EXARC JOURNAL 2016/3
10 Articles | Open Access

Reviewed Article:

An Energy Saving House from 3400 Years Ago

Persistent Identifier: https://exarc.net/ark:/88735/10253

EXARC Journal Issue 2016/3 | **Publication Date:** 2016-08-15

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New conclusions concerning the supporting construction

The fact that people of the Bronze Age built houses with very good insulation was already presented by Staeves (2010) based on the results of an archaeological excavation in 2003 where an archaeological team of the Main-Kinzig district examined remnants of a Middle Bronze Age settlement. Prior to this, it was assumed that the walls of Bronze Age houses consisted of one wattle that was covered with clay on either side. The burnt fragments of clay found in Langenselbold (2003) show that here the walls consisted of two parallel wattles with the space in between being filled with dry grass. Pieces of clay were recently analysed that let

us conclude how the wattles were fixed in the upholding construction. This will be described in the next five chapters. In the following section, a review will be given concerning the findings that explain the two wattle constructions (See Figure 1 and 2).

> “It is probable that more prehistoric houses with a construction of two wattles were built than has been estimated so far—thus making use of the good insulation. Often the clay that can be found is not really well preserved. In general till now it has not really been considered important and therefore it was not well examined.

Why is a supporting structure necessary?

Experiments have shown that even a 10 cm wall of wattle and daub can barely carry its own weight and therefore would not be able to carry a roof: “When houses in Százhalombatta were reconstructed, the basic problem was that the thin walls could hardly bear their own weight and could not bear the weight of the roof” (Porozlai 1999). The wattle in Langenselbold was weaker still. On the clay fragments one can see the imprints of the vertical poles and horizontal rods where the soft clay had been thrown on. The upright poles are 1-2 cm in width. It could be that they were integrated in a kind of groove in a horizontal bottom beam. No post-holes were found. Up to six poles are standing side by side. Some thicker poles were split up in length in order to produce a flat but very robust structure (See Figures 3, 4 and 5). The 1-2 cm thick rods were wound around the poles in an alternating pattern. Where the horizontal rods pass each other, the wattle is only 1-2 cm thick, but in places where the rods run around both sides of the poles, it is 3-6cm thick. Because of the plaiting the outside became rather undulated (wavy). This undulated surface is equalized by the covering clay. The clay is 1.4–2.5 cm thick in the rod crossings. However, it shows only 0.1–0.9 cm of thickness in the places where the rods are woven around the poles. In this manner, a flat wall is produced that is about 7 cm thick at its maximum. Such a wall is far too weak to carry a roof.

Integration of the plaited (woven) wattles into the supporting construction

So far it was unclear how the wattles were integrated in the upholding construction however 19 pieces of burnt clay may offer a solution. On one side they show smooth clay levelling, on the other side, flat wood grain imprints were identified in a vertical direction. In a rectangular direction to the wood grain imprints there are imprints of rods at the upper and the lower side of the fragments (See Figures 6-11). This means that these fragments had obviously covered a supporting wooden beam. The rods were led along the outsides of the beam thus connecting the wattles firmly to the supporting structure. The imprints of rods on these fragments do not run side by side as in the wattle. They are about a one-rod width apart. It can therefore be concluded that only every second rod was led around the beam on the outside with the remainder being fixed inside the wall. There is an example of a framework

barn in Rauischholzhausen (Hessia), where we can find this pattern of construction (See Figure 12).

Here we find in the infill of the frames a similar wattle to those described above however the rods are of coarser quality. These rods were stabilized with the help of poles running parallel right next to the beams. The horizontal rods in the timber frames corresponding to the rods in the Bronze Age walls were pressed in front of and behind the poles in an alternating fashion. It must have been similar with the double wattle wall in the Bronze Age. Every second rod was led along the front side of the beam while the others were clamped behind a pole next to the beam. This resulted in a firm connection between the beams and wattles (See Figures 13, 14 and 15).

The supporting beams were obviously covered with clay

The fragments with smoothed clay on the one side and wood grain on the backside show that the walls as well as the beams were obviously completely covered with clay. The effect is that the building is more fire resistant. This is also why timber framed houses were covered with plaster in former times. Nowadays, the framework of such houses is mostly uncovered. The uncovered beams of such houses often show deep cuts of axe blows. They were used to ensure that the plaster would stay on the wood (See Figure 16). The Bronze Age houses did not need to be worked with an axe as the rods running around the beams in a horizontal direction kept the clay in place.

Connection of rods and poles to wooden edges

It is probable that the fragments with the narrow imprints of a wooden edge result from the beam construction. These imprints can be seen in places where the covering clay is being thinned out in the form of a hollow profile on a wooden edge. As the clay in these places becomes thinner and thinner, the further width of the wood cannot be recognized.

Nevertheless, the imprints show that poles or rods of the wattle were cramped behind a piece of edged wood in a vertical as well as a horizontal direction. It is difficult to decide to which part of the construction this piece of edged wood belonged, perhaps to a door or window. Whether this wooden edge was horizontal or vertical can only be concluded by one fragment: Here a clay drop fell on the hollow profile indicating that this piece of wood had a horizontal position (See Figures 17 and 18).

A wall with two wattles can easily be adapted to the thickness of the beams

In many reconstructions of pre—historic houses built with only one wattle there is a discrepancy between the width of the beams carrying the roof and the width of the thinner wattle. As the supporting beams should at least be 10-15 cm, the wattle only comes up with 7

cm. With two wattles there is no such problem as the two wattles can be adjusted to fit to the width of the beams (See Figure 2).

Review of the findings that indicate/suggest the construction with two parallel wattles

Excavation results make conclusions possible

The archaeological team of the Main-Kinzig district examined the remnants of Middle Bronze Age settlements from May to November 2003. The location is called Steinheile, a little elevation near Langenselbold in Hessia (Schmitt 2004) that was threatened by erosion. One hundred kilograms of burnt clay were rescued. The most important objects from these excavations can be seen in the local museum in Langenselbold accompanied by a reconstruction of the Bronze Age wall.

Description of the clay of the huts

The hardness of the clay fragments varies considerably. There are softer, rounded fragments and some burnt at high temperatures with very clearly preserved structures as well as pieces with a glass-like bubbly outside produced by exposure to great heat. It seems that there was a significant fire that caused the clay of the huts to be burnt at high temperatures thus ensuring the degree of preservation present today. Remnants of settlements from the Middle Bronze age from Heldenbergen, Oberwöllstadt and Runkel-Wirbelau (nearby excavation sites) show similar structures, but not in such a clear way. The majority of the remnants are of an ochre coloured clay, but there are also reddish, greyish and blackish pieces. Fragments of different colours and hardness due to the burning were lying side by side. The clay clearly shows at the outside its smoothed surface. A small part has ochre, grey, greenish, reddish or off-white plaster coverings. There are also prints of rods and poles, and of flat or edged wooden pieces as well as two clear imprints of cord windings (See Figures19 and 20) that may have come from different buildings. We have some knowledge of the size of pre-historic houses because of the arrangements of the pole holes but we do not know much about the buildings on top.

Not one wattle but two parallel wattles

Compared to the wattle and daub of timber framed houses the reconstruction of most pre-historic houses is done with only one wattle. This wattle is covered with clay on both sides, and then the surface of the clay is smoothed down. The clay pieces found in Langenselbold do not fit into this pattern as the remnants often show bulges on the backside. A smoothed down backside or a fractured surface on the other hand, would be expected if there had been only one wattle. Here the soft clay was pressed through the gaps between the rods without

hitting any resistance. It is also remarkable that on 114 (about 4%) of these bulging parts the imprints of grass blades are very clearly seen. These grass blades must not be mistaken for leaning traces as they appear on the flat surface of the clay. In the interior of the clay there are no grass imprints. Although the clay is reduced organically, grass imprints differ greatly from the pores due to the leaning of the clay. These can be seen at the fracture's surfaces where they are much smaller. Some pieces show the complete width of one wattle and daub in the clay: smooth outside clay, imprints of the rods that run in front of the poles, and then imprints of the rods that run behind the poles. In the place where one would expect the opposite side of the smoothed clay covering there are bulges with quite clear grass imprints (Fig. 21-24). Fragments showing smoothed wall clay in the cross-section, then the imprints of wattle and then smoothed wall clay again would prove a construction with only one wattle. Such fragments do not occur.

If the wall was thicker and more compact, so that the wattle would fill almost the entire wall, bulges could occur where the clay had not penetrated deep into the wattle. However, the findings of Langenselbold do not give evidence of such a thick wattle construction. There are not enough clay fragments from the inner section of the walls. In our case there are 2313 fragments that show a smooth surface and only 778 without. A construction with one wattle would explain the wattle imprints, but never the bulges with the imprints of grass blades on them.

It is logical to conclude that two parallel woven/plaited wattles had been stuffed with dry grass. With two such wattles of about 5-6 cm in width where the interior was filled with grass, a complete wall of 20-30 cm could be constructed depending on the volume of the beams and the opening for the grass.

Advantages of a construction with two parallel wattles

A wall with two parallel wattles filled with grass as insulation material has significant advantages when compared to a single wall construction.

- The main advantage of the wall with two wattles is the improved insulation obtained by the stuffing of dry grass in the interior.
- A wall with two wattles is more stable and can provide greater support than a wall with one wattle. In addition, wooden beams can be placed within the two wattles thus stabilizing the building. One hundred and fifty-one fragments from Langenselbold show flat imprints of up to 7 cm wide pieces of wood. Their grain is mostly vertical to the direction of the rod weaving, meaning they could be from a supporting wooden construction. There are also imprints of round timbers up to 30 cm in diameter.

- It is easier to clay-cover a wall with a filling of grass. A film about the reconstruction of a prehistoric house with only one wattle shows quite an amount of clay penetrating through the rods to the other side when thrown on.

Double wattles of the Stone Age

Schliz presumed walls were constructed with two wattles in the Stone Age settlement of Grossgartach (Schliz 1901). He writes:

> *Many heavy clay pieces show these wood weaving imprints on both sides. So it is probable that the outside walls were of two flat wattles standing in close connection, the inside of which was completely filled with clay, a kind of clay that was mixed completely with pieces of straw and husks. Nowadays naturally these can only be recognized after their decay by the remaining pores.*

This mass mixed up with straw and pelts created good insulation between the two wattles. The loose dry grass provides better insulation, but it does not offer the same stability.

How to distinguish fragments of clay from buildings with one wattle from fragments from buildings with two wattles

Schliz found fragments with the imprints of two wattles, but when one finds fragments with imprints of only one wattle it is natural to think of a one wattle and not of a two wattle construction. Accordingly building reconstructions were made in the one wattle way. Such pieces of clay that clearly show the grass imprints on the backside—as found in Langenselbold—are really lucky finds, the clay was extremely well preserved because of great heat.

A second indication for two wattle walls beyond the grass imprints are the bulges that were to be found beyond the middle of the woven rods. With a one wattle wall the clay of the opposite side would have met the clay that was first thrown on to the other side.

Breakages of the clay near a rod can result from a two wattle construction as well as from a one wattle construction. A clear proof for a construction with one wattle would be a fragment that shows both smoothed outsides with the cavities of the rods in between. (See Figures 25 and 26)

It is probable that more prehistoric houses with a construction of two wattles were built than has been estimated so far—thus making use of the good insulation. Often the clay that can be found is not really well preserved. In general till now it has not really been considered important and therefore it was not well examined.

Live experiments in the Hornstaad House in the lake dwelling museum of Unteruhldingen on Lake Constance

Settlements near the banks of rivers and lakes cannot really be compared to those in higher positions. One experiment is however impressive: The reconstructed lake dwellings (See Figure 27) in Unteruhldingen on Lake Constance were tested as a means of habitation. The experiment shows that the walls did not hold the heat well. They consisted of only one layer of parallel branches of 4-5 cm width, not woven. On both sides they were covered with a thin layer of clay (See Figure 28). It took a long time until the fire warmed up the interior of the hut. From about 9 p.m. the inside temperature started to sink, caused by the colder night temperatures outside. After 10 p.m. when the fire was extinguished the temperature sank rapidly (Kaus, Schöbel, Walter 1998/99).

Reconstruction of the Langenselbold wall

In order to verify the described conclusions concerning the structures on the clay fragments, a double wattle was built using willow rods. It was filled with grass and the outside covered with moist clay. After drying, this clay showed the same structures as the excavated fragments. It showed the smoothed side as well as the same bark structures of the woven wattle we can see on the ancient fragments. In places where the clay squeezed through the rods there were also visible bulges (See Figure 25). On these bulges we can find grass imprints just like those on the Bronze Age clay. The number of the grass however imprints is very small. They could only come into existence in places where there was a certain distance between the horizontal rods. Here, where the clay could penetrate deeply inside and where the grass offered enough resistance, the imprinting lines could emerge.

The Bronze Age House meets the requirements of modern buildings

During the Hessentag in Langenselbold in 2009 a reconstruction was exhibited (Hessentag meaning a kind of fair in one Hessian town with lots of informational as well as culinary stalls). It was the first wall without the vertical supporting beams. It attracted the attention of the leader of the Hessian Energy Saving Action who then calculated the insulation figures of the wall. Using a grass stuffing of 10 cm between the wattles the thermal insulation is surprisingly good. The U-factor/value is between 0.5 to 1.0 W (m^2K) according to how densely the grass was stuffed in and how coarse or fine the grass was. “Very humbly we should acknowledge that comparable high insulation values were not reached again until the heat-protection-regulation of 1995. In the thousands of years in between the insulation grew four to six times worse with timber framed houses, three times worse with solid brick walls. Progress sometimes leads us back to proven methods from the past”, says Werner Eicke Hennig from the Hessian Energy Saving Action (Eicke Henning 2009).

Acknowledgements

My gratitude goes especially to Dr. H.-O. Schmitt for his professional support and advice.
Thanks to Dr. G. Schwitalla for helpful information and to M.A. Claus Bergmann for his encouragement.
Dr. G. Callesen and Dr. J. Lindenthal friendly allowed us the inspection of archaeological finds.
Prof. Dr. A. Kreuz was so kind to confirm the grass imprints.
K. Wurche mentioned the existence of the film to me.
Thanks to W. Eicke-Hennig fort the calculation of the insulation value.

Keywords (re)construction
construction of building
wall

Country Germany

Summary

The discoveries from an excavation near Langenselbold (Hessia) show that even the people of the Bronze Age used methods of insulating their buildings. These methods surpass in their effects the values of framework and brick houses of our time.
Among other findings there was circa 100 kg of clay for huts in mostly good condition. The fragments lead to the conclusion that there was a construction of two parallel plaited (woven) walls, where the interior was filled with dry grass. The clay fragments with the imprints of rods and poles show that the lean woven wall would be too weak to carry a roof. Now fragments of clay with imprints of flat wood grains of these walls were examined. This leads to the conclusion that there were upright beams strong enough to support a roof. Furthermore, they provide evidence of how the woven wattles were linked to the supporting construction:
Every second horizontal rod goes around a beam on the outside and clasps it while the alternating one is clamped behind a pole on the inside. Thus the wattles are firmly connected to the supporting construction. Not only are the wattles covered with clay, but also the supporting beams. This would make the walls more fire proof. It appears easier to adapt walls with two wattles to the thickness of the beams because the distance of the wattles can be varied. Such a wall is easier to smooth down and is more stable than a wall with just one woven wattle inside, and also has the advantage of providing greater insulation. In an experiment such a double construction of woodwork was stuffed with dry grass and then covered up with clay. After drying, the clay had the same structures as the Bronze Age clay.
The Hessian “Save-Energy-Action”, project of the Hessian Ministry (Department) for environment, energy, agriculture and the protection of consumers, made a calculation of the U-factor with a 10 cm thick filling of dry grass in a model construction of the Bronze Age. The result was 0.5 to 1.0 W/(m^2K). This quality was not reached for our modern buildings until 1995, when a new regulation for the saving of energy was established.

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Gallery Image

FIG 1. RECONSTRUCTION OF ENERGY SAVING WALL

FIG 2. VIEW FROM ABOVE ONTO THE WALL WITH BEAM, TWO WATTLES AND GRASS FILLING.

FIG 3. IMPRINTS OF FIVE POLES WITH CROSSING RODS. ONE POLE IS SPLIT ACROSS ITS LENGTH. (VIEW FROM ABOVE)

FIG 4. AS FIG. 3, VIEW FROM THE SIDE.

FIG 5. IMPRINTS OF RODS CROSSING EACH OTHER.

FIG 6. IMPRINTS OF FINE WOOD GRAIN, OTHER SIDE SMOOTHED SURFACE, IMPRINTS OF RODS ON THE UPPER AND THE LOWER PART. INV. 63

FIG 7. AS FIG. 6, OPPOSITE SIDE WITH SMOOTHED SURFACE. INV. 63

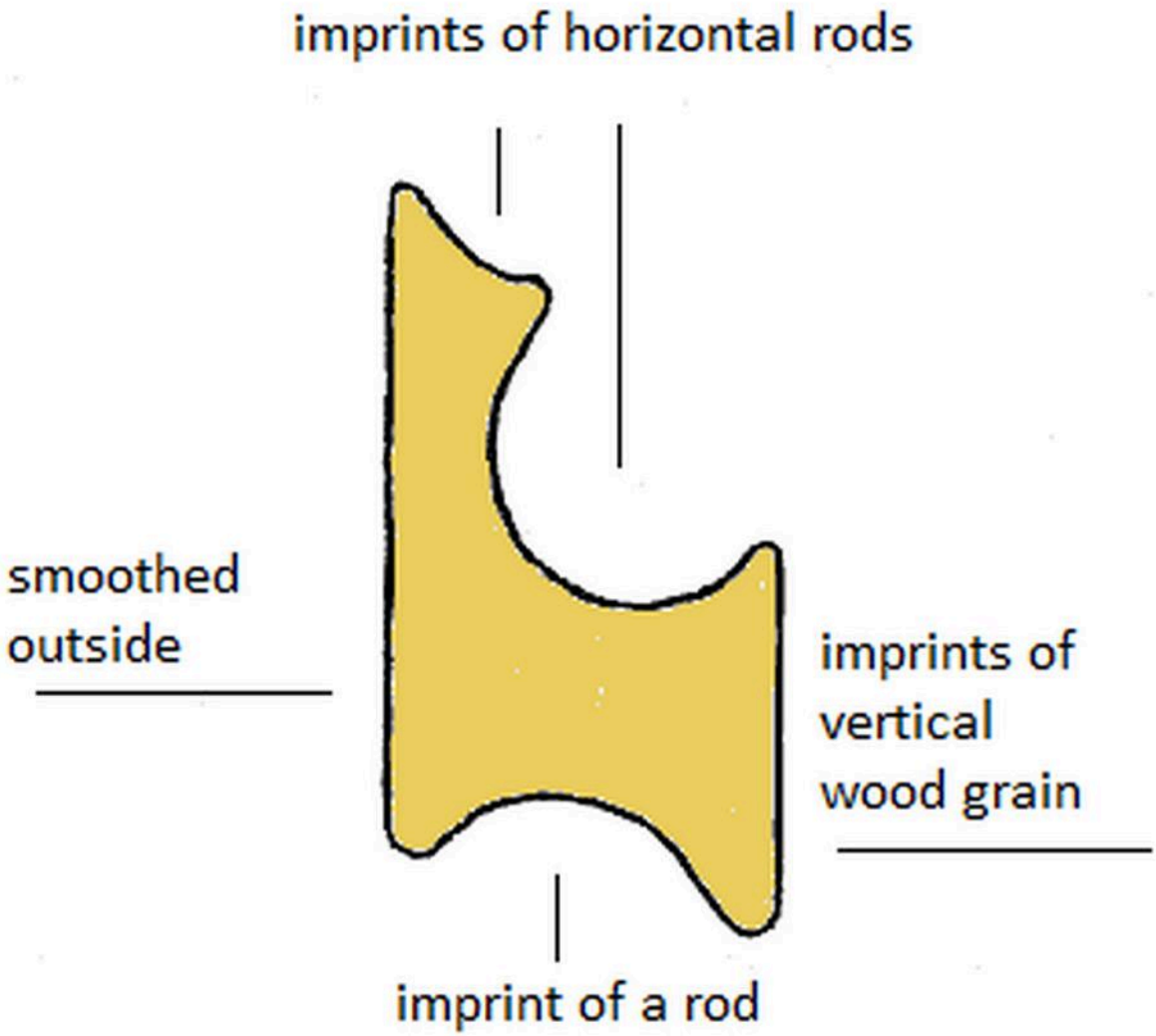

FIG 8. FRAGMENT INV. 63, FIG. 6 AND 7 IN CROSS SECTION

FIG 9. IMPRINTS OF FINE WOOD GRAIN, OPPOSITE SIDE SMOOTHED SURFACE, IMPRINTS OF RODS ON THE UPPER AND THE LOWER PART. INV. 64

FIG 10. IMPRINTS OF FINE WOOD GRAIN, OPPOSITE SIDE SMOOTHED SURFACE, IMPRINTS OF RODS ON THE UPPER AND THE LOWER PART. INV. 62 (SKIP PERHAPS)

FIG 11. CLAY WAS THROWN ON A BEAM WITH CROSSING RODS AS PART OF AN EXPERIMENT. RESULTS SHOW THE SAME STRUCTURES AS THE BRONZE AGE CLAY.

FIG 12. WATTLE OF A BARN IN RAUISCHHOLZHAUSEN (HESSIA). TWO POLES ARE SIDE BY SIDE NEXT TO THE VERTICAL BEAMS. BOTH POLE ENDS ARE CLAMPED IN A GROOVE IN THE UPPER AND LOWER BEAM. THE RODS ARE CLAMPED BEFORE AND BEHIND THESE POLES.

FIG 13. RECONSTRUCTION: RODS LED ALONG THE OUTSIDE OF A BEAM CONNECT THE WATTLE WITH THE SUPPORTING CONSTRUCTION.

FIG 14. RECONSTRUCTION:RODS THAT STAY INSIDE ARE CLAMPED BEHIND THE POLES NEXT TO THE BEAM.

FIG 15. BRONZE AGE FRAGMENT POSSIBLE SHOWING RODS SIDE BY SIDE NEXT TO A BEAM?

FIG 16. BLOWS/CUTS FROM AN AXE ROUGHENED THE SURFACE OF THE BEAMS TO ENSURE THE PLASTER WOULD STAY ON THE WOOD. OLD TIMBER FRAMED HOUSE IN GELNHAUSEN (HESSIA).

FIG 17. THE ANGLE LEFT BELOW IS THE IMPRINT OF AN EDGED WOOD. THE IMPRINTS OF A POLE AND THREE RODS (OR A ROD AND THREE POLES) ABOVE INDICATE THAT THESE WERE CLAMPED BEHIND. IT IS NOT CLEAR IF THE WOOD WAS BUILT HORIZONTALLY OR VERTICALLY. INV. 10.

FIG 18. HERE A HOLLOW PROFILE WAS FORMED OVER AN EDGED OR FLAT PIECE OF WOOD WITH TWO PARALLEL RODS. WHILE SMOOTHING, A DROP OF WET CLAY FELL DOWN AND INDICATED THAT THIS WOOD WITH THE RODS WAS HORIZONTAL.

FIG 19. VARIOUS COLOURS OF CLAY IN PLASTER AND UNDERGROUND.

FIG 20. IMPRINTS OF CORD WINDINGS

FIG 21A.THIS FRAGMENT SHOWS THE COMPLETE THICKNESS OF THE WATTLE: SMOOTHED OUTSIDE, IMPRINTS OF RODS PASSING ON BOTH SIDES OF THE POLE, BULGES WITH IMPRINTS OF GRASS. VIEW FROM ABOVE WITH IMPRINTS OF RODS, BULGES AND IMPRINTS OF GRASS. INV. 14

FIG 21B. SMOOTHED OUTSIDE.

FIG 21C. VIEW FROM BENEATH WITH IMPRINTS OF RODS AND BULGES.

FIG 21D. BULGES AND IMPRINTS OF GRASS ON THE SIDE THAT IS ADJACENT TO THE GRASS FILLING.

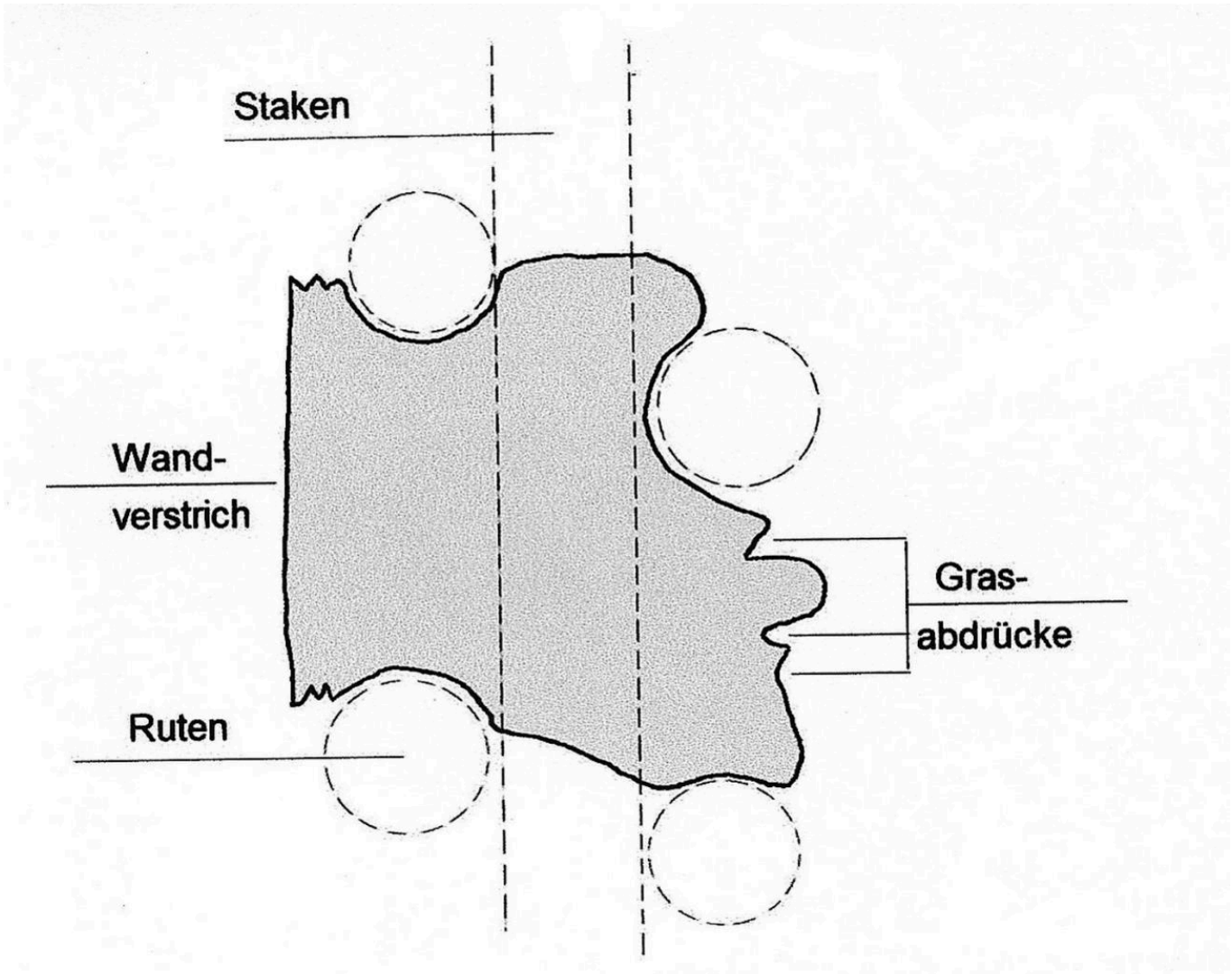

FIG 22. CROSS-SECTION THROUGH FRAGMENT ABB. 21, INV. 14

FIG 23. DETAIL FIG. 21D, ENLARGED IMPRINT OF A GRASS BLADE.

FIG 24. GRASS IMPRINTS OF THE RECONSTRUCTION. THEY ARE SIMILAR TO THOSE FROM THE BRONZE AGE.

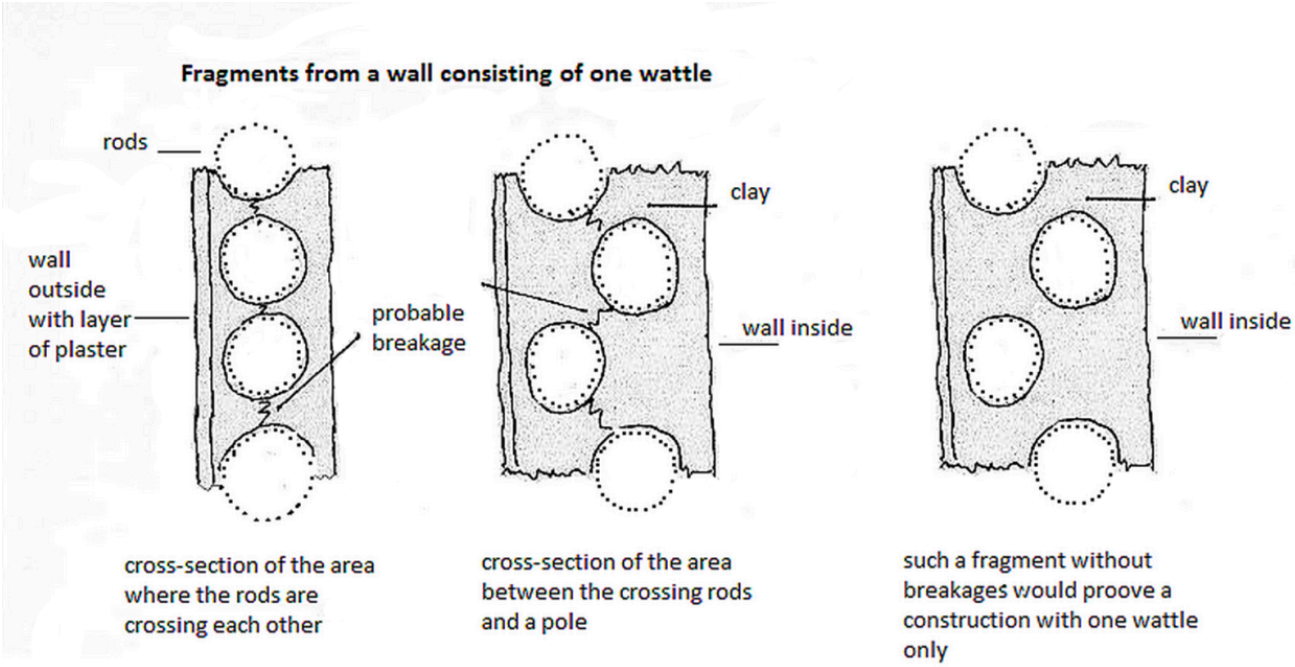

FIG 25. CROSS SECTION OF FRAGMENTS FROM CONSTRUCTION WITH ONE WATTLE

Fragments that indicate a wall with two wattles

Fragments like those from only one wattle result from double wattles as well. But bulges at the inside indicate that the clay had no obstacle at the opposite side when it was thrown on or smoothed down. Even if they do not have imprints of grass, the bulges show that there was just the insulating air but no second layer of clay.

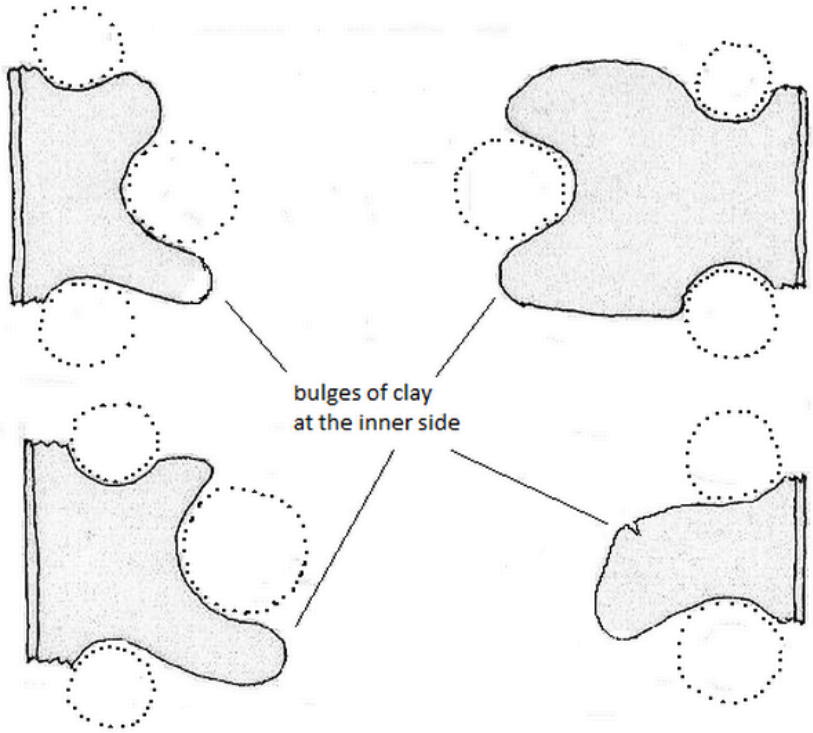

FIG 26. CROSS SECTION OF FRAGMENTS FROM CONSTRUCTION WITH TWO WATTLES

FIG 27. UNTERUHLDINGEN HORNSTAADHAUS

FIG 28. DETAIL OF THE INNER SIDE OF THE WATTLE. THE WET/MOIST CLAY IS THROWN ON FROM OUTSIDE AND SQUEEZED THROUGH THE GAPS BETWEEN THE RODS SO THAT THE GRASS BLADES ARE IMPRINTED ON THE CLAY.