THE SELBJERG PROJECT: INVESTIGATION OF NEOLITHIC POTTERY BY MEANS OF NEUTRON ACTIVATION ANALYSIS

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Introduction

The aim of this project is to discuss certain aspects within the Neolithic cultures of Southern Scandinavia. This is certainly most often attempted mainly using archaeological methods but in the present case neutron activation analysis was supposed to be the more usable technique. Working for instance with pottery and clay samples from a certain Neolithic site neutron activation analysis might be able to tell, whether the pottery found was made locally at the site, or brought there from elsewhere. Now, if the pottery turned out not to have been made locally, this in connection with other information might indicate that the site was only visited part of the year when hunting and fishing took place. During other parts of the year the inhabitants would live at a more stationary site, where farming was practised — and the pottery made.

The Selbjerg site

A site where such an economic model could be tested is the Stone Age site at Selbjerg, Northern Jutland, excavated and published by Marseen (1953). During the Neolithic the site was situated on a small island 6—7 m above present day sea level, which in this area corresponds to the Litorina Maximum (Mertz, 1924). Much could be said about the site itself; it is a kitchen midden with interesting archaeological and faunal remains but a rather complicated stratification. To enter into details on such topics lies outside the scope of the present study, where we shall concentrate on the pottery. In fact, this pottery is the main reason why the Selbjerg site was chosen to be tested according to the model briefly outlined above. We here have pottery belonging to the Funnel Necked Beaker Culture, the Pitted Ware Culture and the Battle Axe Culture, that is, the three cultures constituting the Middle Neolithic of Southern Scandinavia. The pottery in question roughly belongs to the first half of the third Millennium B. C. according to calibrated ^{14}C-datings.

The West Swedish material

Thanks to the co-operation with Jan Eric Sjöberg from the Gothenburg Archaeological Museum it has also been possible to have material analysed from the Swedish West

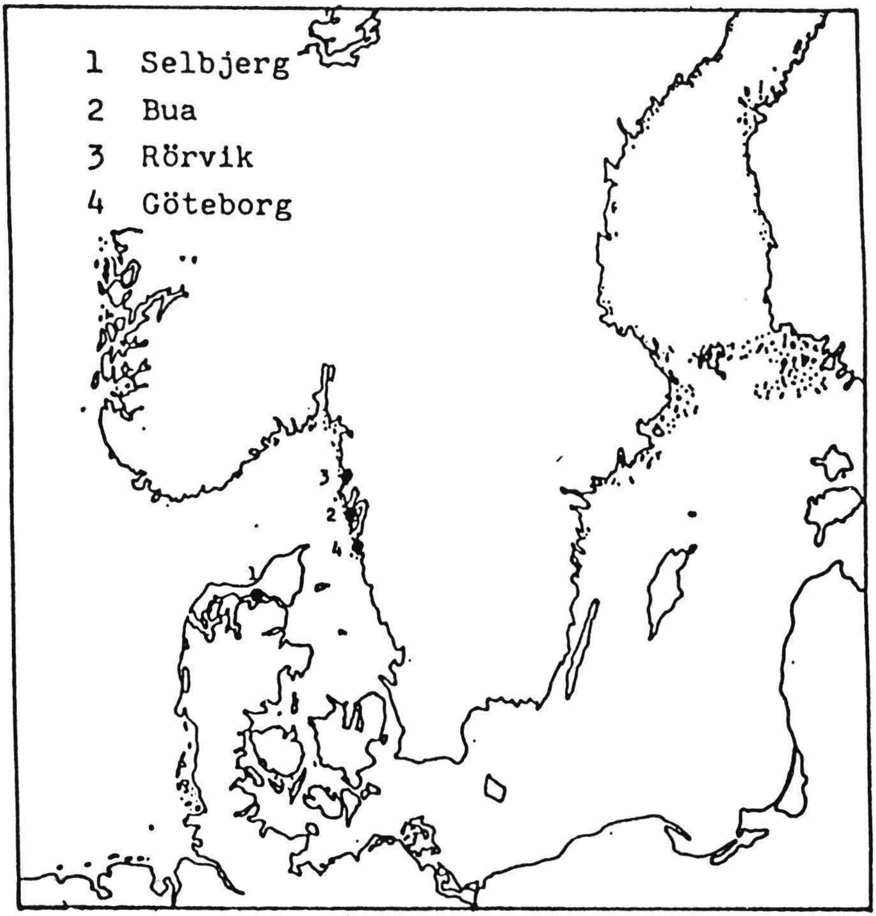

Fig. 1. The localities from where the pottery and clay samples were taken.

Coast. Thus there are pottery samples from the site at Bua, which belongs to the Pitted Ware Culture (Niklasson, 1962). Other samples of pottery were put at our disposal from the well known Pitted Ware Culture site at Rörvik (Janson, 1936) as well as a clay sample dug in the modern city of Gothenburg.

The neutron activation analysis

Already in 1977 the National Museum had accepted that samples were taken from the Selbjerg pottery to be analysed, but it was not until 1980 that this was actually done by Vagn Mejdahl. This year the Danish Research Council for the Humanities agreed to pay for the analysis, and at the same time the material was forwarded from the Gothenburg Archaeological Museum. The neutron activation analysis and the subsequent computer process were undertaken by Leif Højslet Christensen at the Risø National Laboratory. We shall not enter into details with regard to the methods employed, but information about the procedure can be found in Hansen et al. (1982) with further references.

Survey of the samples analysed

For the sake of good order a survey of the samples which have been analysed is given below. The indication "SE" followed by a figure refers to the special numbering of the finds from the Selbjerg site at the National Museum:

SELBJERG	3	samples from a large part of an ornamented vessel belonging to the Funnel Necked Beaker Culture (SE 97)
—	2	samples from a clay disc belonging most probably to the Funnel Necked Beaker Culture (SE 231)
—	3	samples from a large part of an ornamented vessel belonging to the Pitted Ware Culture (SE 116)
—	3	samples from a large vessel without ornaments belonging to the Battle Axe Culture (SE 8)
—	3	samples from a large part of an ornamented vessel, "short wave moulding", belonging to the Battle Axe Culture (SE 2)
—	1	sample from a rim sherd with ornaments belonging to the Battle Axe Culture (SE 203 and 228)
—	1	sample from a rim sherd decorated with nail impressions, belonging to the Battle Axe Culture (SE 10)
—	1	sample of clay dug in the field behind the site
BUA	3	samples from potsherds belonging to the Pitted Ware Culture (GAM 54687, ruta 16)
RÖRVIK	6	samples from potsherds belonging to the Pitted Ware Culture (GAM 55436-37, ruta g 10 — h 10)
GOTHENBURG	3	samples from clay dug in the city
RISØ	2	samples from clay — Risø standard clay, not used in the statistical analysis
TOTAL	31	samples

Data analysis

In this section is described a statistical analysis of the data. Due to the limited number of observations an exploratory data analytic approach has been chosen. The analysis comprises hierarchical cluster analyses, factor analysis and stepwise discriminant analyses. The computations were done by means of software from the statistical packages BMDP and SAS.

In all 29 samples were given, and the contents of 16 elements were determined. The concentrations were standardized at Risø National Laboratory. The means, standard deviations and correlations found from the 29 samples are given in table 1. It must be emphasized that the figures given in table 1 reflect as well the, say natural correlation between the elements, and the co-variation between samples from different sites. Many of the high correlations seem, however, to be due to chemical relatedness like e.g. in the lanthanide series and the elements from the first transition group ('iron' group). This matter is discussed further in the subsection on factor analysis.

Table 1. Means, standard deviation, and correlations for the variables after the standardization performed at Risø.

	Mean	St.dev.	Correlation															
			Sm	Ce	Lu	Yb	La	Ba	Rb	Na	Th	Hf	Cs	Sc	Fe	Eu	Cr	Co
Sm	.892	.223	1.0															
Ce	1.074	.273	.9	1.0														
Lu	.814	.144	.8	.6	1.0													
Yb	.832	.195	.6	.5	.8	1.0												
La	1.024	.271	.9	1.0	.7	.5	1.0											
Ba	1.109	.258	—.1	—.2	—.0	.2	—.1	1.0										
Rb	1.249	.297	.2	.2	—.0	.2	.2	.4	1.0									
Na	1.367	.262	.3	.1	.2	.2	.2	.4	.3	1.0								
Th	1.297	.423	.6	.8	.4	.4	.8	—.1	.6	.2	1.0							
Hf	.751	.252	.1	—.0	.5	.2	—.0	—.0	—.5	.3	—.1	1.0						
Cs	1.120	.278	—.1	—.1	—.2	—.2	—.0	—.2	.2	—.2	—.1	—.4	1.0					
Sc	.938	.212	—.2	—.2	.2	—.1	—.2	—.4	—.5	—.4	—.4	.1	.4	1.0				
Fe	1.079	.242	.1	.1	.2	—.2	.1	—.4	—.5	—.7	—.2	—.0	.2	.7	1.0			
Eu	.934	.165	.3	.3	.4	.1	.4	.0	—.4	—.1	.0	.3	.1	.3	.6	1.0		
Cr	.987	.343	—.3	—.3	.0	—.3	—.3	—.2	—.6	—.5	—.4	.3	.3	.8	.7	.6	1.0	
Co	.952	.351	—.3	—.3	—.0	—.2	—.4	—.3	—.5	—.5	—.5	—.1	.3	.9	.6	.1	.7	1.0

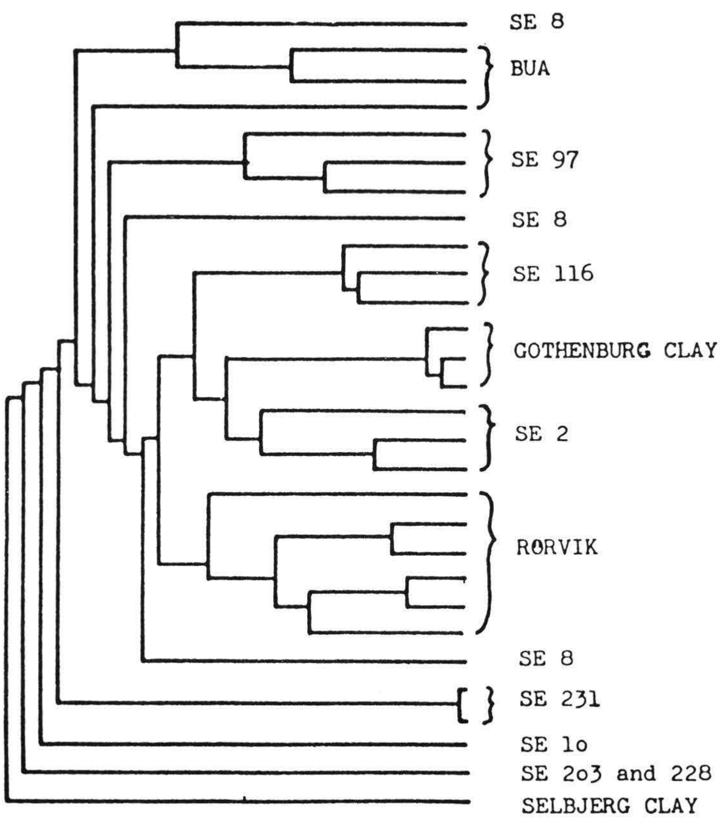

Fig. 2. Tree showing the hierarchical clustering of the samples.

Hierarchical cluster analysis

Hierarchical cluster analyses (see e.g. Sokal & Sneath (1963)) are done in order to investigate whether a multivariate dataset reveals hierarchical structure. The samples themselves follow a hierarchy in an obvious way as for instance

Location → artifact → samples.

If there is a connection between the element concentrations and the origin of the samples it should be possible to find a structure as the one given above in the data. In a hierarchical cluster analysis samples are amalgamated one at a time to already existing clusters according to a distance measure. This will possibly result in a dendrogram or tree revealing the relevant structure in the data. In the present study several measures of distance were used, but only results from applying the euclician distance

$$d_e(\underline{x},y) = \sqrt{\sum_i (x_i - y_i)^2}$$

will be reported. The linking of the clusters were done with a single link algorithm. The resulting tree is given in figure 2.

It is seen that the samples form a tree that is consistent with most of the known structure. The samples from Kville are amalgamated in a single cluster, likewise with the Gothenburg clay and all the multisample artifacts from Selbjerg except for SE 8 (samples 1, 2 and 3) which are not connected with the tree until late in the clustering procedure. One should emphasize that the Gothenburg clay at first is combined with Selbjerg ceramics and then later with the West Swedish ceramics. The Selbjerg clay is the last sample that enters the tree. Therefore there seem to be very little similarity between the clay samples and the ceramics found at the respective sites.

Factor analysis

In order to transform the multivariate, correlated data into a set of independent variates one can use different types of factor analysis, see e.g. Harman (1967). These are basicly eigen analyses of the correlation or the covariance matrix of the observations. Since the variates analysed here do not have a canonical range of variation the natural types of analysis are based on the correlations. In table 2 we show the results of an unrotated and of a VARIMAX rotated analysis. With 5 factors retained we explain 87.0 % of the total variation in the data. The factor loadings in the table can be interpreted as correlations between the variables and the factors. This can be utilized in the interpretation of the factors. We shall briefly do so for the first three factors. The first is obviously characterized by having big correlations with the lanthanides. The second has big correlations with the first transition group — the iron metals — and the third has positive correlation with some alkali metals and barium and negative with Fe, Co (and Sc, Cr); this does not follow from the table, where correlations smaller (in absolute value) than .25 have been truncated to 0). In short the factors show high values for

Factor 1: high values of lanthanides
Factor 2: high values of iron metals
Factor 3: high values of alkali metals combined with low values of iron metals

In figure 3 we have shown plots of the values of the 1st and 2nd, the 1st and 3rd, and the 2nd and 3rd factor scores for the 29 samples. The best separation between the artifacts are obtained in the plot of the 2nd and 3rd factors. The lanthanides do not

Table 2. Factor loadings in the unrotated (principal component) case and in the rotated (VARIMAX) case. Rotated loadings less than 0.25 have been replaced by 0.

Variable Name	No.	Unrotated factor loadings Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Sm	1	0.731	0.610	—0.065	0.009	0.003
Ce	2	0.713	0.582	—0.248	—0.171	—0.122
Lu	3	0.488	0.738	0.263	0.158	0.311
Yb	4	0.612	0.346	0.193	0.265	0.488
La	5	0.750	0.579	—0.222	—0.064	—0.132
Ba	6	0.254	—0.409	0.326	0.648	—0.210
Rb	7	0.596	—0.417	—0.444	0.394	0.055
Na	8	0.550	—0.279	0.440	0.303	—0.073
Th	9	0.788	0.230	—0.314	—0.072	—0.043
Hf	10	0.017	0.293	0.866	—0.115	0.039
Cs	11	—0.283	0.107	—0.610	0.483	—0.059
Sc	12	—0.693	0.571	—0.073	0.224	0.275
Fe	13	—0.550	0.721	—0.189	—0.062	—0.143
Eu	14	—0.087	0.725	0.230	0.226	—0.566
Cr	15	—0.723	0.529	0.123	0.234	—0.199
Co	16	—0.766	0.367	—0.129	0.177	0.354
Var. explained		5.541	4.066	2.066	1.239	1.009
In %		34.6	25.4	12.9	7.7	6.3
Cumulative %		34.6	60.0	73.0	80.7	87.0

Variable Name	No.	Sorted rotated factor loadings Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Sm	1	0.942	0.0	0.0	0.0	0.0
La	5	0.937	0.0	0.0	0.0	0.0
Ce	2	0.914	0.0	0.0	0.0	0.0
Lu	3	0.846	0.316	0.0	0.0	0.364
Th	9	0.764	—0.377	0.0	0.0	0.0
Yb	4	0.720	0.0	0.358	—0.324	0.0
Sc	12	0.0	0.903	0.0	0.0	0.0
Co	16	0.0	0.865	—0.275	0.0	0.0
Cr	15	0.0	0.656	0.0	0.640	0.0
Ba	6	0.0	0.0	0.864	0.0	0.0
Na	8	0.0	—0.353	0.682	0.0	0.0
Eu	14	0.304	0.0	0.0	0.893	0.0
Fe	13	0.0	0.558	—0.502	0.558	0.0
Hf	10	0.0	0.0	0.0	0.0	0.874
Cs	11	0.0	0.390	0.0	0.0	—0.722
Rb	7	0.253	—0.334	0.440	—0.388	—0.604
Var. explained		4.746	3.179	2.039	1.980	1.976
In %		29.7	20.0	12.7	12.4	12.4
Cumulative %		29.7	49.5	62.3	74.7	87.0

separate very well between the samples. From the plot it again follows that the multi-sample artifacts and the clay samples group very nicely, but there is no immediate connection between the clay samples and ceramic samples. If one should conclude then the Gothenburg clay is more similar to some of the SE ceramics than it is to the West Swedish ceramics.

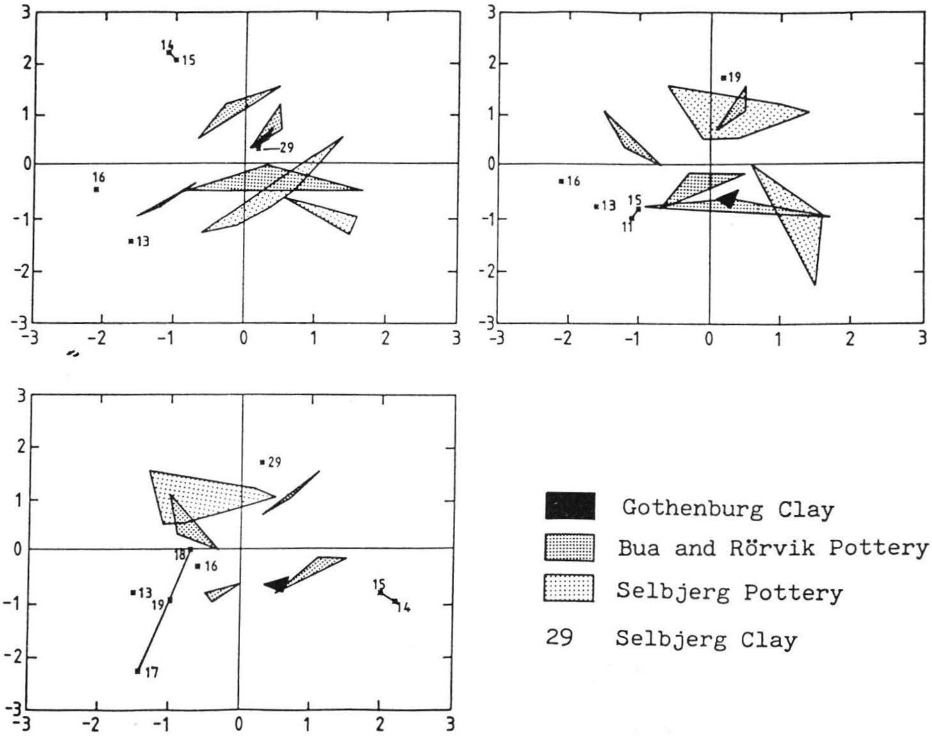

Fig. 3. Plots of the first three factor scores.

Discriminant analyses

In the previous analyses no structure between the samples were used. In the discriminant analysis (see e.g. Anderson (1958)) we consider the 4 populations

1: Selbjerg Ceramics (samples 1—16)
2: West Swedish Ceramics (samples 17—25)
3: Gothenburg Clay (samples 26—28)
4: Selbjerg Clay (sample 29),

and we want to see whether the 16 variables discriminate between those. If so, we furthermore want to establish which variables are the best discriminators.

Since there is only one sample in population 4 (Selbjerg clay) it is not used in the determination of the discriminant functions. The stepwise discriminant analysis program BMDP7M from the BMDP-package was used. The total number of variables allowed to enter was put as low as 5 in order to avoid overfitting. The F-values in step 0 is given in table 3 for all variables. The variables are ordered according to this value. This gives an ordering of the elements with respect to discriminative power. We see that the elements from the 1st transition group (iron metals) are by far the best individual discriminators. They are, however, strongly correlated wherefore not all of them are chosen in the stepwise procedure. The other variables entered are alkali metals (Cs, Rb) and Yb (a lanthanide). We see that the three first factors from the section on factor analysis are represented. In table 4 we have the F-matrix for tests for equality of group means. We find the greatest dissimilarity between Selbjerg ceramics and West Swedish

Table 3. F-values in step 0 for all variables, step where entered and F-to-enter for the 5 'best' discriminators and F-in-last-step for the remaining variables. Three populations: Selbjerg ceramics, Gothenburg ceramics and Gothenburg clay.

Variable	F-value step 0	Step where entered	F-to-enter or in last step
Cr	15.99	1	15.99
Co	9.34	5	1.60
Sc	8.66		1.01
Yb	8.34	2	11.19
Cs	6.00	3	5.00
Sm	5.99		1.03
Th	5.61		0.11
La	5.08		0.57
Rb	4.57	4	3.85
Ce	3.99		0.45
Fe	3.55		1.39
Na	2.65		0.59
Hf	2.25		0.03
Ba	2.13		0.33
Lu	1.61		0.49
Eu	0.83		0.60

Table 4. Testvalues in F-tests for equality of group means. Degrees of freedom (5, 21).

	Sel.Cer.	Got.Cer.	Got.Clay	Sel.Clay
Sel.Cer.	0			
Got.Cer.	16.23	0		
Got.Clay	4.73	6.61	0	
Sel.Clay	3.10	0.67	2.62	0

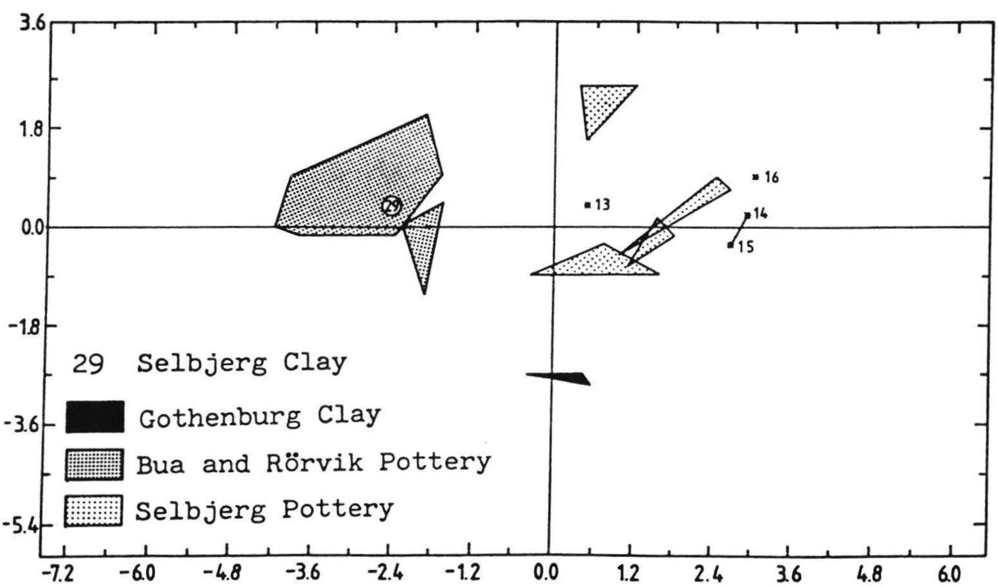

Fig. 4. Plot of the first two canonical variates.

Table 5. Jackknifed Mahalanobis distances from each observation to centroids of groups. Variables used are those given in table 3.

Observation no.		Selbjerg Cer.	Gothenburg Cer.	Gothenburg Clay
Selbjerg Ceramics				
Se 8	1	9.7	13.9	35.8
	2	4.3	11.7	20.9
	3	11.8	23.6	41.6
SE 116	4	7.3	23.5	8.0
	5	13.4	9.7	7.0
	6	5.8	14.7	8.9
SE 97	7	15.2	42.0	32.8
	8	4.1	15.3	7.5
	9	2.2	29.1	17.7
SE 2	10	3.7	20.8	13.1
	11	3.8	22.1	11.4
	12	1.6	14.0	5.0
SE 203	13	21.4	22.0	24.9
SE 231	14	14.6	48.4	27.0
	15	12.6	41.9	18.7
SE 10	16	18.2	55.7	39.3
Gothenburg Ceramics				
54687	17	16.0	8.8	9.4
	18	11.0	4.1	14.2
	19	14.1	1.2	13.8
55436	20	30.6	3.1	32.6
	21	15.0	1.1	13.6
	22	16.1	10.3	32.5
	23	32.7	4.7	26.4
55437	24	12.4	5.5	19.2
	25	43.0	9.2	34.6
Gothenburg Clay				
	26	13.1	14.2	1.4
	27	9.6	18.0	0.5
	28	10.5	19.3	0.4
Selbjerg Clay				
	29	19.6	4.5	20.8

ceramics. Furthermore Gothenburg clay seems to be a little bit more related to the Selbjerg ceramics than to the West Swedish ceramics. In table 5 we have given the jackknifed Mahalanobis distances from each case to the centroids of each group. The term jackknifed means that the particular sample for which the distance is determined is *not* used in the estimation of the relevant parameters. Again we see an almost perfect consistency. The only sample that is not closest to its 'own' group centroid is sample no. 5 from SE 116. It has smaller distance to as well Gothenburg clay as ceramics. In figure 4 is shown the projection of the samples on the plane determined by the first two canonical variates, i.e. the plane that separates the groups most. Again we see that the individual artifacts cluster relatively well, and again there is no obvious connection between the clay samples and either of the ceramic groups.

Conclusion

The statistical analysis has made it possible to put forward some archaeological conclusions. First of all the different statistical methods employed have resulted in a clustering of the samples, which is in accordance with the archaeological grouping. Furthermore, the analysis cannot support the idea that the Pitted Ware vessel from Selbjerg was imported from Western Sweden.

The most interesting result is, however, that none of the Selbjerg pottery seems to have been made of local clay, since this differs much from the clay used to make the Selbjerg pottery. This observation would be in accordance with the model about seasonal sites put forward in the introduction. Thus the Selbjerg site was only visited during short periods of the year when collecting shellfish, seal hunting and hunting birds of passage took place, as it is also reflected in the faunal remains. Bones from such domesticated species as cow and pig are also found, however. Maybe they were brought live to the island in the summer when collecting shellfish took place. Due to the find circumstances it is unfortunately not possible to associate any of the three cultures in question with a certain activity, or parts of the faunal remains within the site. There is, however, reason to believe that the economy within the Funnel Necked Beaker Culture and the Battle Axe Culture would have been almost the same. Thus agriculture within these two cultures must have taken place elsewhere at a more stationary site — where also the pottery was made. At least the size of the island where the Selbjerg site was situated was only 5 km^2, and it could hardly be inhabited for a longer period by a Neolithic population.

More could be said about such economic models though it should be noted that the Pitted Ware Culture is rather tricky in this respect, since the economy within this culture differs from region to region (Nielsen, 1979). Yet, attention should be drawn to Kaelas (1973) who has discussed the economy of the Rörvik site.

— Since this is the first time that neutron activation analysis has been used in this way within the pottery of the Danish Neolithic, a few words should be said about the representativity of the material. Here more samples would have been desirable, especially clay samples from the vicinity of the Selbjerg site, because the elemental composition of clay may vary considerably, even within a limited geographical area (Christensen et al., 1982). In order to elucidate such problems a geological expert should be consulted.

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