was any marked discontinuity in cuisine or eating habits throughout the Mesolithic period at Tybrind Vig, certainly not in the variety of plants being consumed, and only a possibility that the *quantities* of plants being consumed was decreasing in the context of pottery.

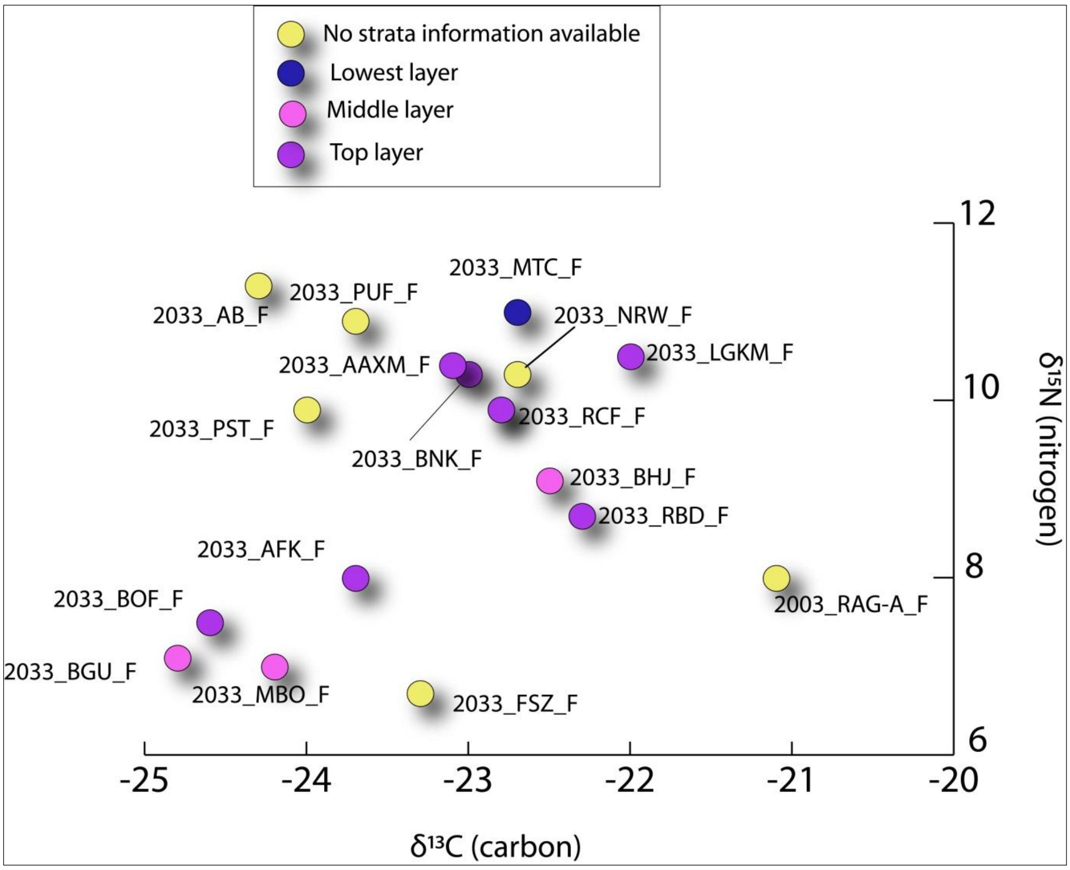


Figure 6.63. A graph plotting the carbon and nitrogen isotope values for the Tybrind Vig foodcrusts. Each datum point is represented by a symbol indicating the stratum from which the sample derives.

6.5.6. Summary of the Tybrind Vig results.

The majority of the sampled sherds derive from the top stratum of Tybrind Vig, correlating with the later Ertebølle period, but there is no evidence for Mesolithic dairy foods as has been seen at other sites in the study. On the basis of single compound isotope results pottery at Tybrind Vig was used to process a wide variety of foods, both of terrestrial and marine origin. Around 38% of the vessels (7/19) plot isotopically in the marine food range. In the region of 22% of the vessels (4/19) are porcine or borderline, and 16% (3/19) were used for ruminant adipose. Isotopic evidence for mixing is provided by the numerous samples on the border of ranges for certain species, plus the recovery of aquatic biomarkers in pots with both pork and ruminant consistent ^{13}C values on C16:0 and C18:0 fatty acids.

None of the terrestrial foods are associated with starchy plants (n5). Two of the four pots with aquatic biomarkers indicative of fish, were also used to process acorns (*Quercus* sp.) on the basis of automated classification. Other important wild plants include hazelnut (*Corylus avellana*) starch forms, which are identified in 4/17 (24%) foodcrusts; higher than at any of the other sites. At Tybrind Vig there is no convincing evidence for the presence of domesticated cereals.

6.6. Stenø.

6.6.1. Do indicators of foods (including phytoliths and starches) survive in association with the vessels?

6.6.1.1. Macroremains.

Only three of the twenty samples contained any visible macroremains under low powered microscopy. Samples ST_x026_222_F and ST_x004_201_F had carbonised fish scale fragments in them (figure 6.64). Sample ST_x036_096 contained a possible piece of bone or fish scale, unidentifiable to greater resolution. In the former two samples the fish scales displayed concentric raised circuli consistent with scales of the Salmonid family (Harland *pers. comm.*). In both instances the fragments appeared blackened and charred, pointing to their incorporation into the original vessel contents. Compared to Åkonge which is from the same lakeside landscape and possessed fish scales in six of its sixteen samples (37%), Stenø preserves fewer macroremains (15%). This issue of reduced preservation is one that has been observed by the excavator (Fischer *pers. comm.*), and is likely a consequence of the drainage of the bog. The foodcrusts were also observed to be thinner during sampling and analysis of the pottery assemblage too.

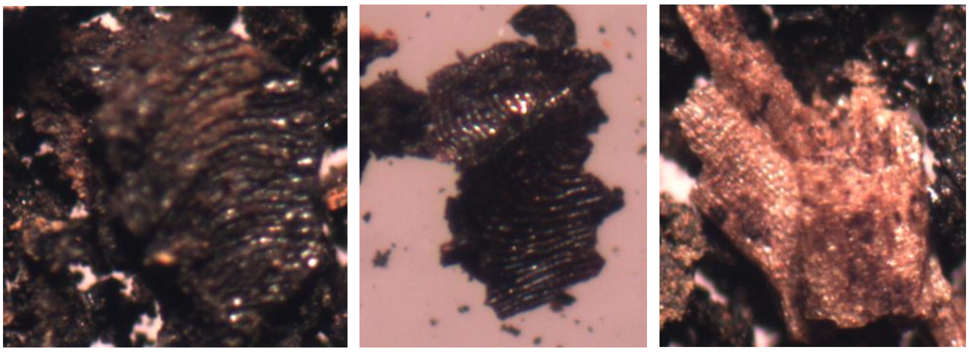


Figure 6.64. The two images on the left display carbonised Salmonid fish scales, and the image on the right is a piece of possible bone or fish scale.

6.6.1.2. Starches.

Poor preservation of the foodcrust is an issue with consequences for the recovery of starches at Stenø. The thinness of the carbonised matrix relative to better preserved examples at Neustadt and Åkonge, represents a less robust barrier to contamination and microbial action of soil bacteria on organic material like the starches. Only 15% of the Stenø surface residues preserved starches but those that *did* demonstrate counts mg^{-1} comparable to those of Åkonge. Figure 6.65 is a random sample of 50 'bean-shaped' starch grains, and shows the degree of heat-induced size and shape alteration. There is a proportional increase in length and width with heat-alteration. The number of samples occupying the region <9x6μm (n=23) is slightly less than the number of samples >9x6μm (n=27), showing that heat alteration is substantial to this assemblage.

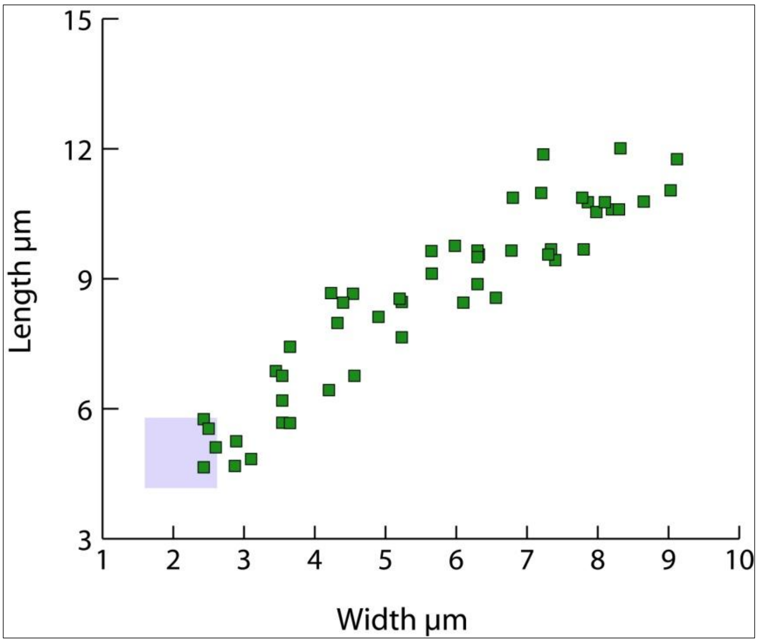


Figure 6.65. A graph showing the length and width measurements (μm) for 50 randomly chosen starch granules of the same 'bean-shaped' class, showing the swelling caused by heat. The shaded region of the graph shows the size range for modern unheated granules of this class.

Compared to sites like Åkonge, which occupies a similar sedimentary environment, the starches at Stenø have a higher average length (av. 8.57μm Stenø, av. 7.15μm Åkonge). The maximum starch length is 12.01μm at Stenø, larger than 11.65μm at Åkonge, and a higher proportion of the Stenø grains are at this larger end of the size range. This greater prevalence of swollen grains helps to explain why the presence of starches in the Stenø foodcrusts is generally fewer. Swollen grains have a greater degree of molecular disorder, which makes them more susceptible to microbial attack in the burial environment. Granules were confirmed as starches using α-amylase degradation (figure 6.66). In samples positive for amylase starches were degraded and absent. In both archaeological and modern samples negative for amylase however, starch granules were present in similar classes to those analysed with automated classification.

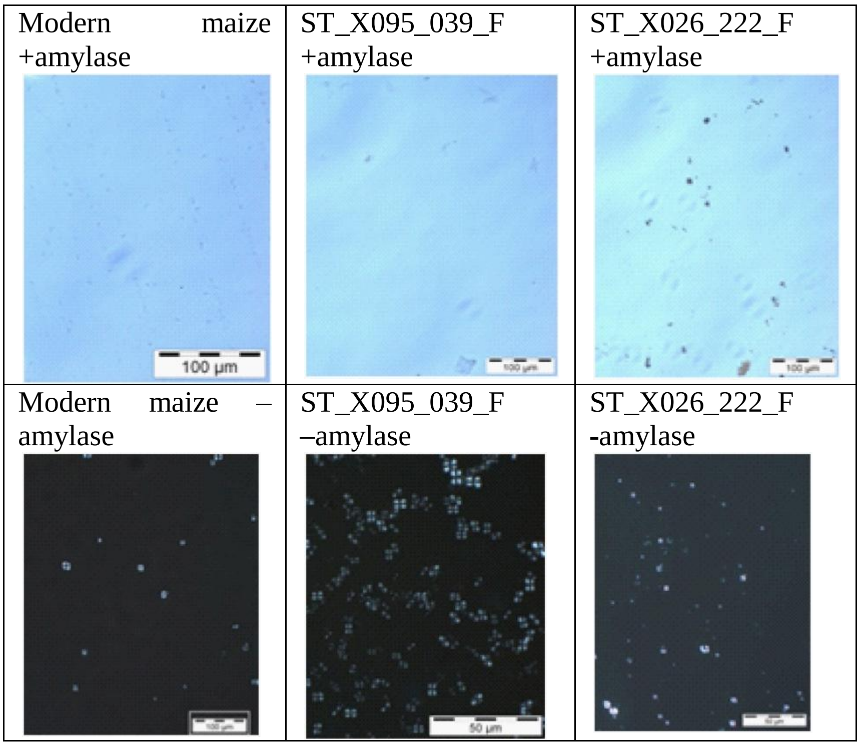

Modern maize +amylase
ST_X095_039_F +amylase
ST_X026_222_F +amylase
Modern maize –amylase
ST_X095_039_F –amylase
ST_X026_222_F -amylase

Figure 6.66. The α-amylase degradation of starches from two of the Stenø foodcrusts.

6.6.1.3. Phytoliths.

The recovery of silica bodies at Stenø is comparable to that of the more waterlogged and better preserved Åkonge residues. At Stenø 40% of the residues produced high counts mg^{-1} of phytoliths, only slightly less than the 56% at Åkonge. The robusticity of the silica would suggest that these results give a more reliable impression of plant use at Stenø than the starches. If this is the case, it would seem that the starch results are indeed the subject of degradation factors, compromising the representation of the extent of plant foods.

6.6.2. Are these indicators related to vessel use or are they derived from the burial environment?

6.6.2.1. Starches.

Figure 6.67 is a graph of the counts mg^{-1} of starches from interior (F) and exterior (S) surface deposits. There is a clear nominal difference between samples that have a high count >100 starches mg^{-1} and those with background levels of starch. Statistically there is no difference between counts from samples on the interior (F) and exterior (S) surfaces (t-test, p= 0.13 (>0.05), t=2.14, N=5 (S), N=15 (F)). Neither is there a statistical difference between those samples >100 mg^{-1}, and those that are not (t-test, p= 0.10 (>0.05), t=4.30, N=3 (>100/mg^{-1}), N=17 (<100/mg^{-1})). However, the sample count of three is too low for the statistical measures to accurately discriminate the groups. These three samples with >100 starches mg^{-1} are clearly higher than background levels of the microfossils- the maximum of which was only 3.5 grains mg^{-1}- and so were provisionally included in subsequent automated classification.

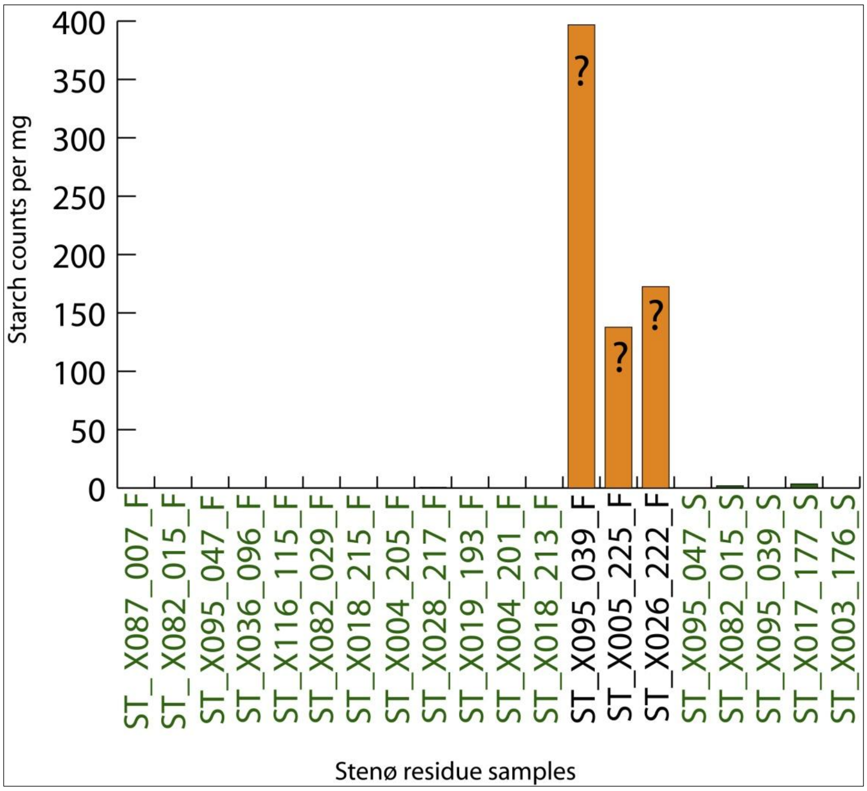


Figure 6.67. A graph of the starch counts mg^{-1} for the Stenø foodcrusts. High counts are indicated by samples with an orange bar, whilst low counts are indicated by a green bar. Bars with question marks indicate samples provisionally accepted for starch classification.

6.6.2.2. Phytoliths.

Figure 6.68 shows the counts mg^{-1} of silica bodies in the Stenø samples. There is a less clear difference between high and low counts mg^{-1}, than for starches. However, there is a statistical difference between interior (F) and exterior (S) surfaces (t-test, p= 0.0007 (<0.05), t=2.10, N=15 (F), N=5 (S)). This confirms that the interior of the ceramics was deliberately packed with plant material. A threshold of >40 mg^{-1} was defined for the acceptance of samples that were used for the processing of silica rich plants. Those samples are marked with a green bar in figure 6.68.

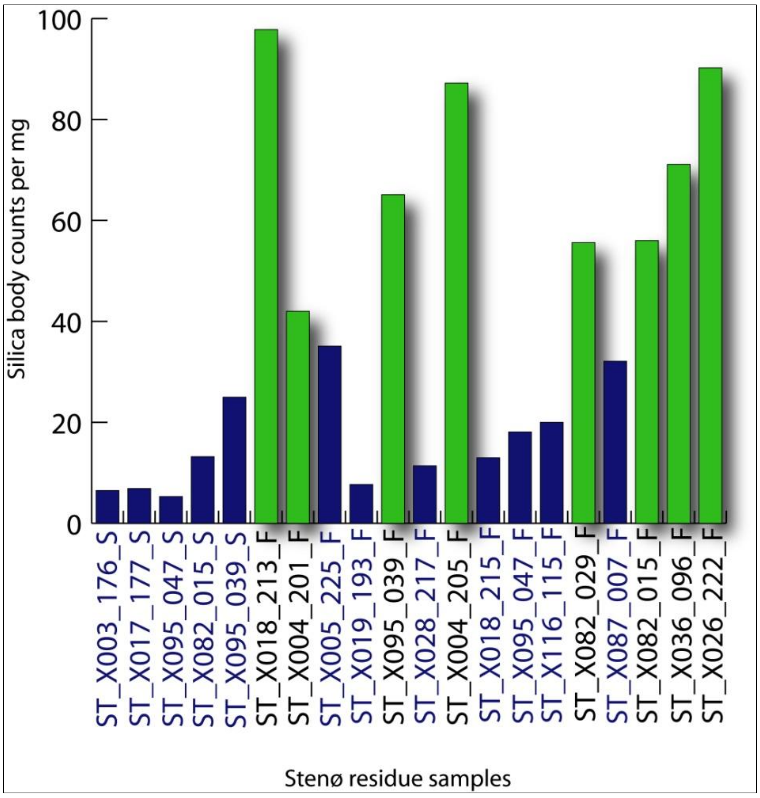


Figure 6.68. A graph of the silica body count mg^{-1} for the Stenø foodcrusts. Those samples with a green bar indicate samples that are considered to have been used to process silica rich plants.

6.6.3. Can the microfossils be identified to a plant food origin?

6.6.3.1. Starch grain classification at Stenø.

Of the three samples put forward for automated classification, information could be extracted for a total of 137 grains. Although there were starches present in ST_x005_225_F photographing and extracting features was hampered by their clustering on the slide, making the definition of their edges impossible in most cases. It was only possible to measure features for one starch, which was a distinctive acorn

(*Quercus* sp.) type grain (figure 6.69). Although we cannot comment on the *extent* to which this vessel was used for the processing of acorns, it was certainly part of the role of the pot.

Sample	**#granules**	***Acorus calamus***	***Arum maculatum***	***Cyperus longus***	***Armoracia rusticana***	***Triticum monococcum***	***Pteridium* sp.**	***Filipendula ulmaria***	***Quercus* sp.**	***Typha latifolia***	***Fagus* sp.**	***Sparganium erectum***	***Corylus avellana***	***Most likely species***
ST_X095_039_F	76	12	0	0	0	0	46	1	29	3	4	5	0	*Pteridium* sp.
ST_X026_222_F	60	2	6	0	0	0	15	0	75	0	0	3	3	*Quercus* sp.
ST_X005_225_F	1	0	0	0	0	0	0	0	100	0	0	0	0	*Quercus* sp.

Figure 6.69. A table of the automated starch classification results from Stenø. The proportion of each plant represented in the starch results is given beneath the respective species.

Acorn (*Quercus* sp.) is classified at this site in all three samples, with a minimum proportion of 29% as shown in figure 6.69. In the two samples with substantial starch grains, fern fiddlehead (*Pteridium* sp.) starch forms are present in high proportions of 46% and 15%. *Acorus calamus* type grains comprise the final substantial contributor in one sample, represented by 12% of grains. The overall representation of starchy plant species is limited to these three in substantial proportions (>10% of the pie chart). It would seem therefore that the potential preservation problems at Stenø have targeted starches of the other species, or that this is an archaeological phenomenon and that these vessels were primarily restricted to the processing of these three plants.

6.6.3.2. Phytolith classification at Stenø.

Of the eight samples that produced significant quantities of silica bodies, only one globular sinuate phytolith (*diam*. 7.6µm) consistent with a seed such as garlic mustard (*Alliaria petiolata*) (av. 6.98µm) was found. This is shown in figure 6.70a, along with examples of the other types of phytoliths that are undiagnostic. The majority of the silica content was made up of silica skeletons (figure 6.70b) and single short cells from the epidermis (figure 6.70c), both of which indicate that vegetable matter was processed in the vessels, but not what plants they represent.

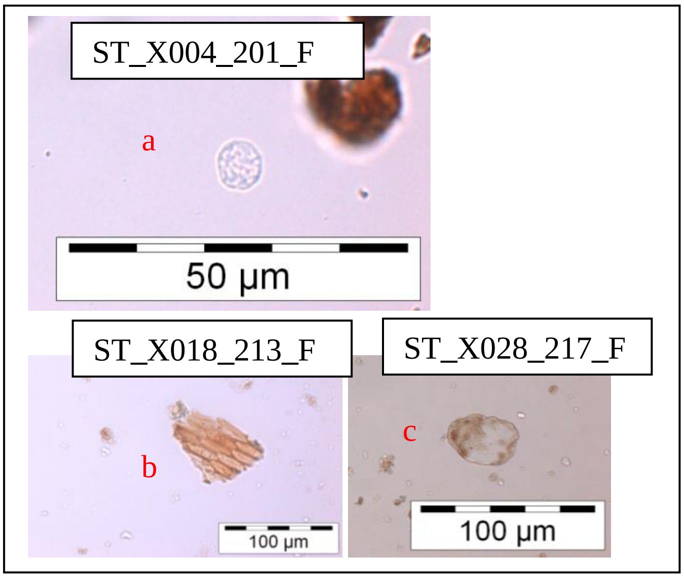


Figure 6.70. The types of phytoliths found in the Stenø foodcrusts.

Although only one example of the globular sinuate form was found in light microscopy, it was possible to document others using Scanning Electron Microscopy. An example is shown in figure 6.71 on the left, with an enlargement on the right. From the SEM we can clearly see that the roughly spherical shape is pitted with undulations, consistent with observation in light microscopy. The artefact is wedged under a crevice in the carbonised matrix, which suggests it originates from the foodcrust. This example is slightly smaller (c. 6µm) than the one observed in transmitted light, but still within the range for *Alliaria petiolata* (4.8-11.2µm). It is not surprising that there are so few examples of this phytolith type when we consider that the seeds of garlic mustard are only c. 3x1mm and contain barely any starch, and could only have been added to food as a spice or flavouring agent, rather than as a bulk carbohydrate source.

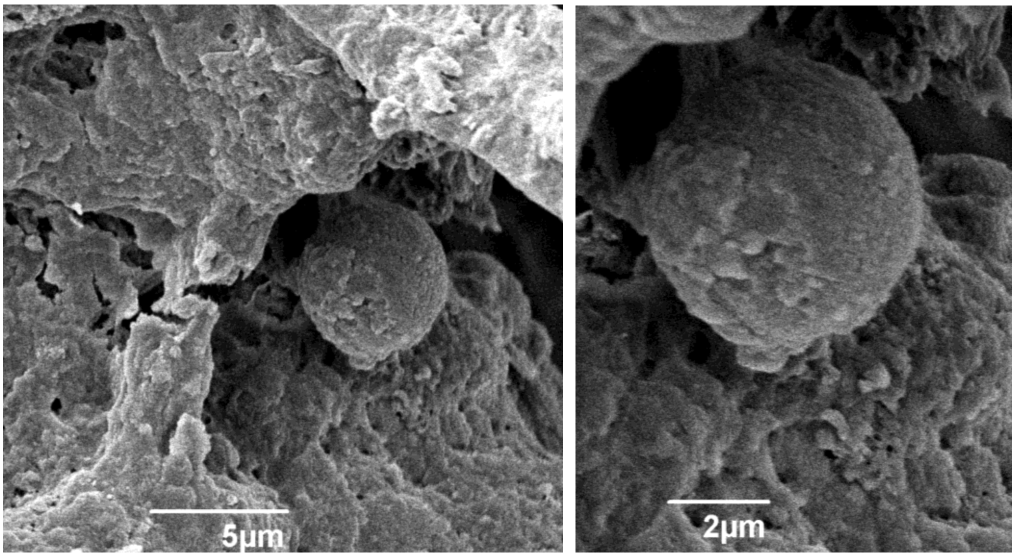


Figure 6.71. Scanning Electron Microscope images of a suspected *Alliaria petiolata* phytolith embedded in the carbonised matrix.

6.6.4. Comparison of plant microfossil data with bulk isotope and lipid residue analyses.

The majority of Stenø samples are depleted in ^{13}C compared to modern bulk isotope values for experimentally cooked references (figure 6.72). The archaeological samples fall in the δ^{13}C range -25‰ to around -30‰, comparable with samples from nearby Åkonge. Carbon isotope values between those vessels with EBK techno-stylistic features and those with TRB features are not significantly different ($p=0.64$ (>0.05), $t=2.13$, (EBK) $N=8$, (TRB) $N=11$). Patterns of food use show continuity at this transitional site, with persistent bulk isotope values consistent with a substantial contribution from non-marine foods. Around 16% ($n=3$) of the samples plot closely to modern mixtures of cooked einkorn and milk.

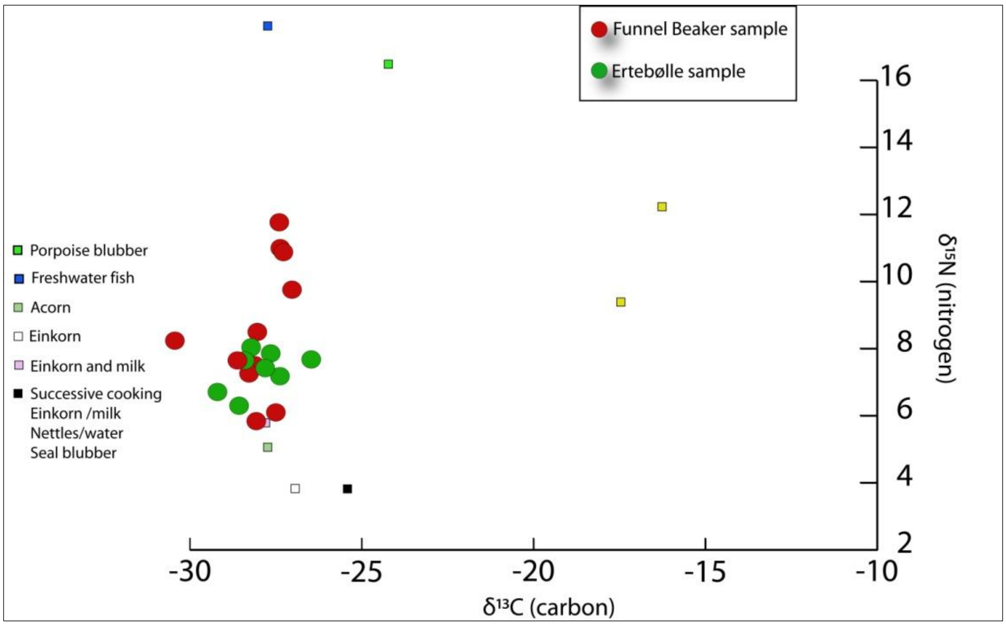
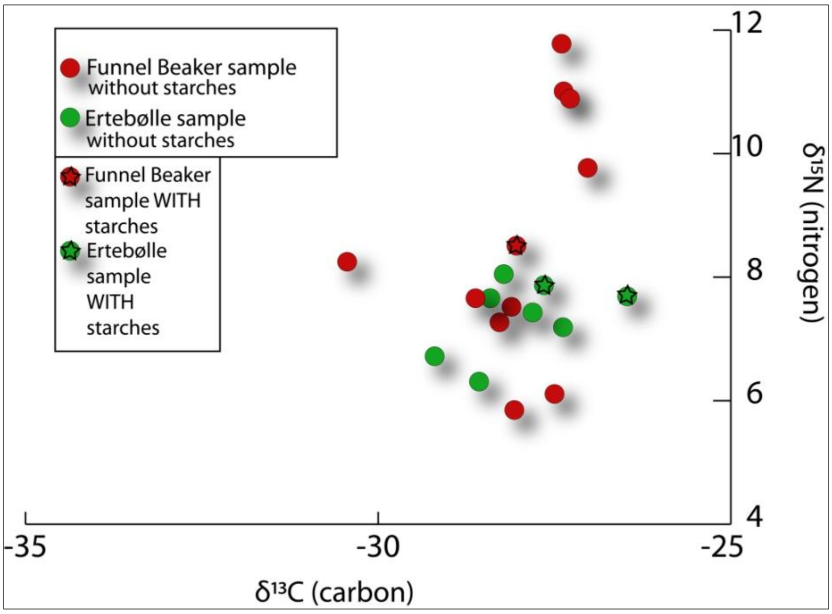


Figure 6.72. A graph plotting the bulk carbon and nitrogen isotope values of the Stenø foodcrusts, also showing the values for modern reference foods.

Overlaying information about those samples with high quantities of phytoliths (>40mg^{-1}) and starches (>50mg^{-1}) does not offer greater insight into any clustering in the data (figure 6.73 a & b). Whilst starches are restricted to those residues exhibiting δ^{15}N >7‰ (figure 6.73 a), plant material is not *absent* from samples with <7‰ ^{15}N because silica bodies are present across the carbon-13 and nitrogen-15 range (figure 6.73 b).



a

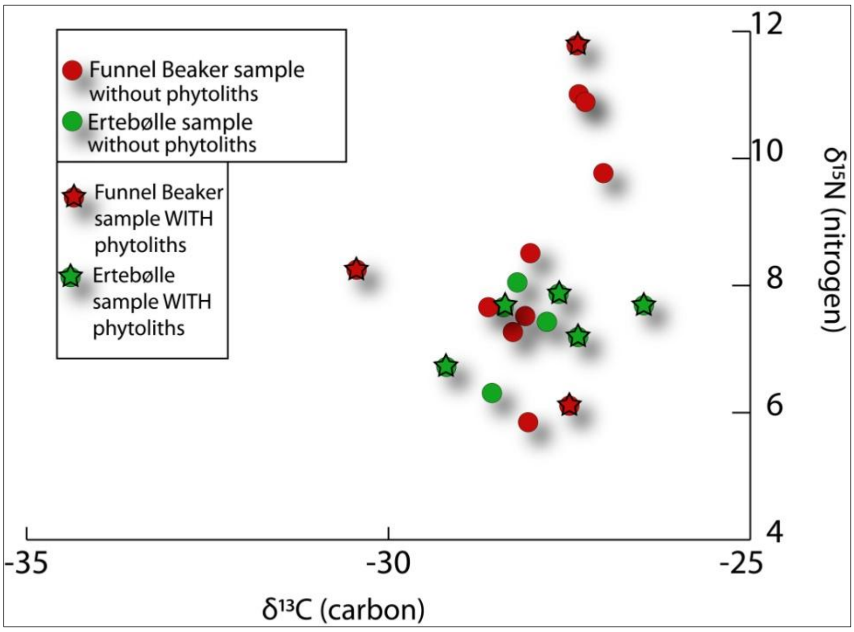


Figure 6.73. a) A plot of the bulk isotope values for Stenø overlaid with samples with high starch counts mg^{-1}, b) The same plot of bulk isotope values but overlaid with samples high in silica bodies mg^{-1}.

There was less lipid preserved at Stenø than at nearby Åkonge, reducing the potential contribution of single compound isotope analyses in the clarification of vessel contents. At the time of writing only four Stenø samples had single compound isotope measurements (figure 6.74) on the absorbed lipid. Two of these came from vessels without corresponding foodcrust, challenging the possibility of discussing potential mixtures or traditions of vessel use. Three of these samples come from vessels with EBK techno-stylistic features, further restricting the comments that can be made about changes in foods through time. Of interest though, is that all three of these EBK-type samples plot outside the isotope ranges of modern reference foods, indicating that these three values are the outcome of greater mixing than the single TRB-type sherd. This latter sherd locates firmly within the ranges for ruminant adipose.

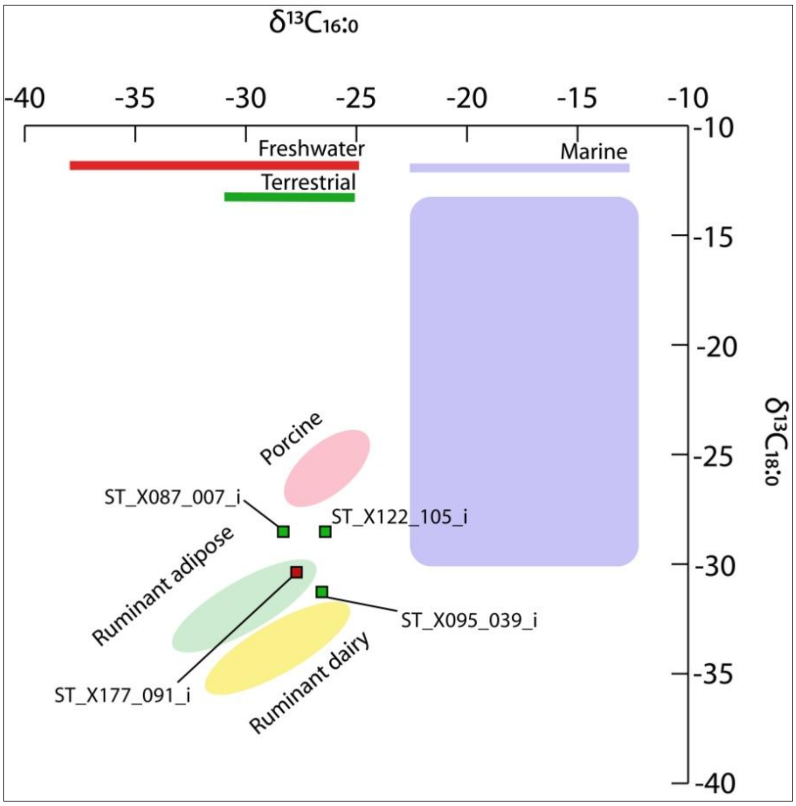


Figure 6.74. A graph plotting the δ^{13}C isotope values from C16:0 and C18:0 fatty acids from the lipid absorbed into the Stenø vessels.

This then, gives a limited dataset for comparison with plant microfossil and bulk isotope data from foodcrusts. It is not possible to state that milk is present or absent from Stenø from this reduced dataset; one sample exhibits a borderline ruminant adipose/dairy signature (figure 6.75). The sample derives from a vessel with EBK-style features, although the ceramic assemblage as a whole must be considered latest Ertebølle, spanning the period of the transition to agriculture in this region. The relatively enriched δ^{15}N value for this sample (ST_X095_039) certainly favours a greater contribution of ruminant adipose, and by no means an exclusive use of the vessel for milk (figure 6.75), as has been witnessed at Neustadt and Åkonge for example. The only other corresponding single isotope value denotes a porcine/ruminant adipose outlier (figure 6.75). This sample plots closely to modern bulk isotope values for einkorn and milk mixtures, but suggests that the other samples with δ^{15}N values <7‰ are unlikely to be exclusively for the processing of dairy foods either.

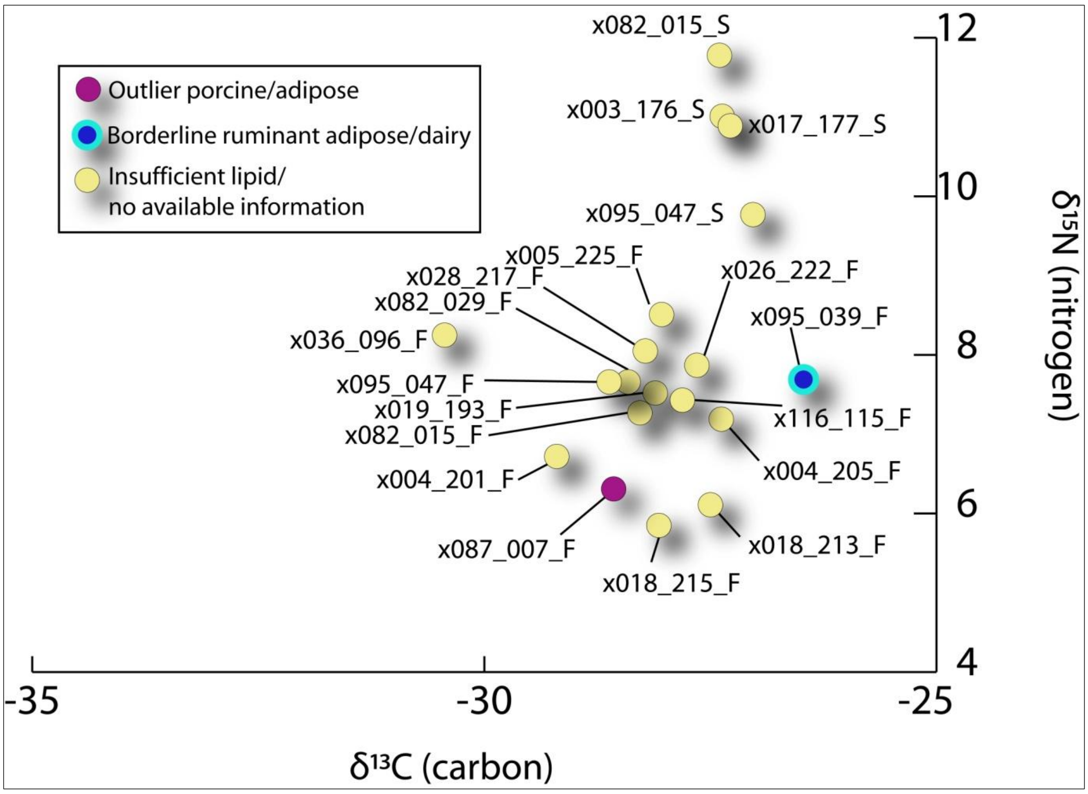


Figure 6.75. A graph plotting the bulk carbon and nitrogen isotope values for the Stenø foodcrusts. Each datum point is represented by a symbol that indicates the corresponding single compound isotope food class that is defined for the sherd.

6.6.4.1. Aquatic foods.

Stenø retains a more complete record from lipid residue characterisation, including evidence of aquatic biomarkers. Figure 6.76 shows the number of aquatic biomarkers recovered from respective sherds, whether ω-(*o*-alkylphenyl)alkanoic acids, phytanic acid or TMTDs. Fourty-two percent (n=8) of the sherds with surface deposits exhibit at least one aquatic biomarker indicative of fish, and considering the predominantly terrestrial contribution to the bulk isotopes and the location, most likely a freshwater fish source. Sixty-three percent (n=5) of these samples with aquatic biomarkers come from vessels with TRB techno-stylistic features. Thus fish use appears to continue into the earliest Funnel Beaker period at Stenø, as has been witnessed also at Neustadt and Åkonge.

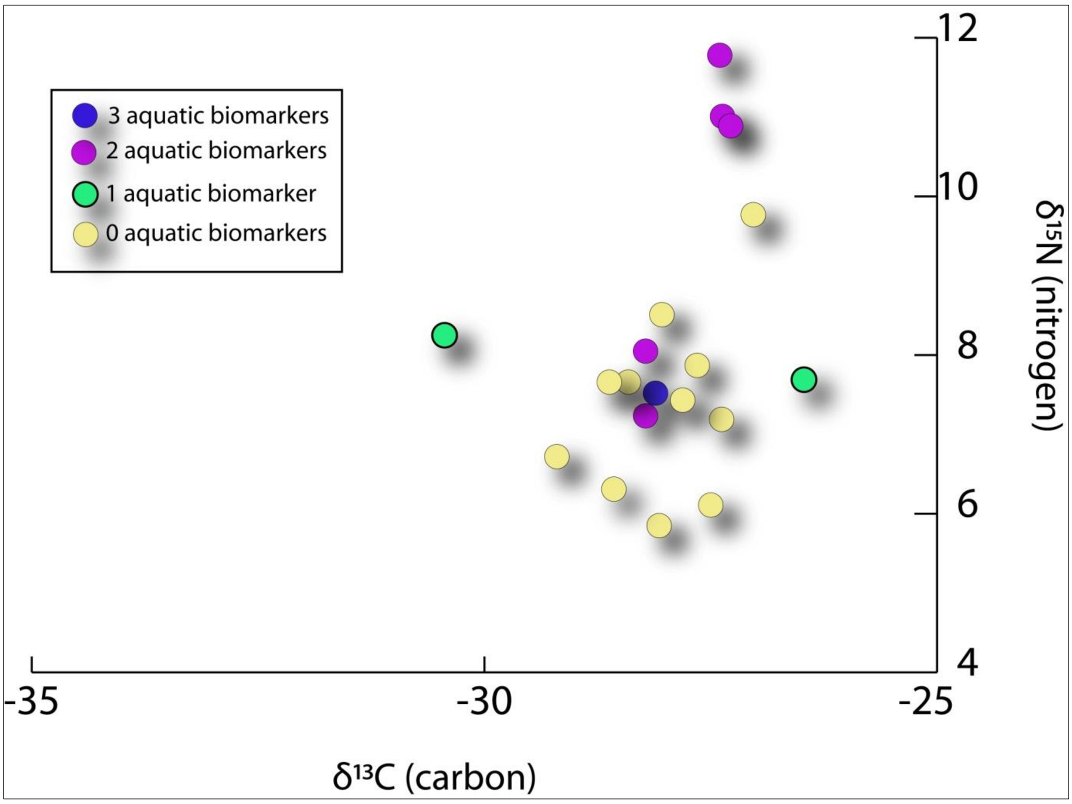


Figure 6.76. A graph plotting the bulk carbon and nitrogen isotope values for the Stenø foodcrusts. Each datum point is represented by a symbol that indicates the number of aquatic biomarkers present from absorbed and surface deposits, based on lipid characterisations.

6.6.4.2. Plant foods.

The very limited number of foodcrusts that recorded high starch counts (>50mg^{-1}) at Stenø continue to suggest that wild plant foods played an important role in cuisine across the transition to agriculture (figure 6.77). Similar species are classified from the recovered starches as are found at the other sites studied here. Granules consistent with acorn (*Quercus* sp.) dominate the automated identifications. They were classified in all three samples, though more reliably in two of the samples where the classifications were made on granule counts in excess of seventy. These three samples originate from both EBK and TRB-style sherds.

Sample ST_x095_039 is the only example where multiple strands of evidence can be correlated. As well as containing the aquatic biomarker phytanic acid, this sherd also registered as a borderline ruminant adipose/dairy. Combined with high proportions of starch ascribed to acorn (*Quercus* sp.), and another forty-six percent classified as bracken fiddleheads (*Pteridium* sp.), this vessel has been used to process multiple food types. It is possible however, that the phytanic acid originates from the high plant content of this sample. Hazelnut (*Corylus avellana*) classifications are again notably absent from Stenø, reinforcing the notion that this wild plant food was less important in the context of pottery.

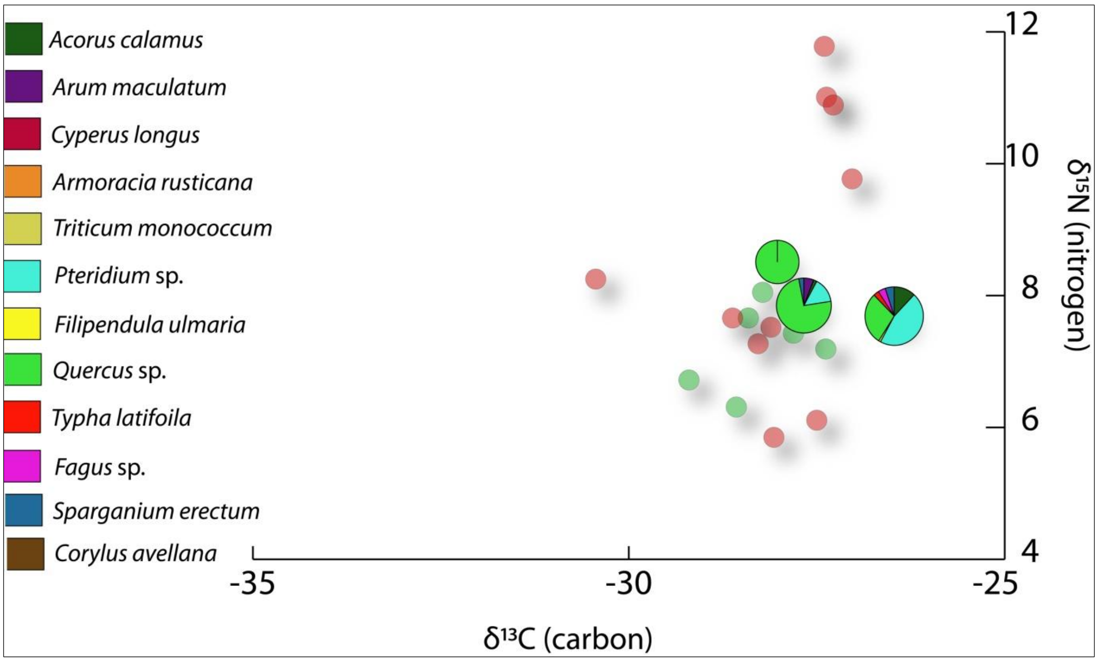


Figure 6.77. A graph plotting the bulk carbon and nitrogen isotope values of the Stenø foodcrusts. Those samples that have significant starch counts are represented by pie charts illustrating the proportions of different plants classified by automated starch identification.

6.6.5. Comparison of identified food contents to vessel features.

The majority of samples come from medium and small sized vessels, cautiously assessed because the assemblage from the site is in smaller fragments than many of the other sites analysed, meaning the curvature of the orifice resists as accurate description. The contents of the vessels are not correlated with size variation in terms of either the marine-terrestrial contributions based on significant differences in $\delta^{13}C$ (p=0.33 (>0.05), t=2.31, (small) N=7, (medium) N=11), or the trophic level denoted by $\delta^{15}N$ (p=0.08 (>0.05), t=2.16, (small N=7, (large) N=11) (figure 6.78). There is one example of a large vessel (ST_x036_096) that corresponds to a sherd with an outlier bulk isotope value, relatively depleted in carbon-13. The sample contains a single aquatic biomarker: phytanic acid, tentatively suggesting a contribution of fish to the contents, and this is supported by the bulk isotope values. Deriving from a vessel with TRB techno-stylistic features, this may be a tentative extension of the practice of using large funnel beaker vessels for the collective consumption of fish witnessed at Wangels.

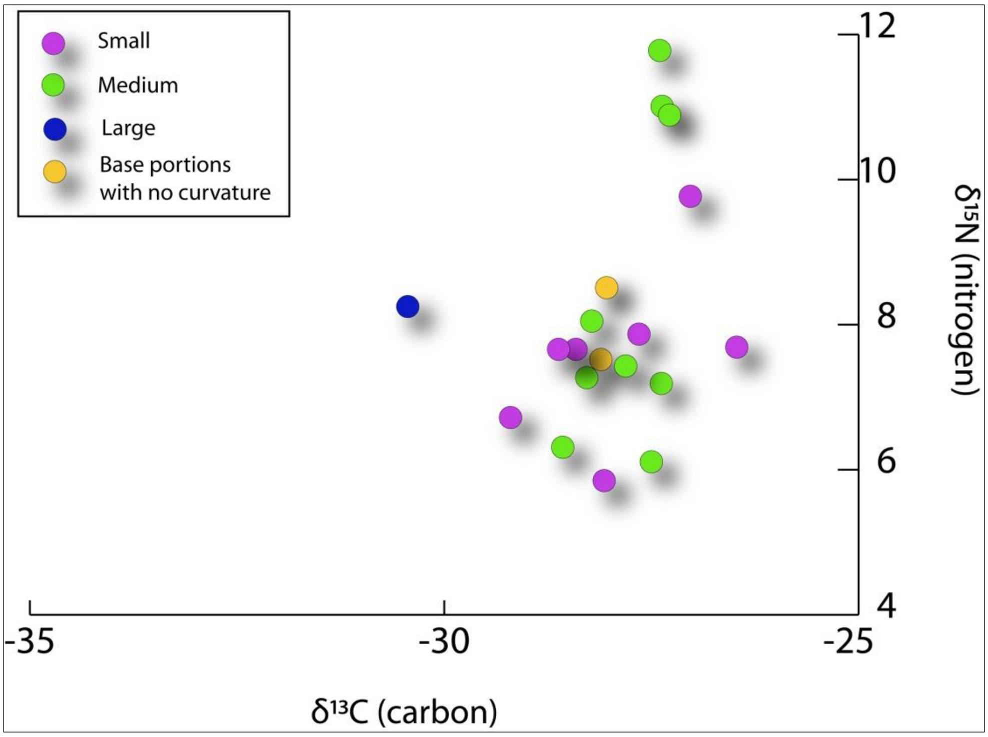


Figure 6.78. A graph plotting the carbon and nitrogen isotope values for the Stenø foodcrusts. Each datum point is indicated by a symbol representing the size of the vessel from which the sample derives. Diameter sizes: small= 5-15 cm, medium= 16-26 cm, large= 27-37 cm, extra large= >38 cm.

On the basis of our limited identifications, there are no discernable patterns between the vessel type and food contents (figure 6.79). Sherds techno-stylistically attributable to the EBK occur across the range of carbon-13 and 15-nitrogen values, as do sherds consistent with TRB features. The two Type 0 Funnel Beakers exhibit aquatic biomarkers indicative of freshwater fish, and in one case a high (>50/mg^{-1}) proportion of starches. Their exclusive use for a restricted food type is not evident.

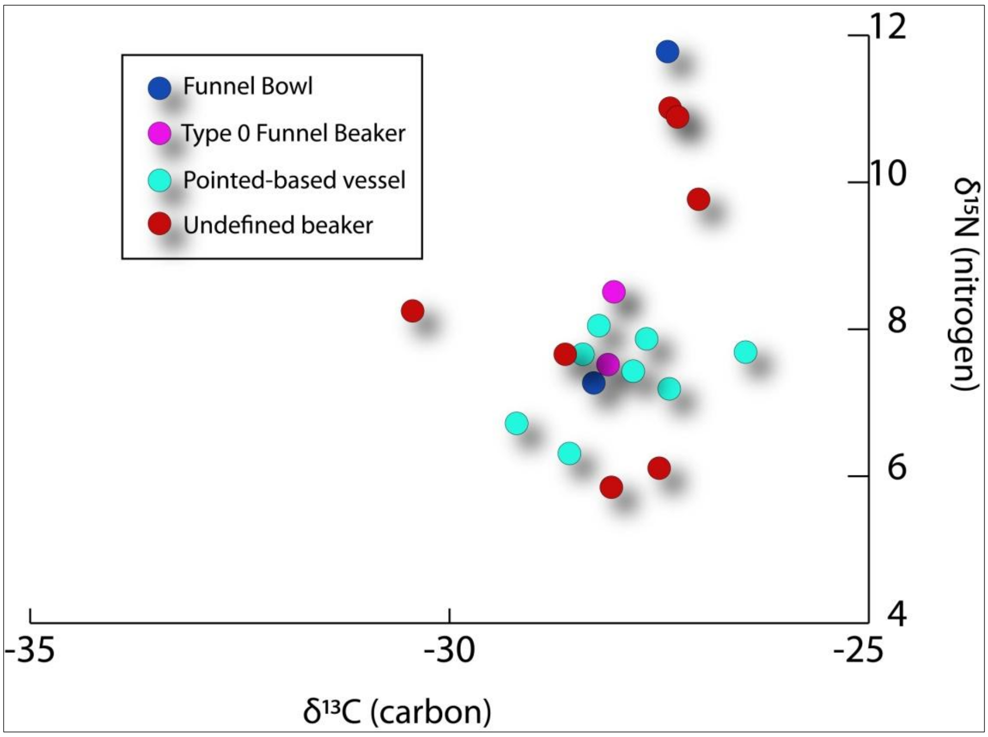


Figure 6.79. A graph plotting the bulk carbon and nitrogen isotope values for the Stenø foodcrusts. Each datum point is represented by a symbol indicating the type of vessel from which the sample derives.

6.6.6. Summary of the Stenø results.

Lipid residue analyses from Stenø record aquatic biomarkers across the range of bulk isotope values. The variable presence of phytanic acid, TMTDs and/or ω-(*o*-alkylphenyl)alkanoic acids indicates the heating of aquatic foods, in this case the source is likely to be freshwater fish based on the predominantly terrestrial contribution to bulk isotope values. The Stenø ceramic assemblage is characteristically of the latest Mesolithic and earliest Neolithic, and the site has been suggested as spanning a relatively short-term occupation across the transition to agriculture c.3950 BC in this region of Zealand. The aquatic biomarkers are present in vessels with both EBK techno-stylistic features and TRB features. Notably, sherd ST_X019_193 which is a rounded based-vessel consistent with a possible Type 0 funnel beaker registered all three aquatic biomarkers. At Stenø therefore, there is evidence that the use of fish persisted into the earliest Neolithic.

Fewer of the Stenø residues recorded high (>50/mg^{-1}) counts of starches than at other sites studied, such as Neustadt. In those three surface deposits that were forwarded for automated starch identification the classifications reinforced traditions of plant use observed at other sites under study. Granules were predominantly classified as wild plant foods such as acorn (*Quercus* sp.) and in one vessel there were high proportions allocated to bracken fiddleheads (*Pteridium* sp.). Despite the borderline presence of domesticated foods like dairy observed in one vessel on the basis of single compound isotope analyses, in conjunction with the firm findings of milk in vessels from nearby and contemporary Åkonge, evidence from plant microfossils is instead dominated by *wild* plant foods.

6.7. Bog Pots.

6.7.1. Do indicators of foods (including phytoliths and starches) survive in association with the vessels?

6.7.1.1. Macroremains.

Of the ten surface deposits from seven bog pots, two produced visible macroscopic animal remains. Vessel NMA_49818_F contained many small fragments of fish scales like the one illustrated in figure 6.80a. These appear to show concentric circuli protrusions which suggest their origin in the Salmonid family. From NMA_40882_F a possible fragment of bone was recovered figure 6.80b, with a longitudinal structure. Further identifications are not possible. All of the residues appeared quite highly carbonised at low magnifications though, which makes these ritually deposited vessels similar in that respect to those acquired from a settlement context. It would seem that these vessels had been used to cook their contents, and that their ritual values were related to the activities of food processing.

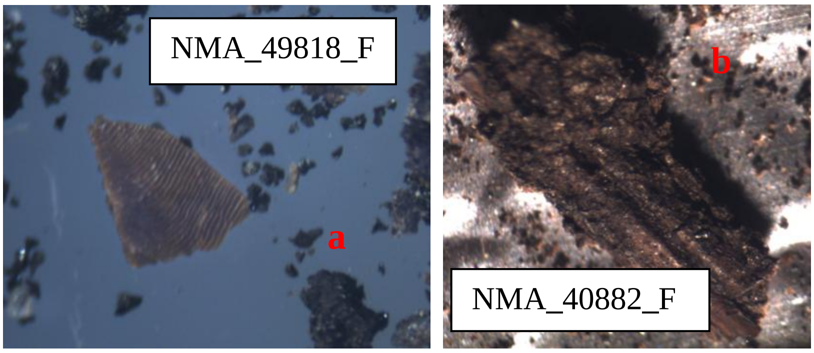


Figure 6.80. a) a fragment of a possible Salmonid fish scale, b) an artefact with a longitudinal structure, possibly bone.

6.7.1.2. Starches.

There were very few examples of the characteristic ‘bean-shaped’ starches that are endemic to many of the samples from other sites. As a result it was not possible to measure size alteration induced by heat, in the same way as for other sites described. Observational comparisons between the bog pot starches and other sites studied would suggest that starch preservation was excellent. Evidence of swollen and cracked granules was low, and the starches displayed sharp extinction crosses as can be seen from figure 6.81, so their molecular order was intact. The granules were confirmed as starch using α-amylase degradation (figure 6.82). Three archaeological samples with amylase added were found to be absent of starch granules after incubation, as was the modern positive control. The modern and archaeological samples without amylase were found to contain starches of similar classes to those analysed by automated-classification.

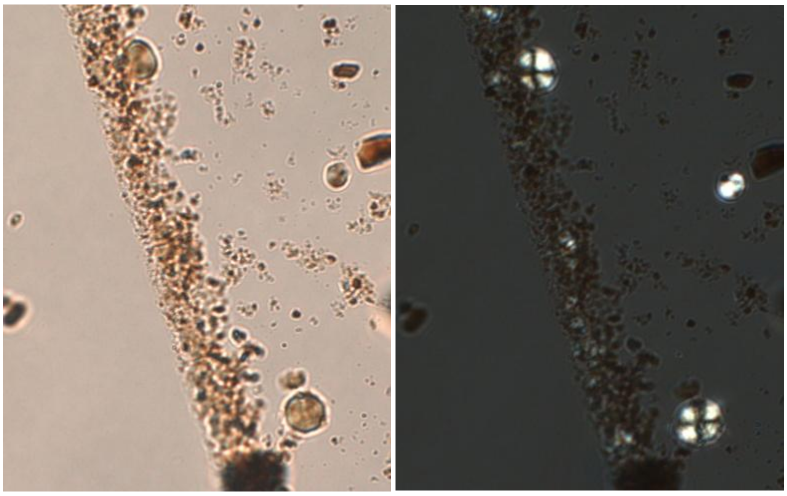


Figure 6.81. A brightfield and polarised image of starches from foodcrust sample NMA_40882 showing an absence of cracking and heat alteration, and a sharp extinction cross indicating maintained molecular order of the granule. Mag x600.

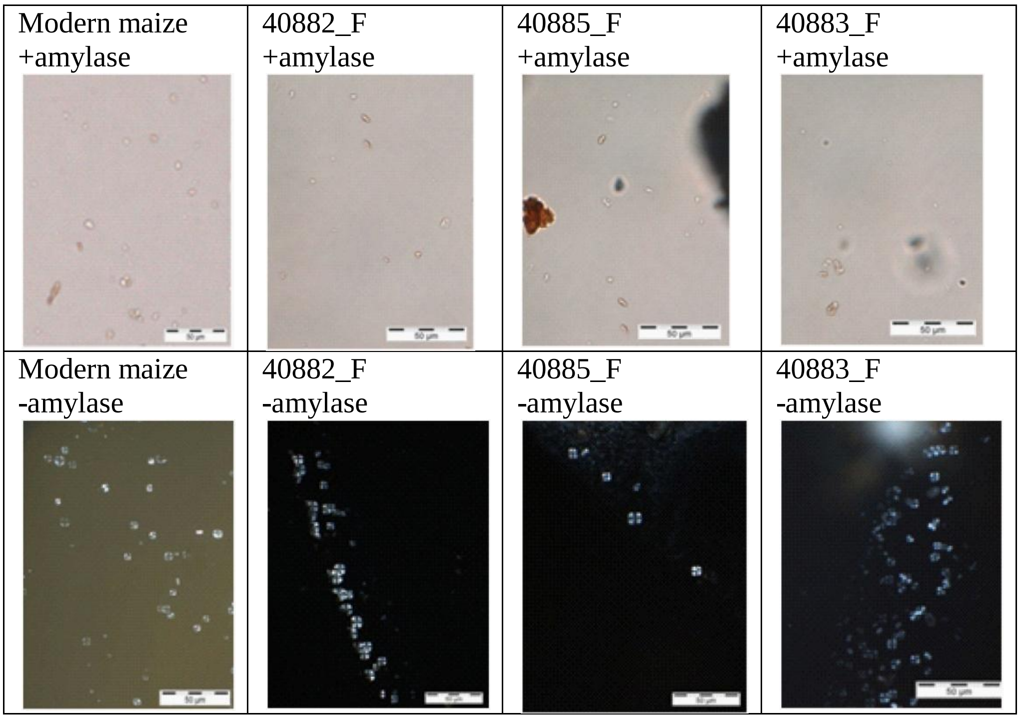


Figure 6.82. The α-amylase degradation of starches from three of the Bog Pot foodcrusts.

6.7.1.3. Phytoliths.

Phytoliths also preserved in the bog pots, although are only in evidence in a two vessels in quantities >60 mg^{-1}. Two of the vessels with high preserved starch counts mg^{-1} also have high silica body counts mg^{-1}. The coincidence supports the postulation that the starch preservation is representative of the vessels that were and were not used to process plant foods.

6.7.2. Are these indicators related to vessel use or are they derived from the burial environment?

6.7.2.1. Starches.

There is no statistical difference between interior (F) and exterior (S) deposits (t-test, p= 0.18 (>0.05), t= 2.45, N=7 (F), N=3 (S)), but four of the interior (F) samples do not seem to have been used for any starchy plant processing, and bring down the average count mg^{-1} of what is already a small sample set. Nominally there are three samples of interior (F) foodcrusts that show high counts >100 starches mg^{-1} (orange bars, figure 6.83). These are not statistically distinct from the samples with low counts <100 starches mg^{-1} either though (t-test, p= 0.09 (>0.05), t=12.71, N=3 (>100/mg^{-1}), N=7 (<100/mg^{-1}). There is a difference of 256 granules mg^{-1} between an interior and exterior crust from the same vessel (40882) though, which points to a deliberate packing of the pots with plant food, rather than contamination. On the basis of this, and the nominal difference between pots with high and low counts, three vessels have provisionally been put forward for automated classification of their starches.

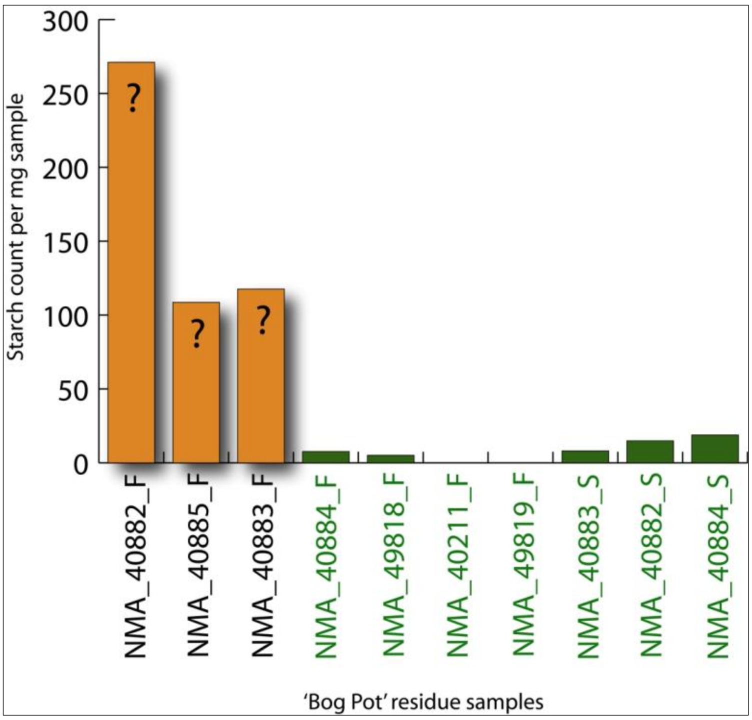


Figure 6.83. A graph of the starch counts mg^{-1} for the Bog Pot foodcrusts. Samples with orange bars (and question marks) indicate samples provisionally accepted for automated classification despite not being statistically different from exterior _S deposits.

6.7.2.2. Phytoliths.

Two of the samples with high starch counts mg^{-1} also have high silica body counts consistent with intentional loading of the pots for plant processing. This further supports the decision to accept the starch samples for automated classification, despite a lower statistical confidence that contamination has not factored in their creation. For phytoliths there is no statistical difference between interior (F) and exterior (S) samples (t-test, p= 0.23 (>0.05), t= 2.45, N=7 (F), N=3 (S)). The same problem exists as was found with the starch counts, that only a few of the vessels nominally show a use for the processing of plant material, and their average count mg^{-1} is reduced by four 'F' samples with a nearly complete absence of silica bodies. Although the confidence improves if one takes the crusts with a count mg^{-1} >60 starches as a sample group (p= 0.08 (>0.05), t=12.71, N=2 (>60/mg^{-1}), N=8

(<60/mg^{-1})), it is still not statistically significant. The mutual correspondence between starch and phytolith samples with high counts mg^{-1}, and their nominally high clustering factored in the provisional acceptance two samples as evidence of plant processing (figure 6.84, green bars).

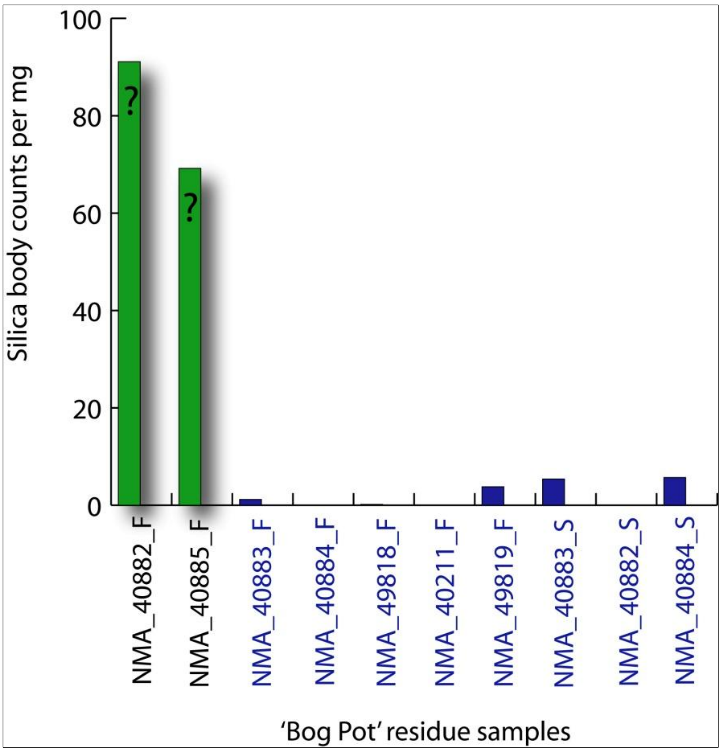


Figure 6.84. A graph of silica body counts mg^{-1} for the Bog Pot foodcrusts. Those samples with a green bar indicate samples considered to have been used to process silica rich plants.

6.7.3. Can the microfossils be identified to a plant food origin?

6.7.3.1. Starch grain classification in the Bog Pots.

Acorn type (*Quercus* sp.) starches are underrepresented in the bog pot samples (figure 6.85) compared to settlement sites in the study group. In the bog pots none of the samples contain proportions >10%, whereas at the other sites the minimum percentage of samples with >10% acorn is 63% at Tybrind Vig. Instead, all three vessels are most intensively classified as bur-reed (*Sparganium erectum*) rhizome, with starch proportions >50% in all cases. Such high proportions point to a primary use for these vessels related to this rhizome.

Lesser proportions of *Typha latifolia* type starch (12% in one sample), and *Acorus calamus* grain forms (14% and 6%) suggest that other freshwater reeds were a minor component of use, or are from a small percentage of more difficult to classify starches. At the least, edible reed rhizomes represent by far the majority of starches present in the vessels, to the exclusion of commonly present grain forms like acorn. In settlement assemblages *Sparganium erectum* is only even classified at three of the sites studied in proportions >10% in residues, and at these sites the proportion of the ceramic assemblage studied that contains *Sparganium erectum* type grains is never over 50%. At the site of Jordløse Mose however, where all of the bog pot samples that have high starch counts (mg^{-1}) are from, all of the vessels were selected for the deposition of high proportions of this reed in intact vessels in the bog. This suggests deliberate reasoning in the selection of this plant for this ritualised deposition.

In this ritual sphere it is not just the presence of certain ingredients that seems important though, but the fact that they undergo cooking. There is symbolism to the activity of transforming the foods as well as the plants themselves.

Sample	**#granules**	***Acorus calamus***	***Arum maculatum***	***Cyperus longus***	***Armoracia rusticana***	***Triticum monococcum***	***Pteridium sp.***	***Filipendula ulmaria***	***Quercus sp.***	***Typha latifolia***	***Fagus sp.***	***Sparganium erectum***	***Corylus avellana***	***Most likely species***
NMA_ 40882_F	18	6	0	0	0	0	0	0	6	0	22	66	0	*Sparganium erectum*
NMA_ 40883_F	18	14	0	0	0	0	0	0	0	0	0	86	0	*Sparganium erectum*
NMA_ 40885_F	31	0	3	0	27	0	0	0	4	12	0	54	0	*Sparganium erectum*

Figure 6.85. A table of the automated starch classification results from the Bog Pots. The proportion of each plant represented in the starch results is given beneath the respective species.

There is a noticeable absence of domesticated einkorn (*Triticum monococcum*) type starch, even though NMA_40883 has a number of possible cereal grain impressions on its surface (Koch 1998). Based on the samples of ritually deposited vessels described here, domesticated cereals were not adopted for overtly esoteric values that would warrant their conspicuous consumption, at least in the context of pottery. It is important to stress the point that of three bog pot deposition locales under review, *only* this one at Jordløse Mose has produced samples with a plant content. It would seem that plants were ritually purposeful or practical, and had specific cosmological uses. In this view, the bog pot depositions represent a diverse collection of esoteric practices each with designed ritual outcomes, only in some were plants a primary element.

6.7.3.2. Phytolith classification in the Bog Pots.

Only one example of a possible *Alliaria petiolata* globular sinuate phytolith was found in the bog pot samples, from NMA_40885_F (figure 6.86a). This example is at the upper end of the size range for modern referents (4.8-11.2µm), being 12.1µm in diameter. It comes from the vessel that displays the greatest number of plant species combinations, totalling 4 species including the garlic mustard, compared to only 2 species in the other two vessel residues respectively. The majority of the phytolith content was made up of silica skeleton sheets such as those in figure 6.86b & c, and short cells not diagnostic to a high taxonomic resolution.

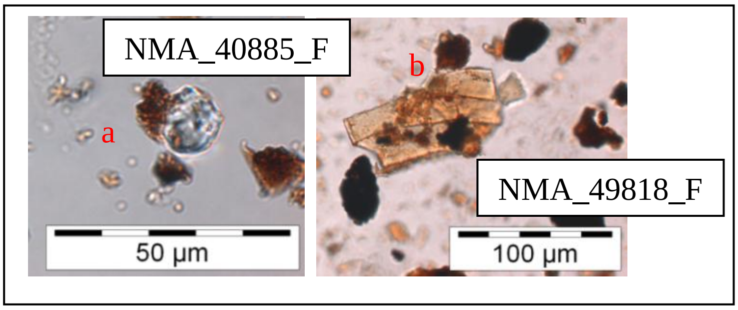


Figure 6.86. The types of phytoliths found in the Bog Pot foodcrusts.

6.7.4. Comparison of the plant microfossil data with bulk isotope and lipid residue analyses.

At the time of writing only bulk isotope analyses had been completed for the small collection of National Museum bog pot contributions (figure 6.87). These surface deposits plot across a similar range to those identified at Åkonge and Stenø, in the same regional context. Terrestrial foods such as milk and ruminant adipose predominated at these latter sites, and the relative depletion of the bog pots in carbon-13 is consistent with this. The proximity of modern einkorn and milk referents on the graph also points to a terrestrial, perhaps dairy-related use for these vessels.

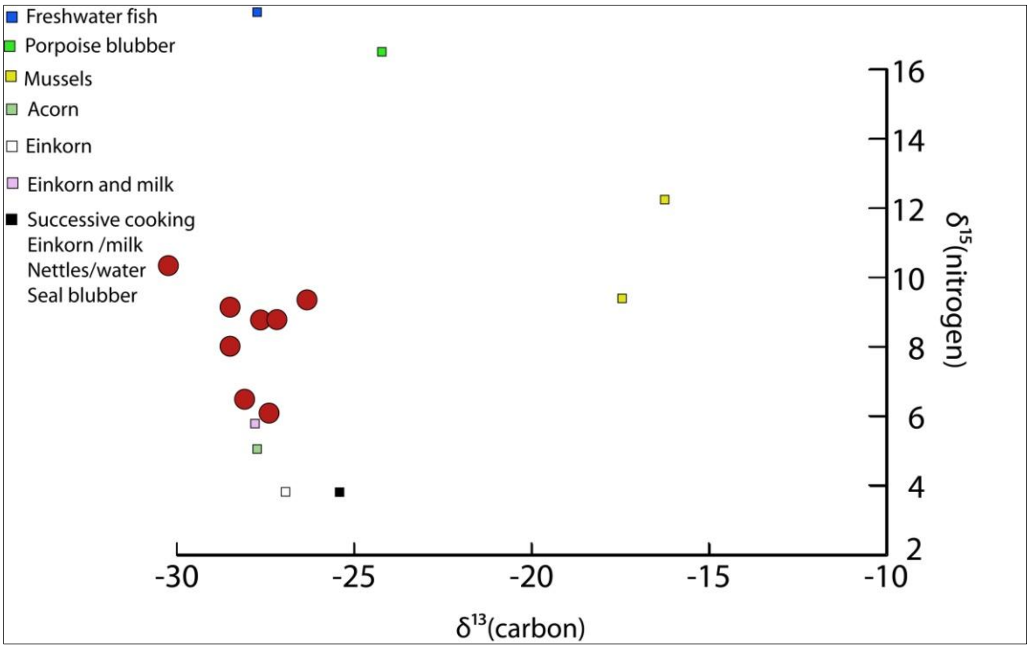


Figure 6.87. A graph plotting the bulk carbon and nitrogen isotope values of the Bog Pot foodcrusts, also showing comparison values for modern reference foods.

The relatively discrete clustering of the values from δ^{13}C -25‰ to -30‰ suggests that these funnel beakers, from different depositional contexts, were utilised for similar culinary practices. The very presence of carbonised deposits indicates that the vessels were in *active* use, subjected to the same processes of food preparation seen in more domestic contexts. Those vessels destined as offerings in these wetland locations were valued in part for the practical potential they afforded. In this sense, their symbolic role incorporates mundane culinary concerns, reciprocally investing domestic cuisine activities with more cosmological values. Ingredients alone were not deposited; the value of the deposition derived from the *accumulation* of the ingredients facilitated by the ceramics, with the *transformation* of those ingredients being a repeatedly important undertaking.

6.7.4.1. Plant foods.

Although similar culinary activities are suggested by these preliminary bulk isotope investigations, two of the funnel beaker bog pots contain significant quantities of starches (>50/mg^{-1}) (figure 6.88). Some flexibility therefore exists in the suitability of certain foods as wetland offerings, implying a non-rigid belief rationale; a doctrine embedded in the wider social realm incorporating symbolic mechanisms for reacting to diverse social concerns. All three vessels with starches predominantly classified to the edible reed *Sparganium erectum* come from the same site, suggesting this locale was particularly associated with the affordances of a distinct plant type like bur-reed. Limited to this site alone, these findings support the idea of a reactionary doctrine, where certain offerings become important in the context of certain social concerns, and certain places periodically adopt greater significance to fulfil them.

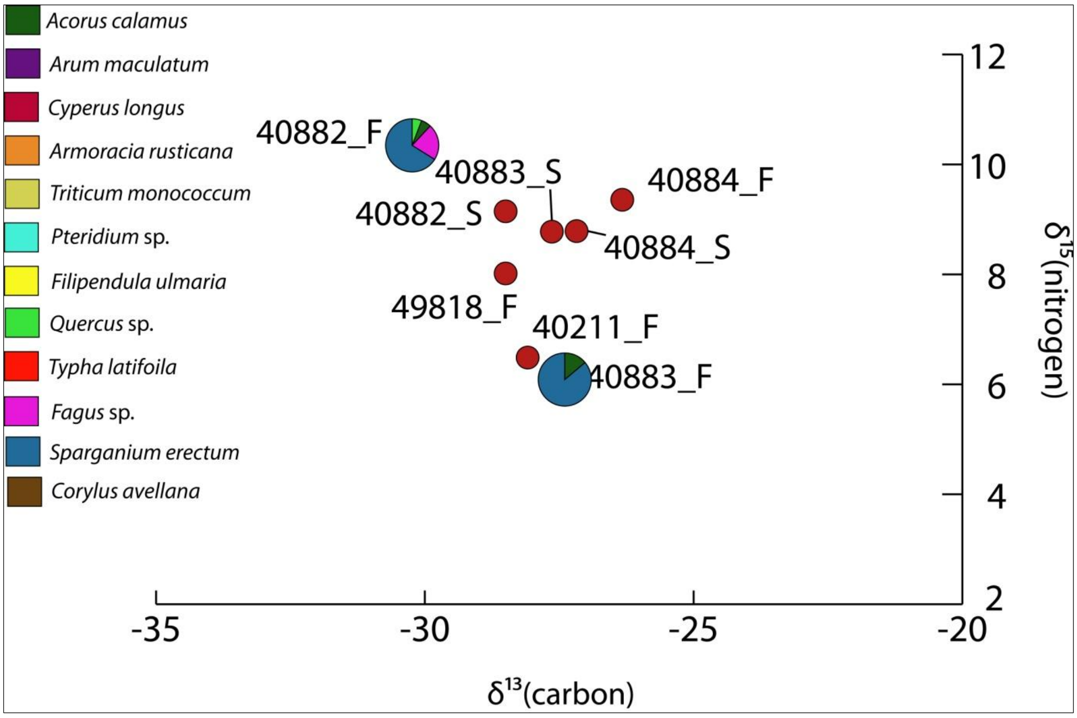


Figure 6.88. A graph plotting the bulk carbon and nitrogen isotope values of the Bog Pot foodcrusts. Those samples with significant starch counts are represented by pie charts illustrating the proportions of different plants identified by automated starch classification.

6.7.5. Comparison of identified food contents to vessel features.

In figure 6.89 although the examples of Type II ceramics tend to be more depleted in carbon-13 than Type III vessels, there is no statistical difference between them (p=0.06 (>0.05), t=3.18, (II) N=3, (III) N=4). Formal stylistic features are not correlated with a difference in the use of the pots by implication. Other decorative features such as ornamentation and applied clay lugs feature strongly in the dataset of wetland depositions, but there are no observable patterns correlating the use of the vessels with decorative design (figure 6.90). Further isotope analysis could clarify the strong terrestrial contribution to the bulk isotope signals. Considering the prevalence for vessels with lugs and other liquid-associated features in association with dairy signatures from single compound isotope analysis at Neustadt, for example, there remains the possibility that these bog pots extend this theme.

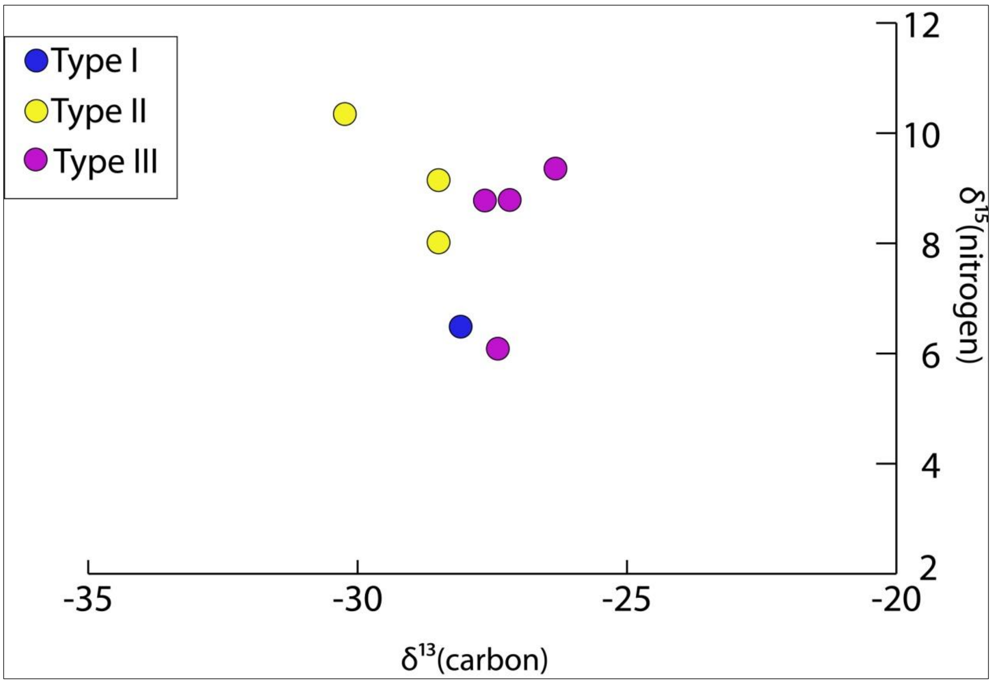


Figure 6.89. A plot of the bulk carbon and nitrogen isotope values for the Bog Pot foodcrusts. Each datum point is represented by a symbol indicating the type of vessel the sample comes from.

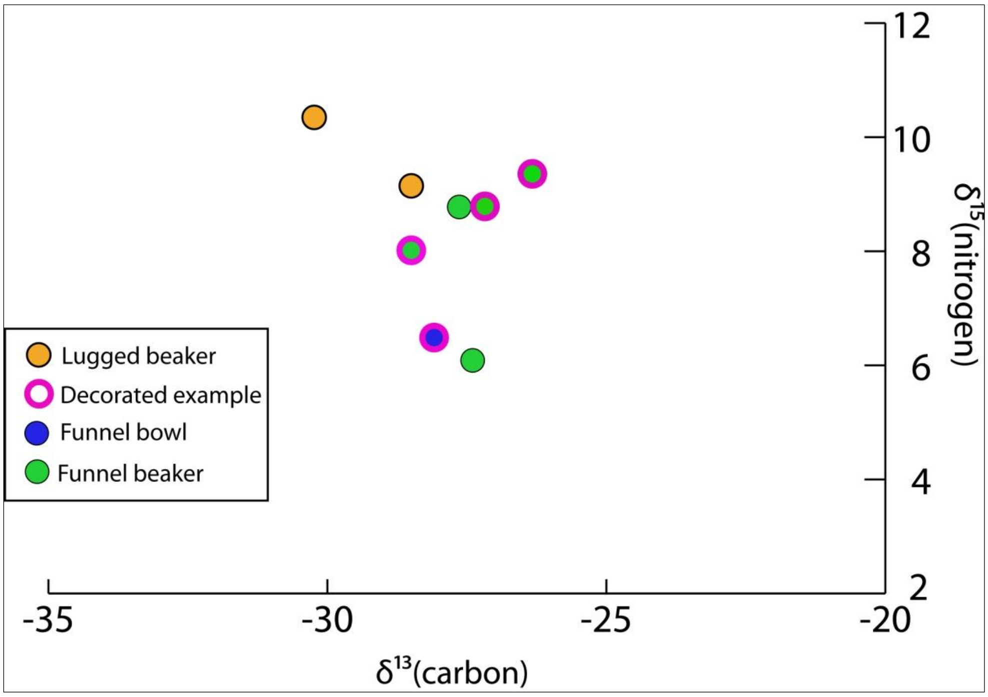


Figure 6.90. A plot of the bulk carbon and nitrogen isotope values for the Bog Pot foodcrusts. Each datum point is represented by a symbol indicating the form of vessel the sample came from.

6.7.6. Summary of the Bog Pot results.

Firm conclusions about the identification of vessel contents from the bog pots is limited to the observation that there is a strong terrestrial contribution to the bulk isotope values of all the vessels; they all register in the relatively depleted carbon-13 range <25‰. The discreteness of their range in this respect implies some similarity of use. However, the presence of starch granules (>50/mg^{-1}) in three of the surface deposits suggests that doctrinated depositional ‘menus’ were not approved practice, and that the belief-rationale was more flexible, perhaps reactive to social initiatives. What is more certain is that the *use* of these vessels to transform the contents was an important part of their significance. The mere presence of surface deposits shows that cooking and food processing was important; the value of the ingredients was enhanced and fulfilled by the specific culinary affordances offered by pottery-transformation.