Technical analysis of earth ovens from Nieder Mörlen

M. L. EILAND[1] J. LÜNING[2] Q. WILLIAMS[3]

ABSTRACT The archaeological background of earth ovens — along with the term itself — is far from straightforward. Earth ovens were built in the ground and were not originally free standing structures. This paper will explore the methods and materials used to construct these ovens, and the probable functions they served. Evidence from replication experiments, as well as thin sections and X-ray diffraction, will be used to demonstrate that these ovens were made using basic technology. They may have been used to bake bread. There is no evidence that the clay was prepared or that a 'plaster' was used.

1. Introduction

This paper will consider the methods and materials used to make earth ovens. Careful excavation shows that these ovens were originally accessed from pits (Währen, 1987), though there is still controversy about exactly how there were made, and what they were used for. While some archaeologists assume that they have recovered a vertical oven — essentially a pit with fuel in the bottom where the bread sticks to the walls — there is no solid evidence that these ovens have been used in Germany. Traditional ovens in Central Europe are typically of a horizontal type, and can be either above or below ground (for experiments using these ovens see Werner, 1987, 1991).

Some archaeologists also assume that earth ovens were built above the ground level. This supposition is supported by the relative ease in which the ovens can be delineated from the surrounding soil, because they are lightly vitrified from repeated heating. Free standing ovens have been recovered in antiquity, though they are often found in houses. Earth ovens are located away from habitation. There have been extensive experiments with the above ground type ovens, as these survived into the 19th century for baking bread. Because earth ovens have received proportionally little attention, there are a number of issues that are still to be resolved.

Were they cut into a wall, or were they constructed from material brought from outside of the pit? The latter question leads to the question of what kind of clay was used to make them, in particular if there were any modification of the natural clay through processing, or the addition of temper. If the clay were locally obtained — a likely supposition — did it originate from one particular layer? Importantly, was a plaster (a specially prepared coating) used to line the ovens?

Earth ovens considered here, from excavations in Nieder Mörlen, date from the period 5500-5000 BC, from the Band Ceramic culture. This culture is well known for its ceramics (eg. Heide, 2003), and some have suggested they could be used as kilns. This and other suppositions are outlined as follows:

FIG. 1 – Original oven Nieder-Mörlen, 1998. The vitirifed structure of earth ovens makes it possible to delineate the structure from the surrounding soil. However, this is not an indication that the oven was originally free standing. In most cases only the base of the oven survives, the roof having been lost through erosion. This has led some to speculate that many ovens had chimneys, though replication experiments clearly show that this is not required.

Firing ceramics
Earth ovens from Central Europe have been reconstructed by chance finds of well preserved ovens. They are typically 60 cm high (with a dome shaped cross section), 60 cm long, and about a metre deep. This means that the ovens are too small for effective firing of ceramics. Typical ceramics of the period show fire clouding (likely from a bonfire). Ceramic vessels are widely encountered over the 500 year span of the Band Ceramic culture, while ovens are relatively rare.

Drying grain
The ovens are not large enough. During the Roman period a family - which may not have had the same cereal consumption as earlier periods - was said to consume about 1,200 kg of grain in a year. Roman drying ovens were many metres long (Evans, 1981; Foxhall and Forbes, 1982; Jasny, 1950). No charred grain has been found associated with ancient ovens in Germany. In addition, the temperature required to kill and dry seeds, about 100°C, is too low to require an earth oven.

Cooking, perhaps bread
The Band Ceramic culture is associated with the spread of agriculture from the East. As a rule wheat, suitable for bread, makes up about 60% of the agriculture during this Band Ceramic period, with the remainder being barley that could be used for beer and porridge (Lüning, 1997; Lüning et al., 1977). Baking, an important way of preparing grains to eat, is clearly of great significance. The history and distribution of baking ovens documents the diffusion of agriculture from the East (Blümel and Boog, 1977;

Boguki, 1996). In considering the ovens and their technological features, one is then documenting a segment of the agricultural revolution. The earth ovens were clearly used for baking bread, as will be demonstrated here.

2. The site

The site is located about 30 km north of Frankfurt, in the Wetterau district. Nieder Mörlen is today a suburb of the city of Bad Nauheim. Archaelogical excavations in the years 1997-1999 have brought to light a band ceramic settlement with a cult complex. This site has to date yielded the largest number of Neolithic idols in Germany. Excavations continue in various sites around Nieder Mörlen. The excavation today is divided into three horizons. The entire landscape is characterized as loess, which was laid down during the last ice age. It ranges from between two and ten metres deep and originates from the Würm period of the last Ice Age. The uppermost level is the A horizon, which contains a preponderance of organic material (humus) with essentially no clay. This layer is about 30 cm deep, and is relatively uniform over a wide area. The next level is the B horizon, which is between 60 and 80 cm deep. The upper level can be brown from enrichment and staining from the humus above — and can have roots from plants (grass) — but this layer contains the majority of the clay. The lowest level is the C horizon, which is chalk rich. At the upper levels of this layer there can be a thin band of clay and chalk, but rigidly defined this layer contains no clay.

The situation during the Mid-Neolithic (Band Ceramic) period was quite different. While there was an A horizon of humus, and a chalk containing C horizon, there was apparently little or no clay, which was formed during this period. A significant question is if the ovens were from the ancient A or 'proto B' or C horizons.

FIG. 2 – Replica oven, Nieder Morlen, 1998. A main focus of experiments was to determine if replica ovens built in the soil of the site were suitable for baking bread. Ovens were easily cut into the clay and baked eatable bread. The clay required no preparation though after firing the surfaces of the ovens had to be smoothed with water.

A typical oven was about 150 cm from the ancient surface of the ground. The first 50 cm consisted of organic rich soil in which it was impossible to build an oven. The second layer of about 100 cm was the loess zone, and at least 50 cm of loess was left as a ceiling over the oven. Because the organic rich layer was well watered from rain and no doubt retained much of the water throughout the year, this depth range was perhaps the minimum to keep the oven dry from seepage. It is also possible that ploughing over the ages, as well as erosion, erased evidence of ovens from levels closer to the surface. There is no evidence, particularly postholes, that the ovens were covered with a structure to keep off the rain. While this may indicate that they were used seasonally, it is clear that houses were occupied all year long. Particularly after a rain, when in a pit, the oven would be difficult to access. This raises the even more serious issue of why so much effort should be expended to put the oven in a pit.

3. Replication experiments

Experimental ovens are made using known materials and techniques, and these can be compared to ancient examples (Pfaffinger and Pleyer 1990). Several of the experimental ovens, not considered here, were built at a depth of 2 m into the C horizon. When fired cracks formed that extended to the surface of the ground that seem to relate to stress from expansion and contraction of the oven and surrounding material. The cracks are not continuous to the surface and do not allow gas exchange, yet the ovens were unsuitable for use.

The fuel, from analysis of ash as well as regional pollen cores, was beech and oak. With Oak the oven could go as high as 840°C, while, with beech the maximum temperature was 905°C, and with Birch it was 980°C (Kaufmann and Heege, 1991). Slow burning wood would have gradually heated the oven. Ample oxygen was drawn through the door, and while the hot gas escaped from the top, cool incoming air would be pulled from the base. As a result the temperature range in the oven was not uniform. The top of the oven reached about 800°C, with an absolute maximum of 900°C, while the base of the oven would be no more than 250°C (and the area below the bread is about 120°C). This is borne out by the oxidised red layer found in both ancient and experimental ovens. The layer, which roughly corresponds with the clay in early stages of vitrification, is thin on the base and sides of the oven, and thicker on the ceiling. The small corner in the back of the oven — though covered with carbon stains was left essentially unvitrified. The fuel would not be effectively pushed into this area which would also be ineffectively supplied with oxygen.

There is a precipitous drop in temperature after the coals are removed. Within five to ten minutes the maximum temperature drops from 800°C to 300°C. Some ancient ovens from southern Germany were lined with cobbles in the base. Bread that is baked in the range of 200-250°C (Jacob, 1944) is easily cooked in the earth oven, as when done it falls from the side of the oven.

3.1 The samples (in possession of Professor Lüning):

1. Experimental oven, sample from ceiling.
2. Experimental oven, same as sample 1.
3. Experimental oven. Raw materials from horizon B.
4. Experimental. Raw materials from horizon B with material from horizon A.
5. Experimental oven.

6. Original oven (025965). In hand specimen this sample is essentially identical with the experimental ovens.
7. Original oven (025965). Sample from surface of fragment.
8. Original oven wall (025965). Fragment was taken from inner portion of fabric.
9. Experimental oven (1 25.9.99).
10. Original oven (23.9.99).
11. Original oven, sample from bottom of oven.
12. Experimental oven (1 25.9.99).
13. Experimental oven (25.9.99), ceiling.
14. Experimental oven, material from B horizon (1\2001).

3.2 Plaster

Some authors have suggested that a plaster was used to line the ovens. This supposition appears logical, as a fine grained 'no stick' surface would leave little residue on the bread. Unfortunately, thin section studies suggest that the same material was used for the body and surface of the ovens. There is, however, a surface layer that is consistent with burnishing. By rubbing the surface of the oven when still wet, smaller particles tend to migrate to the surface. This layer may appear visually to be quite distinctive from the matrix — even having a lighter or darker colour — though it is a very different conceptual step from burnishing to adding a plaster that has been specially prepared. Particular evidence for burnishing is the pellets of clay that are lodged in the first several millimetres of the ovens. They

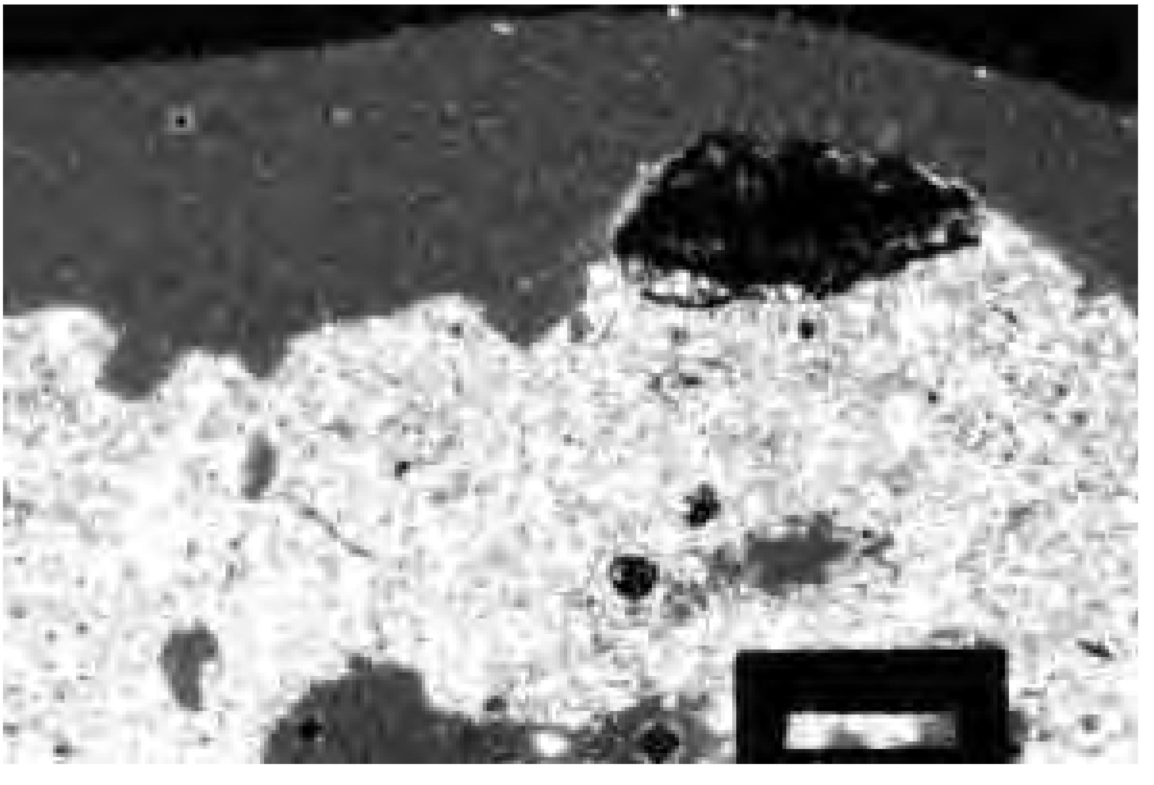

FIG. 3– Microphotograph, surface of original oven, sample #6. The surface of this sample has a thin layer or oriental small grains (difficult to see here) and a large pellet. The latter is clearly due to smoothing the surface of the oven, which likely took place after firing or perhaps after a long period of inactivity. The body matrix has few inclusions of any kind.

arose from the rolling motion during burnishing, and as they are fairly common, one can suggest that the burnishing took place using fingers or part of the hand. The hand, being relatively hot, quickly dried out clay that came into contact with it. Pellets do not occur in the matrix of the ovens — below several millimetres — further suggesting that the ovens were not built from coils or slabs but rather cut into the pit.

3.3. Body matrix

Because the matrix of the ovens contained essentially no rock and mineral inclusions, consistent with samples of the surrounding clay, one can assume there was no rock or mineral temper added to the natural clay. This is distinctive from a typical ceramic body for vessels (Maniatis and Tite, 1981). Yet the natural clay did contain some naturally occurring organic material in the form of rootlets. The next question to determine is whether the small roots were desirable. While no one can be certain that areas of clay with roots were selected by choice, or indeed if the ancients appreciated the function of them, the fact that all the ancient samples contained them is significant. It is likely that at some level there was an appreciation of their function. Organic temper was used in ancient pots to reduce drying stress and perhaps aid in resisting thermal shock (Skibo et al., 1989; Tsetlin, 2003). Ethnographic parallels with other regions are also instructive. In northeast Syria, traditional ovens are still made using hair, which gives great strength to a drying structure. In this region where the clay is quite plastic and is difficult to manipulate due to ease of structural deformity, hair keeps the structure together long enough for it to dry before being permanently set into place after firing. Perhaps one or both factors were considered when selecting the level in which to cut an oven.

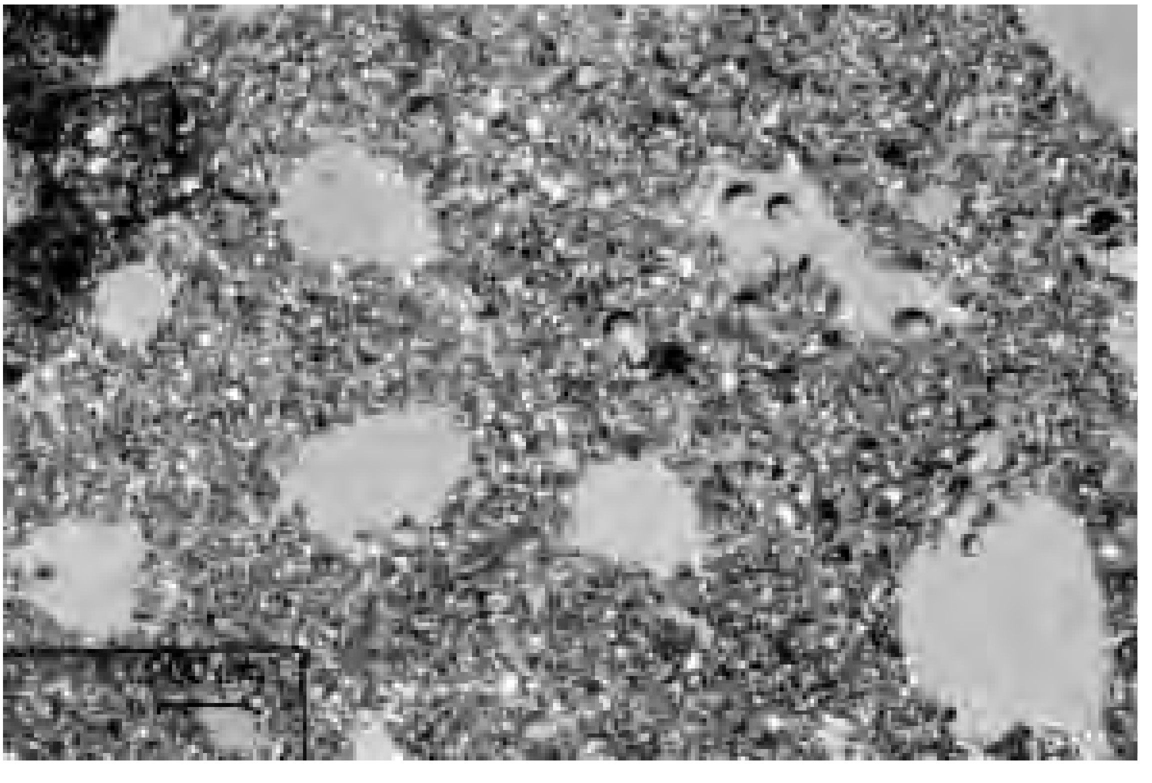

FIG. 4 – Microphotograph (same scale as Fig. 3) of sample #6. The voids, here revealed in basal section, permeate the sample. They are almost certainly from rootlets.

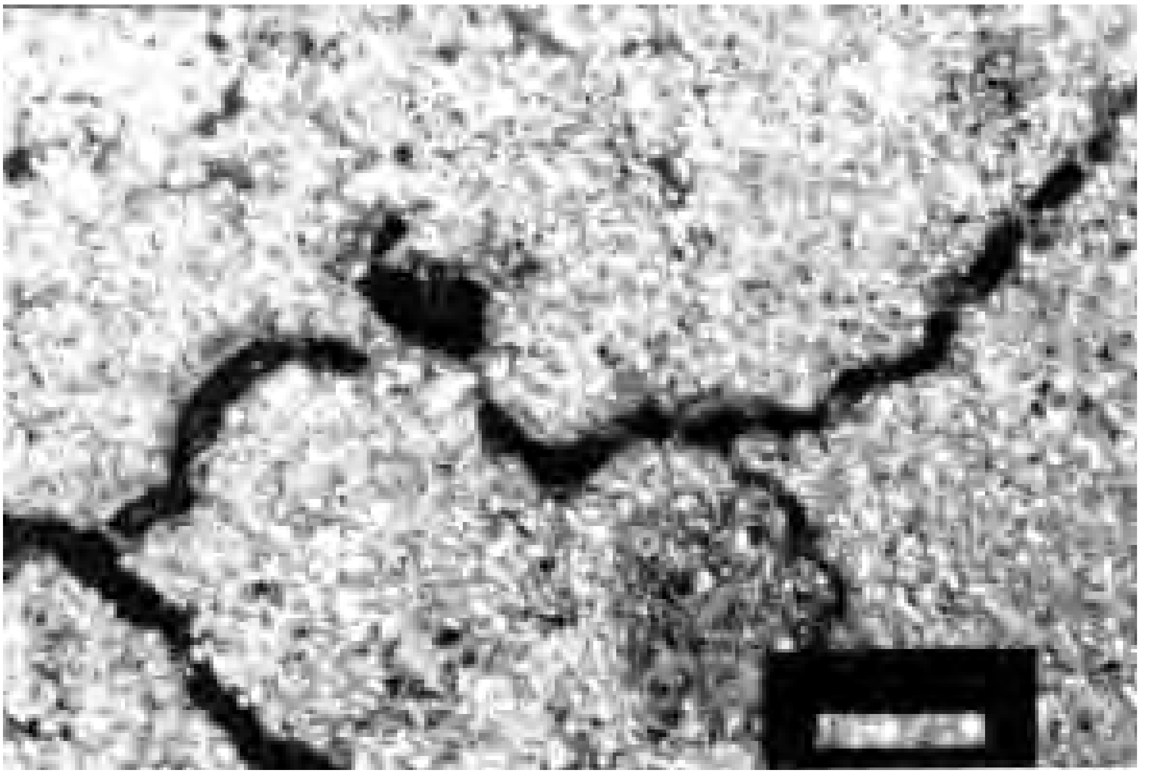

FIG. 5 – Microphotograph of replica oven, sample #5. The structure of a rootlet is clearly visible in this picture. The matrix of the replica oven - like the sample of the ancient oven - has essentially no inclusions.

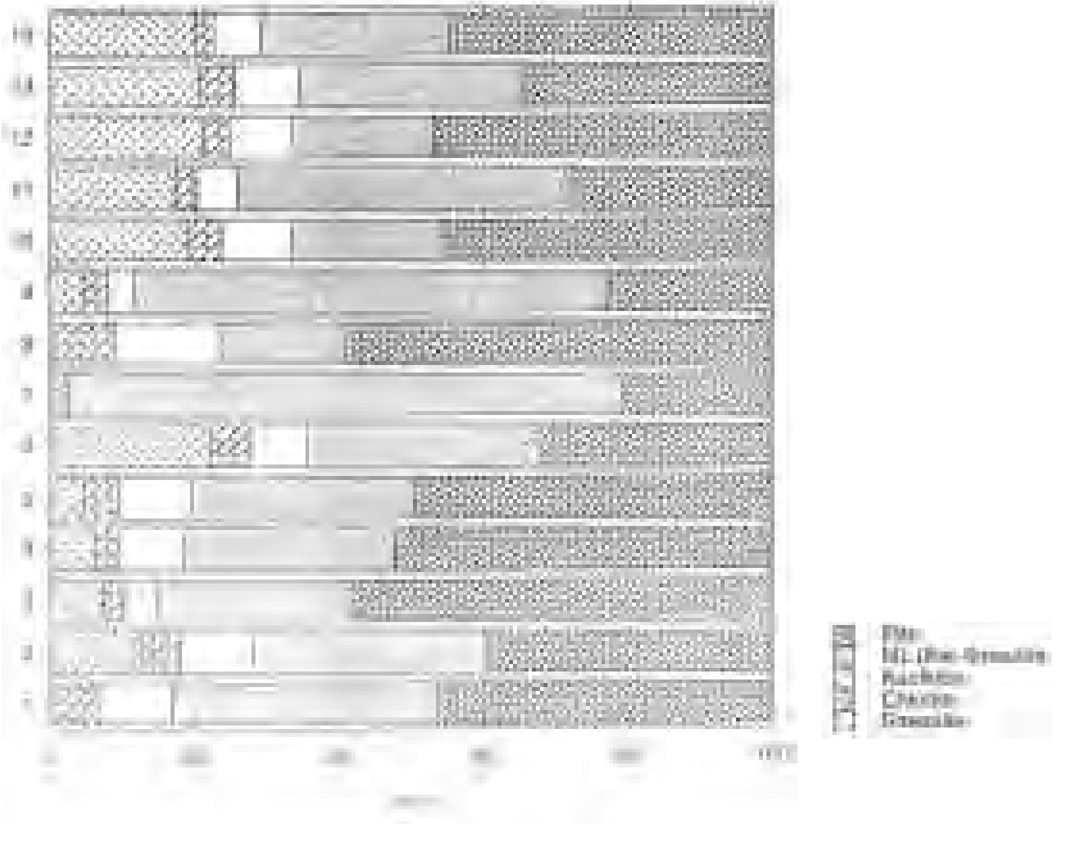

FIG. 6 – Results of X-ray diffraction (prepared by Dr. Petschick) of surfaces of samples.

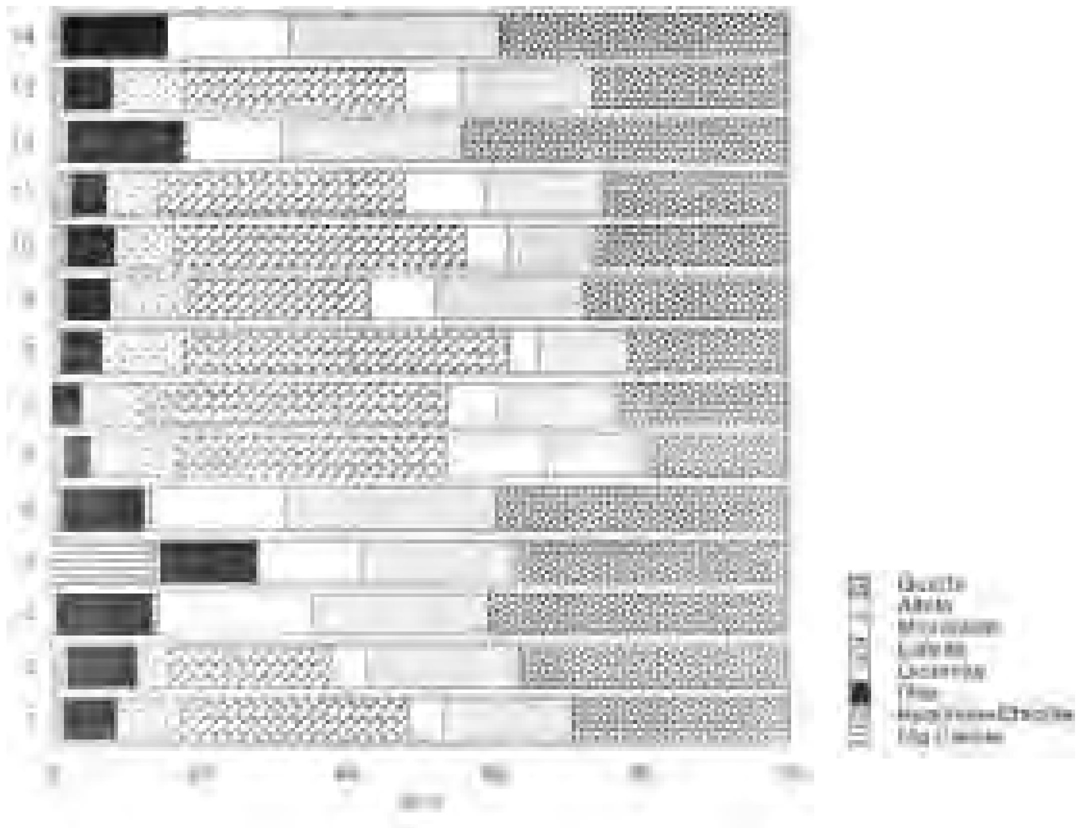

FIG. 7 – Results of X-ray diffraction (prepared by Dr. Petschick) of body matrix of samples. Powder was taken from non-vitrified areas at least 5 cm from the surface of the sample.

4. X-ray diffraction

The analysis presented here was prepared by Dr. Rainer Petschick, Geologisch-Paläontologisches Institut, Frankfurt aM. Until a more complete discussion is published, there are several notable trends as revealed by the diagrams. The identities and relative abundances of minerals within the oven fragments provide rather close constraints on the peak temperatures at which the ovens were used. Beyond the major quartz and feldspar constituents, the presence of calcite and illitic material within the fired ovens each provides bounds on the temperature to which the ovens were exposed. The precise temperature at which illites break down depends on their chemistry, grain size and crystallinity. The comparatively small abundance of illite in the oven walls (Fig. 6) relative to that in the protolith clayey material (Fig. 7) implies that considerable amounts of illite have decomposed, and that the remaining illite in the ovens is likely reasonably refractory, and probably sericitic. Such sericitic illites begin to break down to spinel-bearing assemblages and disorder at temperatures in the 850-950°C range, with the amount of spinel produced by illite-breakdown steadily increasing until mullite becomes stable near 1100°C (Grim and Bradley, 1940; Grim and Rowland, 1942; Roch et al., 1998). In the chemically complex assemblage present in these materials, the spinel generated likely reacts with alkali or alkaline-earth bearing material in the sample to form feldspar. The key point with respect to the illite in the oven material is that it puts an upper bound of ≈1000°C on the oven temperatures. Correspondingly, the lack of smectite, and its abundance in many of the starting clays, implies that temperatures in the vicinity of 800-900°C were achieved. This is the temperature at which smectites typically breakdown to quartz-dominated assemblages (Earley et al., 1953). The presence of small amounts of kaolinite (Plancon and Zacharie, 1990) in the oven material provides an additional constraint. Spinel generally begins to form near 925° from kaolinite (Sinha and Guha, 1992; Carty and Senapti, 1998), and the presence of small quantities of kaolinite (with the notable exception of sample #7, which likely achieved the highest temperatures of any of the oven materials) in most of the oven materials implies that temperatures in excess of 925°C were probably not achieved. Accordingly, although the precise stability limits of clays depend on their detailed chemistries and crystallinity (Grim and Rowland, 1942; Roch et al., 1998), a general bound of between 800 and 900°C can be achieved on purely mineralogical grounds. This bound is in full accord with the ubiquitous presence of calcite in the archaeological oven materials: calcite is expected to decompose at temperatures near 885°C (Wyllie and Huang, 1976; Eiland and Williams, 2000). This bound was likely only exceeded in synthetic sample #12 (Fig. 7), from the base of a replica oven.

An additional mineralogic anomaly which may be connected to high temperatures within the replica ovens involves the presence of Mg-rich calcite (and no dolomite) in sample 4 of Fig. 7. Such magnesian calcite may indicate that this sample achieved higher temperatures, or alternatively greater degrees of equilibration, than the replicas shown in samples 1 and 2. Magnesium solubility in calcite progressively increases with temperature — particularly above 800°C — with complete miscibility occurring above about 1020°C (Anovitz and Essene, 1987). It is possible that this sample was sufficiently fine-grained so that dolomite and calcite were in textural contact during heating. This allowed the two phases to react, and the calcite to dissolve dolomite into its structure. The organic material derived from Layer A may have played a role as a flux in sample 4, which could have allowed the dolomite and calcite to react.

Finally, the slightly higher abundances of calcite within the ancient oven fragments (≈40% in samples 6-8, 10 and 11 in Fig. 7) relative to the replica ovens (≈25% in samples 1, 2, 9, 13 and 14 of Fig. 7) implies that the original oven recipe may have contained a slightly larger percentage of the chalk-rich layer C relative to the replica oven mixture. This moderate shift in carbonate concentration should not, however, affect the presence or absence of minerals within the experimental ovens relative to the original materials. The overall pattern of mineral abundances between the replica ovens and the original ovens indicates that for samples fired at comparable temperatures, the replicas accurately simulate the mineralogy of the original ovens, with the sole exception of the modest enrichment in calcite in the original ovens.

5. Conclusion and future work

On the basis of replication experiments and analysis of ancient ovens, earth ovens clearly reached temperatures suitable for baking bread as well as cooking food in general. They were simple to make, and required no clay preparation, though it is likely that rootlets played an inadvertent role in consolidating the structure of the oven. Thus, it seems that clay was selected for certain characteristics even before it was removed and processed for ceramics.

All evidence suggests that the samples of ancient ovens were made in the 'proto B' horizon. There were slight differences between ancient and modern materials, though it is likely that there was little functional difference. There is no evidence that plaster was used to line inside surfaces of the ovens. While it is unlikely that raw materials were transported over any distance — with suitable materials available at hand — it would be important to determine if ovens could be built in all areas or are geographically limited in distribution.

Experimental ovens need to be fired for a long period of time to determine what kind of changes is apparent over longer time frames. It would be significant to note the effect of multiple firings as well as time. It is likely that ovens were preferentially built at one time of year — that corresponds with the end of the rainy season — as in many parts of the Near East. In addition it is likely that the decay with use would lead to disuse of the oven. How long did ovens survive in antiquity? These and other issues will be addressed in a later publication.

NOTES

[1] Institut für Mineralogie, Frankfurt aM, Germany.

[2] Seminar für Vor und Frühgeschichte, Universität Frankfurt aM, Germany.

[3] University of California, Earth and Marine Sciences Bldg, 1156 High Street, Santa Cruz, California, USA.

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