A DIET STUDY FROM THE MIDDLE NEOLITHIC SITE IRE

Analyses of stable carbon isotopes, amino acids and trace elements

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ABSTRACT

This study is an attempt to enhance the knowledge of the diet from the middle neolithic site Ire, Gotland. In order to complement earlier research a comparison between analyses of trace elements, such as zinc and copper, and delta ^{13}C on skull bones were made. Delta ^{13}C gives information on the relation between marine versus terrestrial protein intake, and trace element analyses give information on the amount of different kinds of protein intake. It was found that the delta ^{13}C results correlated well with the results of the trace element analyses as well as with the earlier known osteological data. It could hereby be concluded that marine protein dominated the dietary intake on Ire. It could be stated that though the food remains from the pottery was of a vegetable origin, vegetable protein did not contribute to a major part of the dietary intake.

Introduction

Prehistoric diet can be studied from many different angles. The surroundings could be one starting point, i.e what these surroundings were able to supply and what one could utilize from it. Another starting point could be analyses of remnants after meals such as bones, seeds, husks, and other organic remains. Together these analyses is usually called "site catchment analysis" (Higgs & Vita-Finzi 1972). The last starting point could be the human being per se, i.e. analysing the skeleton according to palaeopathology, trace elements, stable isotopes etc. One could also combine these archaeological data with anthropological data, such as ethnoarchaeology, and medical science.

This study is an attempt to combine some of these different aspects to enhance the understanding and knowledge of prehistoric diet. The study area is chosen to get a simple dietary situation. Hence it was natural to choose the middle neolithic site Ire, Hangvar parish, Gotland; a hunting and gathering society where marine resources played (Janzon 1974) or may have played a major role. The stable isotope analysis were performed at Simon Fraser University, Vancouver, Canada in 1989 together with Erle Nelson. The trace element analyses and amino acid analyses were made at the Archeological Research Laboratory, University of Stockholm in 1984 (Arrhenius 1990).

Studyarea: Ire, the settlement

Ire is situated in Hangvar parish on the north west coast of Gotland. It is located on the beach, oriented west southwest, facing the sea on one side and chalk cliffs on the other (fig 1). This protected location is considered to be characteristic for middle neolithic sites on Gotland (Englund 1982). The site was discovered in 1914, and a preliminary excavation was carried out by Wennersten (1914). The site was measured out by Nihlén (1927) in 1924, when he also carried out some smaller excavations that resulted in large amounts of ceramics. The first major excavation was carried out during the 1950's by Greta Arwidsson in connection with an intensified use of the site as a gravel-pit (Janzon 1974). The surface layer had then been removed and other layers had been disturbed as a consequence of the gravel-pit use. Despite this, but thanks to a very thorough sieving and a favorable soil composition, there was a possibility to find small fish vertebrae and other material of the same size (Janzon 1974). This would later prove to be very valuable concerning the interpretation of the prehistoric diet at Ire. The grave material from Ire has been published by Janzon (1974) along with the grave material from the contemporary sites Gullrum at Näs, Hemmor at När, Visby, Västerbjers at Gothem and Vesterbys at Hall. The final extension of the site was established by Österholm (1989) by the use of the so called "Spot test" method, a phosphate mapping method to find cultural deposits. Österholm (op.cit) concluded that "the site had on a considerate distance been situated along the river of Ire".

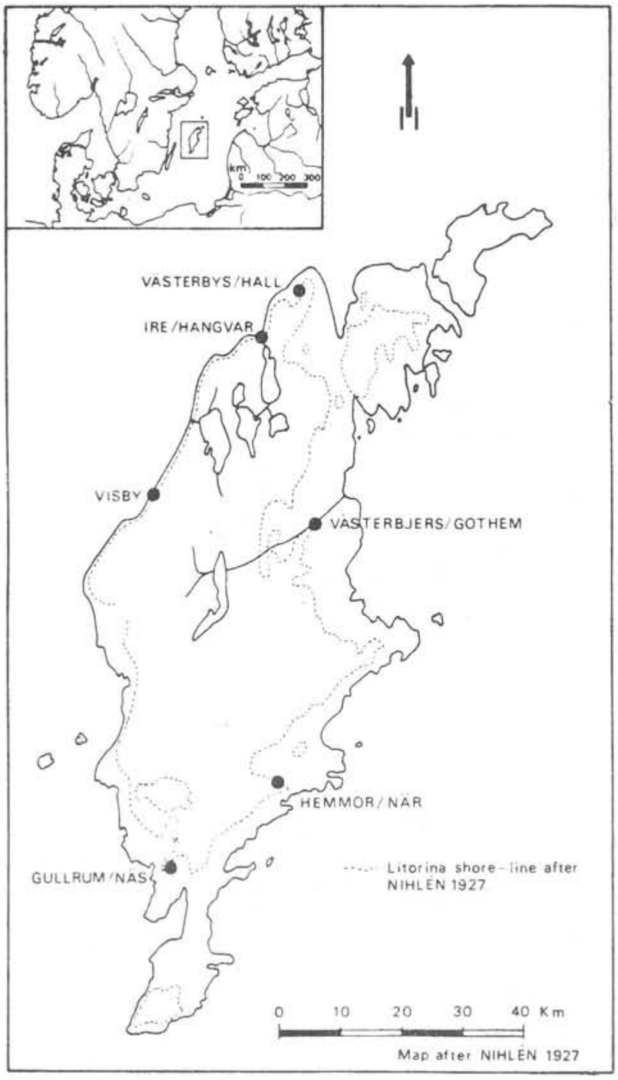

Fig 1. Map of Gotland from Sjøvold (1974 fig 1)

Some changes of the landscape occurred during Neolithicum on Gotland that could inflict the diet. The wood clearings for instance, that denotes Early Neolithicum on Gotland, ceased during the latter part of Neolithicum. This can be observed in pollen-diagrams where the coal curve decreased to a level close to mesolitihic standards (Österholm 1988). This decrease was also supported by lack of evidence of cereals in pollen-diagrams and ceramics (Österholm op.cit). Regarding the fauna at the time there are no evidence of a decrease neither in numbers nor in diversity during Middle Neolithicum (Ekman 1974, Österholm op.cit).

The settlement was dated by five uncalibrated ^{14}C values (tab 1)(Janzon 1974). Calibration was performed by the use of "CALIB AND DISPLAY" a computer program by Stuiver (1986). Values were calibrated by different calibration curves depending on from which time period they derived. Hence, the values from grave nr 2, 3 and 4 were calibrated according to Pearson et al (1986) and the values from grave 5 and square N2 were calibrated according to Stuiver and Becker (1986), declared with one standard deviation.

Table 1. Calibrated (BC) and uncalibrated (bc) ^{14}C datings from Ire, Hangvar parish, Gotland

Grave	sample	mat.	age bc±	max (age BC) min
2	st 3780	bone	2075 ±100	2861(2574,2533,2508)2460
3	st 3781	bone	2330 ±100	3028(2911)2706
4	st 3782	bone	2270 ±100	2919(2885,2794,2786)2626
5	st 3779	bone	1900 ±100	2470(2388,2386,2342, 2319,2315)2143
S98	st 4278 nut shell	hazel	2069 ±150	>2497(2496)2350

Ire holds an unique position among middle neolithic settlements on Gotland because of its high frequency of seal bones. This high frequency was explained by Janzon (1974) as, "the settlement has first and foremost been occupied when it has been easy to catch seal, i.e during fall, winter and spring". An alternative theory brought about at a seminar by Greta Arwidson (Janzon 1974) was "the lack of sealbones on the other settlements is due to their butchering of seals on the hunting ground rather than at the settlement". Ire was also the first neolithic settlement on Gotland where herring bones were found, it also holds the highest frequency of fish bones (Ekman 1974). An explanation for this could according to Ekman (op.cit) be, except for an extra ordinary high fish consumption, good preservation conditions and thorough excavation techniques.

The large amount of jaws from wild boar found in grave nr 7, are to be regarded as burial gifts, they should not be categorized as bones from food remains mixed in the graves with burial gifts (Ekman 1974). It has been discussed whether they originates from wild boar (Ekman op.cit) or if they could have been domesticated (Österholm 1989). The time for the domestication of wild boars on Gotland is still a question that needs to be answered.

Methods

To get a good estimate on the relation between marine and terrestrial protein in the diet, delta ^{13}C was measured. This value has shown to be a good estimation of this relation (Tauber 1981 a & b, 1983, 1985, Chisholm et al 1982, 1983 a & b, Johansen et al. 1986). The method relies on differences in fractionation of ^{13}C and ^{12}C in marine versus terrestrial environment (Ehleringer & Rundel 1988). This difference, approximately 7 permille (Craig 1953), follows the food web all the way up to the top predators (Chisholm et al 1982, 1983 a). Delta ^{13}C is then measured in collagen, a bone protein. This protein has a complete turnover in the body of approximately 30 years and is isotopic inert in postmortem environments (Stenhouse & Baxter 1979).

Before collagen extraction, according to Brown et al. (1988), the bones were ground to a size of approximately 1 mm. After combustion, stable carbon isotopes were measured in a mass spectrometer (PRISM SIRA) at the Department of Geology, University of British Columbia, Vancouver. The quality of the collagen was determined by measuring the carbon nitrogen ratio (De Niro 1985).

The method has been applied earlier in Scandinavia by Tauber (1981 a, 1983). By comparing delta ^{13}C values from a Danish mesolithic population with delta ^{13}C values from a historic population from Greenland (fig 2) he could establish a higher marine protein intake for the danish population, than had earlier been expected. This study was followed by Noe-Nygaard (1983), who measured delta ^{13}C in collagen from mesolithic dogs on Zealand (Denmark). She used collagen from dogs when she compared coastal and inland settlements to find out whether there had been one or several different kinds of human populations. She concluded there must have been two different human populations according to difference in delta ^{13}C values from the dog collagen, then assuming dogs having the same diet as the humans.

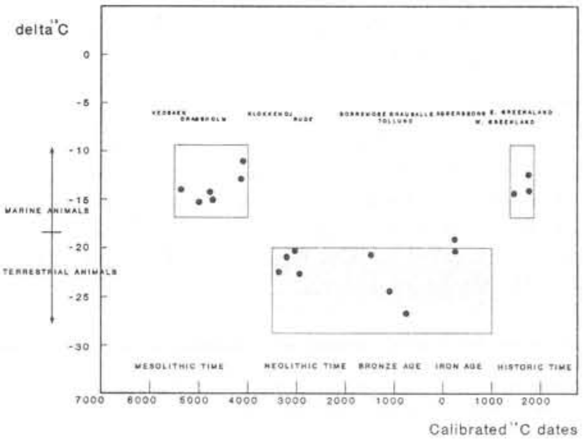

Fig 2. Human delta ^{13}C values from people in Denmark and Greenland versus calibrated ^{14}C dates of the samples from Tauber (1981:a)

In Norway, Johansen et al. (1986) combined, stable carbon isotope analyses with known archaeological and historical data, in a survey over sites from different time periods and different areas in Norway. They concluded that the method was applicable in Norway, and that one could with some precaution be able to calculate percentage of marine versus terrestrial protein intake.

It is more complicated to apply the method in Sweden along the coasts of the Baltic. Here we have to consider the fact that the Baltic is brackish, and also that this amount of "brackishness" has varied over time. Large amount of terrestrial organic carbon is supplied to the Baltic from large rivers in the north (Welinder 1984, Olsson 1986). There are though some measurements done on Swedish material such as the man from Kams, Lummelunda parish, Gotland (Larsson 1982), within the Skateholm project (Jonsson 1988) and from Alvastra (Saelebakke & Welinder 1988).

Trace elements, which are used as indicators of protein intake, were analysed with polarography ("differential puls anode stripping"), dissolved and diluted according to Slytå & Arrhenius (1979). The amount of protein and amino acid composition, which gives an image of quality and origin of the organic remains, were analysed according to Lowry (1951), and identified with HPTLC (Heathecoate 1969). The amino acids were quantified according to Arrhenius & Slytå (1981).

Material

Stable carbon isotopes measurements were performed on four individuals and trace elements were analysed on ten individuals and six potsherds. These potsherds were also analysed on protein content and amino acid composition (tab 2 & 3). All analyses on the individuals were made on skull bone, the most compact bone in a human being (Arrhenius 1990). The individuals originates from grave no 1 to 8. In those cases the grave contained more than one individual (Janzon 1974), a letter is added to the grave number. All graves were excavated by Arwidsson except number 1 which was excavated by Wennersten 1914 (Janzon 1974). None of the potsherds originates from graves, they all come from other excavation areas within the site (tab 3).

Table 2. Graves containing individuals analysed on delta ^{13}C values and trace elements, Ire, Hangvar parish, Gotland

Grave #	Age	Sex	^{13}C	Trace elements
1	> 60	M	X	X
2	40-50	M	X	X
3	25-30	F	X	X
4	40-60	M		X
5	30-40	M		X
6 B	12-13	M		X
6 C	40-50	M		X
7 A	30-40	M		X
7 C	50-60	M	X	X
8	40-50	F		X

Table 3. Potsherds analysed on protein amount, amino acid composition and trace elements, Ire, Hangvar parish, Gotland

Sherd #	Excavation area	Amino acid	Trace elements
1	square 70 N 40	X	X
2	square 70 N 40	X	X
3	square 52 S 26	X	X
4	square 46 S 18 layer 2	X	X
5	square 70 N 40	X	X
6	square 70 N 40	X	X

Results

To test the quality of the collagen, a carbon/nitrogen ratio was measured on two samples. The C/N ratio was close to 3.0, the ideal value (tab 4). All other samples were visually estimated as being of the same high quality. The delta ^{13}C values, average of 14.93 and s.d 0.464 (tab 4). Indicating a dominating intake of marine protein. The variation between individuals was relatively low, thus suggesting the same dietary proportion of marine vs terrestrial protein. Lovell et al. (1986 a) found no difference in delta ^{13}C diagenesis between sex or age.

One can emphasize the low selenium values, average 1.6 ppm (tab 4), compared to other prehistoric populations, 3.0-4.0 ppm (Arrhenius 1990). Arrhenius (1990) gives two explanations for this, seasonal burials and extremely selenium poor soils on Gotland. High copper values in prehistoric populations are usually interpreted as being caused by a high consumption of molluscs, insects or crustacean (Underwood 1977, Gilbert 1985, Arrhenius 1990). These high values are particularly found in mesolithic populations (Arrhenius 1990). Thus are the copper values here only one hundreth of the copper values from the mesolithic settlement at Skateholm, Scania (Arrhenius 1989). The zinc values are ten times as high as the copper values, also this can be a result of a high mollusc consumption, especially marine molluscs. They could also origin from a high fish-, liver- or kidney consumption. Here it seems more probable that a high fish consumption is the cause of the high zinc values, due to the low copper values.

Table 4. Trace element analyses (ppm) (Arrhenius 1989), stable carbon isotopes (permille) and carbon/nitrogen ratio (Lidén, K and Nelson, E) on skull bones from the Middle Neolithic settlement Ire, Hangvar parish, Gotland

Grave #	**Se**	**Cu**	**Zn**	**^{13}C**	**C/N**
Grave 1	1.70	21.9	496.2	-15.27	3.0/1
Grave 2	2.79	41.2	329.4	-14.25	
Grave 3	1.78	25.0	291.0	-15.16	
Grave 4	2.13	38.0	354.4		
Grave 5	0.86	32.0	432.6		
Grave 6 B	1.03	25.9	331.9		
Grave 6 C	2.00	48.9	313.3		
Grave 7 A	0.70	33.0	530.3		
Grave 7 C	0.99	37.4	572.3	-15.05	2.9/1
Grave 8	1.75	31.6	162.8		
$\bar{x}$ =	1.57	33.5	381.4	-14.93	
sd =	0.66	8.20	125.1	0.464	

Interesting are the differences between individuals in some of the trace element amounts. If one compare male and female zinc values, which could be hazardous due to the small sample size, there is a tendency to differences. Female zinc values are significantly lower than male zinc values (tab 5). Also female copper values are lower, though not significantly. There were no difference in selenium amounts. One should also emphasize that the male connected to the lowest copper value is a child. The interesting about trace elements is that they are indicating protein intake, which according to above gives us a discrepancy of protein intake between males and females on Ire. This might also be the explanation to the lowest male copper value if one regard the fact that a male child might not have the same access to protein as a male adult.

Table 5. Trace element analyses on skull bones from the middle neolithic settlement Ire, Hangvar parish, Gotland. Mean and standard deviation

	Females	**Men**	**Significance**
Zn	$\bar{x}$= 226 sd= 91	$\bar{x}$= 420 sd= 102	*
Cu	$\bar{x}$= 28.3 sd= 4.7	$\bar{x}$= 34.8 sd= 8.6	N.S
Se	$\bar{x}$= 1.8 sd= 0.02	$\bar{x}$= 1.5 sd= 0.07	N.S

Protein occurrence could be established on all potsherds except no 2 (tab 6). The protein content was low compared to other stone age settlements, e.g the middle neolithic site Löddesborg, Scania (0.25 -2.10 mg/100 mg sample) (Arrhenius 1984) or the mesolithic site Tybrind vig, Jutland (0.97-2.75 mg/100mg sample) (Arrhenius & Lidén 1988). The six potsherds amino acid composition is relatively homogenous (tab 6), i.e those amino acids that occurs on one sherd occurs at large on all. Potsherd nr 2 though, where surprisingly no protein could be indicated, has an amino acid composition similar to or even more complex than the rest of the potsherds, this could be due to the presence of free amino acids. Note also the occurrence of proline on potsherds nr 2 and 3. Glycine is the dominating amino acid in all potsherds, followed by glutamine and alanine. Glutamine is the amino acid that dominates in all food, which glycine doesn't and makes it's high frequency hard to explain. The high alanine frequency could indicate that the organic remains had been broken down since alanine, which is the simplest amino acid, often occurs in degraded products.

The high trace element amounts show us the same concentration that has been seen earlier in prehistoric food remains (tab 6) (Arrhenius & Slytå 1981). One can notice the high zinc values, twenty to hundred times as high as the copper values, also the high iron values are notable. The high zinc values agree well with the skeleton material.

Table 6. Protein, amino acid and trace element analyses on pot sherds from the middle neolithic settlement Ire, Hangvar parish, Gotland. From Arrhenius (1983)

Sherd #		**1**	**2**	**3**	**4**	**5**	**6**
Protein g/100 g d.w		0.6	-	0.4	0.3	0.4	0.4
Amino acid g/100 g protein							
	Thr	-	-	-	-	-	-
	Trp	-	-	-	-	-	-
	Leu	-	-	+	-	0.1	0.1
	Arg	-	-	-	-	-	-
	Gly	0.5	0.5	0.5	0.5	0.5	0.3
	Glu	0.5	0.3	0.3	0.5	0.5	0.3
	Cys	-	-	-	-	-	-
	Tyr	+	0.1	-	0.5	-	-
	Met	-	-	-	-	-	-
	Ile	-	-	-	-	-	-
	His	-	-	-	-	-	-
	Ser	0.5	0.3	0.05	-	-	0.1
	Ala	0.5	0.5	0.05	0.5	0.5	0.3
	Val	+	0.3	0.05	0.5	0.1	-
	Phe	-	-	-	-	-	-
	Lys	-	-	-	-	-	-
	Asp	0.5	0.3	0.05	-	0.1	0.3
	Pro	0.3	-	0.05	-	-	-
Trace elements							
ppm	**Cu**	2.0	3.3	2.7	3.7	1.9	4.2
	Zn	236	82	138	168	167	83
	Fe	6020	1830	2820	3420	3520	2490

Arrhenius (1983) concludes her potsherd analyses that a probable origin for organic remains is vegetable. This due to the fact that the for animal tissue so obvious amino acids, leucine and lysine, totally are missing. The high amounts of iron and zinc indicate that some animal product should have been mixed in the food. High amounts of zinc usually indicate molluscs and crustacean, especially marine (Francalacci et al 1989). Talking against this is the relatively low amount of copper, which makes it more probable with a mixing of some blood product, particularly regarding the high iron amount (Arrhenius & Slytå 1981).

Discussion

There has been no doubt in earlier publications that the nutrient supply on Ire were based on hunting and fishing (Janzon 1974, Ekman 1974). The distribution of these two nutrition sources has been discussed by Ekman (1974). He shows by percentage calculations on the distribution of wild boar versus seal bones, which assumes to be the most important mammals, that the amount of seal bone on Ire holds an unique position (fig 3). This marine dominance is also supported by the delta ^{13}C values which, despite the low sample size, gives us a clear picture of a dominating marine protein intake.

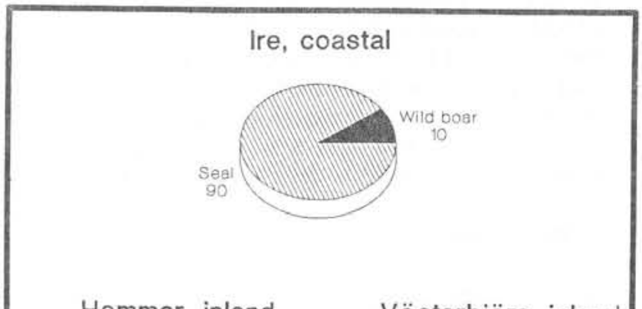

Fig 3. Percentage distribution of seal/wild boar from the middle neolithic settlements Ire in Hangvar, Gullrum in Näs, Hemmor in När, Visby, Västerbjers in Gothem and Västerbys in Hall, based on data in Ekman (1974)

The trace element analyses also supports the interpretation of a dominating marine protein intake on Ire. High copper and zinc values are used as indicators of a high protein intake in form of crustacean, molluscs and fish (Underwood 1977, Gilbert 1985). The copper values in this case are to low though to indicate a high crustacean or mollusc intake which makes it more probable that the zinc values are due to a high fish intake. It is here clear that by using different analysing methods in dietary studies one gets supplementary answers, in this study we can add fish to our earlier established high seal intake, based on the trace element analyses.

One could, according to the differences in trace element amounts, suspect a certain nutrition deficiency for the women at Ire, this does not seem to be the case though. Gejvall (1974) mentions that he finds no signs of nutrition deficiency, such as retardation lines on the skeleton or alterations in the tooth enamel. An alternative explanation to the differences could then be that females lose and therefore need more zinc during pregnancy and lactation (Davidson et al 1979). If one look at the two female individuals age it appears that the oldest female is 40-50 years old, maybe too old for still being fertile, while the younger female, 25-30 years old, ought to be in best fertile age. If one then compares average height, which could be a measure on nutritional status, for women at Ire with women at contemporary sites on Gotland (Visby, Gullrum, Hemmor, Västerbjers), we find that the women at Ire are significantly higher (Sjøvold 1974). When one does the same comparison for males, we find no difference. This could be explained by the extra zinc input the Ire females got by a higher marine protein intake. This would give them a higher nutritional status compared to females from other sites. Whether the Ire females have a higher zinc amount in their skeletons compared to the other women can only be answered if complementary analyses of trace elements are performed on the other Middle Neolithic females.

Lidén, K. and Nelson, E. (unpub.) gives evidence for good possibilities of applying the delta ^{13}C method within the Baltic area. By a survey of different populations separated in time and space in the Baltic area, they were able to prove that terrestrial delta ^{13}C values well agree with contemporary Norwegian values. They also prove that results from sites along the brackish Baltic are promising. Considering these results, and using percentage calculations according to Lovell et al (1986 b), we find that marine protein might represent as much as 70 % of the protein intake at Ire. It is then interesting to compare this method, which gives us a measure on the actual protein intake with a method that doesn't. The calculations by Ekman (1974) for instance, based on osteological data, gives us a seal/wild boar ratio of 9:1. The question on the domestication of wild boars are for instance one of the questions that could be answered by using stable carbon isotope analyses. The prediction would then be that totally wild boars should be feeding on 100 % terrestrial protein while domesticated or partly domesticated boars should have a diet similar to the human population which they are living together with or nearby. They should therefore get the same or similar delta ^{13}C value.

Comparing Ekman's figure (9:1) with the delta ^{13}C figure (ca 70 %) one find an over representation of seal at Ire. Comparing the seal/wild boar ratio at Ire with contemporary sites on Gotland (Visby, Gullrum, Hemmor, Västerbjers) (fig 3), one finds that Ire holds an unique position. This could be explained by the location of the different sites, Hemmor and Västerbjers are inland sites while Visby and Gullrum are coastal (Ekman 1974). What this doesn't explain is why Ire still holds a unique position compared to Visby and Gullrum. Maybe we have to look for an explanation elsewhere, among differences in sieving techniques, preservation conditions etc.

If one disregards from the marine over representation shown by the osteological data at Ire and makes the approximation that the same source of error occurs on the other sites, we can get a bit further.

Let us here refer to Noe-Nygaard (1983) and her report on mesolithic settlements on Sjaelland, Denmark, where she established two different kinds of settlements, inland and coastal of which at least one was stationary. To draw a parallel between Mesolithicum in Denmark and Middle Neolithicum on Gotland might be risky, but one can try to apply the idea of having different kinds of populations,

I. *stationary inland populations*
II. *migrating coastal populations*
III. *stationary to partly migrating coastal populations*

the different categories would then be represented by

I. *Hemmor and Västerbjärs*
II. *Visby and Gullrum*
III. *Ire*

This under the presumption that Ekman's (1974) values reflects the true diet and also without taking in account that considerable trade or exchange might have existed between the populations. The fact that trade or exchange existed is without doubt, which on Ire means, according to Janzon (1974), oriented towards the sea, referring among other things to similarities in burials. Examinations of the skeleton material by Gejvall (1974) supports this theory of travels across the sea. He has, on Ire, found so called popliteal pits in the femur of four individuals, all men. These pits are caused by a muscle that has been under stress for a long time. This stress could be due to uniform work of long duration in a certain position, e.g canoeing or archery (op.cit).

As shown by Tauber (1985) there exists a difference in delta ^{13}C values in collagen from Danish populations from different time periods i.e Early Mesolithicum, Late Mesolithicum and Early Neolithicum. This difference does not exist in delta ^{13}C values in food crust on ceramics from the same time periods. Since the delta ^{13}C values from the skeleton material gives us the true value on the dietary input as a contrary to the values from the food crusts, which only gives us the value of the content of the pot, Tauber (1985) concludes that the ceramics have been used for cooking or storing food in a similar way over time. The foodcrusts should therefore not be used as indicators of the dominating dietary intake but rather as indicators of the pots' content. Consequently, one can on Ire state that the potsherds reflect a food of vegetable origin, a food probably not representing the dominating diet. The same phenomena can be seen on the mesolithic coastal settlement at Tybrind Vig, Denmark, where one could expect the dominating protein intake to be marine (Andersen 1975), while the food remains on the potsherds were of a terrestrial vegetable origin (Arrhenius & Lidén 1989). Arrhenius (1985) argues that the pots with their structure full of holes are excellent for a fermentation process, where micro organisms "survive", thrive and are able to initiate new fermentation after refilling of organic material. Such fermentation does not of course exclude the possibility of adding animal protein in any form, to complement the fermented food, but it might have been easier to make that protein digestible by putting it on the fire. What has to be emphasized here is that the food crusts only reflects a part of the diet while the stable isotope analyses reflects the true nutrient input.

Conclusion

The diet on Ire was dominated by marine protein with the addition of terrestrial protein as e.g. wild boar, (domesticated?) and vegetables. This picture given to us by stable carbon isotope- and trace element analyses agrees surprisingly well with that given by the archaeological and osteological data. The vegetable element has been established by analyses of potsherds through which it also could be stated that they had been mixed with some blood product. It could further be emphasized the importance of including as many different dietary elements as possible to get the most accurate picture of prehistoric diet and also to be able to separate diet from dietary input. One can finally state that the introduction of farming on Gotland at this time, seems to have had no or little impact on the dietary input.

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