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Mobility and exchange in the Middle Neolithic: Provenance studies of Pitted Ware and Funnel Beaker pottery from Jutland, Denmark and the west coast of Sweden

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ABSTRACT

This paper presents the results of a ceramics study that forms part of a larger research project, "CONTACT". The aim of this study was to trace the provenance of pottery found at Middle Neolithic sites on both sides of the Kattegat and to discuss possible pottery exchange between Jutland in Denmark and the west coast of Sweden. A combination of pXRF, ICP-MA/ES and thin-section analyses was applied to 524 Funnel Beaker culture (FBC) and Pitted Ware culture (PWC) sherds to investigate their fabric and technology. The different analyses supplemented each other well: The elemental composition of the ceramic material evident from both the XRF and ICP analyses was appropriate for determining the provenance of the clay, while the thin sections gave an indication of techniques recipes and materials employed in pottery production. The PWC pottery proved to be more heterogeneous than the FBC pottery, and several plausible explanations are suggested for this. Some regional exchange was observed, but only two vessels were identified, which could have crossed the Kattegat.

1. Introduction

This study forms part of the project "CONTACT – The Pitted Ware Phenomenon in Djursland and Maritime Relations across the Kattegat in the Middle Neolithic", under the direction of Lutz Klassen, East Jutland Museum, Denmark. Its aim is to identify possible imported pottery on both sides of the Kattegat during the Middle Neolithic. In order to investigate potential contact networks in a longer perspective, Pitted Ware and Funnel Beaker pottery from northeastern Jutland in Denmark and from the Swedish west coast is included.

The Funnel Beaker culture (FBC) in central and southern Scandinavia is dated to the Early Neolithic and the first half of the Middle Neolithic, and its appearance is associated with the introduction of agriculture around 4000 BCE (Malmer, 2002; Welinder, 1998). In its early stages (EN I to MN A II), the FBC is defined by ornamented pottery, funnel-shaped beakers, thin-butted flint axes, causewayed enclosures and megalithic burial monuments (Hallgren, 2008; Sjögren, 2003). The megalithic graves were constructed over a rather short period at the transition between the early and the middle Neolithic periods, 3300–3000 cal. BC (Persson and Sjögren, 1995; Sjögren, 2011). According to current research, the Pitted Ware culture (PWC) existed in Scandinavia at the end of the Early Neolithic and in the Middle Neolithic. It emerged slightly earlier in central eastern Sweden than in the more southerly and westerly parts of the country and in Denmark. The PWC is characterised primarily by pointed- or narrow-based pottery decorated with pit-shaped impressions, cylindrical cores and tanged arrowheads (Edenmo et al., 1997; Larsson, 2009; Papmehl-Dufay, 2006). It is a heterogeneous cultural phenomenon that, in the eastern and central parts of Sweden, is linked to marine hunter groups, while in western and southern Sweden and Denmark it consists of short-lived sites, with a few larger sites in the coastal zones, characterised by a mixed economy (Iversen, 2010, 2015; Strinnholm, 2001). Despite this cultural heterogeneity, similarities between Jutland and southwest Sweden have been observed in subsistence and material culture, including the pottery and flint arrowheads (Iversen, 2013, 2015, 2016; Edenmo et al., 1997; Malmer, 1969; Jennbert, 2015; Rasmussen, 1991; Richter, 1991; Strinnholm, 2001). Contact networks between Jutland, Denmark, and the west coast of Sweden have recurrently been brought forward in Neolithic research, mostly based on similarities in megalithic structures and in artefacts (Kaelas, 1953; Persson and Sjögren, 1995; Iversen, 2013, 2016; Edenmo et al., 1997 etc.).

Provenance studies of ceramics from archaeological sites are useful for identifying networks and mobility during prehistory. The classification of pottery on the basis of typology is an important and

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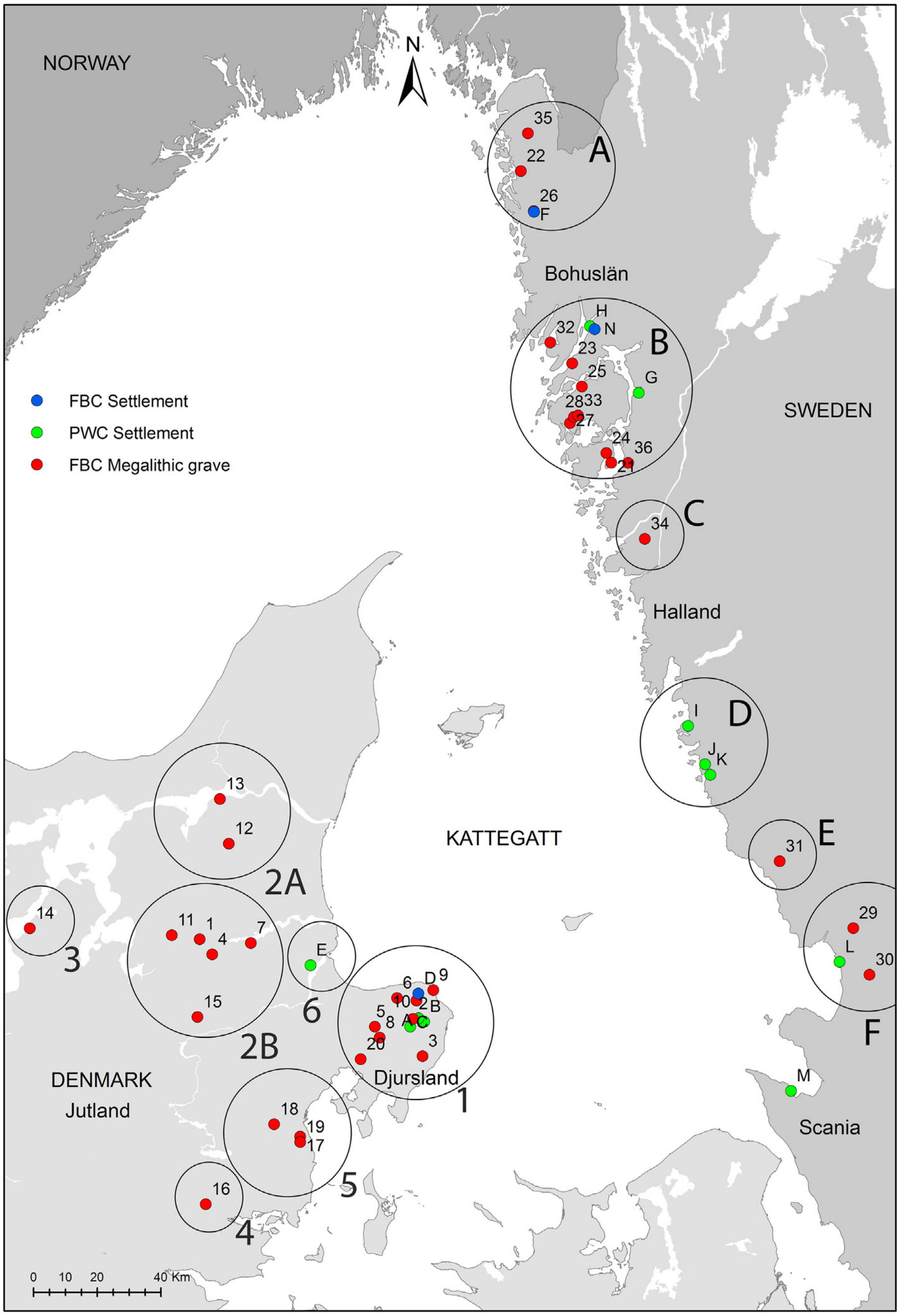

Fig. 1. Provenance of pottery included in this study from different sites and regions in western Sweden and Denmark.
1: Snæbum, Hobro, Spanskhøj & Snibshøj, 2: Skærvad, 3: Lykkesholm, 4: Væggedal, 5: Nimtofte, 6: Birkelund, 7: Voldstedlund, 8: Baunehøje, 9: Gjerrild Klint, 10: Svapkæret, 11: Tulstrup, 12: Hæsum, 13: Bjerglund, 14: Knud, 15: Lee, 16: Lund Skolehave, 17: Hørret Skov I, 18: Ormslev II, 19: Langballe IV, 20: Åkærslund, 21: Valla 98, 22: Lur 43, 23: Bokenäs 43, 24: Valla 50, 25: Röra 39, 26: Tanum 579, 27: Tegneby 54, 28: Tegneby 28, 29: Snöstorp 31, 30: Veinge 64, 31: Årstad 88, 32: Lyse 7, 33: Tegneby 111, 34: Säve 57, 35: Skee 173, 36: Jörlanda 120, A: Kainsbakke, B: Kirial Bro, C: Ginnerup, D: Albæk, E: Højvang, F: Tanum 663, G: Ljung 71, H: Skredsvik 106, I: Värö 202, J: Lindberg 121, K: Lindberg 89, L: Trönninge 22, M: Jonstorp, N: Skredsvik 154. Encircled areas: Geogroups.

established method of interpreting the origin of pottery in time and space. A few chronologies have been published for PWC and FBC pottery; the most important of these, based on pottery from sites in the eastern and southern parts of Sweden, have been presented by Bagge (1951), Bagge and Kaelas (1950–1952) and Malmer (1969). FBC pottery production in Scania has also been described by Hulthén (1977). Recent technical advances have, however, provided improved methods of investigating the raw materials used for ceramics. As a result, more detailed information can be obtained about the production and provenance of pottery by studying its unique chemical composition.

The geology of the Swedish west coast and the northeastern Jutland in Denmark differs significantly which enhances the ability to identify exchange of ceramic pottery by elemental analysis. The geology of Denmark is relatively homogenous and is characterised by a comparatively young carbonate rich basement rocks (Frei and Price, 2012; Larsen, 2006). Northern and central Djursland, where most of the Danish samples derive from, are geological very similar and dominated by Danien limestone (Schack Pedersen and Strand Petersen, 2000). Strontium levels correlate with calcium (Andersson et al., 2014, 136), and for this reason the Danish sherds are expected to show high levels of strontium. Sweden, on the other hand, exhibit a much more complex geology dominated by older Precambrian bedrock. Both regions have, in different degree, been affected by depositions of glacial transported moraines from the last ice ages (Larsen, 2006; Lindström et al., 2000). The Swedish west coast, except for the southwestern part of Scania which is geologically similar to Denmark, consists mainly of granites and gneisses (Andersson et al., 1999; Lindström et al., 2000). In the west coast the calcium and strontium values measured in the moraines are generally low except for in the southwestern Scania (Andersson et al., 2014, 65).

In this paper, the results of ceramics analyses obtained from portable XRF (pXRF), ICP-MA/ES and thin-section analyses are presented.

The pXRF method has, despite its limitations, proved to be an important tool for investigating the provenance of pottery (Hall, 2004; Speakman et al., 2011; Ownby, 2012; Papmehl-Dufay et al., 2013; Eklöv Pettersson, 2013). The ICP-MA/ES and pXRF methods are used to investigate the elemental composition of ceramics and clay. In this case, pXRF analysis was used primarily to identify pottery groups based on their elemental composition and to select sherds for further analysis (thin section and ICP-MA/ES). Thin-sectioning is a well-established method of studying the type of clay and temper used in manufacturing pottery (Hulthén, 1977; Quinn, 2013); these can be important factors when discussing the origin and exchange of ceramic artefacts. An additional aim of this study was to evaluate the various methods employed.

2. Materials

2.1. Ceramic material

Different members of the CONTACT team selected sherds for analysis in Denmark and Sweden. Sampling was based on location in the study area and cultural affinity, as well as access to the material in the different museums. Sherds from Middle Neolithic megalithic graves and settlements were chosen.

The material included in this study consisted of 530 sherds recovered from archaeological sites located in Jutland, Denmark, and along the Swedish west coast (Fig. 1, Appendix 1). Of these, 524 were dated typologically by visual inspection and classified as belonging either to the PWC or the FBC, while six were dated to later periods (the latter are included in Appendix 1, but not commented upon further here). The differences between the PWC and FBC pottery types are often rather small, and it can be difficult to differentiate between them. It should also be noted that the FBC pottery analysed in this study not only included funnel beakers, but also of footed beakers and other vessel types found in or near megalithic graves. A majority of the analysed sherds are dated to the Middle Neolithic but there may also be a few vessels from Early Neolithic classified as Funnel beakers. Most of the sherds have according to the sherd thickness belonged to vessels of medium sizes, aimed for storage and cooking.

The PWC pottery from Denmark was excavated at Middle Neolithic settlements on the Djursland peninsula, while the Danish FBC pottery derives from a settlement and megalithic graves on Djursland and in the northern parts of central and eastern Jutland (Fig. 1, Table 1).

The Swedish PWC pottery included in this study comes mostly from Middle Neolithic settlement sites in Halland, while the FBC pottery was excavated in or by megalithic graves and settlements in Bohuslän and Halland (Fig. 1, Appendix 1).

Most of the FBC pottery derives from numerous megalithic graves in different locations, but pottery from some FBC settlements was also included. In contrast, the PWC pottery derives exclusively from settlement sites (Table 1). There is consequently a structural difference between the FBC and PWC sherd material, in that the FBC material derives from a large number of different sites, with a few specimens from each, while the PWC material comes from only a few sites of a single type (settlements), but with a large number of specimens from each (cf. Tables 1 and 2). Focus of the project has been the relationship of the PWC in the Kattegatt area and that is the reason why the analysed material classified as PWC are much bigger than the FBC material. The rather long time span of the included pottery, as well as possible differences in functions of the vessels etc., are some factors which might affect the variation in the samples (see Results and discussion).

A total of 520 sherds were analysed by pXRF (Table 2, Appendix 1). Of these, 95 were selected for ICP-MA/ES analysis. An additional ten sherds, not analysed by pXRF, were also analysed by ICP-MA/ES (Appendix 1, Table 2). As shown in Table 2, thin sections were examined for 60 of the sherds (Appendix 1). Sampling was based on the results of the pXRF- and ICP-MA/ES-analyses and it was ensured that material from different regions, sites, cultural groups and types of sites (settlements and graves) was represented. One of the sherds (521), the only pointed vessel in the material, was analysed by pXRF at a later stage and was therefore not included in the other types of analyses.

Table 1
Number of included sites in the performed analyses.

	FBC settlements	FBC megalithic graves	FBC sites total	PWC settlements	PWC sites total	Sum
pXRF						
Denmark	1	22	23	4	4	27
Sweden	1	16	17	6	6	23
Sum	2	38	40	10	10	50
ICP						
Denmark	1	8	9	4	4	13
Sweden	0	9	9	7	7	16
Sum	1	17	18	11	11	29
Thin section						
Denmark	0	2	2	4	4	6
Sweden	0	4	4	7	7	11
Sum	0	6	6	11	11	17

Table 2
Number of sherds included in the conducted analyses.

	FBC	FBC?	FBC/PWC	PWC	Other	Sum
pXRF						
Denmark	57	0	0	282	1	340
Sweden	42	3	2	127	6	180
Sum	99	3	2	409	7	520
ICP						
Denmark	12	0	0	41	1	54
Sweden	14	2	0	35	0	51
Sum	26	2	0	76	1	105
Thin section						
Denmark	2	0	0	25	0	27
Sweden	7	2	0	24	0	33
Sum	9	2	0	49	0	60

3. Method

The pottery was studied by pXRF-, ICP-MA/ES - and thin-section analyses.

3.1. Portable XRF

Analysis by portable X-ray fluorescence spectrometer (pXRF) is a non-destructive qualitative and quantitative method, based on X-ray fluorescence, used to measure the elemental composition of different materials. The method is described in detail in Kalnicky and Singhvi (2001). Portable devices (pXRF) were originally designed for the mining industry but have been used to analyse archaeological material since the 1970s (Piorek, 1997). The use of pXRF instruments for archaeological purposes has increased as the technology has developed (Cesaro et al., 1973; William-Thorpe et al., 1999; Buxeda et al., 2003; Emery and Morgenstein, 2007; Hughes et al., 2010; Frahm, 2013). It is now a well-established method in archaeology and is considered to be a suitable alternative to destructive analysis and a way of investigating artefacts that cannot be removed from museum collections.

Most ceramics research based on pXRF analyses concludes that the method is useful for provenance studies, even though it has its limitations and pitfalls (Hall, 2004; Speakman et al., 2011; Ownby, 2012; Eklöv Pettersson, 2013; Papmehl-Dufay et al., 2013; Hunt and Speakman, 2015). Several authors point out that the method is not as sensitive for detecting trace elements and not as accurate as destructive analyses such as ICP MA/ES (Speakman et al., 2011, 3484; Ownby, 2012, Hunt and Speakman, 2015). Speakman et al. (2011, 3484) argue that factory calibrations are not satisfactory for quantification of elements in, for example, pottery. Account must be taken of the fact that pottery is a heterogeneous material consisting of clay and temper. A way of calibrating the instrument has been suggested by Helfert (2013).

The X-rays penetrate 2–5 mm into the material and the area depends on the size of the beam. The use of a large beam size is suggested to average out some of the chemical variability (Speakman et al., 2011, 3495; Ownby, 2012). An uneven surface morphology can cause scattering of the secondary electrons and affect the precision of the data. Another factor that can impact on the results is variation in distance from the sample (Ownby, 2012). Some suggestions aimed at optimising pXRF results are to reduce the distance to the sample and to increase both the duration of the analysis and the number of analyses per sherd (Bergman and Lindahl, 2015).

3.1.1. Implementation

The pXRF method was primarily chosen for its ability to analyse a large number of samples in a rather short time without destroying the sherds. The specific aim was to identify different clusters of ceramics based on their chemical elemental compositions. Consequently, quantification of the various elements was only important in relation to other sherds included in the study. The method was not used as a substitute for other forms of quantitative ceramics analysis, but to complement them. Considering the limitations and uncertainties of this method, careful preparation and implementation were employed to avoid the key problems.

A handheld *Niton XRF-XL3t* was used and a total number of 1491 pXRF analyses were conducted. To avoid inconsistency in the distance from the samples and interference caused by movements and variation in temperature, the device was held stationary in a stand. A large beam of 8 mm was used to average out some of the chemical variability. The sherds were brushed and then cleaned and smoothed using diamond abrasive paper. Areas were selected for analysis that were as flat as possible, without decoration or visible temper. Each spot was analysed with four different filters, concentrating especially on the lighter elements, for 380 s (recommended settings by Laboratory for Ceramic Research, Lund University; see also Papmehl-Dufay et al., 2013, 130; Bergman and Lindahl, 2015). Each sherd was analysed in at least two or three different areas.

The data from the pXRF analysis were adjusted and Excel spreadsheets were prepared for the multivariate statistical software MVSP. Principal Components analyses (PCA) (centred data, standardised data, no data transformation and axes to extract used Kaiser's rule) were performed and bivariate scatter plots created. The PCAs were performed on all the detected elements (Ba, Nb, Zr, Sr, Rb, Bi, As, Pb, Zn, Cu, Fe, Mn, Cr, V, Ti, Ca, K, Al, P, Si, Cl, S, Mg, Sb, Sn, Cd, Pd, Ag, Mo, Se, Au, W, Ni, Co), with the exception of magnesium which have shown to be unsuitable for pXRF studies (Helfert, 2013). In addition, analyses were conducted exclusively on a few selected elements (Al, Cr, Mn, V, Ca, Fe, Sr, Co and As), some that were also included in the ICP-MA/ES analysis. These elements were chosen as they, in this case, are considered to be affected by the local geology and not so much of the ceramic composition.

The mean and standard deviation of different elements were calculated for all the sherds (Appendix 2). Furthermore, the mean and standard deviation of the selected elements were calculated for the different cultural affiliations and locations (Table 4, Appendix 3).

A large number of different statistical analyses were performed, whereby various categories were compared (Danish vs. Swedish finds, Pitted Ware vs. Funnel Beaker finds, different regions, different locations and different geogroups). Geogroups were defined on the basis of the geographical proximity (clustering) of different sites as shown in Fig. 1. The geogroups are medium-sized geographical units independent of administrative boundaries. An extensive number of PCA and bivariate plots were conducted, although only a few could be included in this paper.

The pXRF data were primarily used as a tool for selecting sherds for further analysis. Several sherds that deviated from the normal group were selected, as well as sherds within the normal group for their category or location. The sherd from the pointed bottom from Kirial Bro (521) was analysed at a later stage and was therefore not included in the ICP-MA/ES and thin-section analyses.

3.2. ICP-MA/ES

ICP-MA/ES analysis of pottery has been used in the United States since the late 1980s, and in Europe since the 1990s (Thompson and Walsh, 1989; Vince, 2008). Like many other methods, ICP-MA/ES was primarily developed in other research areas. The usefulness of analysing ceramics with ICP-MA/ES is, however, now well established. In a recent study, rather large amounts of Scandinavian pottery have also been analysed (Brorsson and Ytterberg, 2018). Only a few studies have, however, been undertaken of Neolithic pottery, but with very good results (e.g. Brorsson, 2015). These have shown, among other things, that the impact of added or natural temper on the results of the analysis is insignificant.

3.2.1. Implementation

A total of 105 sherds have been subjected to ICP-MA/ES analysis (Table 2). This enabled the identification of non-organic elements, which were subsequently utilised to allocate the individual samples to distinct reference groups.

A minimum of 0.5 g of sample material was taken from each sherd. This was ground into a fine powder and dissolved in an acid solution, which was then injected into excited argon plasma. When atoms are targeted with this massive energy, the electrons produce coloured rays which are unique to each individual element. The spectrum of atomic emissions can subsequently be measured by MA/ES (Mass Atomic Emission Spectrometry). The studied non-organic elements which are used in the analyses are the post-transition metals aluminium (Al), chrome (Cr), gallium (Ga), manganese (Mn) and vanadium (V); the alkaline earth metals calcium (Ca), magnesium (Mg) and strontium (Sr); the lanthanide lanthanum (La); the alkaline metal sodium (Na) and the transition metals, niobium (Nb) and cobalt (Co). The massive amount of data was processed using the software SPSS statistics, which generates cluster analyses and dendrograms. The ICP-MA/ES-analyses were carried out by OMAC Laboratories Ltd. in Loughrea, Galway, Ireland.

3.3. Thin-section analysis

Thin-section analysis is a well-established method in scientific investigations of prehistoric pottery in Scandinavia. The first analyses were carried out here as early as in the 1920s (Bøe, 1931) and it became the most common scientific technique for studying pottery in the 1970s (e.g. Hulthén, 1977).

Thin sections enable identification of the type of clay and temper used in pottery. A thin section, which is exactly 0.03 mm thick, is made from the sherd and studied under a polarising microscope. Here it is possible to identify minerals in the silt and sand fractions. It is also possible to study different structures in the ware, such as vessel-forming techniques, and to distinguish between added and natural temper, as well as the amount and grain size of this material, and detect organic matter, for example diatoms, plant material etc. Sherds with the same type of clay and temper could be originating from the same production area.

Table 3
Sherds deviating from the general cluster in the PCA plot.

Sherd no	Site	Culture affiliation	High levels	Low levels	Sherd Cluster
239	Kainsbakke	PWC	Sr, Ca		1
235	Kainsbakke	PWC	Sr, Ca		1
231	Kainsbakke	PWC	Sr, Ca		1
141	Kainsbakke	PWC	Ca, Co	V, Mn, Al	1
142	Kainsbakke	PWC	Ca		1
143	Kainsbakke	PWC	Ca	V, Mn, Al	1
146	Kainsbakke	PWC	Ca, Co	V, Mn	1
161	Kirial Bro	PWC	Sr, Ca	Mn, Fe	1
493	Trönning	PWC	As, V, Fe	Sr	2
363	Hørret Skov	FBC	V, As, Fe, Cr	Ca, Mn	2
497	Trönning	PWC	V, As		2
498	Trönning	PWC	V, As, Fe	Sr, Al	2
384	Højvang	PWC	V, As, Fe	Sr	2
521	Kirial Bro	PWC	As, Fe, V	Ca, Mn	2
472	Lindberg	PWC	Co, V, As		2
477	Lindberg	PWC	Co, Fe, Al	Sr, Mn	2
478	Lindberg	PWC	Co, V, As, Fe, Al	Sr, Mn	2
380	Højvang	PWC	V, As, Fe	Sr	2

4. Results

4.1. pXRF

The elemental composition of the sherds from the different countries, regions, locations and cultures was quite similar, considering the variability within the different categories. It was therefore problematic to distinguish any discrete groups. Most of the pottery plotted in one large cluster in the PCA, even though some of the sherds deviated from this group (Table 3).

In the PCA plots and in simple plots, the Swedish and Danish sherds overlapped to a great degree. As can be seen in Fig. 2, the deviant sherds forming cluster 1 are exclusively from Danish sites and extend in the opposite direction to cluster 2. The first cluster, is bordered mainly by PWC sherds from Kainsbakke and Kirial Bro, Djursland and contains sherds from these two sites (Table 3, Fig. 2). Cluster 2, includes several PWC sherds from Halland, Sweden and two Danish PWC sherds, one from Højvang (384) and one from Kirial Bro (521) (Højvang is located at randers Fjord just west of Djursland). Furthermore, a FBC sherd (363) from Hørret Skov, close to Aarhus, Denmark, is placed among the deviating sherds of this cluster (Table 3, Fig. 2). A large number of sherds from the PWC settlements of Trönninge and Lindberg (Halland, Sweden) lie next to cluster 2, together with several sherds from the Danish PWC settlement of Højvang and a single sherd from Kirial Bro (Table 3, Fig. 2).

The FBC and PWC sherds overlap to a great degree in the PCAs (Fig. 3). Despite originating from a much larger number of sites than the PWC sherds, the FBC sherds had elemental components that were more homogenous than those of the PWC. The greater compositional variation of the Pitted Ware pottery, compared with that of the FBC, is even more conspicuous when the analysis is restricted to the Swedish FBC and PWC sites (Table 1; Fig. 6).

The variation within the different categories also appears when statistics of the selected elements are compared between these groups (Table 4). As can be seen from Table 4, some of the Swedish pottery has slightly higher concentrations of aluminium and cobalt than the Danish material, while the Danish sherds have significantly higher levels of calcium than those found in the Swedish pottery. There is a tendency of lower strontium, iron and manganese levels in the FBC sherds than in the PWC ones, and detectable levels of cobalt were only found in Pitted Ware pottery (Table 4). The Danish FBC and PWC pottery overlaps, even though clear differences can be observed. The Danish FBC sherds have generally lower strontium and calcium levels and higher chromium levels than the PWC ones (Table 4). The lower levels of Ca and Sr can be a consequence of the different locations of the FBC and PWC sites (Fig. 1, see below), but might also be a result of an active choice of

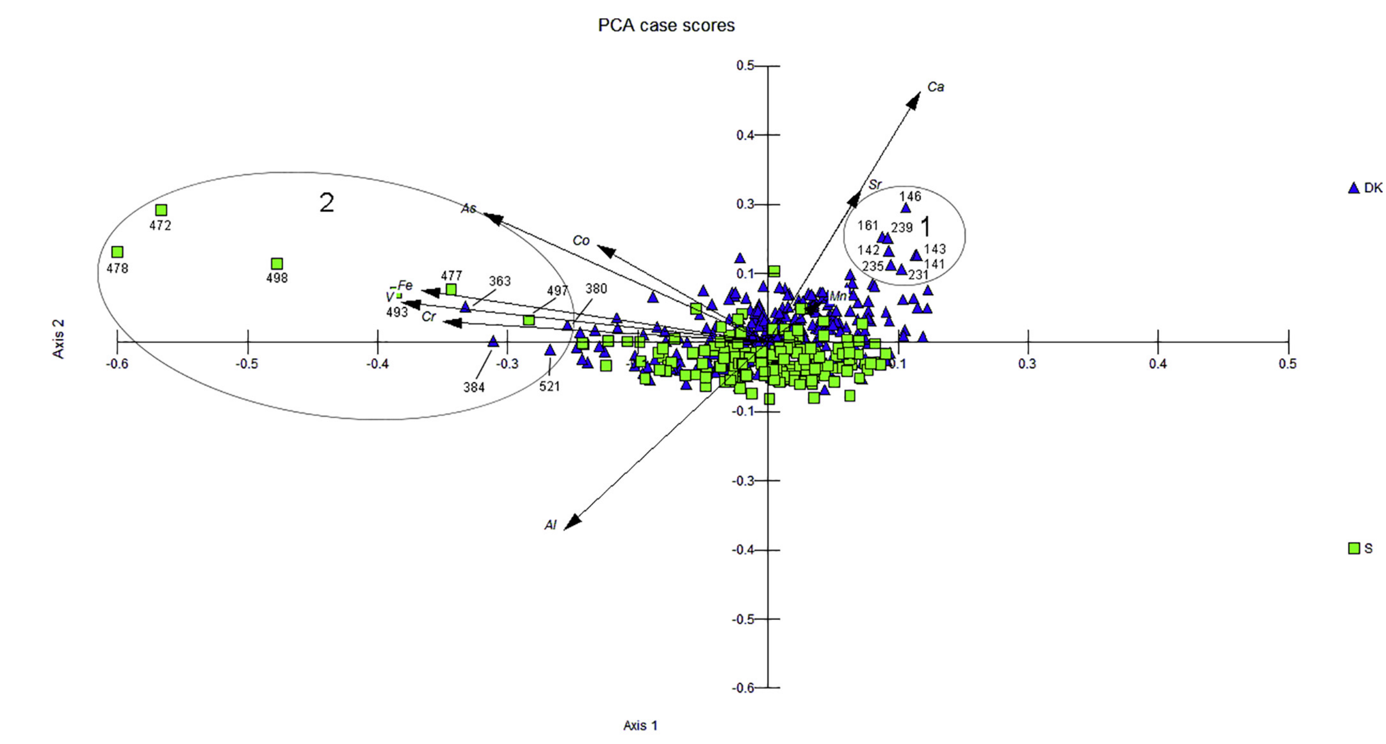

Fig. 2. PCA plot of selected elements by pXRF analysis for comparison of Swedish and Danish sherds.
DK: Sherds from Denmark. S: Sherds from Sweden, 1 and 2: Clusters from Table 3.

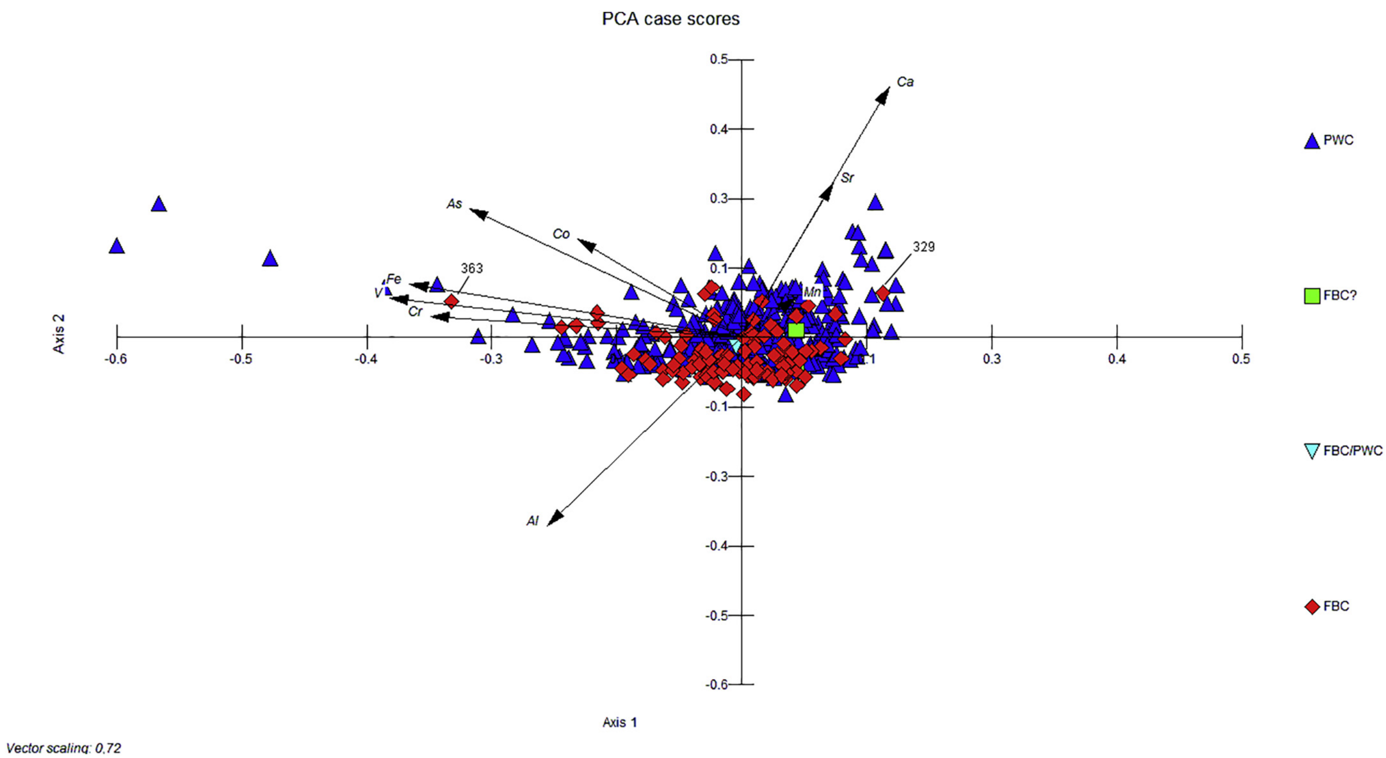

Fig. 3. PCA plot of selected elements of the Swedish and Danish sherds for the two cultural groups. PWC: Pitted Ware culture sherds; FBC: Funnel Beaker culture sherds.

Table 4
Median and Mean percentage values, with standard deviation, for selected elements in different categories.

Category	Statistics	Sr %	V %	As %	Cr %	Fe %	Mn %	Ca %	Al %	Co %
PWC (DK + S)	Mean	0.0109	0.0196	0.0007	0.0175	4.6237	0.1007	2.0572	4.9606	0.0003
N:410	Standard deviation	± 0.0035	± 0.0044	± 0.0003	± 0,0019	± 0.8915	± 0.0685	± 1.4465	± 0.6194	± 0.0032
	Median	0.0103	0.0190	0.0007	0.0175	4.5239	0.0876	1.5795	4.9814	0
PWC (DK)	Mean	0.0106	0.0192	0.0007	0.0177	4.5262	0.1039	2.6139	4.8349	0.0001
N:282	Standard deviation	± 0.0027	± 0.0032	± 0.0002	± 0.0018	± 0.6062	± 0.0609	± 1.4224	± 0.6066	± 0.0008
	Median	0.0103	0.0190	0.0007	0.0177	4.5395	0.0891	2.4364	4.8296	0
PWC	Mean	0.0117	0.0205	0.0007	0.0172	4.8520	0.0945	0.8334	5.2330	0.0009
(S)	Standard deviation	± 0.0048	± 0.0062	± 0.0004	± 0.0022	± 1.2917	± 0.0827	± 0.2404	± 0.5552	± 0.0055
N:127	Median	0.0105	0.0191	0.0006	0.0168	4.5131	0.0786	0.8017	5.2612	0
FBC (DK + S)	Mean	0.0093	0.0201	0.0008	0.0176	4.3928	0.0850	0.7515	5.1005	0
N:103	Standard deviation	± 0.0042	± 0.0028	± 0.0004	± 0.0020	± 0.6285	± 0.0699	± 0.3103	± 0.7027	
	Median	0.0081	0.0197	0.0007	0.0172	4.3029	0.0584	0.7161	5.1696	
FBC	Mean	0.0091	0.0208	0.0009	0.0182	4.3591	0.0873	0.7117	4.9926	0
(DK)	Standard deviation	± 0.0051	± 0.0032	± 0.0005	± 0.0020	± 0.6930	± 0.0693	± 0.3850	± 0.5825	
N:57	Median	0.0073	0.0201	0.0008	0.0178	4.2080	0.0604	0.5928	5.0353	
FBC	Mean	0.0095	0.0192	0.0006	0.0168	4.3460	0.0821	0.8010	5.2342	0
(S)	Standard deviation	± 0.0028	± 0.0019	± 0.0001	± 0.0017	± 0.5428	± 0.0712	± 0.1713	± 0.8149	
N:47	Median	0.0088	0.0189	0.0006	0.0166	4.3100	0.0573	0.8079	5.3807	

clays types in the two cultural complexes.

When the Swedish FBC sherds were plotted against the Danish FBC examples in the PCA, both groups overlapped to some extent, but the Danish sherds were more scattered. Two of the Swedish FBC sherds, both from Årstad, deviated from the others: 318 (high Ca) and 319 (high Al) (Appendix 3). The Danish and Swedish PWC sherds overlapped to a greater degree than the Danish and Swedish FBC sherds. The Danish PWC sherds have, however, more varied and generally higher levels of calcium (Table 4), whereas the Swedish PWC sherds have slightly higher levels of cobalt and aluminium (Table 4). A likely explanation is that most of the Swedish PWC sites are found in geogroup D, where the moraines contain higher levels of cobalt, compared to the other areas (Andersson et al., 2014, 70). The higher levels of calcium in the Danish sherds could be explained by the geology of the Djursland peninsula, where most of the Danish sherds were found, as this consists of Danien limestone (Schack Pedersen and Strand Petersen, 2000, 22; Frei and Frei, 2011), while the Swedish west coast mainly consists of granite and gneiss and moraines with rather low calcium concentrations (Andersson et al., 1999; Andersson et al., 2014:63). Most of the Danish FBC sherds derive from sites located in the areas less dominated by the Danien limestone basement (Larsen, 2006), which might explain why these sherds measured lower calcium and strontium values then the Danish Pitted ware ones.

The elemental values for the sherds from Kainsbakke in Djursland showed the greatest scatter on analysis plots. It is important to point out, however, that Kainsbakke is the locality with by far the largest number of analysed sherds (170). The only distinct group observed comprises the results for the PWC pottery from the Højvang settlement in Jutland. Many of the Kirial Bro and the Kainsbakke sherds, as well as several sherds from the nearby settlement Ginnerup (all on Djursland), were quite similar. This could be the result of regional exchange or the use of raw materials from the same places and/or geological similarities. These three lie only a few kilometres from each other. The PWC settlement of Højvang, on the other hand, is located further west (Fig. 1). As mentioned above, the calcium levels detected in the Danish PWC showed greater variation and were generally higher, something which might be explained by a more heterogeneous pottery production and/or an increased exchange of pottery during this period or within this cultural complex.

Despite the large variation found in the elemental composition of the pottery from Kirial Bro, Kainsbakke and Ginnerup, the sherd from the pointed vessel from Kirial Bro (521) still differs significantly from the sherds from these regional PWC sites (Table 1; Appendix 3). The calcium level is relatively low and more similar to the levels measured in the TRB pottery from some parts of Jutland and the sherds from the Swedish west coast, although the other elements did not match. Considering all measured elements the composition of the PWC pointed vessel is most similar to the PWC Højvang sherds in Jutland and the Swedish PWC pottery, especially from geogroup F in southern Halland (Figs. 2, 4; Table 4; Appendix 3).

Sherd number 331 is the only sherd in the study from the central part of Jutland (found at Røddinge, Knud). Geological differences between this area and the eastern part of Jutland (see Frei and Frei, 2011) probably affected the elemental composition of the local clay, thereby explaining why it deviates from the rest of the pottery sherds (Fig. 5, Appendix 3). This FBC sherd has higher calcium values, compared to other Danish FBC sherds, and resembles the Danish PWC pottery in this respect (Appendix 3). Other FBC sherds that plot closer to the PWC pottery are sherd number 329 from a collared flask (Ginnerup, Skærvad dolmen), dated to EN II, and sherd 347 from a passage grave at Nimtofte (Appendix 3; Figs. 3, 4). Both of these originate from Djursland, in the same geogroup (1) as the PWC sites, and the similarities may therefore be explained by the local, comparatively homogenous geology.

The strontium levels in the sherds from the Aarhus region (geogroup 5 in Fig. 1 and Appendix 2) include both the lowest and the highest values measured. The sherds derive from three megalithic graves in a limited geological area (see Fig. 1). Sherd 364, with high levels of strontium, is one of two analysed sherds from the Ormslev dolmen, which is located further inland than the other two sites in the Aarhus region (Figs. 1 and 5). The difference between strontium levels of the two sherds from Ormslev might therefore be due to different provenances of the pottery or clay. Compared with the other regions, both in Denmark and Sweden, Geogroup 5 have slightly higher arsenic values (Appendix 3). The As levels in the Swedish and Danish soils are generally low, although higher in the south eastern part of Jutland (Andersson et al., 2014; 32). As indicated by Table 3 and Fig. 2, sherd 363 from this area, deviates from the rest and seems closer to some of the sherds from Halland and Højvang. However, it contains very high levels of As and therefore it is plausible that it originates from further south instead.

It is difficult to identify any groups in the Swedish sherds based on geographical location. This could be a result of the many different sites that were included in the sampling. In Fig. 6, a tendency towards a division between the two provinces Bohuslän (geogroups A, B, C) and Halland (geogroups D, E, F) can be seen. The two cultural groups, FBC and PWC, are geographically distinct in the Swedish material, as most of the included FBC sherds are from Bohuslän, while the majority of the PWC sherds derive from the more southerly province of Halland.

The geogroup D, is deviaded into two sections: the Lindeberg sherds which plot with geogroup F and the Värö pottery which plot in the other direction with higher Sr, Ca and Mn (Fig. 6). There is a group of sherds from Trönninge and Lindberg in Halland that stands out, with detectable concentrations of cobalt and high levels of vanadium, arsenic and iron (Table 3, Appendix 3). The highest concentrations of strontium were found in Värö, Bohuslän (Appendix 3; Fig. 6). There are several sherds with concentrations of one or more elements that differ from the average for the sites where they were found (Appendix 3). For

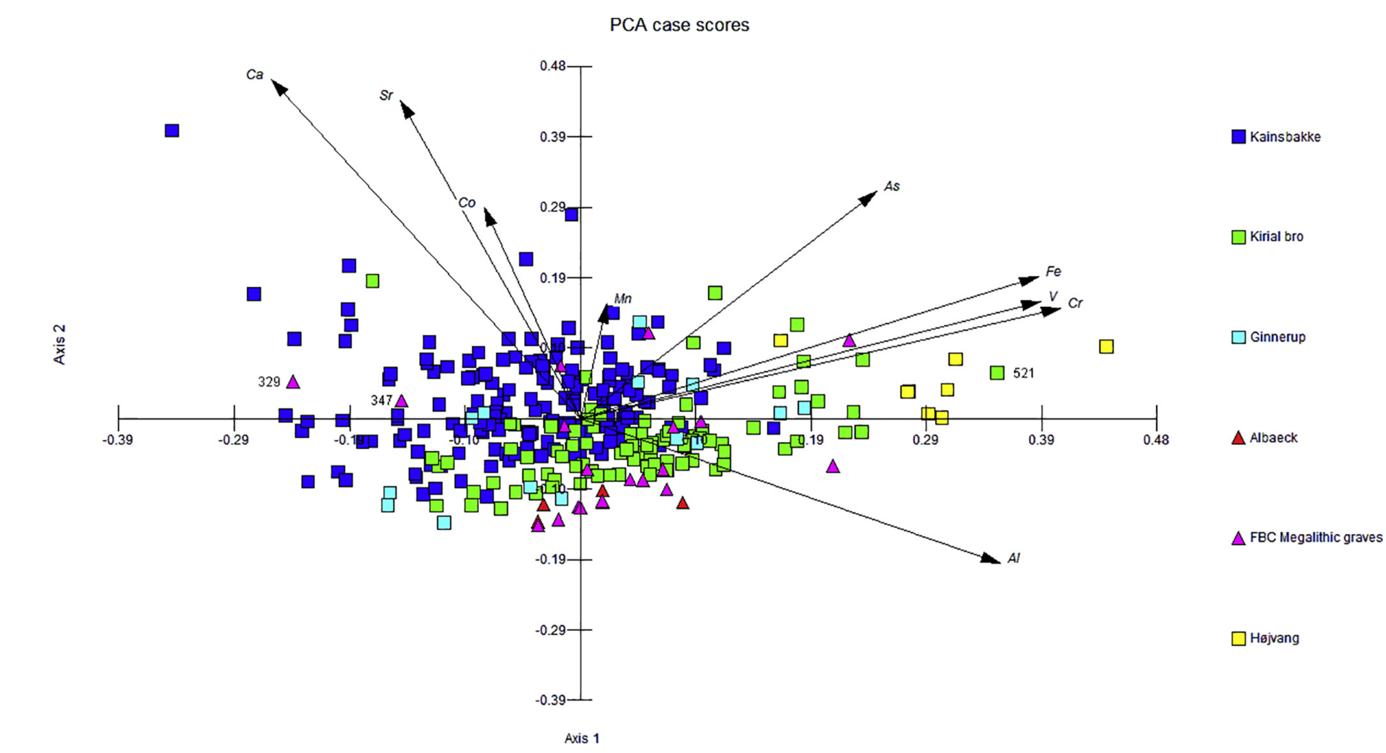

Fig. 4. PCA plot of selected elements (Danish sherds) by pXRF analysis, for comparison of geogroups. Sherds from PWC sites are marked by squares and from FBC sites by triangles.

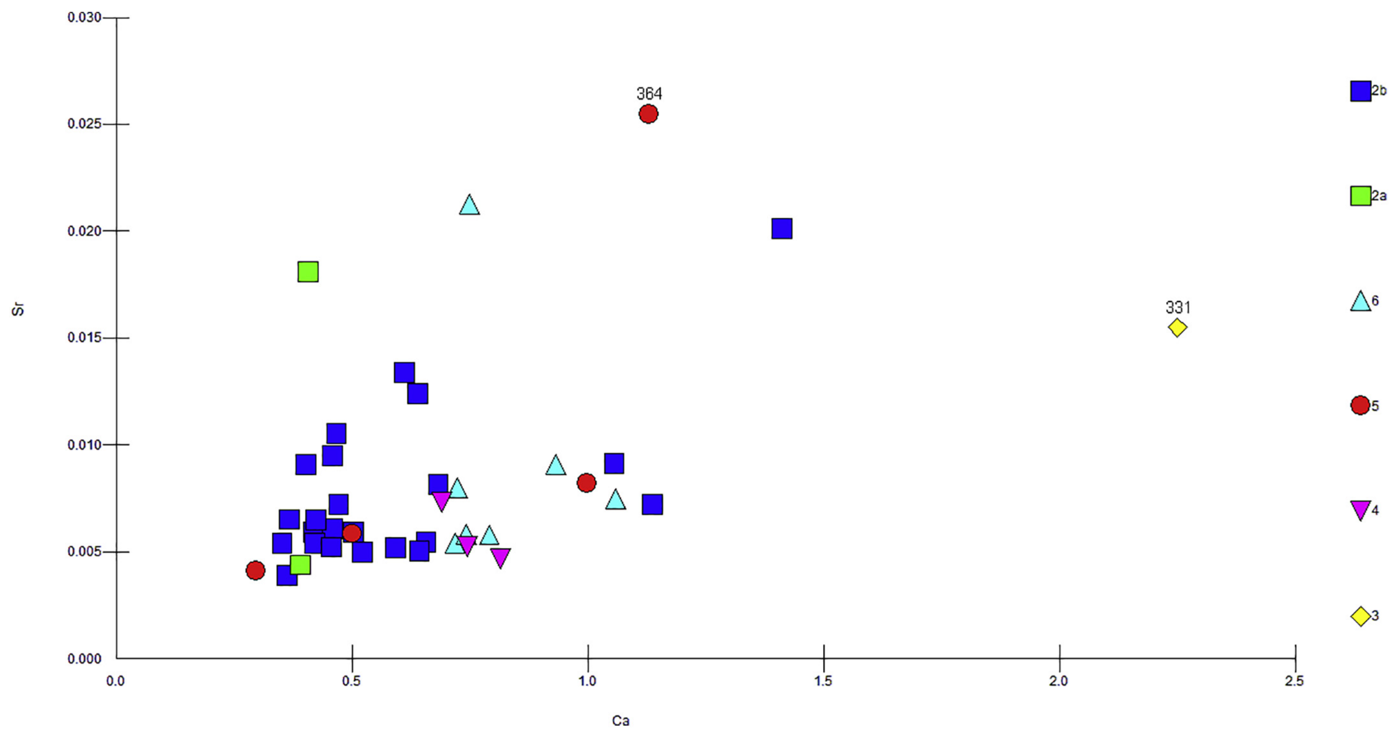

Fig. 5. Bivariate scatterplot for strontium and calcium comparing geogroups 2–6, Denmark.

example, in the passage grave of Bokenäs, Bohuslän, one of the sherds (281) deviates from the others, displaying higher concentrations of chromium and iron and lower levels of silicon (Appendix 3). As shown in Fig. 6, FBC sherd 281 is closer to the PWC in Halland than to the Bohuslän pottery.

Based on these results, sherds within the normal group for their category and/or location, sherds deviating from these, and sherds that plotted closer to opposite categories or other locations (potentially exchanged items) were sampled for further analysis (Appendix 3). An even distribution of PWC and FBC sherds was also aimed for, within each country. It is important to stress that the selected sherds do not represent the same variation, as they only represent some of the pottery analysed by pXRF and as the two different methods do not detect exactly the same elements. Therefore it is important to keep in mind how

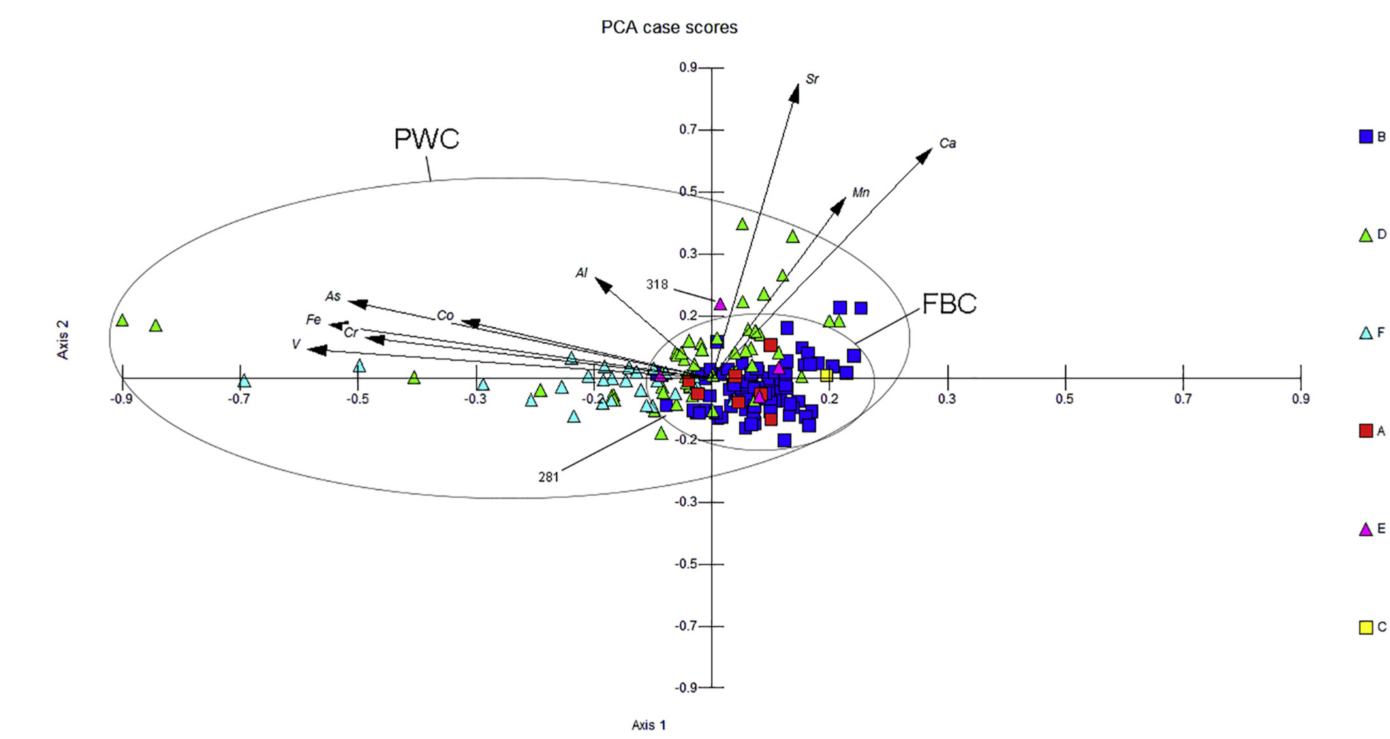

Fig. 6. PCA plot of selected elements, for all Swedish sherds, comparing geogroups. Geogroups A, B and C lie within the Bohuslän province (squares), while geogroups D, E and F are situated in the province of Halland (triangles).

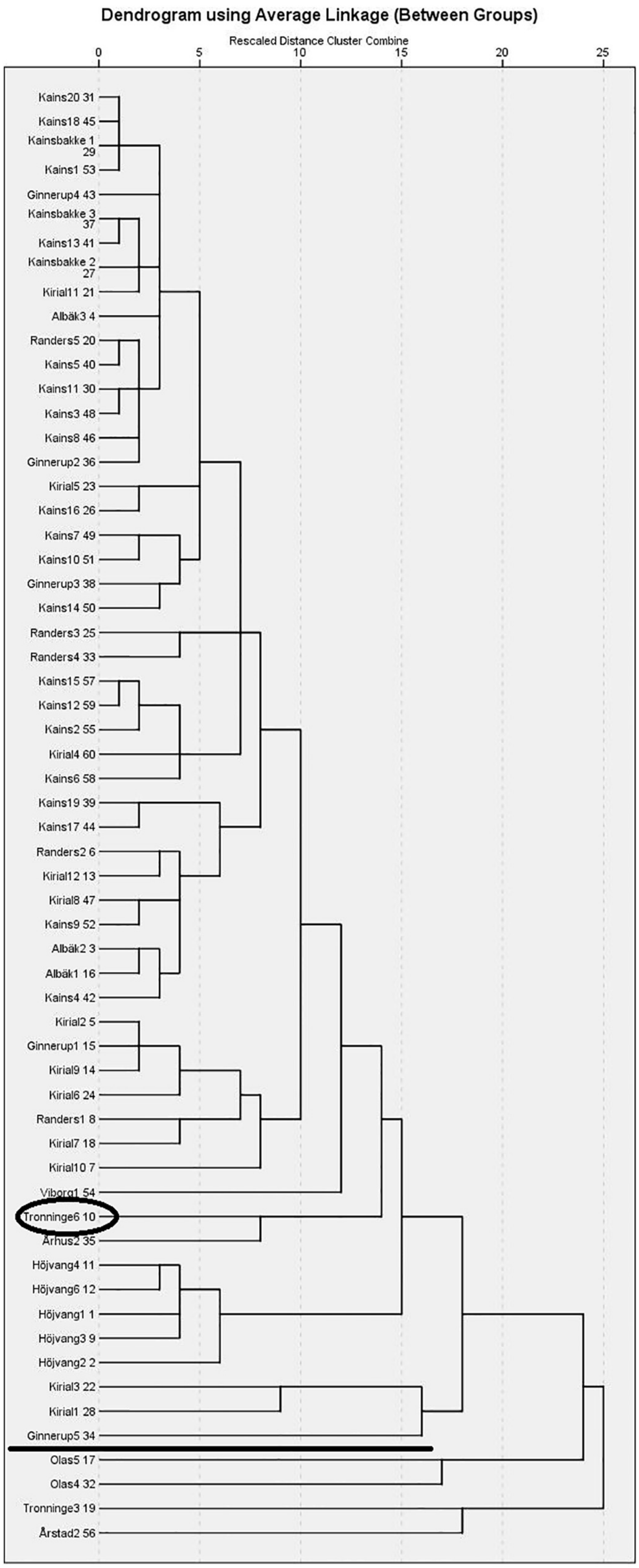

Fig. 7. Result of the ICP analysis of Danish sherds, together with five sherds from western Sweden. The PWC sherd Trönninge 498 was made of raw material similar to that used for some of the Danish pots. Four of the Swedish sherds (at the bottom) show no similarities with the Danish pottery.

these sherds relate to their local groups (Appendix 3).

4.2. ICP-MA/ES results

A total of 105 sherds were subjected to ICP-MA/ES analysis (Appendix 4). Because ICP analysis results in a very large amount of data, a meaningful analysis is not possible when all the sample results are investigated together. The statistical analyses were conducted separately on the data for the Danish and the Swedish pottery. The sherds that deviated from their respective groups on each side of the Kattegat were then compared with the pottery from the other side, with the aim of identifying possible incidences of pottery exchange across the Kattegat.

In a first stage, 58 sherds from Jutland in Denmark were analysed. The PWC sherds from Kainsbakke and Kirial Bro were very similar and belonged to the same group. PWC and FBC pottery from Albaek, Ginnerup, the Aarhus region, Røddinge, Snibshøj, Nimtofte, Birkelund, Baunehøje and Spanskhøj fell into another major group. The data for the PWC sherds from the Højvang settlement, which is in the same geogroup, deviate significantly from this main Danish group and itself forms two distinctive subgroups. In between these two subgroups lies a FBC sherd (363) from Hørret Skov, close to Aarhus. This sherd has a lower calcium content and higher chromium levels than other Danish sherds (consistent with the pXRF results; Appendix 3). The data show that the vessel from Hørret Skov may have been manufactured near the site of Højvang, but it is not possible to rule out a different provenance, as previously suggested (pXRF results). Højvang deviate from the other sherds from Denmark shows that this pottery was probably produced from raw materials obtained in the vicinity of the settlement. It can be seen that the calcium content of the PWC pottery found at Kirial Bro and Kainsbakke is more than twice that found in the PWC pottery from Højvang. This difference can also be seen in the aforementioned XRF data (Appendix 3, Table 4), and most likely reflects the geologically confirmed presence of limestone in the subsoil of the Kainsbakke-Kirial Bro region.

Fifty sherds have been analysed from the Swedish side of the Kattegat from localities extending from Scania in the south to Bohuslän in the north. The majority of these form several related groups (45 sherds in total), while five others differ somewhat. The greatest deviation is shown by a FBC sherd from Årstad in Halland (318) and two PWC sherds from Värö in Halland (430, 436). Two other PWC sherds from Trönninge (495, 498), from the same province, constitute a group on their own (cf. pXRF results above). The other Swedish ceramics form groups with no clear relationship to the various provinces, i.e. there are sherds belonging to vessels from different regions within the same analytical groups. However, several of the Bohuslän sherds form part of one, larger group while pottery from the same megalithic grave at Bokenäs displays varying results (see also pXRF result above). Sample 281 from Bokenäs, in particular, indicates that some of the pottery at this site may have a non-local provenance, most likely somewhere in western Sweden.

There are different elements which indicate that not all vessels from specific sites, for example Värö or Trönninge, originated from the same production sites. Trönninge sherd 498 has a high level of niobium (Nb), whereas Trönninge sherd 495, has high levels of lanthanum (La). Värö sherd 430 contains a large amount of strontium (Sr), while in Värö sample 436, both strontium (Sr) and calcium (Ca) levels are high. The large amount of strontium was also detected in these two sherds in the pXRF analysis (Appendix 3). Årstad sherd 318 is quite different from the others since its fabric contains a high amount of calcium (Ca), cobalt (Co) and magnesium (Mg). Årstad sherd 318 also deviated from the other sherds in the pXRF analysis (see pXRF results).

The outliers in each region have been compared to sherds from the opposite side of the Kattegat. This comparison revealed no similarities between the divergent sherds from Denmark and the main Swedish group, consisting of 45 sherds. There is consequently no evidence whatsoever in the data of this study to indicate pottery exchange across the Kattegat from western Sweden to Denmark. When looking for possible exchange in the opposite direction, it can be stated that a PWC pot from Trönninge in Halland (498) is very similar to FBC pottery found at Røddinge and in the Aarhus region. This sherd could therefore have belonged to a vessel that was made somewhere in Denmark (Fig. 7). It must also be stated that all the steps and the interpretations of the ICP analysis have not been possible to publish because it would have taken too much space and it is mainly the more obvious results that have been possible to publish in this article. However, all the data are present in Appendix 4.

A closer look at the samples from Halland and Scania in Sweden demonstrates that there are no major differences between the sites and that it is not possible to distinguish the Jonstorp pottery found in Scania from the samples found in Halland. However, there are a few sherds from vessels that appear not to have been manufactured in Halland; these come from the PWC settlement at Trönninge (495) and from the megalithic grave at Snöstorp (311). Of the pottery from Bohuslän, a sherd from a pot found in a megalithic grave at Bokenäs (281) differs from the others, as does another sherd from a PWC settlement at Ljung (511). Both of these vessels could actually have been made in Halland. Especially calcium was an important element in the process of distinguishing the different sherds from each region, but the amount of strontium was also central.

4.3. Thin-section analysis

Thin-section analyses or petrographic studies were carried out on a total of 60 potsherds from Denmark and Sweden. Microscopy of the clay type and the added or natural temper has been made (Appendix 5). The sampling was undertaken on the basis of the results obtained from the pXRF and ICP-MA/ES analyses. The main aim of the thin-section analysis was to identify any differences in the choice of clay and temper between the sherds and whether or not there was a correlation between any evident differences and the results of the pXRF and ICP-MA/ES analyses.

The thin-section analyses show that the pottery from Denmark and Sweden is rather homogenous and there are no sherds that deviate significantly from the others. The clays used to make the pottery were fine, medium or coarse and were tempered with either granite or quartz. Calcium (calcite, sea shells or bone), in particular, is very common as a tempering agent in the Pitted Ware pottery in eastern Sweden, but very rare in the western part of the country (Strinnholm, 2001, 46; Brorsson and Ytterberg, 2018). The present analyses confirm this picture. It can be seen that all the sherds that were associated with the FBC and PWC were of a ware that was tempered with crushed rock. No sand tempering, calciferous tempering or naturally tempered clay has been identified. Calcium has been identified in the pXRF- and ICP-analyses but it has not been identified in the microscopy. Calcium was most likely not added to clay, and it may occur naturally.

The 60 investigated sherds have been divided into four different groups, based on the coarseness of the clay (Fig. 8). Fourteen of the sherds were made of fine, dense clay, 33 of silty fine clay, nine of medium-coarse clay and only four vessels were made of coarse clay. The latter group exclusively comprises sherds from PWC pots found at Kainsbakke and Kirial Bro. These pots were also tempered with crushed quartz, which shows that their fabric was very coarse. The medium-coarse clays comprised eight PWC from Kainsbakke (3), Kirial Bro (1), Ginnerup (2) and Trönninge (2) and a FBC example from a dolmen at Årstad in Halland. The Årstad sherd 318 also differed from the others in both the pXRF and the ICP-MA/ES analysis. The two fine-clay groups include both FBC and PWC pottery from Denmark and Sweden and it has not been possible to subdivide these groups further. The FBC sherds with fine clay originate from several megalithic graves and two settlements.

An important result of our study is its demonstration that the FBC and PWC pottery was manufactured in the same way, and that either quartz or granite was used as temper (contrary to what has been observed for the eastern Swedish PWC – see above). One detail usually associated with FBC pottery is that the temper was often sieved before it was added into the clay (Brorsson, 2010, unpublished manuscript). In this study this technique has been identified not only in the FBC pots, but also in the PWC pottery. The average size of the largest temper grains within each cultural group is 3 mm for the PWC and 2.8 mm for the FBC pottery. Furthermore, the mean temper contents have been found to be 14.8% (PWC) and 12.6% (FBC). These figures clearly demonstrate that there are no clear differences in the added temper between these two cultural units. There is, however, a significant difference in the choice of clay. While more or less all FBC vessels were made of fine clay, medium-coarse or coarse clay was used to a significant degree in the production of PWC vessels. Most of these coarse-fabric vessels originate from the settlements at Kainsbakke, Kirial Bro and Ginnerup, on Djursland.

Three different hypotheses can explain the observed differences in the choice of clay for vessel production in the FBC and PWC:

1. The vessels made of medium-coarse or coarse clays have a different provenance. This possibility is, however, contradicted by the compositional analyses (pXRF and ICP-MA/ES).
2. The vessels may have been manufactured within the same settlement, but by different groups of people.
3. The vessels from the same settlement had different functions and therefore the potter chose different types of clay. A coarse clay is, for example, more heat-resistant than a fine clay.

It is important to note that the differences between the clay used in the FBC and PWC pottery cannot be explained by the finds contexts of the vessels. The absolute predominance of fine clay in the FBC pottery is not due to only pottery from graves being investigated, as two of the 11 FBC sherds analysed were found on settlements (Appendix 1). Furthermore, the use of fine clay in the FBC has also been demonstrated in previous studies of FBC pottery from western Sweden, for example Early Neolithic Funnel Beakers from Veddige in northern Halland and Björlanda on Hisingen in northern Gothenburg (Brorsson, 2009, unpublished manuscript).

The reason why different types of clay were used during the PWC is therefore either that the vessels were produced by different groups of people or that they had different functions.

5. Discussion

Overall, the results of this investigation of PWC and FBC pottery from western Sweden and northeastern Jutland, by way of three different techniques (pXRF, ICP-MA/ES, thin-section analyses), are very consistent with each other. No significant differences were observed between the FBC and PWC sherds. However, the thin sections indicated that the FBC pottery is similar to other FBC pottery found in western Sweden, while the PWC pottery differs from those of eastern Sweden.

All three analyses, and especially the thin-section analyses, show a more heterogeneous pottery production in the PWC than in the FBC. Virtually every sherd that was classified as belonging to the FBC was made of fine clay, while the PWC pots were made of fine, medium-coarse or coarse clay. As already mentioned, the PWC complex is often described as a rather diverse cultural phenomenon (Iversen, 2016, 69; Strinnholm, 2001, 123), which could, to some degree, explain the variability in the choice of clay and temper. However, the results of all three methods show that the PWC pottery is more heterogeneous than the FBC pottery, even though it originated from fewer sites. Furthermore, large variations were even observed within pottery from the same PWC site. A source critical aspect may be added into this discussion and it is that there were more sherds from the PWC analysed that sherds belonging to FBC. However, other studied that already been

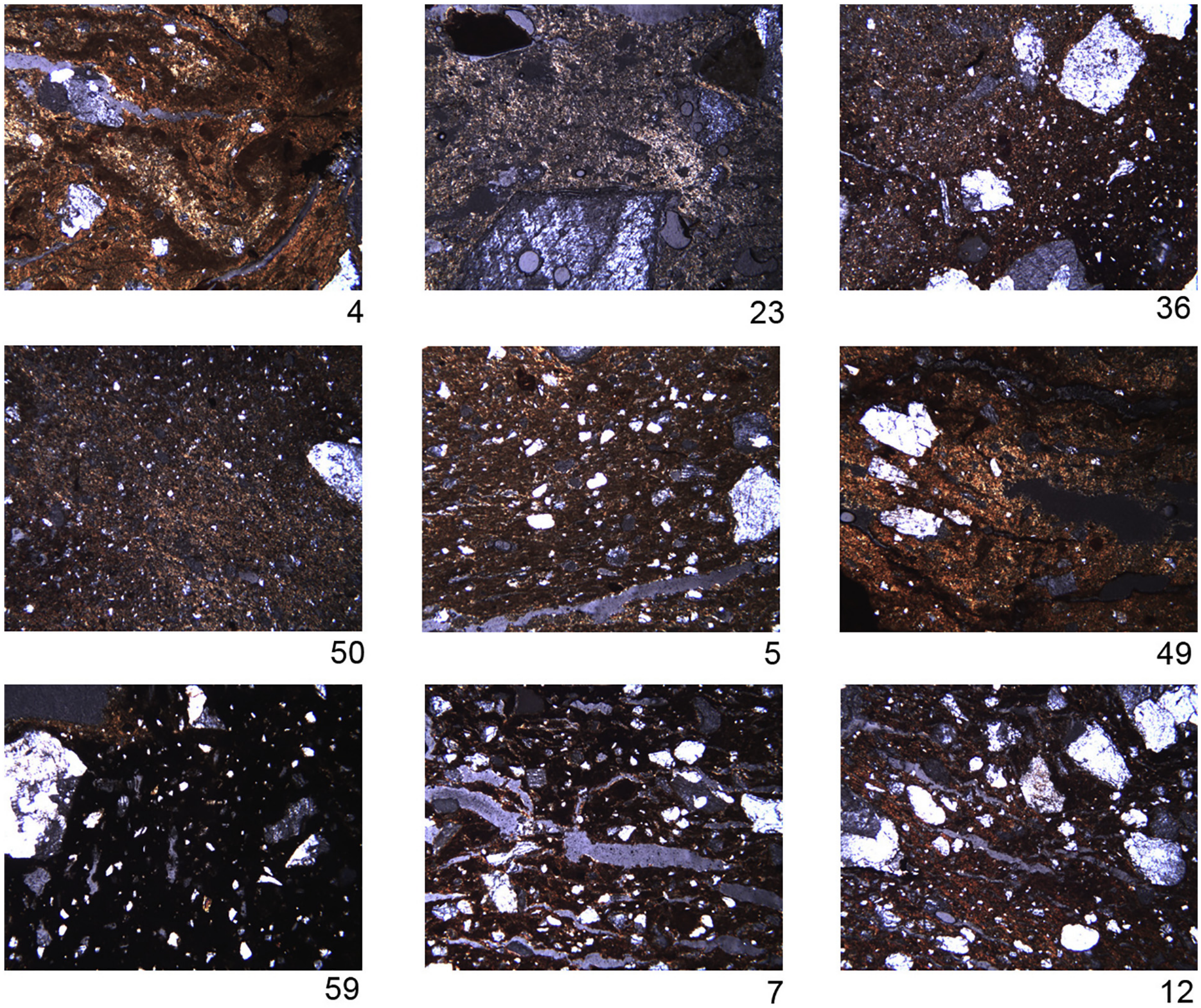

Fig. 8. Thin-section analyses of pottery. Nos. 4, 23, 36 and 50 are fine clays. Nos. 5, 49 and 59 are medium-coarse clays. Nos. 7 and 12 are coarse clays.

mentioned in this article have shown that the FBC pottery in Scandinavia normally are homogenous.

Plausible explanations for this heterogeneous PWC pottery could be: increased mobility of humans and/or pottery, an increased number of groups of potters and/or an increased need for pottery with different functions on the PWC sites. An alternative interpretation is that the pottery in the PWC had less ritual significance and was less controlled than in the FBC. The results of the pXRF and the ICP-MA/ES analyses show that the elemental composition of the sherds from Kainsbakke, Jutland, is the most heterogeneous, even though these sherds mostly were deposited within a very limited time frame or even in the same event (Wincentz, 2018).

The pXRF and the ICP-MA/ES analyses show that some sherds may have come from vessels with a different provenance than western Sweden and Djursland. One example is a FBC sherd from a megalithic grave at Årstad (318) in Halland, which differed from the others in both the pXRF and the ICP-MA/ES analyses. However, this sherd did not stand out in the thin-section analysis, since all the FBC sherds had more or less the same fabric.

Another example is the FBC sherd from Hørret Skov (363). According to the pXRF and ICP-MA/ES analyses, this constitutes a group of its own, while its fabric (thin-section analysis) matches that of many of the other FBC sherds from Djursland and western Sweden. The results of the ICP-MA/ES analysis of two sherds from PWC pots found at Värö (430, 436) and Trönninge (495, 498) in Halland differ from the others. However, the thin-section analysis showed that they were made out of the same raw material as the rest of the pottery from these two settlements. In general, there is no relationship between the fabric and the elemental composition of the sherds.

There are some indications of the exchange of pottery in the analysed material. The ICP-MA/ES and pXRF analyses show that there were differences in the pottery from inside the passage grave at Bokenäs, Bohuslän. The thin-section analyses demonstrate that a dense, fine clay was used for one pot, while another vessel consists of a silty fine clay. However, the craftsmanship behind these two vessels was the same. Differences in the choice of clay could indicate that the vessels in the passage grave came from different locations. In a previous study of pottery from a passage grave, Västra Hoby in western Scania, vessels made from three different clay qualities were identified: this was interpreted as showing that the pottery came from three different places (Brorsson, 2007). The ICP analysis of a PWC pot from Trönninge in Halland (498) produced results very similar to those for FBC pottery found at Røddinge and in the Aarhus region in Jutland (Fig. 7). The sherd could therefore have belonged to a vessel that was made somewhere in Denmark. Furthermore, the pXRF result from the pointed vessel 521 from Kirial Bro differed from the remaining Kirial Bro and Kainsbakke pottery and is not likely to reflect a local origin. The elemental composition of the sherd showed similarities to the Swedish PWC pottery especially from southern Halland, as well as to the Danish PWC pottery from the Højvang site. A Danish origin of this item is unlikely nevertheless, as pointed bottoms are unknown in the abundant ceramic material from Kirial Bro (ca. 2000 sherds), Kainsbakke (ca.

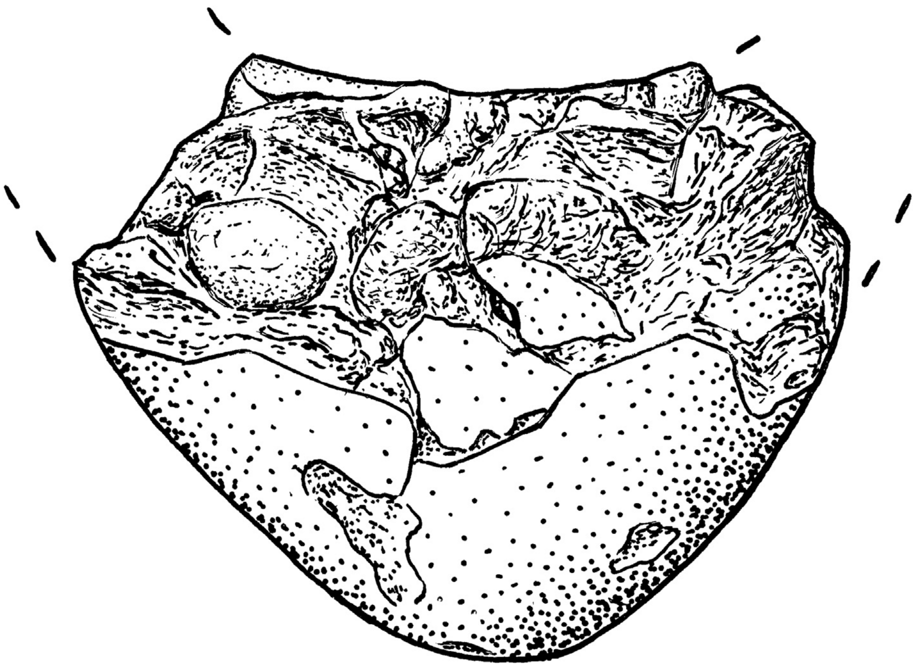

Fig. 9. Pointed vessel (521) from Kirial Bro. Drawing: Freerk Oldenburger.

10,000 sherds) and Højvang itself (ca. 2000 sherds). The find in question here (521) is the only of its kind known from the region (Fig. 9). In western Swedish PWC inventories on the other hand, pointed bottoms do appear, even though in restricted numbers (e.g. Jonstorp M, H and M2: Lidén, 1940; Olas: Persson, 2000). The elemental composition of sherd 521 shows a lot of similarities to the Jonstorp pottery from Scania. However, as this material only was analysed by ICP, the results cannot be considered directly comparable. It can be concluded that western Sweden more precisely southern Halland or northwestern Scania (Jonstorp) is the most likely origin of the pointed bottom 521 from Kirial Bro.

As mentioned previously, differences between the PWC of the eastern and western regions of Sweden have been discussed and the question has been posed of whether the cultural expression seen in the western part is actually PWC, or something else (Larsson, 2009). In this paper, it has been demonstrated that the pottery production in the Kattegat region, as evident from the thin sections, is consistent with the previously identified traditions of western Sweden, and different from the eastern Swedish traditions. Contacts between Jutland, Denmark, and the west coast of Sweden have long been discussed in archaeological research, and similarities in both cultural complexes have been pointed out (Kaelas, 1953; Persson and Sjögren, 1995; Iversen, 2013, 2016; Edenmo et al., 1997 etc.). Concurrence in archaeological constructions (Kaelas, 1953; Persson and Sjögren, 1995; Iversen, 2013) and artefacts, including pottery production and pottery ornamentation (Bagge and Kaelas, 1950–1952; Iversen, 2010; Edenmo et al., 1997; Malmer, 1969; Jennbert, 2015, this study), indicate contacts and, to some extent, a shared ideology between Jutland and the west coast of Sweden during the Middle Neolithic. With the exception of two potential examples (498 and 521), no systematic exchange of pottery/clay between the west coast of Sweden and Jutland in Denmark, either in the FBC or in the PWC, can be confirmed by this study. Nevertheless, this certainly does not exclude the possibility of established contacts across the Kattegat (see Iversen, 2016). Contacts between the two regions do not necessarily imply exchange of goods, but could have comprised the transmission of craftsmanship of for example pottery production. It is more likely that craftsmanship was spread by humans than by new objects and ideas.

The ICP-MA/ES and the pXRF techniques are much more suited than thin sections to indicating the provenance of pottery. However, the only method that can give us information about the clay and temper is thin-section analysis. The pXRF technique is a good non-destructive means of analysing a large number of pottery samples. ICP-MA/ES is, however, a more precise and sensitive method of measuring trace elements. Some of the trace elements detected in the ICP-MA/ES study, such as niobium, could not be traced with pXRF, but the pXRF results are generally consistent with those of the ICP-MA/ES analyses. The concentrations of the different elements measured in the pottery do, however, differ between the two types of analysis, probably due to the calibration and settings of the equipment and the inaccuracy of measuring the lighter elements with pXRF (see Method). The different methods used in this paper can therefore be seen to be, in many respects, complementary, and to be useful in providing new information about Middle Neolithic pottery from Jutland, Denmark, and the west coast of Sweden.

6. Conclusion

This study encompasses a total of 524 Neolithic potsherds and is hitherto one of the largest investigations undertaken of Neolithic pottery in Scandinavia. The results show that the elemental composition of the pottery, as revealed by both the pXRF and ICP-MA/ES analyses, were most suitable for determining the provenance of the clay used, while thin sections, on the other hand, provide indications of techniques and recipes used in pottery production. The PWC pottery was significantly more heterogeneous than that of the FBC, with respect to both the fabric and the elemental composition of the clay. Most of the pottery appears to have been locally produced, even though there are indications of regional exchange and non-local pottery. Of all the sherds analysed, only two was observed that could possibly have crossed the Kattegat. However, this does not exclude the possibility of frequent contacts between the west coast of Sweden and Jutland, Denmark.

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jasrep.2018.06.004.

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