# The development of pottery technology in Eythra from the Early Linear Pottery culture to the Late Stroke Ornamented Pottery culture

## Vývoj keramické technologie v Eythra od časné kultury s lineární keramikou po pozdní kulturu s vypíchanou keramikou

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*The site of Eythra, a former village located on the western bank of the White Elster River, has yielded numerous remains of a settlement that existed there during the early Neolithic cultures – the Linear Pottery culture (LBK) and the Stroke Ornamented Pottery culture (SBK). The site covers some 30 hectares, making it the largest excavated settlement of the LBK and SBK areas to date. Chemical analyses of the ceramic fragments from the consecutive stylistic phases that were represented in Eythra were carried out. The objective of this was to find out whether the stylistic changes in the shape and the decoration of the ceramic material correspond to technological changes in regard to such aspects as clay composition and tempering. The transitions between the earliest and the early LBK phases and between LBK and SBK were of particular interest in this respect, as also were the localised developments that took place within the two phases of the LBK and SBK.*

Linear Pottery culture – Eythra – ceramic technology – chemical analyses of ceramics – continuity – discontinuity

*Z lokality Eythra, bývalé osady na západním břehu řeky Bílý Halštrov, pochází mnoho pozůstatků osídlení, které zde existovalo v průběhu prvních neolitických kultur – kultur s lineární keramikou (LBK) a vypíchanou keramikou (SBK). Lokalita se rozkládá na ca 30 ha, což z ní činí dosud největší zkoumané sídliště v oblasti LBK a SBK. Byly provedeny chemické analýzy keramických střepů z jednotlivých stylistických fází, které byly v Eythra zastoupeny. Účelem těchto analýz bylo zjistit, jestli stylistické změny ve tvaru keramiky a její výzdobě odpovídají technologickým změnám, např. co do složení keramické hlíny a ostřiva. V tomto ohledu byla zvláštní pozornost věnována přechodu mezi nejstarší a časnou fází LBK a přechodu mezi LBK a SBK, stejně jako lokálním inovacím, které se uskutečnily ve zmíněných fázích LBK a následující SBK.*

kultura s lineární keramikou – Eythra – keramická technologie – chemické analýzy keramiky – kontinuita – diskontinuita

## Introduction

Starting in 1993, large-scale excavations were conducted in the former open-cast lignite mining district of Zwenkau (located some 15 km to the south of Leipzig) by the State Archaeological Heritage Office Saxony (LfA, or *Landesamt für Archäologie Sachsen*) at the site where the village of Eythra had once stood on the west bank of the White Elster River. Numerous traces were uncovered there of a settlement that had flourished during the Neolithic cultures of Linear Pottery and of Stroke Ornamented Pottery (e.g. *Stäuble 2007*; *Cladders et al. 2012*). In a joint project of the LfA and the Chair for Pre- and Protohistoric Archaeology (*Ur- und Frühgeschichte*) of Leipzig University, which was funded by the DFG

(*Deutsche Forschungsgemeinschaft*), the structural remains and the found material of the Bandkeramik culture from Eythra were examined between 2009 and 2016. More than 9,000 structural remains of the Bandkeramik culture had been documented in an area covering some 30 hectares (ca. 75 acres), including some 300 houses, a circular enclosure consisting of three concentric rings, and two wells dated dendrochronologically to 5098/97 BC and 5221 ± 10 BC respectively.[1] This makes Eythra the largest excavated settlement site of the Bandkeramik to date. The ceramic typology indicates that the site was occupied from the early phase of the LBK until the late SBK period (*Frirdich 2016*).[2] In addition, the remains of a small settlement of the earliest LBK period were discovered across from Eythra on the eastern bank of the White Elster River in Zwenkau-Nord (*Hohle 2011*; *2012*; see *fig. 1*). As some of the pottery fragments from Eythra also display certain traits of the earliest LBK[3], it is a distinct possibility that there was a simultaneous settlement on both banks of the river during this initial phase of the LBK, which needs to be considered. In order to ascertain this contemporaneity, a series of samples of ceramic fragments from Zwenkau-Nord were analysed and compared with fragments from Eythra of the earliest and the early LBK (*Mecking et al. 2012*). Some of the sherds were recovered from a house-site that probably dates to the earliest period of the LBK (*fig. 2*: the house, picked out in dark grey, lies in the northeast part of the site plan).

In the region south of Leipzig, a large number of Bandkeramik sites are strung out along the White Elster River like pearls on a string (*Stäuble 2014*). One well-known site lies at Zwenkau-Harth. This settlement, which existed both during the LBK and the SBK, was excavated in the 1950's by Hans Quitta. Against this background, it was one of the objectives of the Eythra project to explore the significance of the find site both within its micro-region and beyond, in the wider context of the distribution areas of the Bandkeramik in Northwest Saxony and in Central Germany (*fig. 3*). In addition, a ceramic chronology was established on the basis of the material found in Eythra and the more distant Saxon sites which provides, for the first time, a comprehensive data set that covers the entire stylistic development of LBK pottery (*Frirdich 2016*).

Because the settlement at Eythra existed for a very long time (unlike most of the other sites of the Bandkeramik) it provided a welcome opportunity for a closer study of the continuities and the discontinuities in the development of pottery. In this respect, the examination extended beyond the mere observation of shapes and decoration by also taking into account possible technological changes in ceramic production too. Further questions concerning the correlation of such changes with the evolution of other groups of artefacts, the construction of the houses and the overall settlement pattern, could then be appended.

Two essential questions were intended to be answered through chemical analyses of the ceramic materials (*Mecking et al. 2012*):

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[1] An earthwork and a palisaded enclosure were also discovered, but their chronological position in the Linear Pottery culture remains tentative (cf. *Tischendorf – Girardelli 2016*, 34–37).

[2] The terminology of the Bandkeramik sub-phases that is used in this text is based upon the chronology of *D. Kaufmann* (*1987*).

[3] For the supposedly oldest house site of the Linear Pottery, House 236, and the ceramic material of Interval 1 of the type chronology, cf. *Cladders 2016*, 54–56. The series does not include lugs, however, which are interpreted here as traits of the earliest LBK (*Cladders et al. 2012*, fig. 7, especially A, B, C, E, G).

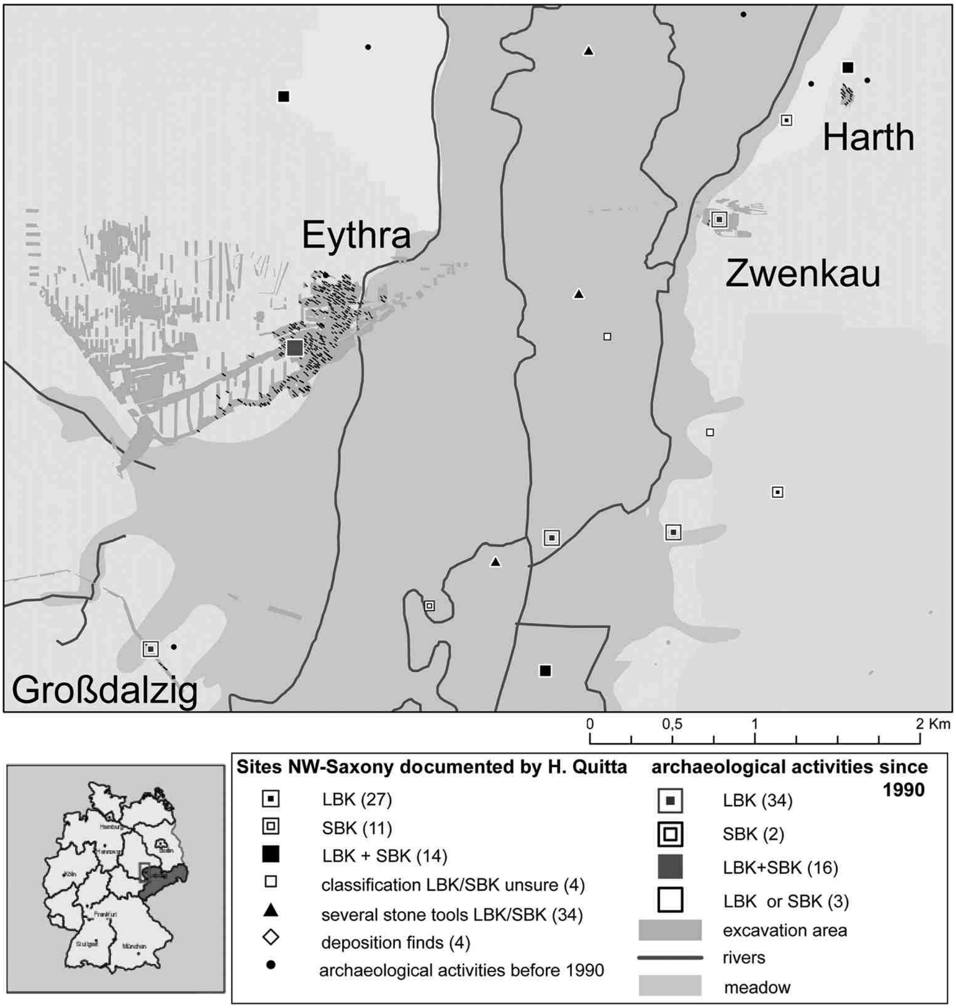



Fig. 1. Bandkeramik on both sides of the Weiße Elster River: the sites Eythra and Zwenkau-Nord (source: *Stäuble 2014*, fig. 4). The symbols on the left in the legend mark the sites that were compiled by Hans Quitta, the symbols on the right mark excavations since 1990.

1. How do changes in the decoration of vessels correspond with changes in ceramic production (e.g. in clay composition and tempering)?

2. To what extent can continuities or discontinuities displayed by ceramic materials also be discerned in other contemporary or non-contemporary aspects of the material culture?

As an answer to the second question is only possible based on a joint evaluation with the colleagues examining the artefacts and the houses of Eythra, the present paper concentrates on the first question.

In this context, the transitions from the earliest to the early phase of the Linear Pottery culture and from the LBK to the SBK are of particular interest, as representing the most


Fig. 2. Plan of Eythra and of the plot that was the original source of the samples. The rondel and the earthwork are both highlighted in dark grey as well as the probably earliest LBK house (© Landesamt für Archäologie Sachsen).

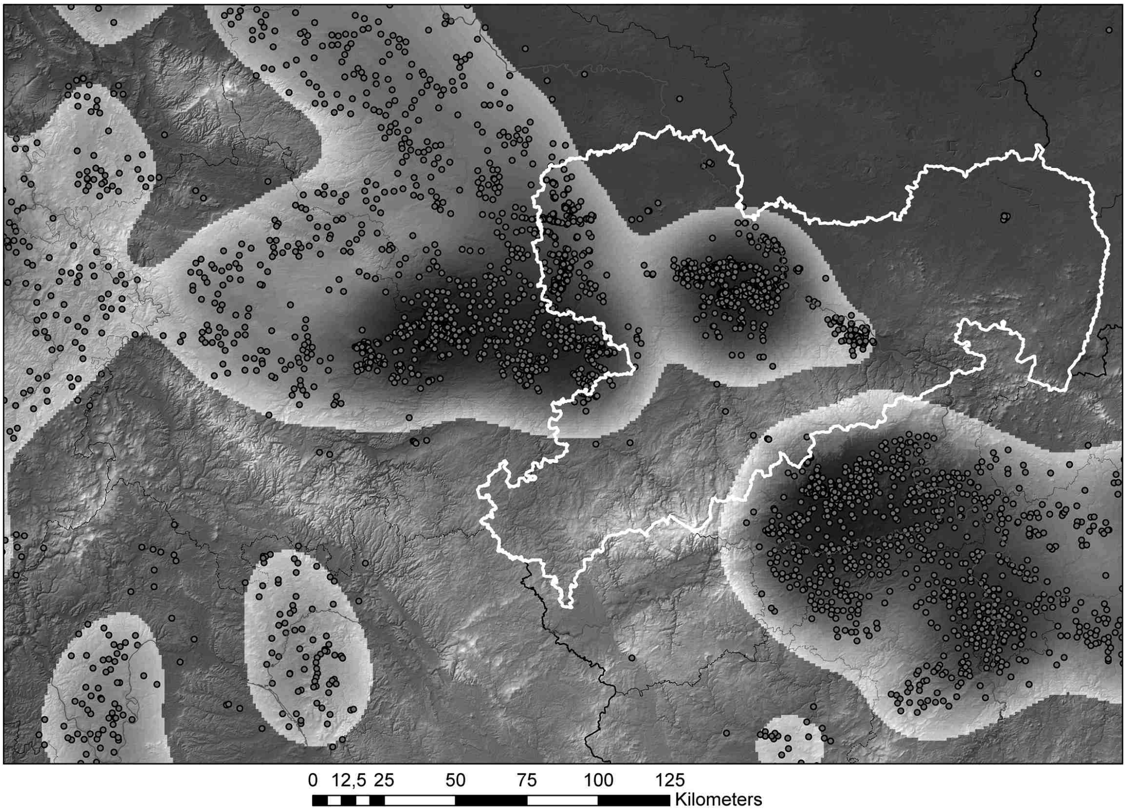



Fig. 3. The distribution of Bandkeramik sites in Central/East Germany and in Bohemia (source: *Stäuble 2014*, fig. 3); Saxony is highlighted in white.

distinct changes that can occur in respect to pottery shapes and decoration (in addition to house construction and settlement patterns) that can be found here. The developments in ceramic technology both within the LBK and the SBK are likewise the subject of our study.

The results are able to provide crucial stimuli to the interpretation of stylistic changes in the development of ceramics or of possible continuities in ceramic production that may not be discernable through purely typological analyses. Concerning the relationship between the earliest and the early phases of the LBK, it is a point of debate as to whether they constitute two distinct variants of a single cultural tradition that existed alongside one another for some length of time (*Cladders – Stäuble 2003*), or whether the early LBK may have evolved directly from the earliest phase – a theory that is supported by several find sites in Baden-Württemberg, e.g. Gerlingen (*Neth – Strien 1999*). According to the present state of research on the relationship between the LBK and the SBK, it appears that the actual break in the development occurred as late as the transition from the early to the late phases of the SBK. The early SBK itself seems to be rooted firmly in LBK traditions, especially as far as fine-ware is concerned, and on a regional level it displays continuous development rather than any definite break (*Link 2014*, 216–220; *Hoffmann 1963*, 118–120; *Kaufmann 2009*). While the decoration of early SBK vessels does display a greater degree of the standardisation of ornamental motifs, the characteristic angular line motif with vertical strokes had already been around prior to the late phase of the LBK. Shapewise, the gourd-like vessels of the early SBK resemble those of the LBK, while the beakers only acquire their position as being the dominant vessel-type as the SBK progresses. Even the eponymous stroke ornaments are not really a novelty of the SBK. Such ornaments were applied with tools, which had either one or several lines, and the later ornament is certainly considered a characteristic trait of the late LBK in some regions (*Jeunesse 2008*; *Jeunesse – Strien 2009*; *Einicke 2014*, 281–286; *Kaufmann 1987*, 286–287). Even the floor plans of the houses of the early SBK can be shown to be continuing a trend that had already existed during the late LBK. The settlement site of Dresden-Prohlis (*Link 2014*) is currently the only find site where this continuous development is documented in an unambiguous fashion, but evidence of settlement continuity from the LBK to the SBK also appears in Eythra and also numerous additional find sites. With these insights in mind, it seemed promising to take a closer look at our recent findings regarding the development of ceramic technology. From the material from Eythra a total of 153 sherds were selected for this approach. These came from a variety of vessel types and wares belonging to all the stylistic phases that are represented here, which were recovered from a wide range of structural remains (*fig. 2*).[4] A selection of the vessels that were chosen for this sampling can be seen in *figs. 4* and *5*.

Compared to later periods, the chemical, physical or mineralogical analyses of Neolithic ceramic materials are actually quite rare (*Daskiewicz et al. 2008*; *Hagn 1995*; *Jorge et al. 2013*; *Lehmann 2000*; *Maggetti 2012*; *Martineau et al. 2007* and others). In regard to the scientific study of the Bandkeramik, the analyses of the material from Eythra definitely fulfill a pioneering role both in terms of their chronological scope and their breadth.

## The scientific analyses of the Bandkeramik sherds from Eythra

For producing a vessel, several distinct and successive steps need to be completed. Apart from finding a suitable clay deposit, these may include the preparation of the clay mixture and the addition of tempering materials, as well as using various different methods for shaping the vessel, decorating its surface and firing the result. These diverse steps can influence the properties and the appearance of a vessel to varying degrees (*Maggetti 2012*; *Hoard – Brien 1995*; *Kilikoglou et al. 1998* and others). Each step taken may leave traces in the sherds, which include the clay matrix, the material used for tempering, various kinds of pores, and the appearance of the surface (*Maggetti 2008*). Unfortunately, it is not always possible to connect specific traits of the sherds to specific steps of the production process. But in spite of this reservation, our analyses can provide useful insights into the techniques that were used for Neolithic ceramic production. Two aspects which stand out in this respect are the tempering of the clay and the treatment of the vessels' surfaces. It stands to

[4] The distribution of the sampled sherds across the settlement area mirrors the progress of the project at the time when these samples were taken. As just the pottery of the area in the north, in the circular enclosure and in the earthworks was examined the samples do not represent the entire area of the settlement (see *fig. 2*).

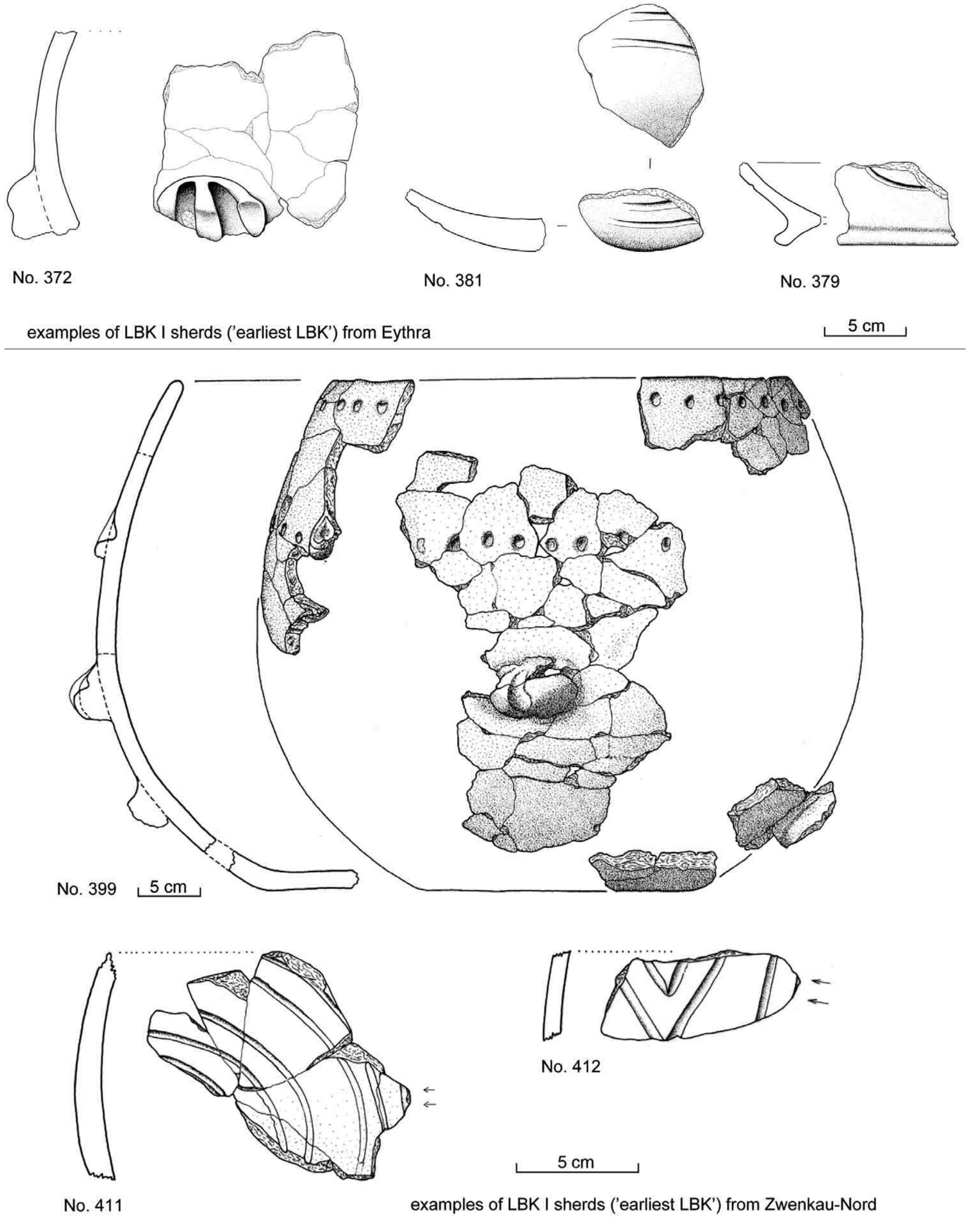



Fig. 4. Examples of earliest LBK sherds sampled from Eythra and Zwenkau-Nord.

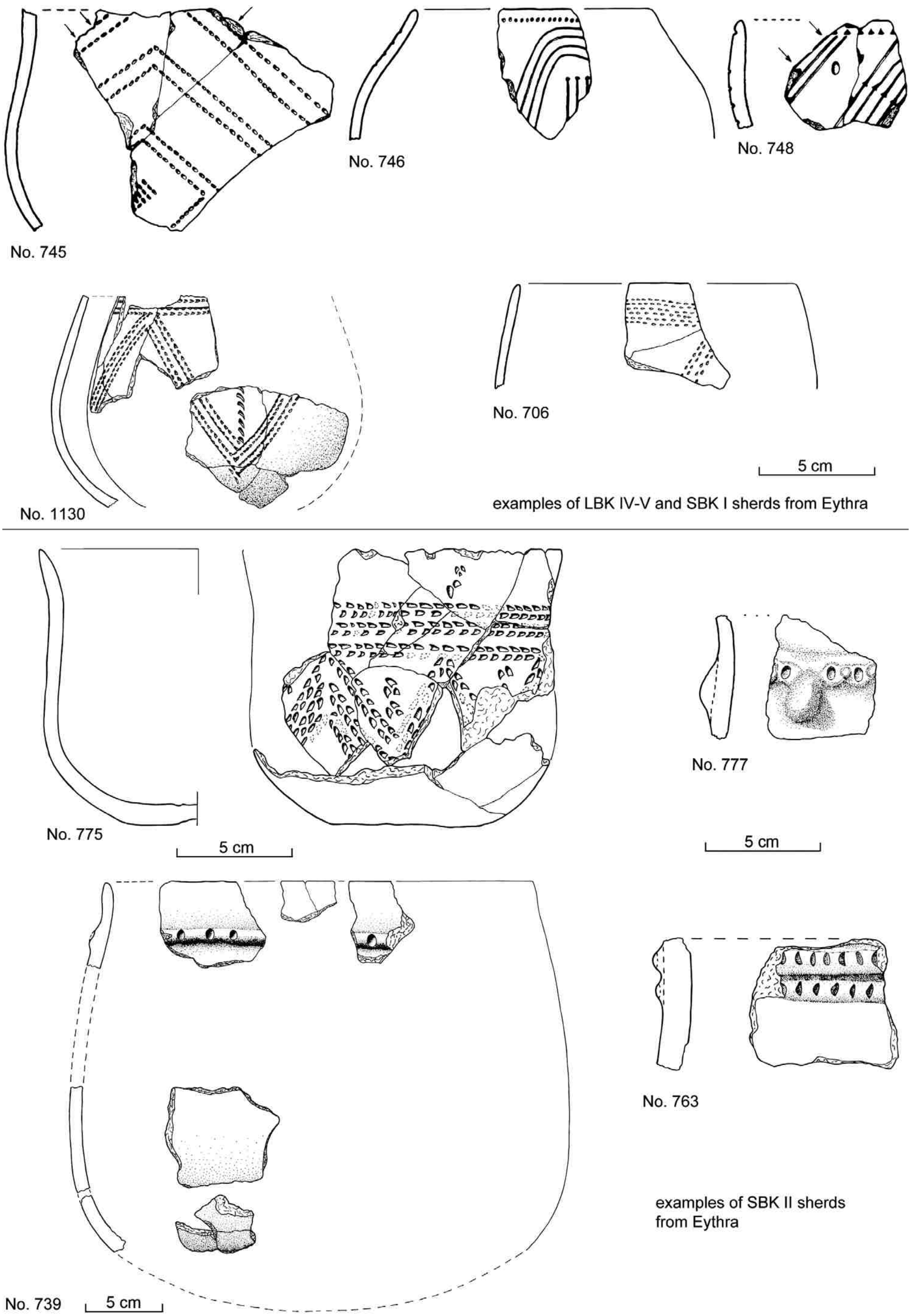



Fig. 5. Examples of sherds sampled from Eythra: late/latest LBK; early and late SBK.

reason that the occurrence of unusual tempering materials of a large diameter and irregular shape means that either a specific type of clay was deliberately chosen which already contained such non-malleable particles, or that these were purposefully added to the clay.

Each kind of clay possesses a geochemical composition that is distinct from that of other clays. But when clay is processed and mixed with a tempering material obviously this will result in the altered composition of the vessel or the sherd (*Sterba et al. 2009*; *2012*). Frequently this will hamper the reconstruction of the composition of the original clay as it was taken from its natural deposit, though the attempt may be successful in individual cases (*Xu 2013*). Finds of refuse material from potteries can help with solving this problem: Wherever such material can be recovered from a site, its characteristic trace elements can be determined (*Bartle et al. 2007*; *Biegert et al. 2002*; *Mommsen 2003*; *Mommsen et al. 1995*; *Maggetti – Galetti 1980* and more). This can provide a reference group to which sherds of an unknown provenance can be compared. However, as the production of vessels during the LBK seems to have been located predominantly at the level of the individual household, finds of distinctive pottery refuse can hardly be expected.

Changes in the composition of trace elements may indicate that different types of clays have been used or an altered manner of processing the clay, or the introduction of new tempering materials. When the results display an extreme variety, this may point to the ceramics having been produced in individual households. On the other hand, if within this variety a distinct trend becomes discernable, some degree of organisation of ceramic production above that of the household level may safely be assumed to have taken place.

In order to better understand the evolution of the ceramic material from Eythra, analyses were carried out both to determine the nature of the tempering materials and the geochemical composition of the sherds. For determining the tempering materials, measurements were taken from a freshly fractured cross-section of each sherd using micro-XRF spectroscopy.[5] A point matrix was superimposed on the sherd to guide the sequence of the measurements that were taken automatically. The observed element content was then translated onto a diagram as colour-coded information – e.g. the higher the proportion of a specific element the lighter the colour, and the lower the proportion the darker the colour. A black colouration indicates that the element was not encountered at all. This method enables the determination of both the composition of the clay and the nature, the volume and the size and shape of the requisite tempering material.

In order to facilitate the interpretation of the element distribution data in the diagrams[6], the tempering materials were sorted into four size categories. The first category included those samples that had no trace of tempering. The next category was defined by sherds that were comprised of small tempering particles. This group was further subdivided into samples comprising either a few or multiple particles, and this same approach was also applied to the other size categories. These included a group comprising medium-sized particles, and a group that encompassed all the larger particles (*figs. 6* and *7*).

Two distinctive types of tempering materials – i.e. potassic and ferrous – were found to exhibit marked differences across the separate stylistic phases of the Bandkeramik in Eythra. A third element, silicium, appears as a distinctive marker for quartz tempering, but as our

[5] Eagle III by *Röntgenanalytik*, with a 300 micrometers Spot.

[6] The element distribution patterns of 143 sherds were documented.

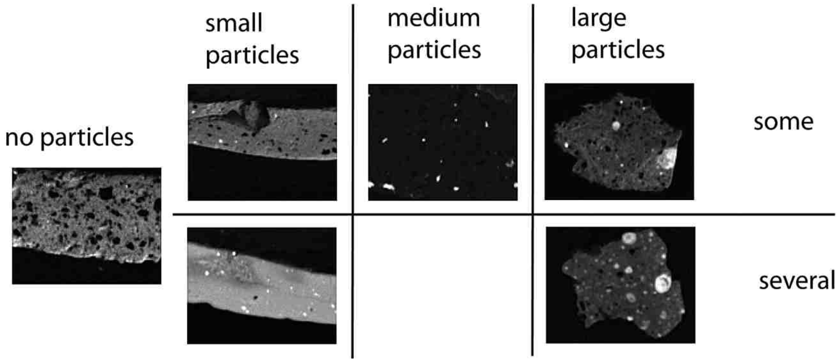



Fig. 6. The determination of the ferrous tempering materials.

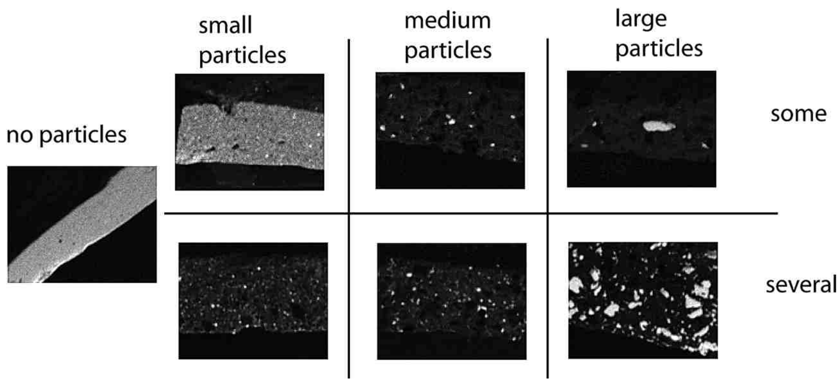



Fig. 7. The determination of the potassic tempering materials.

examination did not discover any significant trends across the chronological phases in this instance, it is not further discussed in this paper.

As is described above those samples with ferrous tempering were sorted into seven separate groups and subgroups (*fig. 6*). The changes that occur within these groupings in the course of the Linear Pottery culture (*fig. 8*) are remarkable. In the earliest phase of the LBK, some 20 % of the samples (i.e. four sherds identified as: Ker 391, 393, 394 and 395) exhibit more than three large iron particles. Another sherd with fewer large iron particles (Ker 409) can be added to this group. In the early LBK only one sherd (Ker 388) comprised several large iron particles. Three of the sherds (Ker 365, Ker 377 and Ker 390) all now display less than three iron particles. In the following chronological phases, samples comprising several large iron particles are completely absent. Thus, only the earliest phase of the LBK exhibits a larger proportion of sherds that comprise more than three ferrous particles. This phenomenon seems to disappear with the advent of the middle phase of the LBK. Only isolated samples with large ferrous particles occur during the early and middle LBK (Ker 721 and Ker 734). A single example was detected in a sherd (Ker 706) from the early SBK.

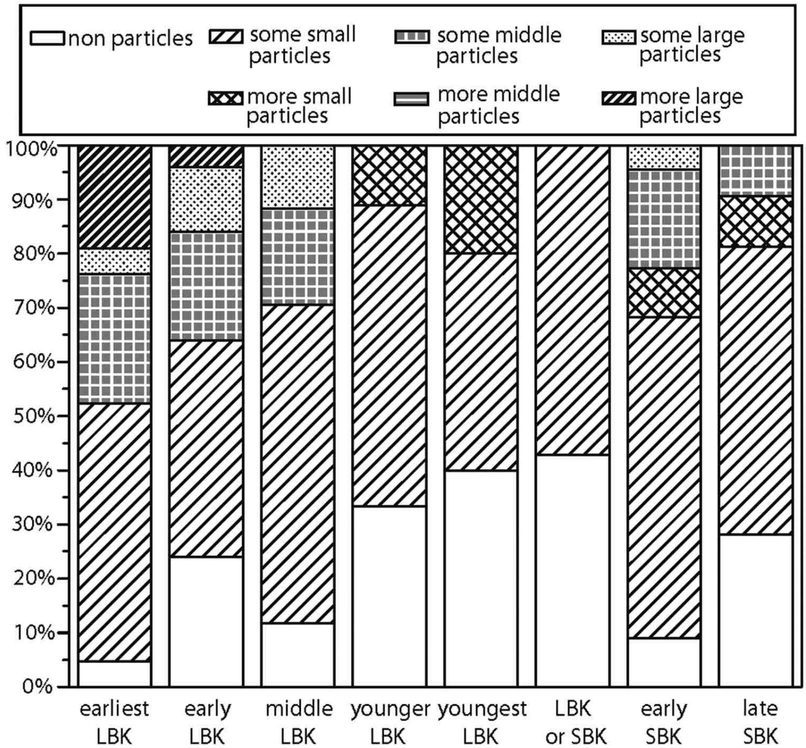



Fig. 8. The chronological development of the ferrous tempering material; "LBK or SBK" indicate the undecorated sherds that could be either one or the other.

This evident trend is mirrored in the overall iron content of the samples. On average, the sherds of the earliest and the early LBK display a higher content of iron than those of the subsequent phases. The iron content of the samples from the earliest LBK averages around 7.99 % of $Fe_2O_3$, dropping to 7.28 % in the early LBK, with an additional drop to 6.24 % in the late LBK. Thereafter, the mean value for the sherds of the SBK sinks to only 5 % of $Fe_2O_3$.

The ferrous component of the samples does not consist solely of iron oxide. In order to clarify the exact composition, micro-XRF spectroscopy measurements were taken (*fig. 9*). These evaluated the iron content in relation to a fundamental parameter. The result was that the content of iron oxide could be shown to have risen significantly, approaching values of up to 40 %. In contrast, the values of all the other elements (with the exception of manganese) exhibited a distinct decline. This indicates that hematite was not used for tempering, as this would have resulted in a higher iron content. The utilisation of an iron-enriched type of clay is much more likely.

Sherds from Eythra and Zwenkau were also examined by *Ramminger et al.* (*2013*) in the manner of polished thin-section analyses. These analyses confirmed the absence of pure hematite. Some differences between the basic substance of the sherds and the zones of iron enrichment are discernible, however. As these concentrations of ferrous mineral appear to

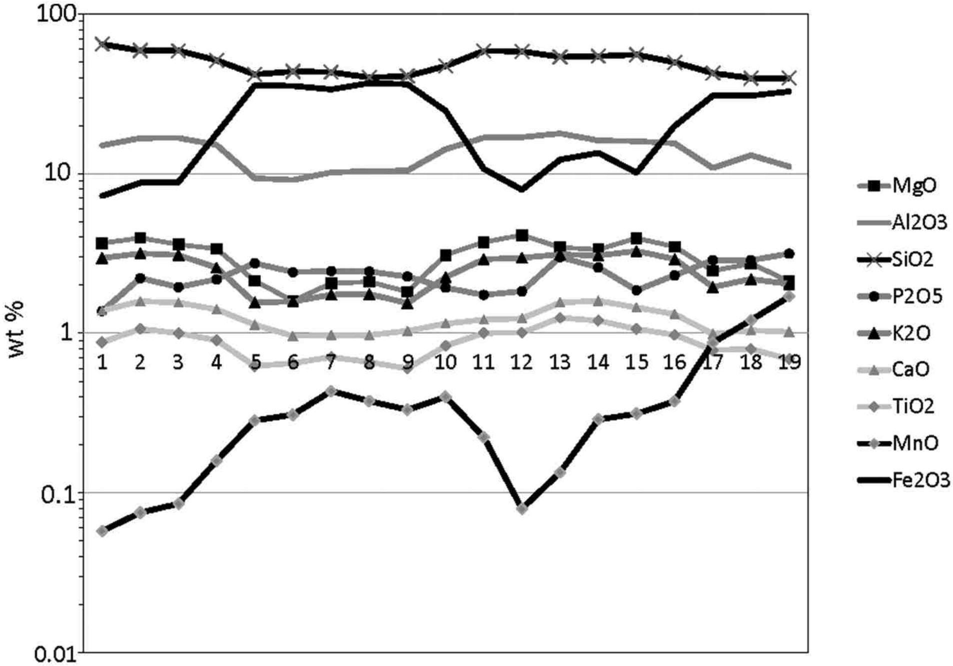



Fig. 9. A scan of a ferrous particle.

be rounded, it is conceivable that they were created by a natural tempering and were not an intentional addition (*fig. 6*).

A contrasting chronological development is evinced by such potassium-based tempering materials as potassic feldspar (*figs. 7* and *10*). Only a single sherd (Ker 384) in the earliest and early LBK contained a large potassic tempering particle. All the other samples emanating from these chronological phases displayed either small or (rarely) medium sized potassium particles or none at all. From the middle phase of the LBK, there are three samples that include individual large potassium particles (Ker 723, 728 and 731). Turning to the late LBK, only a single sherd out of a total of nine (Ker 720) featured a significant number of large potassium particles. Likewise, the youngest LBK provided a single sample containing several large tempering particles (Ker 738) out of the five sherds of this phase that were examined. Of the ceramic fragments that could be ascribed to both the SBK and the LBK[7], two out of the seven sherds displayed a number of larger tempering particles (Ker 737 and Ker 749). A distinct increase in the number of samples with large potassic tempering particles is discernible in the SBK: 19 of the 54 sherds that were examined contained several large inclusions. This constitutes a full third of all the samples.

A remarkable feature shared by all of these samples is the angular shape of the tempering particles (see *fig. 7*). This trait suggests that some kind of material was intentionally

[7] The analyses also included some undecorated sherds. These were potentially attributable to both the later LBK and the SBK, and the clarification of their status was a desirable goal.

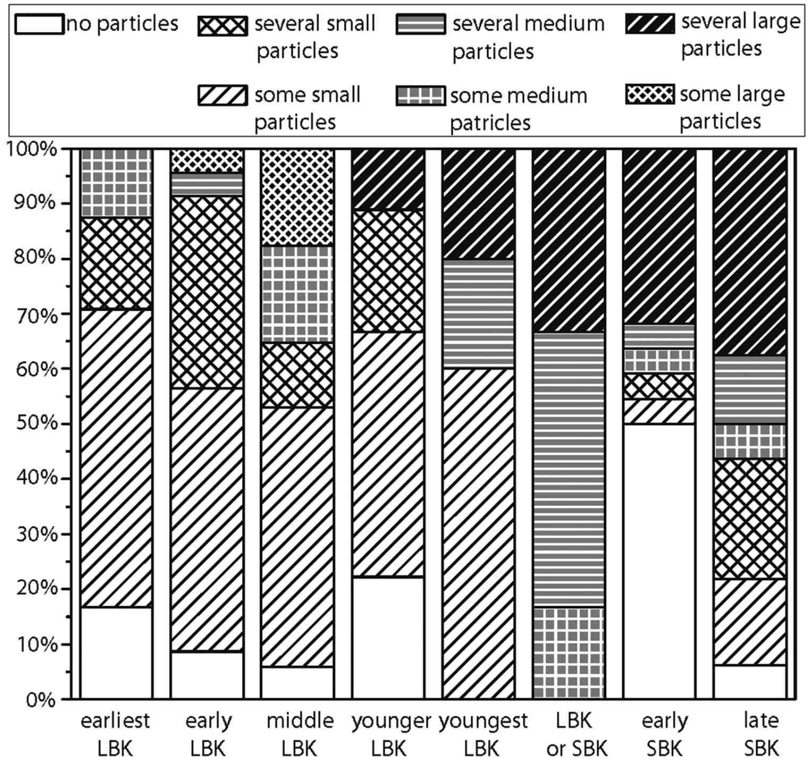



Fig. 10. The chronological development of the potassic tempering material.

added to the clay and this manner of tempering occurs mostly in relation to the coarser kind of pottery. One conspicuous result of the examination is the complete absence of any small potassium particles in the early SBK, particularly in samples of fine-ware.

Thereby two potential trends can be identified: First mostly used during the earliest LBK there were clay types that contained several larger ferrous inclusions and they made some isolated appearances during the early LBK. Second, during the SBK, potassic tempering materials such as feldspar were added to the clay, which was mostly used for producing coarse pottery, a method that had isolated the precursors during the late and the latest LBK.

In addition to tempering materials, the content and the proportions of major, minor, and trace elements in the samples were also examined. This was carried-out by first detaching a fragment from a sherd, from which the surface layer was then removed in order to preclude any possible contamination (*Franklin – Vitali 1985*; *Schneider 1989* and others). This purified piece was ground-up in a ball mill, and the resulting powder was heated to 800 °C to remove any organic components. In order to determine the major elements and some trace elements[8], a precise 600 mg of this powder were weighed and mixed carefully with

[8] Magnesium, aluminium, silicon, phosphorus, potassium, calcium, titanium, manganese, iron, strontium, rubidium and zirconium.

20 % of wax. A pressed pellet was then formed and measured using micro-XRF spectroscopy (Eagle III, by *Röntgenanalytik*). Each pellet was measured at twelve different points, and in each instance an area of 4.5 x 4.5 mm of the surface was scanned. The samples were analysed with reference to 26 different clay standards in order to guarantee their comparability with the external measurements.

To determine the trace elements, 100 mg of the sample was dissolved with 4.5 ml of hydrofluoric acid (HF), 0.5 ml of hydrochloric acid (HCl) and 1 ml of nitric acid ($HNO_3$). The mixture was then digested at 240 °C in a microwave oven (*The Multiwave 3000 by Anton Paar*). The solution was then vaporised and absorbed by diluted nitric acid. The resulting solution was measured by means of the ICP-MS (*Elan DRC by Perkin Elmer*) using rhodium for an internal standard.

One particularly interesting result is the extremely low calcium content of the samples. Their mean value is 1.2 % by weight of CaO, and the maximum value lies at 2.5 % by weight. This could indicate either that clay types that were low in calcium were intentionally used to produce this pottery, or that these clays were processed prior to their use to lower their calcium content.

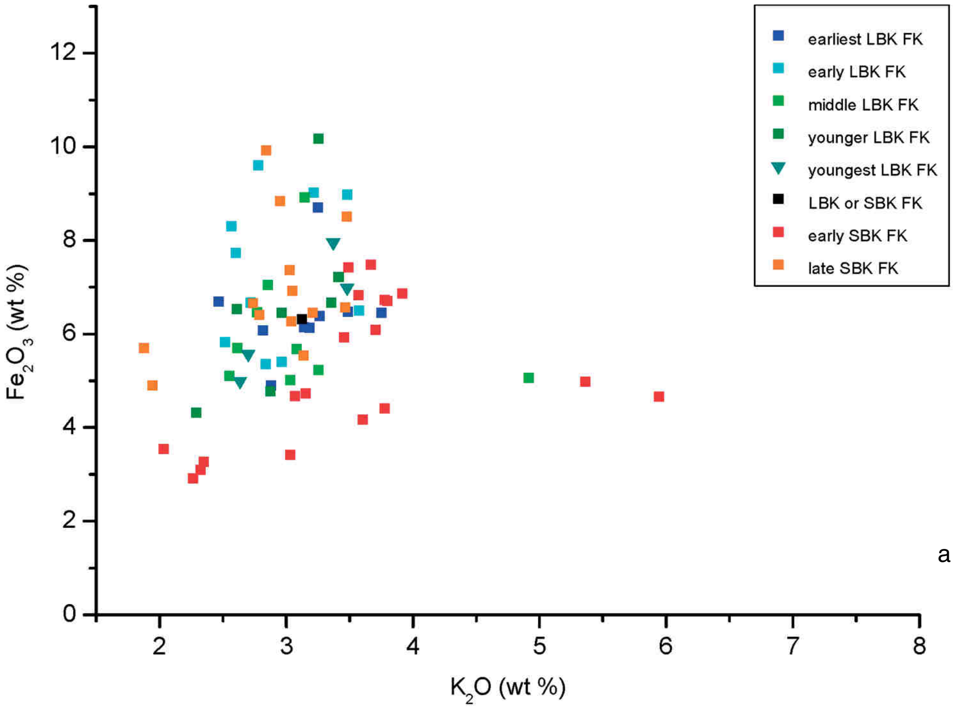
The analysis of elements is a useful tool for determining the chemical composition of the sample sherds. We must bear in mind, however, that each sample is composed both of clay and of tempering materials. As was described above, clearly employed were clays with ferrous inclusions as well as potassic tempering and this should be reflected in the results of the analyses. This aspect is best illustrated by a diagram that compares the occurrence of iron and potassium (see *fig. 11*).

On average, it is the earliest LBK phase that displays the highest iron content of all the samples, with the values for coarse pottery being somewhat higher than those of the fine ware. At the same time, the values for potassium oxide ($K_2O$) are closely grouped, with a median value of 3.06 and a standard deviation of 0.42.

During the early LBK period, the iron content remains comparatively high, though it decreases slightly to 7.28 % from the weight of the $Fe_2O_3$. At the same time, the potassium content remains within a comparable order of magnitude (with a median value of 2.84), while the values vary, but little (with a standard deviation of 0.32).

In the middle LBK, the iron contents decrease further to 7.07 % by weight on average, a value that is still high. The contents of potassium remain within an order of magnitude that is comparable with the previous phases (with a median value of 3.05 % by weight of potassium oxide ($K_2O$), but the distribution of the values widens slightly (with a standard deviation of 0.57). This can be explained by the occurrence of a few odd samples that contain isolated large potassium particles.

In the late LBK, the iron contents decreased more markedly, to settle at around 6.24 % by weight on average. In contrast, the potassium contents increased slightly to 3.31 % by weight, while at the same time their standard deviation increased to 1.05. This trend continued into the latest LBK: The values for iron sink to 5.51 % by weight while the potassium contents rise to 3.72 % by weight. More significantly, the standard deviation of the potassium contents increases further to arrive at a value of 1.54. These trends can definitely be associated with the observed changes in tempering material. Those samples of coarse pottery (*fig. 11b*) that contain feldspar tempering also display the highest potassium content.



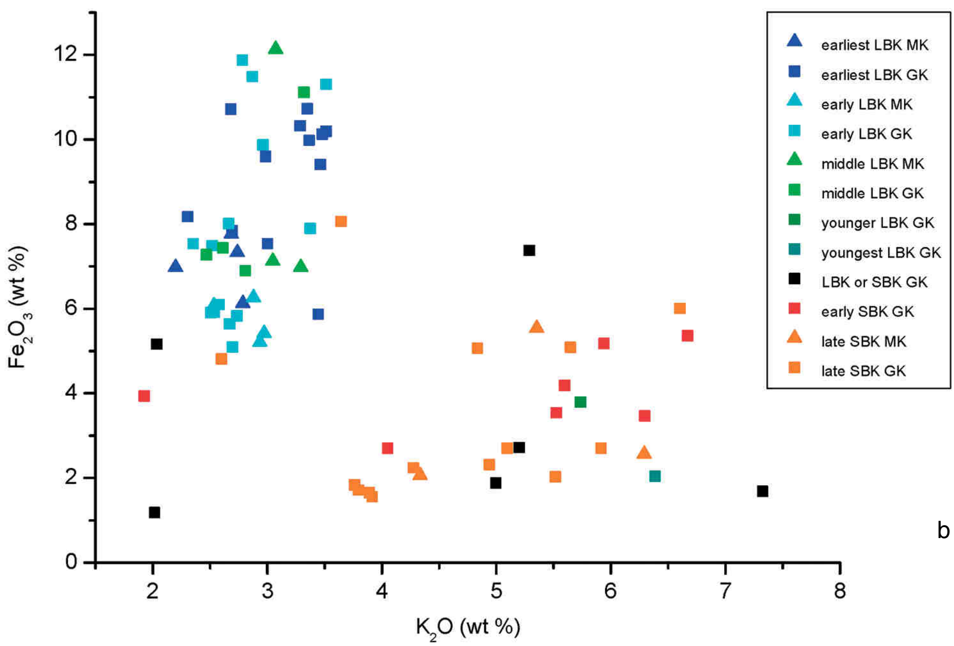




Fig. 11. A comparison of the K and Fe tempering materials (FK: fine-ware, MK: medium-ware and GK: coarse pottery; “LBK or SBK” indicate the undecorated sherds that could be either one or the other).

This is a clear (but anticipated) confirmation of our initial assumption that tempering affects the sherds composition.

Using archaeological criteria, the ceramic material was sorted into the following categories: fine-ware (*Feinkeramik*, FK), medium-ware (*Mittlere Keramik*, MK), and coarse pottery (*Grobkeramik*, GK).[9] High potassium contents are found predominantly in coarse pottery, thereby constituting a distinctive group. In the fine-ware of the SBK, some sherds display lower iron and potassium contents than the samples from the LBK. This would seem to indicate that different clays or mixtures were used to produce the respective ceramic vessels.

While tempering was intended as a means of introducing new elements into the clay, it is also conceivable that particles that were geochemically related to the original material might have also been introduced. If a method using multivariate statistics (e.g. cluster analyses, main component analyses) were applied to our data set, this would merely lead to a sorting of the sherds according to specific tempering materials. It is also conceivable that identical clays were used, but that different tempering materials were added. In order to measure the actual composition of the samples, the Pearson's correlation coefficients for all the possible element combinations were determined.

Certain elements will correlate with one another because of their geochemical similarities. This phenomenon can best be described using the rare earths as an example. These will frequently display coefficients with values that exceed 0.9 (specifically in the cases of neodymium-cerium, lanthanum-cerium, holmium-erbium, gadolinium-dysprosium and others). This is due to the fact that rare earths have similar geochemical traits because of their closely related atomic radii and charges (*Markl – Marks 2008*, 473–480). Apart from the rare earths, there are other elements that also correlate with one another, such as calcium – both with strontium and barium. In this case, the correlation for strontium is 0.71 and for barium 0.64. The reason for this close similarity is that these elements all belong to the second main group of the periodic system of elements, where they appear in sequence as calcium, strontium and barium. This proximity also results in a strong geochemical similarity and correlation of these elements. At this point, a closer look at those elements that were introduced through tempering may be of some interest. Of these affinities iron has close correlations with cobalt (0.645), chromium (0.717), nickel (0.762), scandium (0.701) and vanadium (0.777). The correlations with manganese (0.426), copper (0.487) and zinc (0.472) are distinctly weaker. Potassium displays close correlations with rubidium (0.6), cerium (0.677), caesium (0.626), lanthanum (0.654), neodymium (0.608) and thorium (0.597). Its correlations with other rare earth elements are significantly weaker, though europium with a correlation of 0.213 constitutes an exception. As europium can occur in two different valences, separate sources for these rare earths are probable. If the above aspects are not taken into consideration, any multivariate statistical analysis of the samples is likely to mirror only the development of the tempering processes. Pottery, however,

[9] The definition of the wares is based on three factors: the thickness of the sherds, the sherd's surface and the amount/size of the tempering materials. From fine to coarse the sherds become thicker, the tempering increases in size and quantity, and finally the surface changes from polished to roughly smoothed. Because the recognition of a medium ware is difficult and not necessarily distinguishable, in future studies it is suggested to ignore this ware.

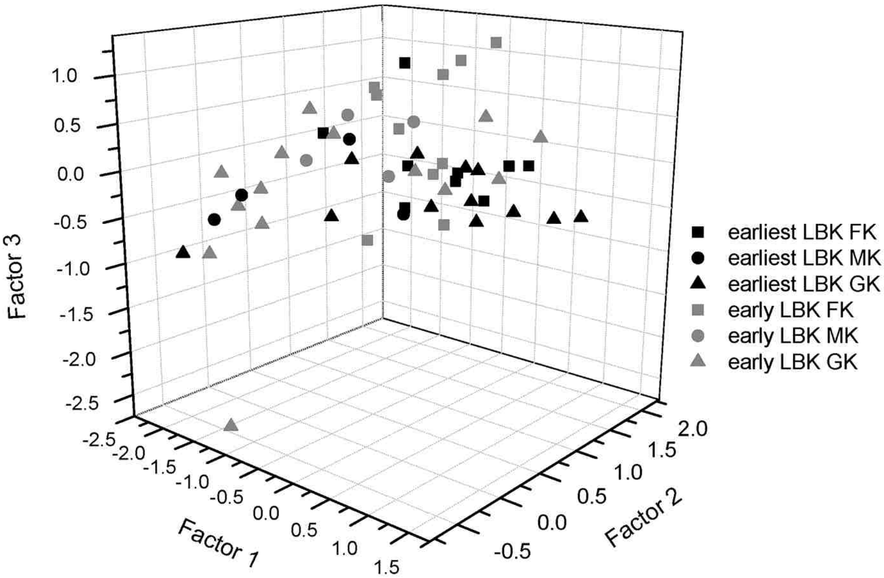



Fig. 12. An analysis of the main components with a reduced number of elements for the earliest and early LBK (FK: fine-ware, MK: medium-ware and GK: coarse pottery).

consists of both clay and tempering material. In order to assess the actual development taking-place during the use of clay types, it is necessary to filter the influence of tempering from our observations. To achieve this, as the next step of our study, an analysis of the main components excluding the above-named elements was carried.

During the earliest and the early LBK phases potassic tempering was not yet being used. Consequently the rare earths, such as rubidium, potassium and thorium can all be retained for this part of the study. An analysis of the main components exhibits only minor differences at this stage compared with the later phases (*fig. 12*). The diagram also displays some specific groupings (see *Mecking et al. 2012*). The variances in the earliest phase of the LBK are much stronger than those of the early LBK. The differences between the individual sherds are also significant. This may indicate that the selection or the processing of the clays was more varied. While the sherds of the early LBK overlap with those of the earliest LBK period, whereby the distribution of the measured values is generally closer in the former. This trend continues after the early LBK, in regard to both fine and coarse pottery. While sherds that display strong similarities to samples from the earliest and the early LBK can still be found, the number of fragments with marked differences is now on the increase (*fig. 13*). This development still persists in the late and the latest LBK. This can only mean that new clay deposits were accessed and new clay-processing methods were utilised that had not yet been developed during the early and the earliest LBK phases. With the transition to Stroke Ornamented ware, the composition changes once again, mainly as a result of the introduction of potassic tempering for coarse pottery. This change can be ascribed to the different clays or clay-mixtures that were employed for producing this type of pottery; however changes in the composition of contemporary fine-ware also occurred (*fig. 13a*).

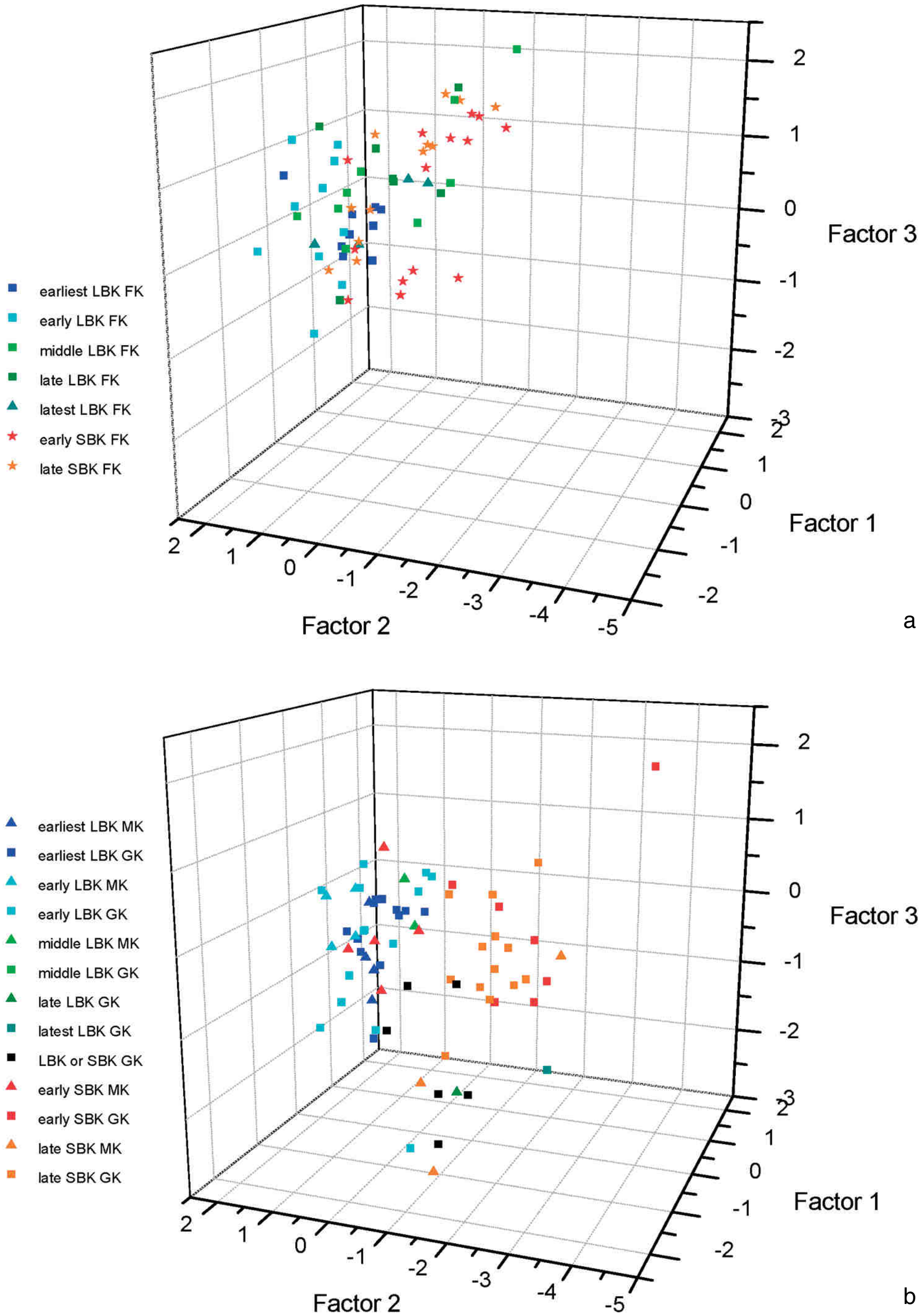



Fig. 13. An analysis of the main components with a reduced number of elements (FK: fine-ware, MK: medium-ware and GK: coarse pottery).

Most of the coarse pottery sherds from the SBK come from beakers, a vessel type that is characteristic of this late phase (for samples from Eythra see *fig. 5*). Potassic tempering may also occur occasionally in sherds of the middle and late LBK, perhaps introducing the early stages of the development of this new method.

## Summary

The ceramic analyses of the sherds of the Bandkeramik from Eythra have basically confirmed our assumptions that the most significant changes in ceramic technology can be discerned between the earliest LBK and the fully developed LBK on the one hand, and between the LBK and the SBK on the other hand. But a more detailed scrutiny suggests that we should assume that as distinctive overlapping phenomena are still in evidence there is some sort of continuing development between the earliest and the early LBK with an actual break in ceramic production. Nevertheless, there are also clear indications of an increased standardisation in the composition of the early LBK clay, which contrasts with the greater variance in the earliest LBK period, which, in turn, may be attributed to the individual preference for a manner of production that is based on household units.

The nature of the database makes the interpretation of the "break" in ceramic production between the LBK and SBK difficult. From the point of view of ceramic chronology, the material is burdened by an imbalance between the individual stylistic phases of the LBK in Eythra. As only a handful of ceramic fragments display the traits of the latest LBK, the number of samples from this phase was barely sufficient (for examples see *fig. 5*). Nevertheless, the results are very interesting: on the one hand they show the conspicuous evolution in clay processing between the earliest and the fully developed LBK, and, on the other hand, a distinct change in the tempering methods during the course of the transition between the LBK and the SBK.

The irregular and angular shapes of the potassic feldspar particles in the SBK samples indicate the addition to the clay of an external material, demonstrating the practice of intentional tempering. An approach of this nature is difficult to ascertain for the LBK, with the exception of the vegetal tempering that is used in the earliest phase. In the late SBK intentional tempering only seems to become a standard procedure with the appearance of a new vessel shape. A large number of the potassic sherds belong to coarse-ware beakers, which frequently are beakers decorated with moulded ribbons (*fig. 5*). These vessels are a characteristic type of the late SBK (*Kaufmann 1976*, 20). Thus, the change in the tempering materials between the LBK and SBK can also be described in both a typological and a functional sense as representing the introduction of a specific new vessel shape and type of ware.

In contrast to this, in some cases the fine ware that the SBK continues to exhibit has pronounced similarities to that of the LBK. There are some indications that the evolution of clay composition actually occurred from the middle LBK into the late LBK. As indicated above, the change from LBK to SBK, which initially appeared to be a distinctive break in regard to the ceramic decoration, in some respects might now be defined as a gradual development. This assessment has been confirmed by the results of ceramic analyses: while a in the composition of the coarse pottery of the Stroke-ornamented ware a clear break is obvious, the fine-ware exhibits do not undergo such radical changes.

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