TRACE ELEMENT ANALYSES OF HUMAN SKULLS

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ABSTRACT

Analyses of copper, zinc and selenium from skulls from populations from different sites from Sweden belonging to Stone age, Medieval period and 17th century are presented. The high copper content from populations from Early Stone Age in hunter/gatherer cultures are discussed and compared with the high copper content from refuse heaps from the same cultures. It is proposed that the high copper content is due to a diet where protein from gastropods, molluscs an arthropods take an important part. The choice between e.g. molluscs, which characterize the South Scandinavian so called Ertebølle culture, and gastropods or arthropods may only be depending on what is available in different areas and seasons. Finally a hypothesis is put forward that arthropods (maggots) could have been deliberately grown and this may have been one of several preludes to the farming of the Neolithic period.

Introduction

At the Archaeological research laboratory in Stockholm we have been studying paleonutrition (cf Slytå and Arrhenius 1979, Arrhenius et al 1981, Arrhenius 1985). Our material has been food remains on pottery and refuse heaps from Prehistoric and Medieval settlements and our methods have been chemical analyses. In this connection we have found that cultural deposits belonging to Stone Age from northern and central Sweden have a high content of copper as a trace element. This result corresponds with what has been found in shellmiddens (cf Sokoloff and Carter 1952). It was proposed that the high copper content is due to a high intake of food rich in copper such as molluscs. This explanation would however not be valid for Northern Sweden. Although in some cases shells of mollusks as *Mytilus edulis* have been found in some settlements in Northern Sweden (cf Broadbent 1979) molluscs seems not to have been an abundant resource in this part of Sweden.

I have therefore proposed that insects which also have a hemocyte based on copper, perhaps as maggots, have been an important part of the diet (cf Arrhenius 1985). The main trait of the South Scandinavian so called Ertebølle culture, characterized by the enormous shellmiddens, where obviously molluscs formed an important part of the diet should in fact only be one side of a cultural trait where an intake of food rich in copper, in some cases molluscs but in other cases insects or gastropods from freshwater. If the hypothesis that the main element in this kind of hunter/gatherer cultures are the preference for food rich in copper, this trait should be possible to trace in the human bones. It would therefore be of a certain interest to analyse the trace element of human bone to see if the hypothesis that e.g. the hunter/gatherer cultures from Scandinavian Stone Age had a diet specially rich in copper could be confirmed. Analyses of trace elements from human bones used as diet indicators has been used specially in American archeology (cf Lambert, Szpunar and Buikstra, J. E 1979 and there cited works). Whereas copper as a dietary discrimination mostly has been used to sort out maize cultivators from hunter and gatherer strontium has been used specially to sort out mollusc eating (cf Schoeninger and Peebles 1981). For our purpose, as we wanted to compare our results with the analyses of the cultural deposits copper and zinc were the most suited trace elements. We also added selenium, Se, as this element occur very rarely in Swedish soils and the change of the level would indicate a nutrition specially based on marine resources from the North Sea.

As early was noted by Lambert et al (1984) there could be a certain diagenesis of metals specially copper in bone. Whitmer et al (1989) has produced a very thorough study on recent works dealing with this problem and have also in detail studied the movement of copper and manganese from the Mucking Silhouette (a.a. 249). In the Mucking example the skeleton was totally destroyed and from the analyses published it is quite clear that the copper from the surrounding soil was absorbed by the skeleton and later with change in pH again released. These results are interesting but I am not sure that they have a immediate relevance for the trace element studies of less decayed bones. The decaying of bones is in itself a complex chemical process. Copper seems in bone to be specially linked to the lysyloxidase in collagen (cf Stryer 1988). Collagen is a protein which can remain stable in bone, cf Lidén 1990, and therefore bone still containing collagen should also contain the original copper content. The eventual enrichment from surrounding soil is also very unlikely when the bone still has its protein content as the protein would block other enrichment than water soluble. The possible enrichment will be discussed further below. For our purpose we therefore have chosen to use bones from the skull which are the most compact bones of a skeleton. The bones all contained collagen, cf Lidén 1990. The skull fragments were carefully washed, first with acetone, (to remove traces of a lacquer) and there after with ethanol and water in an ultrasonic. The analyses with a SEM, energidispersive X-ray fluorescence, did not show any significant (e.g. in the ppm level) differences between the outer cleaned surface and the inner part of the skull bone, cf fig 1. The problem with a diagenesis will be further discussed below.

Fig 1. Skullbone, photographed in SEM, showing the cleaned outer surface and the inner part (top). Photo by Birgit Arrhenius.

Material

The material used for the analyses for this purpose were human skull fragments from the mesolithic grave fields at Skateholm (Skateholm I and II, cf Larsson 1984 a and b, and 1988) and from the Middle Neolithic gravefield with hunter/gatherer at Ire, Hangvar, Gotland (cf Janzon 1974) analysed. Used as comparative material were skull fragments from the boat gravefield, Tuna in Alsike, belonging to the Viking period (cf Arne 1934), from a Medieval cemetery found below the porch at Leksand church (from 1050-1350 (cf Serning in Hofrén et al 1982) as well as from the 17th century part of that cemetery (not published but mentioned by Serning in Hofrén (ed) 1982, p. 93 belonging to the uppermost layer, cf also the discussion of the building of the church in the 17th century by Nisbeth in Hofrén (ed) 1982:42 ff). Further added to the analyses series were a skull from a grave dated to Migration period from Tolleby, Bohuslän and a skull from a Viking Age grave from Björkö, Adelsö, gravefield 116 (none of the graves are published) as well as a skull from the Middle Neolithic period from Vesterbys Hall, grave 1, Gotland (cf Janzon 1974). The analyses were made with voltametry, the stripping technique (cf Slytå in Slytå and Arrhenius 1979 a). The analyses were repeated three times. The recorded values are pictured in fig 2 and fig 3 (table 1). For the comparative material cf fig 4 (table 2). Lilly Johansson and Lovisa Brännland assisted in the laboratory and dr Ebba During made the osteological examination of the material.

Discussion

The highest mean values for Cu were found in Skateholm and Ire whereas the lowest mean for Cu was found in Tuna Alsike. The test sample from Vesterbys Hall fits very well with the mean from Ire and the graves from early Medieval period from Tolleby and Björkö fits in with the mean from Tuna in Alsike. The altogether lowest value of Cu was measured on the 17th century population from Leksand.

The possibility of diagenesis

In the Swedish moraine soils the Cu content is depending on the Cu content in the local rocks. Therefore one should in main expect a higher Cu content in Dalecarlia where several copper mines are localized compared with Scania or Gotland with a calcareous underground and without any known copper findings. The main picture of the analyses therefore speaks against an interpretation of the values as caused by diagenesis. It should however also be pointed out that in the Skateholm sites also high copper content was measured in the cultural deposits. In Skateholm I the values were slightly below index 1 (0.96) that is compared with the highest known natural values measured in Sweden (20 ppm dry weight, cf Pettersson 1976) whereas Skateholm II the oldest settlement were slightly above index (1.26). Some of the Skateholm graves were found below the settlement deposits. The skulls with the highest copper content were however *not found within the settlements deposits but outside the settlement boundary*. Also in Ire some of the graves were found below the settlement deposits (grave 4, 6 and 8, cf Janzon 1974, 117) without showing any special enrichment compared with those found outside the settlement layer. It seems therefore be fully justified to believe that the high copper content in Skateholm and Ire has been caused by a special diet. And it should also be noted that the copper content in these populations are higher than the values known from the Middle Woodlands sites (cf Lambert et al 1979) as well as the Eskimos from the 15th century (cf Hansen et al 1985, 187 ff). When we however study the values from Skateholm more in detail there is a remarkable uneven distribution of the values. There

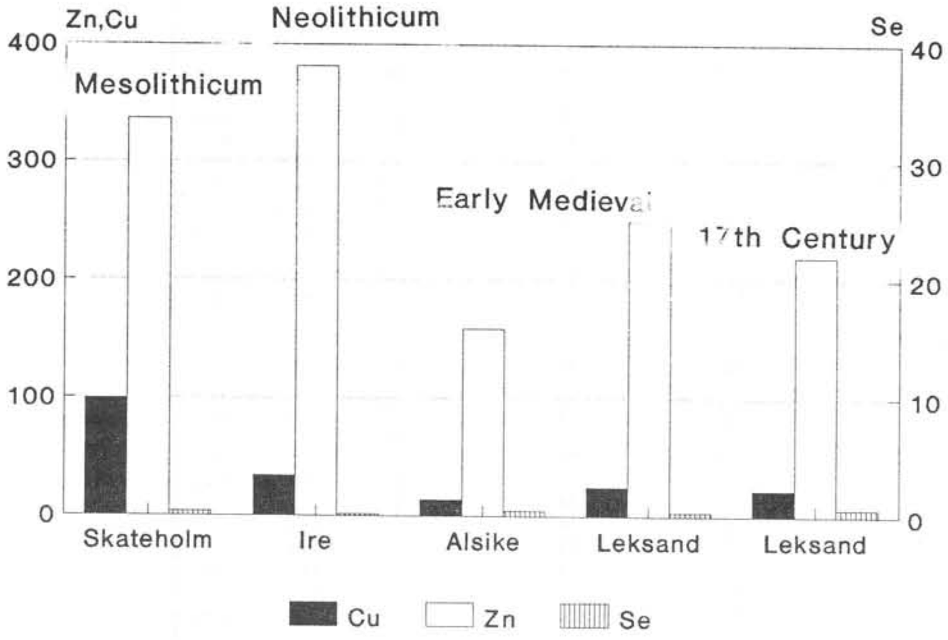

Fig 2. Mean values of trace elements (Cu, Zn and Se in ppm) in human skulls from different time periods

are some extremely high values (>100 ppm) from Skateholm, consisting of two females and one man, all adults, and there is one low value, <20 from a child, (inf. II). In Ire the values are much more even with a standard deviation of only 8.18. In both populations there seems to be no correlation between high resp low copper values and zinc values. Here we can note a difference between the examined Stone Age population and the Medieval population from Leksand. In the two cases high copper content, e.g. > than 50 ppm Cu, was measured these measurements were combined with very high zinc values (>400 ppm).

There are certain linked traits other than the copper values between the population from Skateholm and Ire. In both cases the main economy seems to be based on hunting and fishing. Lars Larsson gives a record of altogether 87 identified species (mammals, birds and fishes (cf Larsson 1984b) and Jan Ekman has given an account of 38 species from Ire, Hangvar (cf Janzon 1974, 40 ff). There seems to be a greater dominance of fish in the Ire material but it should be emphasized that the recovering technique in the Skateholm excavation was more developed (cf Larsson 1984 b:16) which might influence the amount of species found. Anyhow we can note that the Zn content is somewhat higher in the Ire skulls compared with the Skateholm skulls. There is a peculiar decrease of selenium in the Ire-analyses compared with the other analysed material. If this decrease is accidental, due to seasonality of the burials or because Gotland altogether has a very low selenium content in the soil, is difficult to judge. In this connection it should be noted that the Se values from the 17th century population in Leksand are fairly high. A possible explanation could be, as Dalecarlia in main is an area poor in selenium, that the population have had a large consumption of salted herrings, a rather common diet in old time.

However the most striking fact in these analyses is the obvious enrichment of Cu in the two Stone Age populations. In my opinion this evidence is a strong support for the hypothesies that the diet for these populations of hunter and gatherer was more rich in copper than what is known from later Swedish populations (cf also Lind 1980 who gives an account on modern Swedish populations where the Cu values all are below 10 ppm). As there is in the Stone Age populations no correlations between the Zn and Cu values, the possibility that the enrichment of Cu is caused by e.g. a high intake of liver is excluded. Liver is rich in Cu but actually there is 25 times more Zn than Cu in for example a liver from calf (cf Prasad 1976, 12). This would be an indication that the Cu-enrichment comes from the intake of gastropods, arthropods and molluscs rich in Cu. It may be of interest to study the distribution of the high copper values in the Skateholm population. The three persons having more than 100 ppm, 2 females and one man, are adults, however all three have severe damages in there jaws (cf Alexandersen in Larsson 1988:106 f). Thus the extreme high intake might be explained by the fact that these people have had some difficulties eating larger and tougher food. Among the other analysed humans from Skateholm we can notice high values in a small child, whereas an infant II had, to be in Skateholm, fairly low copper content. In the Ire population the highest value (48.9 ppm) was found on a man who is characterized by what Gejvall (Gejvall in Janzon 1974) describes as popliteal pitting coming from a special stress on the left thigh bone (femur). Gejvall proposes that this muscular exertion possible could have been caused for example by paddling a canoe following a flock of fleeing seals and to rush up in the right moment to launch the harpoon towards the prey. Thus it seems that even hunters in special circumstances would have a copper rich diet.

Table 1.

Hunter/gatherer Skateholm, Mesolithic period

Sample	site	age	sex	Se	Cu	Zn
28	Skate 2	>60	M	4.1	44.0	832.0
29	Skate 43	Ad	F	2.8	104.2	262.4
30	Skate 47	Inf		3.3	42.5	98.2
31	Skate 47	Inf II	M	3.4	17.4	104.4
32	Skate III	Ad	F	3.3	284.4	170.0
33	Skate VII	Ad	M	3.6	101.3	552.1
			$\bar{x}$=	3.4	98.9	336.5
			sd =	0.4	97.2	295.2

Hunter/gatherer Ire, Neolithic period

Sample	site	age	sex	Se	Cu	Zn
SB1	Ire grave 1	Ad	M	1.7	21.9	496.2
SB2	Ire grave 2	M	M	2.8	41.12	329.4
SB3	Ire grave 2	Ad	F	1.8	25.0	291.0
SB4	Ire grave 3	Ad		2.1	38.0	354.4
SB5	Ire grave 4		M	0.9	32.0	432.6
SB6	Ire grave 6B	Inf II	M	1.0	25.9	331.9
SB7	Ire grave 6C	M	M	2.0	48.9	313.3
SB8	Ire grave 7A	Ad	M	0.7	33.0	530.3
SB9	Ire grave 7C	Ad	F	1.0	37.4	572.3
SB10	Ire grave 8	Ad	F	1.8	31.6	162.8
			$\bar{x}$=	1.6	33.5	381.4
			sd =	0.7	8.2	125.1

Cemetery Tuna/Alsike, early Medieval period

Sample	site	age	sex	Se	Cu	Zn
34	Tuna III	Ad	M	2.7	16.1	184.0
35	Tuna XI	Ad	M	2.7	15.9	117.8
36	Tuna VI b	Ad	F	3.7	-	98.6
37	Tuna IV	Ad	F ?	7.2	0.85	118.7
38	Tuna I	Ad	M	8.0	0.69	300.0
39	Tuna VII	Ad	M	5.1	2.54	161.7
40	Tuna VIII	inf II	M	2.9	0.98	129.2
			$\bar{x}$=	4.6	13.8	158.6
			sd =	2.2	6.9	68.8

Church cemetery Leksand, Dalecarlia, Viking and Medieval period

Sample	site	age	sex		Se	Cu	Zn
3	Leksand S 122	Ad	F		2.9	21.7	146.0
4	Leksand S 145	Ad	F		2.8	27.8	363.0
5	Leksand 243:1	Ad	F		3.2	2.66	138.0
6	Leksand 256		?		5.0	21.5	175.9
7	Leksand S 19	?			5.3	8.70	137.9
8	Leksand S 31	Ad	F		5.4	18.6	119.6
9	Leksand S 24	?			1.3	19.6	249.7
10	Leksand S 87	?			2.6	17.3	349.0
11	Leksand S 91	Ad	F		3.0	14.5	88.8
12	Leksand S 132	Ad	F		3.8	77.6	425.4
13	Leksand S 157	Ad	F		1.5	16.5	553.9
				$\bar{x}$=	3.3	24.9	249.7
				sd =	1.4	18.3	151.7

Church cemetry Leksand, Dalecarlia, 17th century

Sample	site	age	sex	Se	Cu	Zn
14	Leksand A 26	no osteological data		6.3	25.7	271.2
15	Leksand A 29			6.3	53.8	464.0
16	Leksand A 33			6.9	10.2	203.9
17	Leksand A 34			4.9	9.80	129.2
18	Leksand A 36			6.5	33.6	235.5
19	Leksand A 42			5.4	29.9	255.8
20	Leksand A 43			6.3	13.1	133.7
21	Leksand A 58			6.9	16.2	134.5
22	Leksand A 75			5.9	7.10	143.4
23	Leksand A 10			6.3	23.1	223.4
			$\bar{x}$=	6.2	22.2	219.5
			sd =	0.6	14.3	101.5

Fig 3. Trace elements in human skull fragments in ppm

Table 2.

Hunter/gatherer Vesterbys/Hall, Neolithic period

Sample	site	age	sex	Se	Cu	Zn
SB 11	grave 1	?		1.8	32.9	206.7

Cemetry Björkö/Tolleby, early Medieval period

Sample	site	age	sex	Se	Cu	Zn
1	Björkö 116		F	4.6	10.9	206.7
2	Tolleby A XIV	Ad	M	3.3	13.5	92.1

Fig 4. Trace elements in human skull fragments in ppm

Conclusion

The importance of these analyses is that they give an indication of a habit in some Stone Age cultures to provide a diet rich in copper probably gathered from all kinds of small insects or gastropods and molluscs, which exist in abundance and therefore are easy to collect. The clear enrichment in the bones indicate that the diet rich in copper has not been occasional but more or less regular. In fact one would suspect that this part of the diet has been more important than protein from other sources.

It is in this connection of interest to get the evaluation of the intake of fresh-water gastropods on the Hayes site, Middle Tennessee (Klippel and Morey 1986). Although the amount of shells is enormous, the estimated gastropod meat never reach more than at highest a third of estimated deer meat. Perhaps the explanation for this low figure is that the gastropods with shell is in itself only a small part of the copper in the diet. For the Samis as well as the Eskimos it is a well recognized habit to grow maggots in the stomach of a slaughtered reindeer. This dish is thought to be delicious (cf Birket-Smith 1941: 181).

It is therefore possible that food rich in copper, not only were gathered, but could have been deliberate grown on fish or meat. This hypothesis which of course has to be proved in much larger analyses-series opens a new perspective on the food resources in the Stone Age.

There is in fact another detail that indicates that the utilization of fish was somewhat different in the Stone Age compared with later periods. Although there has been found large amounts of fish bones in Stone Age settlements (cf Noe-Nygaard 1983 who gives account from Danish Mesolithic settlements which however also corresponds to Swedish finds) the Zn values are much lower than what is known from the Medieval period (cf Arrhenius 1981:70). I will thus put forward the hypothesis that growing arthropods e.g. maggots was utilized as food in the early Stone Age. In fact this utilization might be one of the implements to what later should develop into growing seeds, e.g. the Neolithic farming.

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