Fig 47 Removing charge of fired pottery from the horizontal one-chamber kiln (CEA Všestary, August 2004). ■

Experimental Pottery Firing in Closed Firing Devices from the Neolithic – Hallstatt Period in Central Europe*

A pilot study based on experiments executed at the Centre of Experimental Archaeology in Všestary

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• This work attempts to evaluate the results of a series experimental pottery firings with particular regard to closed firing devices of the Neolithic – Hallstatt era, which took place on the grounds at the Centre of Experimental Archaeology in Všestary from 1999 – 2004. It brings together comparative data, partial interpretations and attempts to put forward new hypotheses and research aims.

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1 Introduction

Within the experimental programme of the Centre of Experimental Archaeology in Všestary near Hradec Králové (CEA) we carry out a wide range of activities with the aim to reconstruct individual chains of activities leading to the creation of elements of material culture and their use in a connection to archaeological evidence. The activities are currently related to the Neolithic – Hallstatt era (to the conception of experiment in CEA see *Thér – Tichý 2002*). Pottery production including firing is one of the key activities of the CEA programme. This work attempts to evaluate the results of the experimental pottery firing with particular regard to closed firing devices from the researched eras. This work is a pilot study, bringing together comparative data and partial interpretations. At the same time it attempts to put forward new hypotheses and research aims. It attempts an overview of the problem from the methodological point of view and discusses the data in the context of known results of experimental archaeology in this field.

Structure	Figure	Note
Bonfire	1.I	Firing structure without any special insulation construction
Clamp	1.II	Firing structure with temporary insulation construction (types of clamps see chapter 3.2)
Kiln	1.III, 1.IV	Firing structure with permanent insulation construction
Open	1.I, 1.III.a	
Closed	1.II, 1.III.b, 1.III.c, 1.IV	
On closed devices:		
One-chamber	1.III	Inner space not divided
Two-chamber; vertical	1.IV.a	Inner space divided horizontally with a permamnent partition
Two-chamber; horizontal	1.IV.b	Inner space divided vertically with a permanent partition
Two-chamber; oblique	1.IV.c	Inner space is divided by the different levels of the firebox and the oven
Oval shaped		
Round		
Rectangular		
Horse-shoe shaped		
Horizontal	1.III.c, 1.IV.c	The length of the kiln is at least twice its width
Surface	e.g. 1.I.a, 1.II.a	The whole structure is on the surface
Partly subsurface	e.g. 1.II.b	Part of the structure is below the surface
Sunken	e.g. 1.I.b	The whole structure is below the surface

Table 1 Division of firing devices according to the morphology of the structure. ■

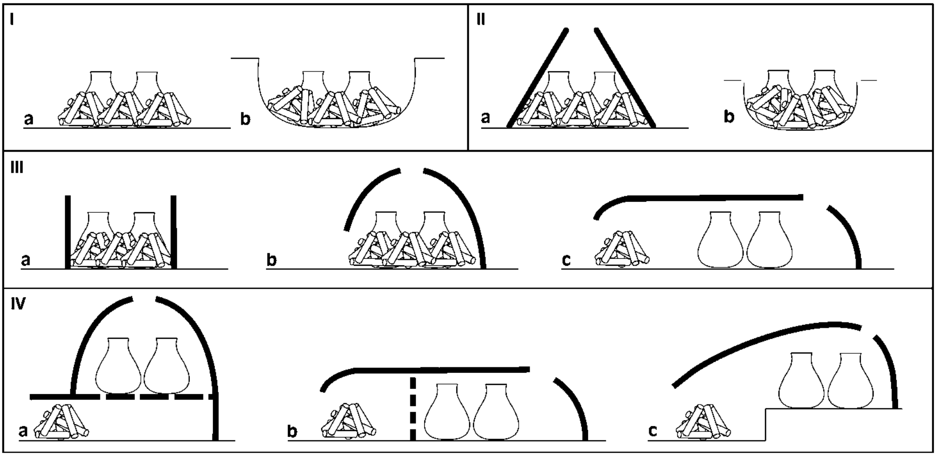


Fig. 1 Typology of devices for pottery firing. ■

The series of experimental firings from years 1999 – 2004 does not present a set of data gained according to a well-thought plan and documented in a consistent manner. The quality of documentation and execution of single firing varies. Some of the firings were planned and prepared, others were carried out more or less spontaneously and these are documented only by a short entry in the diary or a few photographs. The firing were executed either by the members of the SEA or in co-operation with other experimenters during occasional pottery workshops. The co-operation with the Prague children's group of experimental archaeology 'Mamuti' and the group of experimental archaeology in DDM Litomyšl were very prolific. Leaders of both groups are experienced potters, who use their experience to attempt to create replicas of prehistoric pottery. The current peak of this co-operation was the 'Pottery seminar Všestary 2002' that took place on the 12 and 13 of October 2002 on the grounds of CEA. During this event we carried out a mass firing in four devices to allow us to compare the characteristics of the four types of firing devices under the same conditions. Petr Toms, a lecturer of the pottery college in Kohoutov near Dvůr Králové, who has experience of pottery firing in a one-chamber kiln from Pozdišovce in Slovakia, took part in the last experimental firings in August 2004. Altogether we are dealing with 20 firings in closed firing devices, of which six are firings in a clamp-kiln, which were published in the article by R. Tichý and L. Tintěra (*Tichý – Tintěra 2001*) and will be mentioned only as synoptic data.

2 Starting points

2.1 Pre-experiment

In all parts of the chain of pottery production: prospecting, preparing material, forming pots, decorating and firing we are for the time being in the phase of so-called pre-experiment. The term pre-experiment has its specifics in experimental archaeology and does not fully correspond to the use in the theory of experiment (*Campbell – Stanley 1963*). Therefore I think it necessary to specify the term in more detail.

The most important problem is to secure sufficient experience for the experimenter. One of the types of experiments carried out in archaeology attempts to reconstruct and test processes caused by people, who took place in a researched era and given region (often the term experimental archaeology is reduced to only this type of experiments). In these experiments the experimenter functions as an independent and sometimes dependable (see for example the article by M. Štěpán in this number) variable, which can have a fundamental effect on the course and results of the process. In the case of pottery firing this is the potter operating the firing devices. The role of earlier experience was for example evaluated by J. Coles (*Coles 1973*, 149) and it is more or less evident from the majority of partial firing experiments. Sufficient experience is reached at that moment when the results of the process start to stabilize. In our case this is when the curves of measured temperatures during single firings (for given type of device, method of firing and charge) do not differ from each other. One of the aims of pre-experiments is to reach this level of experience.

The concept of experience partially overlaps with a concept of firing strategy. The potter – an independent variable of the experiment, which has not experience with the given firing device, tests various procedures and observes which of the procedures is the most effective. It depends on his invention if he chooses unconventional procedures in an attempt to adapt to the device or just adapts his well-tried procedures. In any way the approach will be different to the approach of prehistoric potters who learnt the firing procedure from their teacher. A. Liv-

criterion / type	figure	note
a. According to the relative position of the firebox and the oven		
One-space firing	2.I	Fuel and pottery in contact
Two-space firing with up-draft	2.II	Pottery placed above fuel or smoke/gas approaching from beneath
Two-space firing with horizontal draft	2.III	Pottery placed behind fuel at about the same level and smoke/ gas does not approach from beneath
Two-space firing with oblique draft	2.IV	Pottery placed behind fuel at different level and smoke/gas does not approach from beneath
b. According to the atmosphere of the firing		
Oxidizing firing		
Reducing firing		
Neutral firing		
c. According to the ending of the firing		
Interrupted firing		Pottery removed before cooling
Firing till cooling down of the pottery		Pottery removed after cooling

Table 2 Typology of firing methods (the typology is not exhaustive, it attemps to classify methods of firing discussed in the article). ■

ingstone Smith writes that potters are often not aware of the advantages or disadvantages of their methods of firing and only replicate the tradition without knowing of other firing methods (*Livingstone Smith 2001*, 1000). The different starting points of prehistoric potters and modern experimenters complicate the reconstruction of the firing process and should be an object of discussion.

Another sign of pre-experiment is the absence of a question at the beginning of an experiment. A pre-experiment does not need to start with a hypothesis, to be tested. On the contrary it serves to create hypotheses that are then tested by experiment or against archaeological material. Pre-experiments, which only monitor procedures, do not differentiate between dependent and independent variables.

The last characteristic of pre-experiments that I am going to mention is a little control of variables. The control of experimental variables in pre-experiment does not need to correspond to the demands of inner validity. On the contrary, a larger variability of factors would allow comprehension of the subject in as wide range of manners as possible.

2.2 Typology of devices for pottery firing and their definition

In the literature there are many different typologies of structures for pottery firing therefore I find it necessary to summarise these and explain the importance of some of the term used in this study to avoid ambiguity.

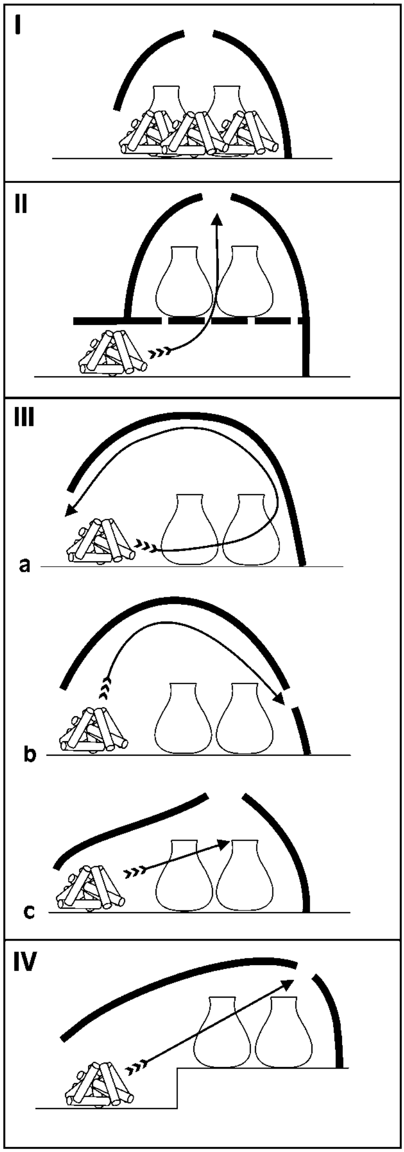


Fig. 2 Typology of firing methods. ■

There are a number of criteria for kiln typology. For the needs of archaeological classification it is necessary to choose grading using interpretational but neutral terms describing the morphology of the structure. For the needs of experimental archaeology, which works with functional interpretations of structures it is more appropriate to choose the functional point of view. One of the basic criteria of firing devices classification is in more or less the conception of grading to what extent the structure is open or closed (*Bareš – Lička – Růžičková 1981*, 192-209; *Livingstone Smith 2001*, 993; *Lička – Košťuřík – Mach 1990*, 8; *Scheufler 1972*, 76-77; *Kovárník 1982*, 106). According to the way the structures are insulated we distinguish between open fire, clamp-kiln and kiln. The term clamp or clamp-kiln sometimes appears in the sense of a one- or two-chamber updraft kiln (*Scheufler 1972*, 76-77; *Kovárník 1982*, 106). The disadvantage of so ambiguously defined a term was pointed out by M. Lička, P Košťuřík and Z. Mach (*Lička – Košťuřík – Mach 1990*, 9) and I am in agreement with them. I see clamp as a firing structure with a temporary insulation (**Table 1**). I do not agree though that the clamp is a transitional form between a simple open firing device and a simple closed device (*Lička – Košťuřík – Mach 1990*, 9). According to me a clamp is an independent structure which has in comparison with other structures its own advantages and disadvantages and its use cannot be explained by the development of firing from an open fire on one hand and a lack of knowledge of more progressive firing devices on the other (see chapter 8).

I consider as an important criterion that characterises the firing procedure by differentiating between the firebox and oven and their respective positions (*Žeglitz 1985*, 148; *Lička – Košťuřík – Mach 1990*, 8). The structural division of a fire-box and an oven divides two-chamber kilns from one-chamber ones with the automatic supposition that the structural division respective the non-division corresponds to a difference in firing procedure (*Lička – Košťuřík – Mach 1990*, Fig 15). In the one-chamber kiln the charge is in straight contact with fuel while in the two-chamber kiln charge and fuel are divided. However, nothing excludes the possibility of placing fuel and charge in the one-chamber kiln separately and there is even the possibility where the fuel in the two-chamber kiln is in contact with pottery. It is therefore impossible to associate only one type of firing procedure with a certain structure. The chosen firing strategy then can have much bigger influence on the characteristic of the fired pottery than the morphology of the structure itself. Therefore it is useful to classify the firing device not only by its morphology but also by the firing procedure. As a basic criterion I shall regard again the division of firebox and oven and their respective positions (**Table 2**). The suggested classification is based on the typology of kilns by P. Rada, which grades the kilns according to way the flame travels to chimney (*Rada 1990*, 174-178). The use of the term 'Oriental kiln' as a transitional kiln between updraft kiln and a kiln with a horizontal draft (*Rada 1990*, 178) I consider a misconception and instead I will introduce an independent type: two-space firing with oblique draft.

Horizontal kilns are a special type. As the criteria for the identification of a horizontal kiln I will use a plan of the structure (**Table 1**). It is a little inaccurate because this type of kiln shows signs according to which we would classify them as oval or rectangular shaped kilns, only the length of the kiln is considerably longer (2times and more) than its width. Despite this I consider it useful to divide off the type of horizontal kiln because its shape indirectly points to a division of the firebox and oven, although we do not have evidence of elements dividing the two spaces. We can identify the division, although not always, by the burning of the kiln floor. In other shape types this implication is not so obvious. I consider it possible for division of firebox and oven in kilns with oblong, rectangular and horseshoe plans, where the length exceeds the width. It is difficult to imagine this division for kilns with a circular plan.

2.3 Archaeological evidence of devices for pottery firing and the role of experiment

We can find quite a lot of evidence for structures that intentionally used the thermal energy of burning for some purpose. Many of these structures are potentionally useable for pottery firing. Unfortunately, the technology of firing does not leave any signs that would allow for the straight interpretation of a structure as a device for firing pottery. J. G. McDonnel differentiates the signs, according to which, it is possible to interpret the function of a structure as diagnostic remains and non-diagnostic remains. The diagnostic remains can be assigned to certain production process. Mostly it concerns the side products of the process. Non-diagnostic remains can be used as supportive arguments but they themselves do not lead to a certain process. McDonnel considers pottery rejects damaged during the firing as diagnostic remains of pottery kilns (*McDonnel 2001*, 502, Table 40.3). These can easily be mistaken for common pottery waste that deposited in the space around the structure secondarily. The same problem occurs with 'uncollected charges' of pottery.

Another sign, supposed to be evidence of a structure for pottery firing, are the construction elements of the structure. They allow the identifying of kilns, which use specific construction elements, such as a grate dividing firebox from oven. If we consider kilns on the basis of such signs, the identification as pottery kilns is disputable, as these elements lead to a limited number of production processes.

In the territory of the Czech Republic there have been discovered several features predating La Tène period and interpreted as pottery kilns. M. Lička, P. Košturík and Z. Mach carried out a critical evaluation of twenty of such structures. As a result they reduced the number of certain pottery kilns from the pre-La Tène era to one: a Lengyel kiln from Kramolín. Another feature from Horní Mostěnice was not, according to the authors, sufficiently well published. The Knovíz feature might be considered as a pottery one-chamber kiln only by supposition that the pottery found inside represents a pottery charge (*Lička – Košturík – Mach 1990*, 14). The certainty of the interpretation of the Lengyel feature from Kramolín as a two-chamber vertical pottery kiln with a grate is of course also only relative. The interpretation is based purely on the morphology of the surviving part of the structure and analogues. From the dome of the kiln nothing has survived and it is only presumed (*Lička – Košturík – Mach 1990*, 7-8). The data contradicting the supposition of a kiln function (the maximum temperature of grate firing only 570° C) is 'bracketed' (*Lička 1994*, 194-195).

The claim that a certain archaeological feature from any period when we do not have other, clear evidence of the function of the feature represents a device for pottery firing is hypothetical. Therefore if we classify a feature by its function we create a hypothesis that needs to be tested. If we should prove by test that the hypothesis is correct we would have to exclude every other use of the structure. If we show that firing pottery is possible in the device than we only prove that firing pottery in it was possible. Proving these possibilities seems at the present pointless because current ethnographic, historical and experimental knowledge shows that it is possible to use for pottery firing any of the above mentioned structures, from open fire to multi-chamber kilns and that they have all been used. In the European tradition the whole range of these devices were used up to the beginning of the 20th century (*Scheufler 1972*, 76-77). The situation is complicated by the fact that these need not be specialised devices for pottery firing, but that they could have been multifunctional structures. The problem of multifunction use concerns mostly the simpler structures but it cannot be excluded even for two-chamber kilns.

A possible solution seems to be to take into consideration the characterisation of fired pottery. Many authors define the difference between open firing devices and closed kilns with help of thermal profiles, which determine each firing structure. These are characterised by the duration, maximum temperature, heating rate and soaking time (the time during which the pottery is subjected to a certain temperature). For kilns it is supposed these will be characterised by a long duration, high maximum temperatures, low heating rate and long soaking time. For open structures it is the other way round (for example *Kingery 1997; McDonnell 2001*). The application of a corresponding analysis of pottery, which allows determining the appropriate thermal characterisation of the pottery, would allow for the identifying of the firing structure type. However, O. P. Gosselain showed that the maximum temperature is not useable for differentiating between firing devices. According to him it is a very variable indicator dependent on, apart from the structure, many other factors. Firing in simple structures on top of this is non-homogenous so it is impossible to use partial temperatures to characterise the whole process. Useable data, according to the author, are indicators describing the dynamics of the process that means heating rate and soaking time (*Gosselain 1992*). A. Livingstone Smith took the critique of the thermal characterisation of each structure even further. Based on 62 firings monitored by him in field and 18 adopted from literature from various regions of Africa and Asia he showed that pottery firing is a combination of many elements. These elements are not only technological but also of a social nature and create vast number of combinations fundamentally effecting the thermal characterisation of firing. Not one of the indicators (duration, maximum temperature, heating rate, soaking time) corresponds to the typology of firing devices. Therefore it is impossible to connect certain thermal characterisation with a certain firing structure (*Livingstone - Smith 2001*). The disproportion between the number of firings in kilns and the number of firings in other structures is a drawback of this study. From the total of 80 examples only 8 concerns all types of kilns. Therefore I consider his conclusions open.

Another characterisation, which could be considered for differentiating between single structures for pottery firing, is homogeneity of the firing. The hypothesis again starts with the supposition that a different level of homogeneity is reached in different structures (*McDonnell 2001*, 495). A certain degree of firing homogeneity is necessary, especially concerning the content of oxygen in the atmosphere of the oven, to reach some aesthetic features of the surface of the pottery (painted decoration, colour slip and 'burnished' surface). This excluded from the production process the firing devices in which it is impossible to reach the necessary homogeneity. In addition, the choice of certain fine mixtures could have been, because of the necessary homogeneity of the firing, a determinator in the choice of a firing device. For example W. Czysz thinks that at least since the Urnfield period with its fine pottery fired in reduction atmosphere it is necessary to presume firing in kilns although there is not evidence of such structures (*Czysz 1990*, 315).

The role of experiment in the field of prehistoric firing technology can be in:

a. determining relations between pottery characteristics and certain types of firing devices,

b. observing the transition of structures from systemic to archaeological context with the aim of determining specific signs allowing for the identification of pottery kilns and their reconstruction.

2.4 Fuel and the methodology of measuring its consumption

If it is not stated otherwise mixed wood mostly from deciduous trees was used, oak wood representing the biggest proportion. There was also a significant presence of birch, willow, cherry, ash, maple and pine. The material was divided into logs approximately 33 cm long and then either left in one piece (to about 8 cm diameter) or split (about 10 cm diameter), the bark was not removed. It was used for firing after at least a year long drying under shelters with turf roofing or beneath thatched roofs alongside house walls in the CEA grounds.

The consumption in published experimental firings is most often given in kilograms of used wood (např. *Mayes 1961; 1962; Bryant 1970; Bareš – Lička – Růžičková 1982; Kovárník 1982*). Although weight of wood is an easily and accurately determined quantity it presents a problematic indicator. The weight of wood changes dramatically with its water content. For example for oak the density at 15% water content is 690 kg/m^3 and at 0% water content 650 kg/m^3, this means a 6% difference with a change of water content of 15% (*Žák 1997*, Table 1) when wood with a water content in the interval 15 – 0% is considered dry (*Žák 1997*, 49). Big weight differences also occur between various wood species. For example fir has at 15% water content 450 kg/m^3 density while hornbeam density is 830 kg/m^3, which is nearly double (*Žák 1997*, Table1). For this reason we measure wood consumption by volume. Volume also changes during drying but not as much as weight. Lengthwise wood changes its volume while drying by 0.1 to 0.3 % and radially by 4 to 8% (*Žák 1997*, 52-53). The disadvantage is that this is a more demanding way of measuring. For the needs of experimental firing we measure wood in following manner. We randomly choose a set of about 50 logs and measure its average length. Then we carefully pile the wood alongside a vertical wall in such way as to minimise the space between single logs. We measure the area of the wall taken by the piled wood and multiply it with the average length of a log. We get information, which gives us not a clear volume of the wood but volume of wood storage. If we apply the same method for the various firings we can compare wood consumption fairly accurately. Different method, for example measuring the wood volume before it is cut and split can give different results. The methodology of measuring is rarely published therefore it is possible to compare our wood consumption with the published data only to a limited extent.

During experimental firings in CEA the wood consumption was measured only during the last 6 experiments from the years 2002 to 2004. The volume of wood burnt during earlier clamp firings can be estimated by volume of the clamp because during those experiments no more fuel was added into a clamp after its closing.

2.5 Methodology of temperature measuring

For measuring temperature we used thermocouples PT-PtRh covered with ceramic capillary and wire probes on basis of thermocouples NiCr-Ni. A thermometer Commeter was used as a recording device.

When the temperature of the pottery firing was measured the thermocouples were placed touching the surface of the pottery. We endeavour to measure the temperature in at least two places of the oven – at the places of supposed highest and lowest temperatures. This sometimes failed due to technical problems with thermometers so some of the firings were measured with only one thermometer.

The external conditions in which the firing took place were also recorded.

2.6 Pottery

The yield of firing documented as a percentage of damaged pottery is one of the datasets characterising the results of experimental firings. The scale of pottery loss is effected not only by the method of firing and firing structure chosen, but also by other factors such as the composition of the ceramic mixture, method of preparation of the ceramic mixture, the technology of working, the technique of forming pots and decorating them, shape of the vessels and their size, respectively the thickness of the walls. All these factors should be accounted for if we want to evaluate the yield of firing. In the case of CEA firings this is not yet possible because there is not sufficient control over the possible causes of single characterisations of pottery. For the time being we do not know contents of the clay we use for making pottery, we do not know its history. Only occasionally was the proportion and character of temper in the ceramic mixture recorded. Despite that I attempt to describe briefly the fired pottery.

The basis of the ceramic mixture is clay from two sources. Most pottery was made from clay with an evident content of grey to green-grey argil. The clay was dug from the surface of backfill of a former hollowed out track. In the years 1998 – 2002 it was stored in a small pit of about 1 m diameter and 0.5 m depth. From summer 2002 the clay was stored in a roofed sunken structure with a kiln. The next source of clay was on the eastern bank of the Rozkoš dam. The clay from there was taken from surface and it was stored in plastic bags. The clay is heterogeneous. There is evident content of brown loess with green-grey argil. The resulting worked material is plastic but has a tendency to crack when dry, therefore it is necessary to add temper to it. Also used for pottery was an ochre loess dug from the clay-pit in the CEA grounds from depth of more than 1 m. Due to a lack of plasticity the products did not reach appropriate quality.

The ceramic mixture was usually tempered by river sand or grog. The proportion of temper was approximately up to 20%. In the case of pottery objects for bronze casting (melting pots, crucibles, forms) they were tempered with siliceous sand, the proportion in the mixture was about 50%. Some pottery forms were tempered with peat.

Apart from our production we fired also pottery brought in from outside, mostly from various industrially prepared mixtures. Because of their different properties their evaluation is distinguished from the production using experimental material.

3 A subsurface clamp-kiln

3.1 Model

A clamp-kiln is a temporary structure. Although it is possible to renew it in situ, it would always be a new construction. After transformation into an archaeological feature it does not show any specific signs, which would allow us to distinguish it from the general category of structures, which used fire for nonspecified purpose. If the base of a daub cover is not preserved from which it would be possible to decide if it was a permanent insulation structure, it would be impossible to decide if was a kiln or a clamp. Material from both of these structures can show the same properties.

The function of the structure would, in the case of clamps, be indicated by charge of pottery, which would itself be shown by a placing of a big amount of whole and mostly whole vessels. Together with traces of scorching, these are the only indicators, which allow us to consider the possibility of a device for pottery firing without permanent insulation construction. Some archaeological situation described as pottery stores could correspond to the characteristics of these firing devices (*Bareš – Lička – Růžičková 1981*, 196). However, most situations do not allow for the interpretation of stores as pottery charges (*Palátová – Salaš 2002*).

Other features, which could be considered as pottery clamp-kilns, are pits with traces of scorching on their walls, often with large amounts of daub, pottery and charcoal in the infill. These features are sometimes interpreted as sacrificial pits. For example V. Dohnal described some sunken features from Unčovice near Olomouc and Holešov (Kroměříž region) as cremation burials on the basis of strong scorching of the features walls and the fact that their infill contained layers of bones, ash, pottery and daub (*Dohnal 1988*). The description of the finds allows for an alternative explanation that the features could have been used primarily or secondarily as subsurface hearths or clamps for firing pottery and then as rubbish pits. The sunken feature of a square plan with burnt walls and daub destruction from Přáslavice is of a similar character. This feature was found in the context of a Bronze Age settlement (*Šabatová - Vitula 2002*, 7, Table 65, Photo 26).

3.2 Reconstruction

The pits with traces of scorching on walls dated to the researched period do not have traces of air channels that would secure an air supply to the lower parts of the structure. For this reason the experimental construction in CEA did not include these elements although there is little probability that they would show in the archaeological evidence.

A temporary insulation structure could have been built basically in three ways:

a. Without a firm construction. For example the placing of turfs over a piled bonfire during firing. At the CEA grounds we tested clamps of this type six times. As the results have already been published (*Tichý – Tintěra 2001*) I will not pay them more attention.

b. With a firm construction. An independent wooden or wicker construction covered with daub is built arounr the pottery. In the cover there are holes for draining fumes and adding fuel. This type of clamp insulation allows the clamp to be used at the same way as a one-chamber kiln and has a better control over firing. This variant was chosen for the experiment described below (**Fig. 3**).

c. Another solution is a mobile dome created by the daubing of a basket. This method was tested by M. Mogielnicka (*Mogielnicka 1974*).

3.3 Firing

The experiment took place as a part of the 'Pottery seminar Všestary 2002'. Preparation and firing were organised by Mr and Mrs Červinka and L. Tintěra. The average external temperature was 3.6°C and an air humidity of 85%. The clamp was prepared during the afternoon. Fortunately, during the preparation it did not rain but during the firing occasional showers changed into continuous rain. The bases of the charge were two storage pots. The bigger one was placed on the bottom of the pit and the smaller one put on top of it bottom up (**Fig. 3, 4**). Pottery and charcoal were placed inside the storage pots. The walls of the storage pots were supposed

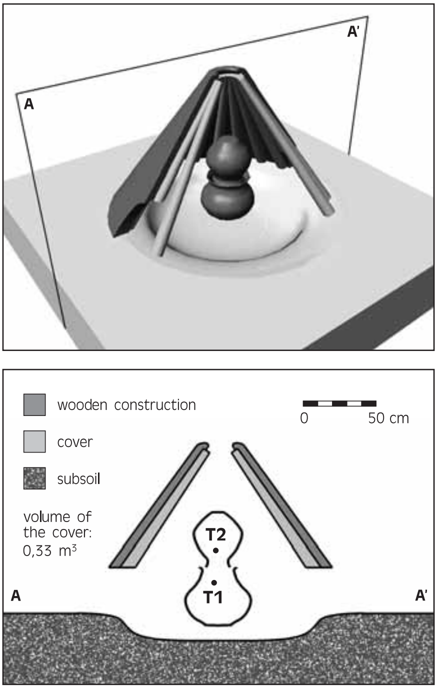


Fig. 3 3-D reconstruction of a clamp; cross section (wooden construction, cover, subsoil, volume of the clamp). ■

to create an anaerobic condition, so that the pots inside were fired in a reducing atmosphere. Other pots were placed around the big storage pot. Also around the charge was built a construction from logs of up to 10cm diameter in the shape of cone. The construction was daubed. The western and eastern sides had openings for stoking the fire and regulating the draught, of approximately 30 by 30 cm. Top of the cone was left open to drain fumes (**Fig. 5**). On the 12th of October at 13:55 a fire was started at the western opening (A) and at 14:39 in the eastern opening (B) (**Fig. 6**). At 14:55 a small hole was created in the north (C) which was enlarged at 15:25. After another 10 minutes another small hole was made near the northern one (D) and at the same time the stoking became more intensive. After 16:00 we were waiting for the levelling of the temperatures inside the pile. At 16:40 we found that the big

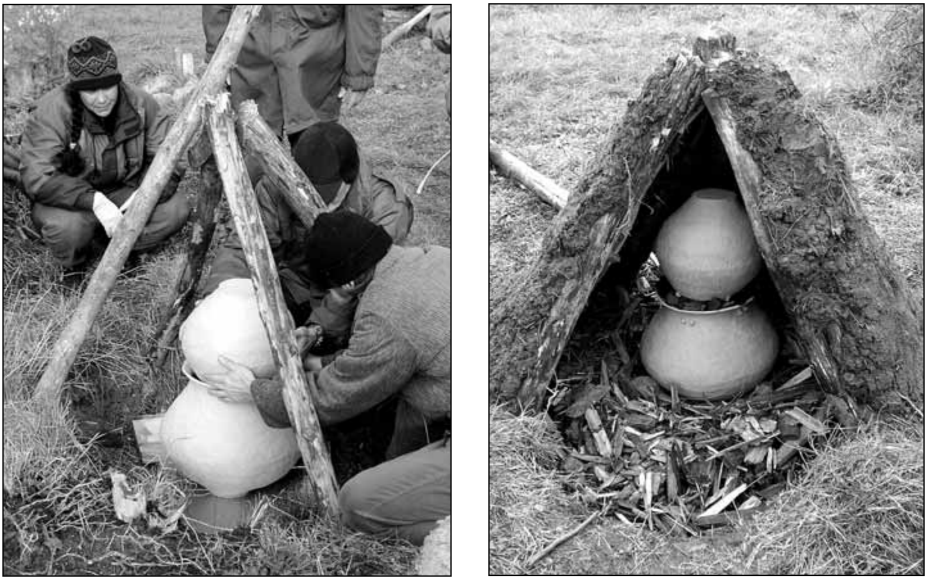


Fig. 4 Placing of two storage vessels in the clamp. ■

storage pot had cracked. At 17:00 the openings A, C and D were open. The opening B on the windward side was left closed. After 19:00 fuel was added for the last time. Between 20:30 and 20:50 all the openings were closed. In the morning, on the 13th at 8:35, the smoke hole was opened but the temperature inside started to increase and therefore it was closed again. However the temperatures did not stop rising. At 15:00 the burn through holes around the openings were daubed. At 17:20 due to organisational reasons it was necessary to stop the recording of the temperatures. This happened at the moment the temperature in the pile reached its maximum (868°C) and seemed to be still rising (**chart 1**). The pottery was removed on the 15th of October at 10:30 when the temperature inside the pile was about 30°C. The big storage pot had broken into a pile of shards. The rest of pottery, including the other storage pot had stayed undamaged. The hope for firing in a reducing atmosphere inside the storage pots had failed. Fifteen pots were fired in oxidizing atmosphere, although there were dark spots indicating firing in a non-homogeneous atmosphere (**Fig. 7**). To remove the pottery it was not necessary to dismantle the whole cover, but only the eastern opening was enlarged. Nevertheless, the cover collapsed within two weeks.

Fig. 5 Clamp after finishing of cover. ■

Fig. 6 Clamp in first stage of firing. ■

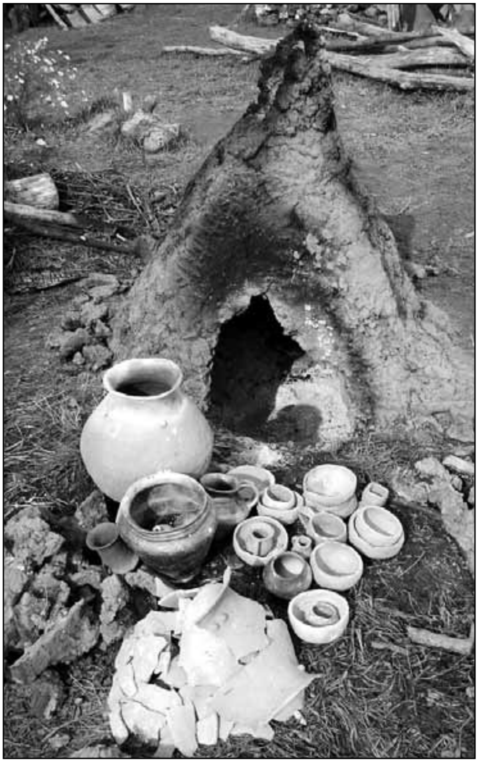


Fig. 7 Clamp after removal of pottery. ■

4 Partially subsurface one-chamber kiln with rectangular plan

4.1 Model

The model for reconstruction chosen was a feature discovered in 1940 in Bořitov. The feature is dated to LBK and consisted of a pit of 380 by 390 cm size with the remains of a kiln partly sunk into the northern wall of the pit. The profile of the pit and its depth are, unfortunately, unknown. The shape of the kiln preserved in the part dug into subsoil indicated a rectangular plan. The kiln was of 85 to 100 cm size. Its bottom was 15 cm deep. The sidewalls were burnt to a depth of 6 to 8 cm. The bottom was flat with a layer of quarried stones and broken quern stones. On the layer of stones there was a layer of daub 4 cm thick. Unusual for this type of structures was a preserved system of postholes, which indicated some sort of roofing. The system presented had two parallel lines with three postholes in each row. The preserved depth of holes was 65 to 80cm (*Čižmář 1998*) (**Fig. 8**).

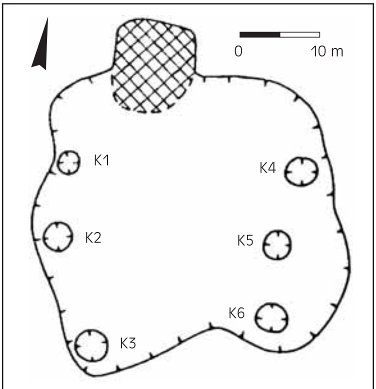


Fig. 8 Plan of the feature from Bořitov (according to Čižmář 1998). ■

The finds of one-chamber kilns are known from many sites and it is clear that these devices belong among the standard structures of LBK settlements. Most often they are interpreted as devices used for the thermal treatment of organic materials – baking, drying, roasting (for example *Tichý 1962*, 207; *Šedo 1983*, 43). This function was experimentally tested several times (for example *Kaufmann – Heege 1991; Pfaffinger – Pleyer 1990; Werner 1990*). In reality we can consider them as multifunctional structures as indicated by ethnographic analogues.

4.2 Reconstruction

Z. Čižmář proposed the roofing of the structure with a gabled roof (*Čižmář 1998*, 105). The lack of a central row of post excludes ridge-supported roof and gabled roof would therefore need a technically complex solution. On top of this the axes of both rows are not parallel but at an angle of about 20°. For the reconstruction we chose a simple single-pitched roof.

The system of postholes is placed eccentrically in the southern part of the feature, on the side opposite to the kiln. Extending the roof over the kiln looked unnatural. Therefore we chose a variant where the roof protected not the kiln but its background. (**Fig. 9**)

The considerable depth of postholes indicated large static demands. These could have been caused by the choice of a heavy roof covering, which would correspond

Fig. 12 Building of a one-chamber kiln. ■

Fig. 11 Construction of a one-chamber kiln. ■

Fig. 13 Ware fired in a one-chamber kiln (12/10/02). ■

Fig. 14 One-chamber kiln: condition in September 2004. ■

to the safety demands of roofing so close to the kiln. As roofing we therefore used turf, which was put on a pre-prepared grid of logs and split oak timber.

The shape of the kiln cover was chosen with regards to it supposed function: the firing of pottery by a two-space method with a horizontal flame. The cover at the front of the kiln, where we placed the firebox, was built in the shape of a low tunnel that slowly changed into a dome, where we planned an oven (**Fig. 10, 11**). The cover was made with a wicker construction and a daub layer about 12 cm thick (**Fig. 12**).

The kiln was finished at the beginning of August 2002.

4.3 Firing

The only experimental firing of this kiln took place as a part of the 'Pottery seminar Všestary 2002'. The weather conditions were unfavourable (see firing in a pile). Pottery was put into the oven through the firebox. Thermocouples were placed on the bottom and under the upper edge of a big kettle-like vessel (**Fig. 19**). Unfortunately, the thermometer connected to the thermocouple on the bottom of the pot failed so for this firing there is only one temperature curve recorded (**chart 2**). The firebox was swept out approximately every hour. Within 6.5 hour the temperature reached 781°C. The kiln was not closed after the finish of the firing. The pottery was removed 20 hours after the beginning of the firing. None of the pots was damaged and the pots were homogeneously fired under an oxidizing atmosphere.

4.4 Formative processes

The construction of the cover was during the 2002/2003 winter damaged by bad weather conditions and collapsed in the area of the firebox (**Fig. 14**).

On the 7th of August 2004 part of the kiln destruction ($0.05m^3$) was used for the repair of a horizontal kiln.

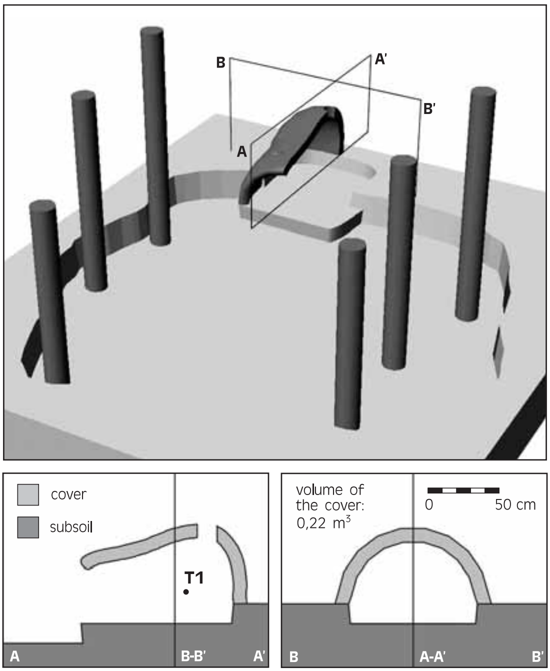


Fig. 9 3-D reconstruction of a kiln with roofed kiln mouth based on the find from Bořitov (cover, subsoil, volume of the kiln). ■

5 Subsurface one-chamber horizontal kiln

5.1 Model

In 1995 a rescue excavation took place at the site 'Pod sv Antonínem' in Turnov, Eastern Bohemia. A feature (84/95) with an elliptic plan (2.65 to 1.1 m, depth 0.3 m) was uncovered within a polycultural settlement. The feature showed the traces of scorching even before the beginning of the excavation. The excavator interpreted the bottom infill layer as the thermo insulating layer of a kiln (light, brown-grey sand with daub and charcoal). The layer above was described as a firebox and was not closely described. Above it was a layer of compact daub, interpreted as a dome destruction. In the southwest part of the feature was discovered part of a daub dome with a hole. The feature produced only atypical pottery that dates the object to the period of Lusatian culture (*Prostředník 1996*, 12, Fig 4).

The ratio of length and width indicates that this structure might have been a horizontal kiln. According to the documentation there was approximately two third of the way along the length an edge dividing the feature into two parts (**Fig. 15**). This element is not described in the text and it is not clear if the smaller part represented firebox divided from the oven or if it represented a kiln mouth. If the whole kiln was domed with a partition to divide it into two parts, then the structure might be considered as a pottery kiln with its shape adapted to its purpose. Interpretation of analogous finds from Poland would rather support the variant with a kiln mouth (*Mogielnicka –Urban 1984*, 27-35; *Piaszykówna 1952*).

Fig. 10 Construction of a kiln with a roofed kiln mouth based on find from Bořitov. ■

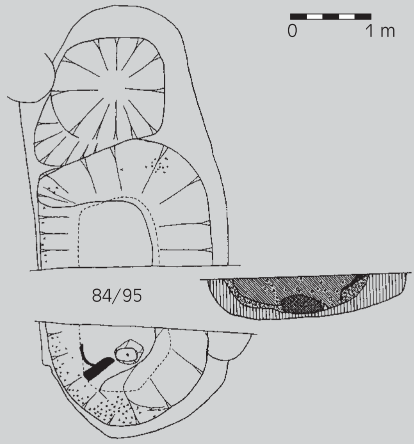


Fig. 15 Plan of the feature from Turnov (according to Prostředník). ■

Horizontal two-chamber kilns appeared for the first time in the second half of the 4th millennium BC in the Near East followed by vertical kilns with a grate (*Bareš – Lička – Růžičková 1981*, 207). In our region classical horizontal two-chamber kilns are known only from the turn of the 14th century and in town environments they gradually pushed out by vertical kilns (*Žeglitz 1985*, 150). In earlier periods we again strike the low evidence value of the archaeological situations. While vertical two-chamber kiln with a grate shows typical elements (perforated grate, channels), horizontal kiln does not have such typical elements and can be confused with kilns for other purposes. Apart from the plan the only remains of partitions can indicate the original purpose of the kiln. Of course a horizontal kiln can also operate as a one-chamber kiln, or the firebox and oven could have been divided by movable partitions (*Bareš – Lička – Růžičková 1981*, 201). This can be presumed especially for smaller kilns where the possibility to remove the partition made manipulation of the pottery inside the kiln easier. With some Neolithic kilns of oval or rectangular plan we can already see attempts to divide firebox from oven. This could have caused later extension of kiln into a horizontal type (*Bareš – Lička – Růžičková 1981*, 201). A feature close to the plan of a horizontal kiln is a sunken feature with a collapsed clay dome dated to the Funnel Beaker culture in Kostelec na Hané, Moravia (*Prudká 1978*, 231). The term horizontal kiln appears more often though in the context of LBA and Hallstatt. In the Czech Republic there are features interpreted as horizontal pottery kilns from Černožice (region Prague - West) and Nové Sedlo nad Bílinou (Chomutov region) belonging to Knovíz cultural complex (*Čtverák – Slavíková 1985*). It is not possible to say unambiguously on the basis of the published plans that their shape corresponds with the shape of horizontal kilns, not to even mention other possible elements. In the case of the two features from Černožice there are even doubts that the structures served as kilns (*Lička – Košťuřík – Mach 1990*, 11). A similar situation is in Poland in the area of Lusatian Urnfield cultures (*Mogielnicka – Urban 1984*, 27-35). Some structures with an oval plan could be considered as pottery horizontal kilns but direct evidence is lacking. In addition, the kilns of Hasseris type are characterised as horizontal (this time two-chamber) kilns. They appear in Northern Europe and are dated to the Iron Age and the Roman periods (*Hingst 1974; Lucke 1990*). Kilns of this type are described as horizontal even if their length does not considerably exceed the width and the ware is placed in higher position than the fuel therefore I classify them as two-chamber diagonal kilns according to the suggested typology (see Chapter 2.2).

5.2 Reconstruction – version 1

The first version of the reconstruction corresponds to the presumption that the feature from Turnov represented a kiln (2/3 of the feature) with a kiln mouth. The area of the kiln was vaulted with a low arch cover designed as a tunnel. The core of the cover was a wicker armature with daub layer of about 10 cm. The smoke hole was placed at the end of the kiln. There is no evidence of daubing of the floor at the Turnov find and so it was not applied in the constructed kiln (**Fig. 16**).

The building of the kiln took one day (01/08/2001). Six people prepared the wicker armature for two hours and in following three hours they daubed it.

5.3 Firing 1

The first firing in the horizontal kiln took place on the 12th of October 2001. The pottery charge was placed in the rear 50 cm of the kiln. In front of it we poured a layer of shards, which was supposed to protect the pots from temperature fluctuations. Thermocouples were placed in the oven on the pottery surface (sensor 1) and it the firebox (sensor 2). The firebox was swept out several times during the firing, so it was not blocked with ashes. During the firing we had an unfavourable eastern wind. After six hours the temperature reached 798°C (**graph 3**). The maximum temperature was not measured in the firebox but in the oven. The kiln was not closed after stoking ended. None of the pots was damaged during the firing and the pots were homogeneously fired in oxidizing atmosphere (**Fig. 17**).

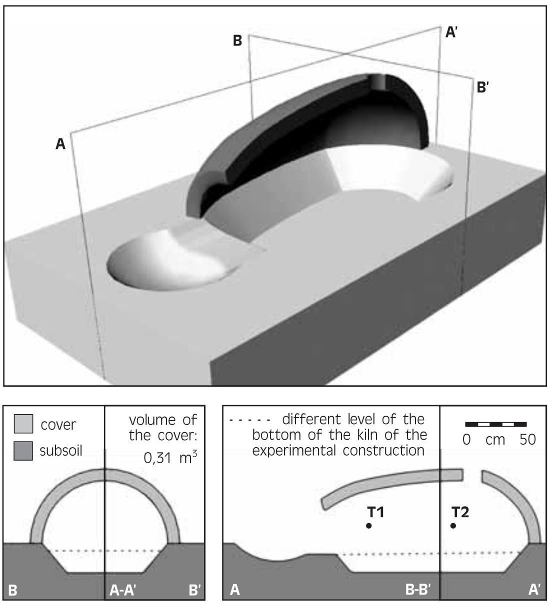


Fig. 16 3-D reconstruction of the first version of horizontal kiln based on the find from Turnov. ■

5.4 Firing 2

The second firing took place as a part of 'Pottery seminar Všestary 2002'. The average external temperature was 3.6°C and air humidity of 85%. After it began to rain the eastern wind strengthened and blew smoke and flames towards the oven. The regime of stoking was the same as during the first firing. The temperature was measured only in one place due to a defect in the second thermometer (**graph 4**). After

Fig. 18 Ware produced during second firing in the first version of the horizontal kiln (12/10/02). ■

Fig. 17 Ware produced during first firing in the first version of the horizontal kiln (12/10/01). ■

Fig. 19 Placing of the thermocouples during the firing in the one-chamber kiln (view through the smoke hole). ■

Fig. 23 Kiln closed after firing to create a reducing atmosphere. ■

Fig. 30 Repair of the horizontal kiln. ■

Fig. 20 Stoked horizontal kiln before the third firing. ■

Fig. 21 Grate from pottery shards dividing firebox from the oven. ■

more than 7 hours the temperature reached 812°C. After the end of stoking grass was added to the kiln and the openings were sealed in order to create a reducing atmosphere. None of the pots was damaged during the firing and they were fired in a reducing atmosphere (**Fig. 18**).

5.5 Reconstruction – version 2

The second version of the construction had the cover extended over the whole length of the Turnov feature, around 2.7 m. This version was based on the supposition that the whole structure was vaulted over with a cover. The inner partition was not put in place. Together with this adaptation the original part of the cover was repaired. The surface layer under the influence of damp and frost had become to crumble and started to fall off, therefore the whole cover was daubed with a new, at least 5 cm thick, layer (**Fig. 30**). The top of the cover was covered with daub from the destruction of the Bořitov kiln and daubed. The cover after the repair is in some places up to 20 cm thick. For the repair we needed about 0.15 m^3 of new daub and 0.05 m^3 of recycled daub. The repair was done by three people on the 7th of August 2004. Together with the preparation of the daub it took about 4 hours.

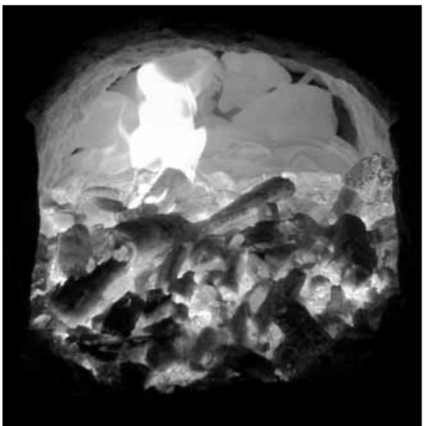


Fig. 22 View into the horizontal kiln after the end of stoking (firing 3). ■

5.6 Firing 3

The third firing was carried out in co-operation with a lecturer Petr Toms from the Pottery college in Kohoutov near Dvůr Králové. The aim of the experiment was to determine the characteristics of the kiln under a maximum charge. The kiln was from 1 to 2 metres of its length fully loaded with pottery (**Fig. 20**). Apart from CEA production (55 pieces) there was pottery supplied by a conservationist from the Museum in Kutná Hora D. Kelerová from her own production

Fig. 25 First phase of third firing: fire was placed in kiln mouth. ■

(28 pieces). Her pottery was made from Hořice pottery clay. A partition from overlapping pottery shards was carefully laid between the firebox and oven (**Fig. 21**). It was made in such a way that channels were left to allow the penetration of fumes into the oven. Thermocouples were placed at the front of the charge in the upper part of the kiln and at the end of the charge in the lower part of the kiln (**Fig. 16**). The fire was started at the stoking hole so that the pottery and the kiln walls would heat slowly. After reaching 150°C the fuel was moved into the firebox. In an attempt to fire as economically as possible we avoided sweeping out the firebox. After 7 hours the fuel was left to burn out to free up space for stoking. This caused a decrease in the temperature. After less than 9 hours the temperature exceeded 900°C (**graph 5, Fig. 22**). The kiln was filled with grass and sealed (**Fig. 23**). After 25 hours the temperature in the oven fell below 200°C. To speed up cooling the smoke hole was uncovered. As the remains of fuel started to smoulder and the temperature started to raise slowly the hole was again covered. Pottery was removed 49 hours after the beginning of the firing. The pottery from CEA production was in order. The pots from Hořice pottery clay were in around 20% of cases flaked on the bottom. That was probably caused by an incorrect choice of material in regard to shape of the pots and the method of firing. Fired Hořice clay is very heavy and has little permeability. The clay was not tempered. The material was used for creating replicas of LBK vessels that have relatively thick bottoms. Pottery with such properties probably does not tolerate a high rate of heating during the transition from 150°C to 430°C, of 6.8°C a minute.

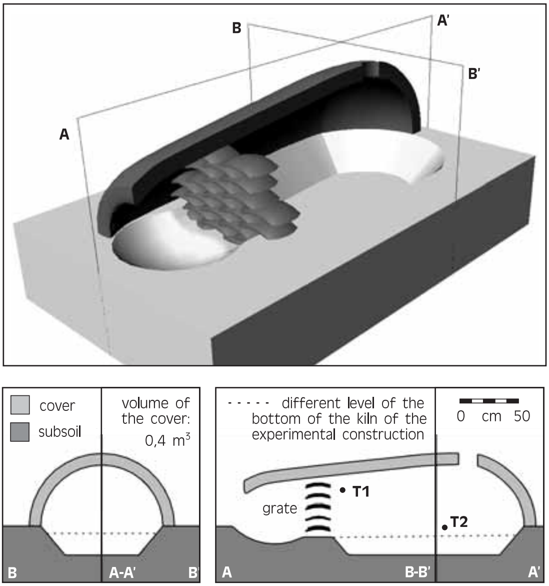


Fig. 46 3D reconstruction of the second version of the horizontal kiln based on the find from Turnov. ■

6 Subsurface two-chamber vertical kiln with grate

6.1 Model

In 1973 the body of a sunken kiln was excavated in the area of Lengyel settlement near Kramolín (region Třebíč, Moravia). The feature consisted of two pits: a simple oval shallow pit of 190 cm maximum diameter and horseshoe shaped pit, divided lengthways by a plinth into two channels. The channels were 110 to 120 cm long, 25 cm wide at the bottom and 30 cm wide at the grate. The height of the channels was about 15 cm. The length of the smaller part of the feature was 130 cm; it was 105 cm wide and about 20 cm deep. About one third of this pit was covered with

Fig. 27 First version of the construction of a vertical two-chamber kiln. ■

Fig. 29 Construction of the cover of the vertical two-chamber kiln. ■

Fig. 28 Construction of channels of **a** grate and **b** vertical kiln. ■

a ceramic grate (about 10 cm thick) with vertical air holes. The preserved part of the grate had altogether 16 holes with diameters of about 3.5 to 4 cm. The distance between neighbouring holes was on average 7 to 12 cm (in one case only 3 cm). The grate was made from ceramic mixture with the addition of angular chips of various stones (average: 1 – 15 mm, proportion in material: 20%). From the documentation it is not clear if the plinth was a block cut from the subsoil or a clay built partition. Traces of fire were found in both channels and especially in the 'shallow hollow' at the northeast edge of the bigger pit, which means in the space in front of the channels. Nothing survived of the kiln above the grate level. In the infill of both pits were found shards of Moravian Painted Ware (Lengyel cultural complex) (*Lička – Košťuřík – Mach 1990*, 1 – 3) (**Fig. 24**).

This is the earliest kiln of this type documented in Central Europe. Thermoluminescence analysis of a sample from the grate produces a date of 6 500± 100 BP. According to the authors of the publication it is necessary to look for model of this kiln in the Cucuteni-Tripolye cultural complex of Eastern Europe and in Neolithic cultures of Near East, where the two-chamber kilns are generally spread (*Lička – Košťuřík –Mach 1990*, 13). A feature from Baden culture settlement in Hlinsko near Lipník nad Bečvou (Moravia) was also interpreted as a two-chamber vertical kiln with a grate (*Pavelčík 1983*). However, the published archaeological situation does not prove this interpretation. The interpretation of as yet unpublished find of the Bükk culture from Šarišské Michaľany (Slovakia) is also uncertain (*Lička – Košťuřík – Mach 1990*, 13). Temporarily the closest, conclusive, find of this type of kiln from Central Europe is a kiln with grate dated to the late Urnfield period discovered near Elchinger Kreuz during autobahn construction (*Pressmar 1979*). In the La Tène period this type of kiln became a general device for firing pottery (list of La Tène kilns: see *Princ – Skružný 1977*).

J. Henning considers this type of kiln with a partition dividing the firebox into two separated channels as technologically progressive, because it allows sweeping of the channels alternatively. Because of this the development of the temperature is homogeneous (*Henning 1978*, 449).

6.2 Reconstruction – version 1

The design of the first version of the kiln respected the idea of M. Lička (*Lička 1994*, Fig 3). The hypothetical cover of the oven covers the channels over their whole length. If it covered the whole space of the channels to the kiln mouth it would probably not have the shape of a regular dome with circular plan as suggested by M. Lička (*Lička 1994*, Fig 3). We presume in that case that the design of the kiln respected the shape given by the channels. The cover was made from a wicker armature daubed with clay. The thickness of the cover was about 10 cm. On top of an irregular dome we left a hole for draining fumes. On the side of the cover opposite to the channels a hole was left for putting pottery in. The kiln mouth stayed open without any insulation. The middle partition was shaped from the subsoil. The photo documentation of the find shows that the front part of the right channel was considerably damaged (*Lička 1994*, Fig 2). The right channel was therefore made as a mirror image of the better preserved left channel. The grate construction followed the interpretation of traces found on the original (*Lička – Koštuřík – Mach 1990*, 3). The middle partition and the pit served as a support for an armature from stronger canes (3 cm diameter) which were filled in with thinner sticks with leaves. A 10 cm thick layer of daub was placed on top of the armature, through which were pushed air-channels. The profile of the kiln mouth is not known. According to photographs it seems that the bottom of the bigger pit in front of the channels was probably below the level of channels bottom (*Lička – Koštuřík – Mach 1990*, 7). Due to that the pit in front of the kiln construction was also hollowed out to be lower then the channels bottom (**Fig. 26, 27**).

The preparation for the kiln foundations and the making of the grate took one working day (**Fig. 28**). To build the cover we needed 29 working hours (**Fig. 29**). The kiln was finished on the 27th of July 2000 and on the 2nd of August was used for its first pottery firing.

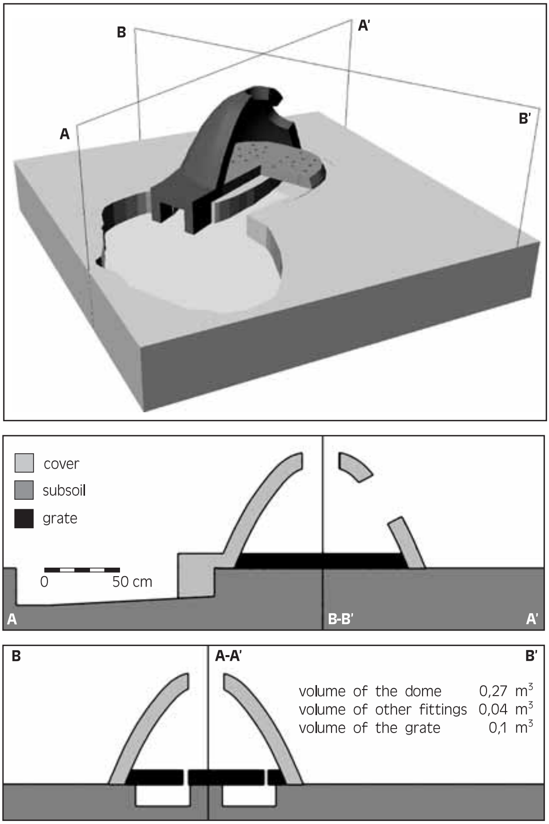


Fig. 26 3-D reconstruction of vertical two-chamber kiln based on the find from Kramolín. ■

6.3 Firing 1 – 3

The set of the first three tests took place several days after the kiln was finished.

The first firing took place on the 2nd of August 2000. Before the firing itself the kiln was dried with a fire for 8 hours. The method of firing was typical for this type of a kiln: two-spaced with updraft. Thermocouples were placed on the lower edge of the kiln below the stoking hole (T1) and in the middle of the kiln (T2). The fire was placed inside the channels. The development of the temperatures did not give hope of a successful firing and the test was aborted. The thermal profile was not preserved.

Following the first experience, a different method was chosen for the second test: a combination of a single-space firing with two-space updraft firing. The firing took place on the 3rd of August 2000. The pottery charge was placed in the oven together with fuel and in addition fire was also in both the channels below the grate until the kiln was sealed after 7 hours. Thermocouples were placed in the same way as during the previous test. An unsatisfactory thermal profile with a maximum temperature of 365°C (**graph 6**) lead to a repeat of the test under the same conditions two days later on the 5th of August 2000. The kiln was sealed after two hours of firing so that the sealed fuel could undergo the same distillation process as in a pile. The thermal profile was more favourable than in previous case but still unsatisfactory (**graph 7**).

6.4 Repair 1

On the 2nd of August 2001 the grate of the kiln, which had collapsed at the front by the left channel, was repaired.

6.5 Firing 4

With the next test on 14th of October 2001 we returned to the classical method for this type of kilns: two-spaced updraft firings. After preheating the kiln the fire was started inside both channels. After three hours of firing the temperature fluctuated around 220°C as the fire in channels would not burn properly and there was no draft.

6.6 Reconstruction – version 2

The inability to reach the temperatures needed for firing pottery lead to consideration of adaptations to the kiln, which would improve its functioning. After consultations with potters from Litomyšl an extension to the channels together with the plinth into a slightly deeper area in front of the kiln was suggested. Then it was checked if the excavated situation would exclude such an adaptation. The published photo documentation shows (*Lička 1994*, Fig 2) that the middle plinth was damaged at the front and its end is not clear, as it could seem from the drawing (**Fig. 24**). Part of the kiln mouth adjacent to the channels, where the bottom should be scorched the most shows on photographs dark spots. In the place of the possible extension of the partition the bottom is lighter and slightly more convex. It does not therefore exclude the possibility that the plinth was originally

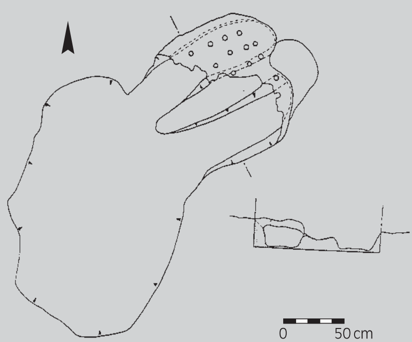


Fig. 24 Plan of the feature from Kramolín (according to Lička 1994). ■

Fig. 31 Adaptation of the vertical two-chamber kiln to second version. ■

Fig. 32 Fifth firing in vertical two-chamber kiln (13-14/04/02). ■

Fig. 33 Kiln after removal of the roof collapsed in the fire. ■

Fig. 35 Damage to the vertical two-chamber kiln on insufficiently protected north-west side of the shelter. ■

Fig. 34 Charge of pottery in the vertical two-chamber kiln after the fifth firing . ■

Fig. 36 Charge of pottery in the vertical two-chamber kiln after the seventh firing (27/08/02). ■

longer and the kiln mouth with traces of scorching could have been arched with a daubed installation. On the basis of this we extended the channels by 20 cm from the dome of the oven (**Fig. 26**).

The rebuilding of the kiln took place during the morning on the 13th of April 2002 (**Fig. 31**). It was immediately followed by a firing.

6.7 Firing 5

The fifth test took place on the 13th to 14th of April 2002 in co-operation with the group for experimental archaeology from DDM Litomyšl. The firing took 12 hours. The temperature reached 843°C (**graph 8**). Fire was burn in the adapted heating channels (**Fig. 32**). The content of the channels was alternatively swept out so there was always fuel burning in at least one channel. Afterwards the firing, sometimes between 4 and 6 am the roof of the shelter above the kilns caught fire and after a load-bearing beam burnt through it collapsed onto the kilns (**Fig. 33**). Both of the kilns beneath the shelter survived the collapse of the roof but the thermometer was damaged so the thermal profile from thermocouples did not survive. Fortunately a written record of the temperature development had been done (temperature of one of the thermocouples, once every fifteen minutes). None of the pots was damaged during the firing (**Fig. 34**).

6.8 Firing 6

The sixth test took place as part of 'Pottery seminar Všestary 2002'. The weather conditions were unfavourable. The average outside temperature was 3.6°C, air humidity 85%. Occasional showers changed into continuous rain. After it began to rain the eastern wind strengthened and blew smoke and flames towards the oven. Despite this it was a successful firing. The temperature reached a maximum of 855°C in less than 9 hours (**graph 9**). The regime of firing was the same as for the fifth test. (**Fig. 44**)

6.9 Repair 2

After 4 years it was necessary to repair the cover of the kiln. Especially the western corner with extended channels was damaged as it was insufficiently sheltered by the roof and the surface layer of daub was being washed off (**Fig. 35**). In better-protected places the surface layer had under the effect of damp and frost begun to crumble and was falling off.

The whole dome was covered with a new layer of daub, at least 5 cm thick. For this repair 0.2 m^3 of material was needed. The repair was done by three people on the 7th of August 2004. It took 4 hours including daub preparation.

6.10 Firing 7

The fifth and sixth tests showed that the kiln is functional. The difference between these and previous tests may have been caused by several factors. The two main factors seem to be the adaptation of the heating channels and the change of the heating method (alternative sweeping of the channels.). The aim of this test was to determine what the effect of sweeping out heating channels on the temperature development would be. We carried out a firing without sweeping out the channels. We used two methods of stoking:

a. Alternative stoking of the channels with wood. In this method the entrance part of one channel was filled with wood at the moment when the fuel in the other one was fully alight. It was difficult to find a rhythm for the stoking because each of channels had a different draft and the wood did not burn at the same rate.

b. Continuous stoking. This way only a few logs were added into the channel mouths. After catching fire they were pushed inside and new logs added in front.

Neither of these methods solved the basic problem. In the narrow channels there is a little space for wood, which burns slowly. The time necessary to wait for it to create space for more wood was too long so the input of thermal energy into the oven was insufficient to accelerate the temperature rise.After12 hours of heating the temperature in the oven fluctuated at around 650°C. During the last phase of firing the channels were swept out and filled with wood. Within the next hour and half the temperature rose by 60°C (**graph 10, Fig. 36**).

7 Discussion

7.1 Evaluation of the human factor

During each single test we attempted to optimise the firing process in the sense of reaching the highest possible temperature with the least energy input, while keeping the pottery charge as undamaged as possible. We exploited the experience of potters who practised firing in so called 'natural' kilns. In this way we subordinated the technology and firing regime to certain social-culturally founded experiences, which do not need to correspond with the experience of prehistoric potters. What ideas does a modern potter follow when deciding on the method of firing? I am not going to consider tradition and subconscious motifs that might be fundamental, as their determination is too complex. Instead I am only interested in rational considerations, on basis of which certain choices are made. The main feature a modern potter considers is the type of ware, which effects the length of firing and the temperature development. This is given by the properties of the ware, which is fired in modern 'nature' kilns. The ware is mostly made from low permeable material without temper. The modern potter tries to avoid contact between pottery and fuel and attempts to create a gradual development of the temperature without any sudden changes. The importance of this cautiousness was shown during the third firing in the horizontal kiln (chapter 5.6), when part of the charge made from industrially prepared material without temper was damaged whereas the tempered ware from local clay was removed without damage. The result of this cautious firing is a length of the firing before reaching the maximum temperature that vastly exceeds the average values published for recent pottery kilns from Africa and Asia. While the firings in kilns on CEA grounds under the supervision of modern potter take between 6 to 14 hours, ethnographic data show times of 39 to 240 minutes with an average of about 2 hours (*Livingstone Smith 2001*, 997, Table 1). The thermal profiles are thus effected by the regime chosen for firing, which might not reflect the actual properties the ware being fired.

7.2 Maximum temperatures

The maximum temperatures of firings in CEA reached the intervals that are presumed for prehistoric pottery from Central Europe. According to M. Hložek's analysis 50% of Neolithic and Aeneolithic pottery was fired to 600 – 700°C. Only 5% of pottery was fired over 1 000°C (*Hložek 2002*, 79).

The maximum temperature does not allow for the proving or disproving of the use of certain type of firing device. To determine thermal limits of firing for single structures on the basis of few experiments is disputable. For example the authors of a high quality experimental project to determine the possibilities of firing pottery in the environment of Neolithic Central Europe carried out 11 firings in a bonfire over 3 years. They considered this experience sufficient to generalise on the results. They determined that the thermal limit for firing in a bonfire was 800°C (*Bareš – Lička – Růžičková 1982*). A complex of ethnographic data from 51 recorded firings in a bonfire on the contrary shows that 59% of firings exceeded 800°C (25% even 900°C) in at least one place of the firing (*Livingstone Smith 2001*, Table 1). J. G. McDonnel wrote that the thermal limit for open firing devices is 1000°C (*McDonnel 2001*, Table 40.1) but theoretically it is possible to presume that even firing in an open devices could, under the influences of weather conditions, undergo an uncontrollable temperature development or that as a result of intentionally installed air-channels the temperature would exceed the limit of 1000°C (*Böttcher – Böttcher 1996*).

Temperatures above 1000°C are within the capabilities of both one-chamber (*Gosselain 1992*) and two-chamber kilns (for example *Böttcher – Böttcher 1991; Mayes 1961, 1962; Bryant 1970; Debat 2002; Gheorghiu 2002*). However the thermal capabilities of these types of devices are usually not fully exploited. The analysis of 24 samples of burnished ware (La Tène) from Southeast Moravia showed that despite the evidence of developed firing structures, able to rise high firing temperatures, the firing temperature was only about 700°C (*Hložek – Gregerová 2001*, 126). If this pottery was fired in a two-chamber vertical kilns with a grate, then it is necessary to consider a different reason for introducing this type of kiln than higher firing temperatures.

7.3 Heat rate

The heat rate distinguishes the clamp-kilns of type A from the closed firing devices. The considerably slower rise of the temperatures of other devices is caused partly by the chosen method of two spaced firing (with the exception of clamp-kiln B) and partly by attempting to slow the increase in temperatures. This can be successfully fulfilled due to the controllability of the process of firing in these devices. However, it is necessary to stress that the low level of control in the case of the clamp-kiln type A could have been a premature conclusion caused by the inexperience of the experimenters. To control the firing in simple firing devices may be for modern experimenters harder than to manage firing in a two-chamber kiln. Potter firing in simple devices needs to react to difficult to describe signs. Such a tradition is difficult to transfer without personal contact.

The heat rate had to be to certain extent adjusted to the properties of the ware being fired and vice versa. It would be interesting to find out what speed of temperature rise single types of materials, combination of vessel shapes and of wall thickness can withstand.

7.4 Uniformity of firing and soaking time

The most uniform firings were observed with the two-chamber vertical kiln. The grate acts as a filter, which levels the temperature changes in the firebox. The development of temperatures in one-chamber kilns is less uniform. The temperature development of clamp-kilns is the least stable. However, even here the data show certain regularities. First is the 'rule of two thermal peaks'. The first peak happens before the clamp's sealing. Afterwards the temperature falls but after a certain time it starts to rise again and the second peak can be higher than the first one. If the temperature between the two peaks does not fall much then the clamp-kiln needs a long time of soaking, several times higher than other kilns (**graph 1**). The way we interpret this phenomenon is that in a reducing atmosphere wood becomes charcoal, which ignites when air penetrates (local burning through the cover often happens). Such temperature developments were observed in all cases when the measuring of temperatures was not aborted during the phase of temperature decrease after the sealing of the clamp.

7.5 Fuel consumption

The fuel consumption during experimental firings at CEA was on average between 0.5 to 1 m^3. The differences in consumption between single firings in any one kiln were often bigger than that between various devices. The parallel firings recorded the same fuel consumption per one hour of firing (0.11 m^3/hour) for the one-chamber kiln, the horizontal kiln and the two-chamber vertical kiln. The consumption of wood approximately corresponds with data gained from other experimental firings. For two spaced firings the consumption is in the region of 0.4 m^3 (one-chamber kilns:

Test	Structure	Date	Outside temperature (°C)	[F] Method of firing	Time of firing to the end of stoking fuel (or to first maximum) (min)	To second maximum (min)	Time of firing to cooloing down (200°C) (min)	Maximum temperature	Biggest difference in temperatures (°C)	Difference of temperatures at maximum temperatur (°C)	Soaking time 1 (>600°C) (min)	Soaking time 2 (>600°C) (min)	Heating rate 1 (°C/min.)	Heating rate 2 (°C/min.)	Wood consumption (m^3)	Charge - total number of vessels (number of large vessels)	Losses
2	Kramolín1	03/08/00	24	A	450		1410	356	75	59			0,79	0,64			
3	Kramolín1	04/08/00	25	A	220	1420	2250	487	217	154			0,22	1,85			
4	Kramolín1	14/10/01	16	BI	185		225	223	42	36			1,22	1,01			
5	Kramolín2	13-14/04/02		BI	726			843					1,10			45 (6)	0
6	Kramolín2	12/10/02	4	BI	525			855	[E]97	11			1,60	1,6	0,99	21 (7)	0
7	Kramolín2	27/08/04	20	BI	850		1400	721	60	32	380	290	0,82	0,78	0,95	60 (5)	0
1	Turnov1	13/10/01	21	BII	360		[A]630	798	248	131	75		2,20	3,2	0,48	21 (4)	0
2	Turnov1	12/10/02	4	BII	438			812			304		1,85		0,89	16 (5)	0
3	Turnov2	24/08/04	20	BII	495		1410	906	355	317	380	10	1,79	1,13	0,55	55+28 (8)	[B]20%
1	Clamp B	12-13/10/02	4	A	430	[D]1646		[D]868	248	[D]20	[D]944	[D]742	1,94	1,4	0,39	[C]2 + 21	[C]1
1	Bořitov	12-13/10/02	4	BII	392			781					1,98		0,86	39 (1)	0
	Clamp A	03/08/00		A	45			787					23,00				
	Clamp A	20-21/05/00		A	110			632					4,96				

Table 3 Recapitulative table ([A] do 273°C; [B] Mrs Kelerová's vessels; [C] storage jar; [D] interrupted measuring; [E] beginning of firing; [F] Method of firing: A - one space BI - two space, up-draft, BII - two space, horizontal draft). ■

Mogielnicka 1974, Görler – Kohtz 1991; two-chamber vertical kilns: *Bryant 1970*) up to 1.5 m^3 [(1)] (*Mayes 1962*). The consumption for one space firing is considerably lower. The consumption for firing in a clamp-kiln type A at CEA is estimated according to the volume of a fully stoked pit to be about 0.4 m^3. The consumption for firing in a clamp-kiln type B was similar (**Table 3**). M. Bareš, M. Lička and M. Růžičková published that wood consumption of their one-spaced firing as from 0.02 to 0.17 m^3. Of course the pottery charge of those firings was at most 6 vessels (*Bareš – Lička – Růžičková 1982*, Table 39 – 44). J. Kovárník published consumption of 0.06 to 0.8 m^3 (*Kovárník 1982*).

As the consumption of fuel for the same devices with different length of firing with approximately the same maximum temperature shows, consumption is not directly proportional to the length of firing. The reason is probably the slow rate of heating in the case of longer firings.

Fig. 45 Example of homogeneously fired pottery in reducing and oxidizing atmospheres as a result of the two spaced firing. ■

7.6 Homogeneity of the firing

The experiments show that it is possible to gain a homogeneous atmosphere in all types of kilns constructed and to fire pottery uniformly in an oxidizing fire, or a reducing fire (**Fig. 45**). The basic condition needed to achieve an homogeneous reducing firing is the division of the oven from the firebox. This can be successfully achieved in closed firing device with self-supporting structure. The division is therefore between the different types of clamp-kilns. In clamp-kiln type A without a self-supporting construction it is impossible to achieve a two-spaced firing while in types B and C it is theoretically possible.

Firing in a homogeneous atmosphere is needed for pottery where importance is given to the colour of the surface. Such pottery was probably fired in a closed firing devices with self-supporting insulation constructions. However it is necessary to point out that a homogenous shade can also be achieved by removing the pottery at the point maximum temperature is reached.

The thermal homogeneity of firings seems to be a different case. This is not automatically achieved by dividing the oven from the firebox. The only device, in which we managed to achieve thermal homogeneity to a satisfactory degree, was in the two-chamber vertical kiln with grate, where at the moment of reaching maximum temperature the difference between the thermocouples was, at most, 40°C.

[(1)] If the authors measured wood consumption by weight then for the purpose of rough comparison I would recalculate weight to volume according to tree species and presuming that the wood was dry.

The situation in a one-chamber horizontal kiln is different. At the moment of reaching maximum temperature the difference between the temperatures was in one case 130°C (Firing 1) and in another over 300°C (Firing 3). The difference between the two firings might have been caused by:

- Differences in the placing of the thermocouples (distance from firebox, height)
- Differences in the size of the kiln (in the second case the kiln had been extended)
- The size of the charge (21 pots in Firing 1, 83 pots in Firing 3)

We can also differentiate between horizontal and vertical nonhomogeneity. Horizontal nonhomogeneity can be caused by the length of the kiln and unsuitable stoking of the oven with pottery. Theoretically it could be eliminated with a scarcer charge of pottery arranged in columns where the fumes can circulate freely. Vertical nonhomogeneity is probably caused by the placing of the smoke hole on top of the dome. The draft travels straight up to the hole. Better homogeneity could be possible by adaptation of the kiln. A partition could be placed across the upper part of the back of the kiln dome. The space at the back part of the kiln could be left free for fume draining. The kiln though would need a chimney to achieve a draft (*Herainová 2003*, 47). Such adaptations can be legitimately considered, as they would not show in the kiln's plan. Medieval horizontal two-chamber kilns are constructed in a similar fashion (for example *Böttcher – Böttcher 1991; Biermann 1998*).

We were unable to establish the temperature variations within the one-chamber kiln. I presume an analogous situation to the horizontal kiln. Part of solution would be to move the smoke hole to the lower part of the dome on the opposite side to the firebox. The question though is if the kiln would then have a sufficient draft.

In both the previous cases, it is possible to speak of a regular nonhomogeneity where it is possible to predict with a degree of probability differences between temperatures and their development in various parts of the oven. In the case of firings in clamp-kilns the nonhomogeneity is irregular. The overall temperature development can be controlled to a certain extent especially in types B and C but the temperature differences between various parts of the kiln are unpredictable.

7.7 Sheltering of kilns

At the CEA grounds two functional interpretation of the relationship of shelters to kilns were tested: [(2)]

a. The shelter protects not the kiln but only its background (pottery, fuel) (**Fig. 9**).

b. The shelter protects the kiln itself (**Fig. 42**).

[(2)] I do not consider shelter for temporary structures such as bonfires and clamps.

Fig. 42 Shelter over the kilns. ■

In case (**a**) it is either necessary to protect the kiln in a different way (for example cover it with a thick layer of straw) or build a new one every year, because under the effects of a combination of natural factors (rain, frost, sun) it will not last longer than a year.

In case (**b**) the protection, especially from rain, considerably extends the serviceable life of the kiln. Regular maintenance and repairs, practical only for sheltered kilns, can extend the service life for decades. The advantage of maintaining a kiln is that the longer it is fired the better its firing properties. I presume that shelters were used especially for bigger and more complicated kilns and for kilns, which were often used. On the other hand in the case of simple and smaller kilns, used only seasonally, maintenance would not be economical and it would be more practical to rebuild it every season.

When considering shelters it is appropriate to take into account the profile of the whole structure. If the deepest part of the structure is at the bottom of the kiln or heating channels then it is necessary to put a roof over both the kiln and kiln mouth. Otherwise the shelter would not work because the water would run from the kiln mouth into the kiln. The kiln would stay damp and would be quickly damaged. If the deepest point of the structure is at the kiln mouth then it is necessary only to put roof over the kiln because all the water would gather at the kiln mouth.

Fig. 37 (right) Destruction of the vault of the one-chamber kiln firebox; there is a visible difference between the fired and non-fired layers of daub in the section of the cover. ■ **Fig. 43** (left) Weathered outer surface of the cover of the one-chamber kiln. ■

7.8 Formative processes

Observing formative processes showed that a freestanding kiln has service life of less than one year. On the other hand a sheltered and maintained kiln can in theory function for decades. Weathering, mostly rain and frost, will damage the outer surfaces of the kiln cover; the daub starts to crumble and fall off or is washed off (**Fig. 43**). If the construction of the cover is damaged than the kiln will either collapse or become deformed and the fired daub on the inner side of the cover will fall off (**Fig. 37**). This would mix with the daub washed from the outer surface. The thickness of daub in the destruction layers does not represent original thickness of the dome but only the layer of fired daub. In the case of the one-chamber kiln modelled on the structure from Bořitov it was possible only to find, after destruction, bits of daub 2 – 4 cm thick (**Fig. 38**) while the original thickness of the dome walls was about 12 cm.

The clogging of the kiln mouth was also recorded on both vertical and horizontal kilns (**Fig. 39**). During a three-year period a layer was created, which in some places is up to 20 cm deep. In the section of a test ditch, three layers were identified: the first was a deposit from before October 2002. Above it there was a layer of charcoal and daub, which was created during the sweeping of the kilns on the 12th to 13th October 2002. Although the swept out ashes had been removed from the kiln mouth some had remained in place. Above the layer of charcoal there is a compact layer of grey-brown sediment. Bellow the edge of the pit, which is strengthened with turf the walls had been widened by erosion.

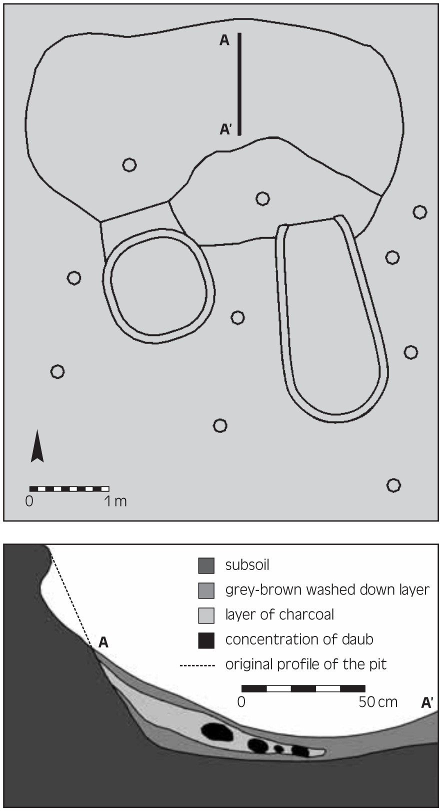


Fig. 39a Section of the cut through the kiln mouth of the vertical and horizontal kilns and their position on the plan. ■

Fig. 39b Cut through the kiln mouth of vertical and horizontal kilns. ■

Fig. 38 Fragment of daub from the one-chamber kiln. ■

The clamp-kiln was visible after two years as a hollow with a destruction layer of small bits of daub in the middle.

The burning of the bottom of kilns was tested with micro sections. In the centre of the firebox of the horizontal kiln a 3 cm thick light ochre layer was found, below which was a 5 cm thick black layer. By the mouth of the fireboxes of both horizontal and vertical kilns the bottom was fired into red-black colour to a depth of 3 cm (**Fig. 40**). A space up to approximately 30 cm long in front of the fireboxes was also burnt (**Fig. 41**).

8 Conclusions: Experiment and interpretation of social-cultural mechanism

In conclusion it is possible to say that the thermal parameters gained from the firings in single devices can differ more between individual firings in the same device than between firings from different devices (**graph 11**). The decisive factor seems to be not the method of firing but the intention of the potter. Experimental firings at CEA support a sceptical view in regard to distinguishing between firing devices according to thermal profiles (*Gosselain 1992, Livingstone Smith 2001*).

The reason for the development or adoption of new types of firing devices does not seem to be part of a systematic search for improvements in the properties of the existing pottery production. Rather it seems to concern newly developed social needs of the society with changes towards more complexity, increasing differentiation and dynamism. New technology might relate to the demands of certain social group or to the emergence of fully specialised craftsmen. If there is a new demand for ware with new properties, either technological or aesthetic, which needs other firing method that cannot be executed in existing devices, than the adoption of a new firing device might occur quickly. This can then become over time the norm for the majority of pottery. The aim of experiments should be to search for technologically demanding types of pottery (for example fine untempered ceramic mixture or painted decoration demanding homogeneous environment) and test what devices it is possible to fire such ware satisfactorily in. The emergence of a fully specialised craft would also lead to the adoption of devices better suited to new organisation and working regimes. The potter chose devices according to his needs. The simple firing devices have advantages which could, in certain situations, be the reason why they would be chosen (low fuel consumption, insignificant amount of energy and time needed for their building, movability, possibility of use for other purpose). Potter with sufficient experience might produce in these devices ware, the properties of which would fulfil his expectations, with minimal losses. The maximum temperature does not need to differ to firings from more advanced devices. We cannot automatically exclude firings in bonfire even when considering firings approaching 1000°C. The choice of more progressive devices does not need to be a natural decision. On the contrary, for a part time potter who produces only small amounts of utility ware, the technical and aesthetic parameters of which can be achieved in any of the above mentioned firing devices, a simple firing device like a bonfire or clamp could be a 'good' choice. The terms of the technological progress may be relative and it can also depend on what parameters we choose for assessing progress.

Fig. 41 Fired bottom of the kiln mouth of the horizontal kiln. ■

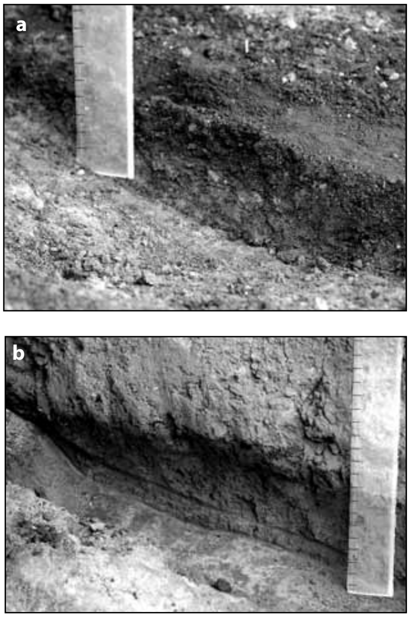
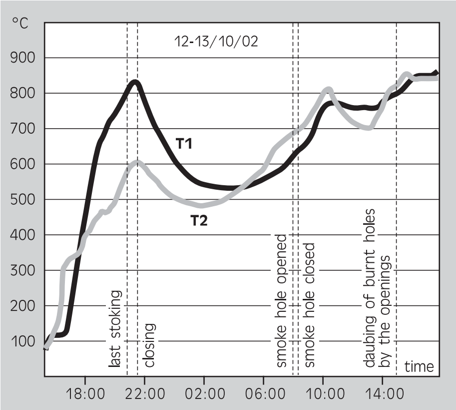
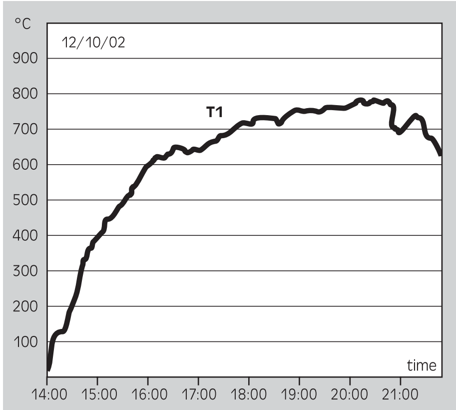


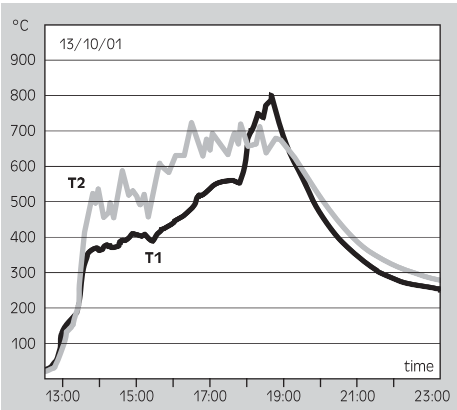
Fig. 40 a Section of the fired bottom of the kiln mouth of the horizontal kiln; **b** Section of the fired bottom of the kiln mouth of the vertical kiln. ■



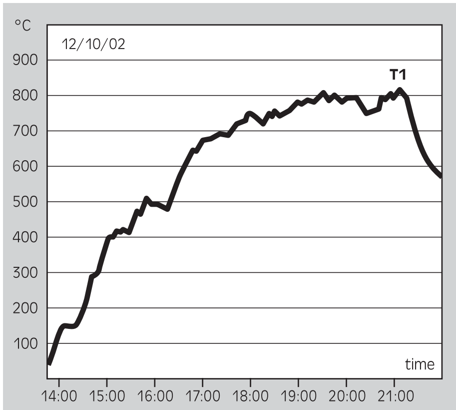
Graph 1 A subsurface clamp-kiln: firing1. ■



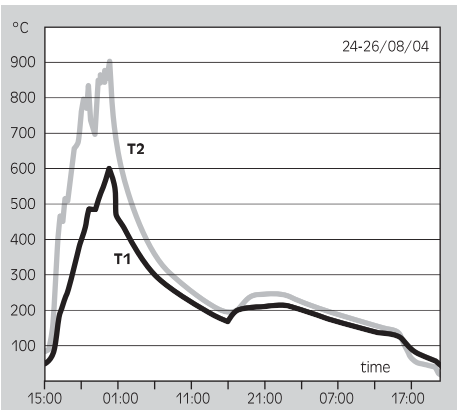
Graph 2 Partially subsurface one-chamber kiln with rectangular plan: firing 1. ■



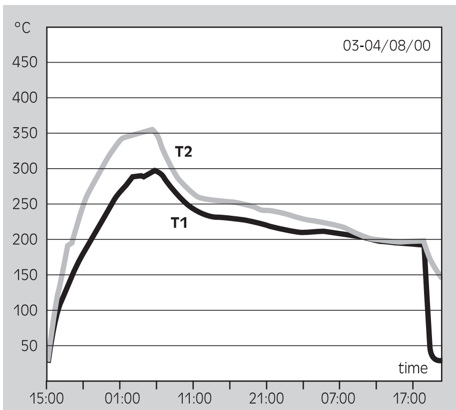
Graph 3 Subsurface one-chamber horizontal kiln, version 1: firing 1. ■



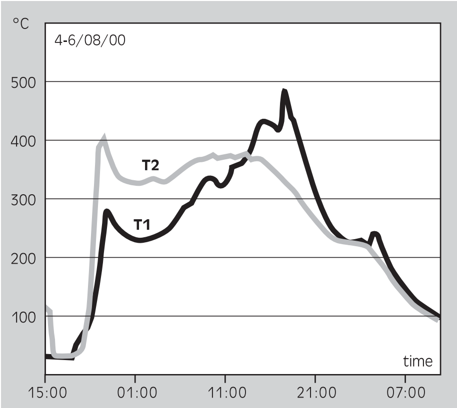
Graph 4 Subsurface one-chamber horizontal kiln, version 1: firing 2. ■



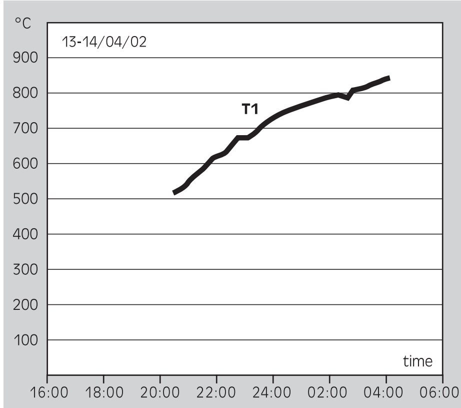
Graph 5 Subsurface one-chamber horizontal kiln, version 2: firing 3. ■



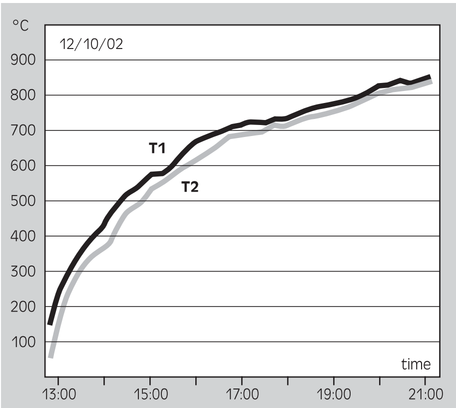
Graph 6 Subsurface two-chamber vertical kiln with grate, version 1: firing 2. ■



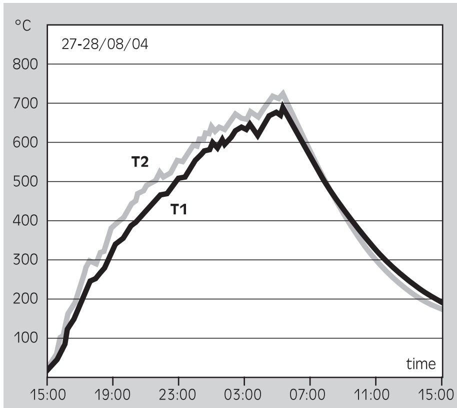
Graph 7 Subsurface two-chamber vertical kiln with grate, version 1: firing 3. ■



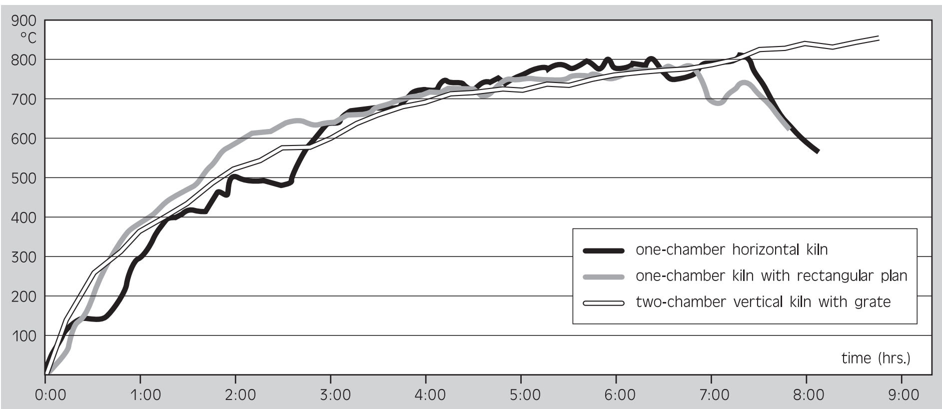
Graph 8 Subsurface two-chamber vertical kiln with grate, version 2: firing 5. ■



Graph 9 Subsurface two-chamber vertical kiln with grate, version 2: firing 6. ■



Graph 10 Subsurface two-chamber vertical kiln with grate, version 2: firing 7. ■



Graph 11 Comparison of thermal curves of firings in three firing devices: one-chamber horizontal kiln, one-chamber kiln with rectangular plan and two-chamber vertical kiln with grate. ■

The history of the use of certain firing device in a given region may be complicated with inherited tradition playing a large role. So a progressive device with a 'good reason' for it use may become redundant when it is replicated in form but without exploiting its possibilities. This process may be shown by the gradual atrophying of some originally functional elements of the firing devices.

Let us try to interpret the find of a vertical two-chamber kiln from Kramolín according to what has been said above. The experimental firings show that despite some unfavourable parameters of the kiln it is possible to adapt the kiln and use it so it is capable of the standard production presumed for vertical two-chamber kiln (homogeneous firing, temperature 800°C). However that is not a proof that this kiln was really used like this. The Kramolín kiln shows certain elements that indicate that the design of the kiln may have been adopted without understanding its basic principles such as the division of the oven from the firebox. This might be indicated especially by the height of the heating channels, which is only 15 cm while the height of the presumed original model from the Cucuteni-Tripolye cultural complex would have channels height of 22 to 40 cm (*Lička – Koštuřík – Mach 1990*, 8). Such a low height of the heating channels does not make the firing process corresponding to a two-chamber vertical kiln with a grate impossible but without an adaptation to the mouth kiln makes it difficult. The temperature of 570°C determined as the maximum temperature from an analysed piece of the grate with a preserved air hole is also interesting (*Lička – Koštuřík – Mach 1990*, 5). Unfortunately, it is not clear from what part of the grate the shard came from. A shard from the kiln infill was also analysed. The shard was fired partially in a reducing and partially in an oxidizing atmosphere. This shows that distribution of temperatures during the firing was probably also nonhomogeneous. The determined maximum temperature of firing was 660°C (*Lička – Koštuřík – Mach 1990*, 5). However the damage to the kiln makes the supposition that the pottery found in the kiln was fired there and left in place unlikely. The pottery shards properties thus cannot be directly linked to the method of firing in the kiln. Despite these limits the evidence of both samples would seem to indicate that users of this kiln might have had problems with its function. This could be supported also by the fact, that there was no daub from the kiln's dome found in the infill of the kiln, which would suggest a low intensity of use. It might be interesting to compare this situation with observation done during experimental firings in this kiln. Participants in the first experimental firings were experienced only with single-spaced firings (bonfire, clamp, one-chamber kiln) which have a relatively high heat rate and as a result a short duration of firing and a low consumption of wood. They considered that the slow development of temperatures in the two-chamber kiln (increased by the small height of the heating channels) as evidence that the kiln was not functioning. The firing was aborted after three or four hours as unsuccessful and there was an attempt to search for more effective methods of firing. This created the strange single-spaced firing use of a two-chamber kiln when fuel was stoked together with pottery charge into the oven. We thus achieved an experimentally derived model for potters meeting for the first time a two-chamber vertical kiln. The construction errors and the unfulfilled expectation

Fig. 44 Results of the sixth firing in the vertical two-chamber kiln (12/10/02). ■

of the firing development, dictated by previous experience with different methods of firing could have lead to 'natural experimenting' with firing methods in this kiln (experimenting limited by traditional firing processes) and in the end to dropping of firing in such a type of a kiln. The exceptionality of this find within the Lengyel cultural complex may be evidence of little experience with this type of device. The motif for adopting this exotic element may have been an attempt to strengthen certain elements in society by prestige based on the relation to a technologically more developed environment. The kiln could therefore be connected to other new cultural elements of this period. The fact that it was found in an upland settlement might not have been mere chance.

The situation in the La Tène environment, where the spread of the vertical kiln with grate went with the emergency of a fully specialised pottery craft, is different. At the same time the kiln might have been a technical adaptation to the new type of ware – wheel thrown pottery. For wheel throwing is more suitable for finer and more plastic material, which demands a relatively homogeneous firing environment with even and slow temperature rise. Vertical kilns with a grate secure such an environment.

The interpretation of the data gained from the experimental firings at CEA supports the idea that in Central Europe pottery making did not develop into a fully specialised craft before the La Tène period. On the other hand there is no evidence that it was a non-specialised activity, or specialised only on a home level. Especially from the Bronze Age, in regard to the increasing complexity of the society, we can suppose that pottery was a partially specialised craft within settlements, or possibly within a small region, which fits the simple firing devices.

Acknowledgement

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Summary

Experimenteller Keramikbrand in geschlossenen Brandeinrichtungen vom Neolithikum bis zur Hallstattzeit in Mitteleuropa. Eine Pilotstudie auf der Grundlage von Experimenten im Zentrum für Experimentelle Archäologie in Vsetary

Diese Arbeit ist bestrebt, die bisherigen Ergebnisse der im Zentrum für Experimentelle Archäologie in Všestary in den Jahren 1999 – bis 2004 durchgeführten experimentellen Keramikbrände einzuschätzen, und zwar mit spezieller Berücksichtigung der vom Neolithikum bis in die Hallstattzeit benutzten geschlossenen Brandeinrichtungen.

Relativ viele Reste von Strukturen, die die durch das Brennen entstandene Thermoenergie absichtlich benutzten, können gefunden werden. Die Mehrheit dieser Objekte können als die für den Keramikbrand potentiell genutzte Strukturen bezeichnet werden. Die Brandtechnik besitzt jedoch keine Zeichen, die eine direkte Interpretation einer gewissen Struktur als eine Keramikbrandeinrichtung ermöglichen. Das Experiment auf dem Gebiet der urzeitlichen Brandtechnik hat deswegen folgende Aufgaben: die Verbindungen zwischen den Keramikeigenschaften und gewissen Typen der Brandeinrichtungen festzustellen, den Übergang der Strukturen vom systemischen in den archäologischen Kontext zu verfolgen und die zur Identifikation und Rekonstruktion der Töpferöfen dienenden spezifischen Hinweise zu bestimmen.

Für die Experimente haben wir folgende Einrichtungen verwendet: einen eingetieften Meilerofen, einen auf einem in die Linearbandkeramik datierten Fund basierenden, teilweise eingetieften Einkammerofen, einen auf einem in die Lausitzer Kultur datierten Fund basierenden eingetieften horizontalen Einkammerofen und einen auf der Grundlage eines Fundes aus der Lengyel-Kultur modellierten vertikalen Zweikammerofen mit Rost. Während einzelner Experimente waren wir bestrebt, den Brandprozess zu optimieren, um die maximale Temperatur bei minimalem Energieverbrauch zu erzielen, und um die zu brennende Keramik minimal zu beschädigen. Dazu haben wir die Erfahrungen derjenigen Töpfer genutzt, die eine genügende Praxis mit dem Brand in sogenannten "Naturöfen" gewonnen hatten. Dadurch haben wir die Brandtechnik und –anordnung einer bestimmten soziokulturell bedingten Erfahrung untergeordnet, welche nicht unbedingt im vollen Einklang mit der Erfahrung des urzeitlichen Töpfers stehen muss.

Die Experimente machten es möglich, Eigenschaften verschiedener Einrichtungen unter gleichen Bedingungen zu vergleichen. Unter anderem versuchten wir, die Temperaturprofile einzelner Einrichtungen festzusetzen. Die Keramikbrandtemperatur wurde mit auf der Keramikoberfläche in Kontaktposition untergebrachten Thermozellen gemessen. Wir waren bestrebt, die Temperatur mindestens an zwei Stellen im Ofen – im Raum der vorausgesetzten höchsten und niedrigsten Temperatur – zu messen.

Unsere Experimente erbrachten die Erkenntnis, dass die maximal erzielte Temperatur die Benutzung eines konkreten Typs an Brandeinrichtung weder zu bestätigen noch zu widerlegen vermag. Es gibt in Hinblick auf die Geschwindigkeit der Erwärmung Unterschiede zwischen den Meilern ohne fester Konstruktion und dem Rest geschlossener Brandstrukturen. Eine markant niedrigere Temperaturbeschleunigung anderer Einrichtungen ist einerseits durch die gewählte Zweiraum-Brandmethode und anderseits durch den Versuch, eine langsame Temperatursteigerung zu sichern, verursacht. Dieses Bestreben war dank der Kontrolierbarkeit des Brandprozesses in solchen Einrichtungen erfolgreich. Am regelmässigsten haben sich die Temperaturen in dem vertikalen Zweikammerofen entwickelt.

Die durchgeführten Experimente zeigten, dass es in allen Typen der rekonstruierten Öfen möglich ist, eine gleichartige Atmosphäre zu erzielen und die Keramik durch Oxidations- oder auch Reduktionsverfahren gleichartig zu brennen. Die Grundbedingung für die Gleichartigkeit des Reduktionsbrandes ist die räumliche Trennung der Ofenstelle und des Feuerraums. Dies kann in geschlossenen Brandeinrichtungen mit selbstragender Konstruktion erfolgreich erreicht werden. Während der Experimente garantierte nur der vertikale Zweikammerofen mit Rost eine befriedigende Temperaturgleichartigkeit. Bei Einkammeröfen könnte man über eine regelmässige Verschiedenartigkeit sprechen, wo die Temperaturunterschiede und –entwicklungen in einzelnen Teilen der Öfen mit einer gewissen Wahrscheinlichkeit vorausgesagt werden können. Bei Einraummeiler-Bränden handelt es sich um eine unregelmässige Verschiedenartigkeit. Die gesamte Temperaturentwicklung ist gewissermassen absehbar, aber der Temperaturunterschied in verschiedenen Teilen des Meilers ist nicht vorhersagbar .

Die Verbrauchsunterschiede waren manchmal grösser zwischen zwei Bränden in einer Einrichtung als zwischen Bränden in verschiedenen Einrichtungen. Ein Parallelbrand zeigte den gleichen Holzverbrauch pro Brandstunde für Einkammerofen, horizontalen Ofen und auch für den vertikalen Zweikammerofen.

Die Grundmotivation für die Entwicklung oder für das Übernehmen neuer Typen von Brandeinrichtungen scheint keine systematische Bestrebung zu sein, um die Eigenschaften der bisherigen Keramikproduktion zu verbessern. Es handelt sich eher um eine Reaktion auf neue Erfordernisse der Gesellschaft, die sich zu einer grösseren Komplexität, Differenzierung und Dynamik hinverändert. Eine neue Technologie kann von der Nachfrage einer gewissen Sozialschicht oder vom Entstehen einer stark spezialisierten Handwerkergruppe abhängig sein. Wenn eine Ware nachgefragt wird, deren technische oder ästhetische Eigenschaften die Benutzung eines neuen Brandverfahrens verlangen, weil dieselben Eigenschaften mit den alten Einrichtungen nicht zu erreichen sind, kann ein neuer Typ der Brandeinrichtung rasch eingeführt werden. Dies kann im Laufe der Zeit zu einer Norm für die Mehrheit der Keramik werden. In diesem Sinne sollte das nächste Ziel der Experimente sein, eine technologisch anspruchsvolle Keramik (z. B. feine ungemagerte keramische Masse oder die ein gleichartiges Milieu verlangende farbige Verzierung der Oberfläche) zu bestimmen, um zu überprüfen, in welchen Einrichtungen man solche Ware befriedigend brennen konnte. Die Entstehung eines stark spezialisierten Handwerkes kann auch zur Akzeptanz einer solchen Einrichtung führen, die sich besser an eine neue Arbeitsorganisation und –ordnung anpasst. Der Töpfer wählt also die geeignete Einrichtung nach Bedarf. Einfache Brandeinrichtungen haben ihre Vorteile, die ein Grund für ihre Nutzung sein können – niedrigen Brennstoffverbrauch, kleine Mengen an Energie, kürzere Zeit für die Vorbereitung der Einrichtung, Mobilität und die Möglichkeit, die Einrichtung auch anderweitig zu nutzen. Mit ausreichender Erfahrung ist der Töpfer fähig, in solchen Einrichtungen mit minimalen Verlusten eine Ware zu produzieren, deren Eigenschaften seine Erwartungen erfüllen. Die erzielte Brandtemperatur muss nicht unbedingt von den in technologisch höher entwickelten Einrichtungen durchgeführten Bränden abweichen. Sogar bei einer Brandtemperatur von fast 1000°C kann man eine Benutzung von offenen Feuerstellen nicht automatisch ausschliessen. Die Wahl einer technologisch höher entwickelten Einrichtung muss also nicht unbedingt eine selbstverständliche Entscheidung sein. Im Gegenteil, einfache Brandeinrichtungen wie eine Feuerstelle oder ein Meiler können eine "gute Wahl" für einen teilspezialisierten Handwerker sein, der sich seinem Handwerk nur ab und zu widmet und der kleine Mengen der technisch und ästhetisch nicht anspruchsvollen Gebrauchware, die in jeder der erwähnten Brandeinrichtungen hergestellt werden kann, produziert. Der Begriff "technologische Reife" scheint manchmal relativ zu sein, es hängt davon ab, welche Kriterien für die Beurteilung der "Reife" oder "Entwicklung" gewählt worden sind.

(Translation into German by Jan Klíma and Rüdiger Kelm)

Cuissons expérimentales de céramiques dans les installations fermées attestées pour la période dès le Néolithique jusqu'au premier Age du Fer

Cette recherche tente de faire bilan des cuissons expérimentales de céramiques effectuées dans le Centre d'archéologie expérimentale de Všestary de 1999 à 2004, eu un égard spécifique aux installations fermées de cuisson attestées pour la période dès le Néolithique jusqu'au premier Age du Fer.

On découvre relativement assez de vestiges des structures utilisant l'énergie thermique issue de la combustion à un but déterminé. En fait, on peut considérer la plupart de ces structures comme les installations potentiellement utilisables pour la cuisson de céramiques. Or, pour la technologie de cuisson, aucun indice n'existe qui permette l'interprétation directe d'une telle structure en tant qu'une installation pour cuire la céramique. On peut donc voir le rôle de l'expérimentation des technologies préhistoriques de cuisson dans l'identification des relations parmi les qualités de la céramique et les différents types des installations de cuisson ainsi que dans l'observation de la transition de ces structures du contexte systématique à celui archéologique en visant à identifier les signes spécifiques qui permettent d'identifier les fours à poterie et de les reconstituer.

Pour nos expérimentations, on a mis en œuvre plusieurs installations: meule en fosse, four à chauffe directe d'après les vestiges datés de la civilisation de la céramique linéaire, four horizontal à chauffe directe d'après les fouilles de la civilisation de Lusace et four vertical à grille d'après une trouvaille datée de la civilisation de Lengyel. Pendant les différentes expérimentations nous avons fait effort pour optimaliser le déroulement de la cuisson en ce qui concerne la température maximale possible en produisant l'énergie minimale, tout en évitant des éclatements pour obtenir la meilleure céramique possible. Aussi nous avons profité les connaissances des potiers qui font cuire leurs céramiques dans des «fours naturels». Nous avons ainsi soumis la technique et le régime de la cuisson à une façon de l'expérience socio-culturelle déterminée sans correspondance nécessaire avec l'expérience du potier préhistorique.

Les expérimentations nous ont permis de comparer les propriétés de différentes installations dans des conditions pareilles. En outre, nous nous sommes essayés de repérer les profils thermiques de ces installations. On a mesuré la température de chauffe avec des piles thermoélectriques disposées de la façon qu'elles touchent des céramiques. Les températures ont été prises du moins en deux positions dans le four - celles à températures minimale et maximale supposées.

Nos expériences ont révélé que la température maximale atteinte pendant la cuisson ne permet ni de confirmer ni de rejeter la pratique d'un type concret de l'installation de cuisson. La vitesse de l'échauffement établit une différence parmi les meules sans construction stable et les autres structures fermées de cuisson. L'accélération thermique beaucoup plus faible de ces autres installations est due soit à la méthode choisie de la cuisson, soit à l'effort que les températures se développent peu à peu à cause du contrôle du processus de cuisson.

Les expérimentations réalisées ont mis en évidence que dans tous les types des fours reconstitués on peut atteindre une atmosphère homogène et alors cuire en cuisson uniforme en atmosphère oxydante, ou bien réductrice. Pour obtenir l'homogénéité de la cuisson réductrice, il faut séparer l'alandier et la chambre de chauffe ce qu'il est bien possible dans les installations fermées de cuisson aux constructions autoportantes. La seule installation où nous avons réussi à obtenir un niveau satisfaisant de l'homogénéité thermique, c'était le four vertical à deux chambres. Dans le cas des fours à chauffe directe, on peut supposer une non homogénéité régulière lorsqu'on peut envisager, avec une certaine probabilité, les différences thermiques et le développement de température dans différentes parties de la chambre de four. Quant à la cuisson en chauffe directe dans la meule, il s'agit d'une non homogénéité irrégulière. Au total, on peut côntroler, dans une certaine mesure, le développement des températures, mais imposible de prévoir les différences thermiques dans différentes parties de la meule.

Les différences de consommation ont été souvent plus importantes parmi les différentes cuissons dans une seule installation plutôt que parmi diverses installations. Les cuissons parallèles ont mis en évidence la consommation identique de bois pour une heure de cuisson dans le four à chauffe directe, le four horizontale et celui verticale à deux chambres.

L'évolution ou l'adoption de nouveaux types des installations de cuisson ne semblent pas être dues à un effort systématique pour améliorer les propriétés de la céramique fabriquée. C'est plutôt la réaction aux nouveaux besoins sociaux dans la société qui est en train de changer pour devenir plus complexe et ainsi plus différenciée et dynamique. Une nouvelle technologie peut se lier à la demande d'un certain groupe social ou à l'apparition des artisans spécialisés. Si l'on demande de nouveaux articles dont les qualités ou celles techniques, ou celles esthétiques nécessitent l'application d'un mode différent de cuisson et celui-ci ne peut pas être réalisé dans les installations actuelles, puis on peut passer vite à l'adoption d'un nouveau type de l'installation de cuisson. Cela peut devenir un certain standard pour la majorité de la céramique. A ce niveau, les expérimentations devraient viser à l'étude de la céramique de technologie difficile (p.ex. L'argile fine sans dégraissants ou le décors peint nécessitent l'atmosphère homogène de cuisson.) et des installations où l'on peut faire cuire une telle céramique d'une façon satisfaisante. La naissance du nouveau métier de potier, tout à fait spécialisé, peut aboutir à l'adoption de l'installation qui répond mieux à la nouvelle organisation et au régime de travail. En effet, le potier opte pour une installation selon ses besoins. Même des installations simples de cuisson ont leurs avantages qui peuvent, dans certaines situations, devenir la raison pour leur option (consommation faible de bois, peu d'énergie et de temps nécessaires pour la préparation, mobilité, possibilité d'utiliser l'installation à différents objectifs). Dans ces installations, un potier habile est capable de produire, avec les pertes minimales, la céramique dont les qualités lui conviennent. La température atteinte de chauffe ne doit pas être différente de celle des cuissons dans les installations de technologie plus évoluée. Même pour les températures à l'ordre de 1000 °C, on ne peut pas automatiquement rejeter la cuisson en plein air. En effet, l'option pour une installation de technologie plus moderne ne doit pas être provoquée par une décision naturelle. Au contraire, une «bonne option» pour un potier partiellement spécialisé qui ne pratique son métier que pendant une partie d'année et qui produit une petite quantité de céramiques d'usage à paramètres techniques et esthétiques qui rendent possible l'utilisation de n'importe quelle installation de cuisson, c'est une installation simple comme foyer ouvert ou meule. Alors, la notion même de l'évolution technique peut se révéler relative, ça dépend des paramètres retenus pour la considérer.