PUTTING WOODWORKING TOOLS OF THE MIDDLE BRONZE AGE TO THE TEST

Building a gateway at the Terramare settlement in Montale, Italy

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Introduction

The VIAS – Vienna Institute for Archaeological Science – is an interdisciplinary research unit of the University of Vienna. For the past 20 years employees of the experimental archaeological working group of the VIAS have been dealing with the evaluation of archaeological findings, implementation of prehistoric architecture models and the study of prehistoric craft techniques connected to that. The aim of our work has always been to recreate wooden buildings or other structures of the past based on individual archaeological findings with the technological means and materials of the era in terms of experimental archaeology. So far all steps were carried out by using original techniques so that it was possible for us to integrate the data obtained to get concrete ideas of the technological possibilities the people of the past had but also to better assess the total effort involved for each project. In addition, modern tools were partly used, whereby we took care to ensure that visitors were only presented with evidence of authentic working methods from the respective eras in the finished architectural models.

To undertake large-scale empirical studies on wooden architecture, it was essential to find project partners, who in turn had an interest in such construction projects and could also provide funding. In the course of different open-air contracted research projects, in recent years employees of the VIAS have been engaged not only in practical studies on wooden architecture of the Stone, Bronze and Iron Age, but also in projects of the Roman Empire and the Early Middle Ages and have in total erected about 50 individual buildings. The result of these ventures was a classic win-win situation: For archaeological research it provided the opportunity to carry out experimental studies on a large scale. The project partners received architectural models that were built according to the current level of research and which in conjunction with archaeological exhibitions, could be marketed for sustainable tourism purposes in archaeological open-air museums. It thereby was possible to make history visible to the public and to enable the visitors to experience it by feeling and touching.

An archaeological open-air museum of the Terramara in Montale

In conjunction with the EU project ArchaeoLive and based on results from local excavations, an archaeological open-air museum of the Terramara Culture was constructed in 2000 in Montale, a small town south of Modena under the guidance of
Dr. A. Cardarelli from the Museo Civico Archeologico Etnologico in Modena (BARTH et al. 2003; CARDARELLI u. PULINI 2004). Additional partners of this EU project were the Natural History Museum Vienna, where, under the direction of Dr. F. E. Barth at the Salzberg in Hallstatt reconstructions of Bronze Age buildings were erected (BARTH u. LOBISSER 2002), as well as the Pfahlbau Museum Unteruhldingen, where under the direction of Dr. G. Schöbel at Lake Constance, similar activities took place (SCHÖBEL 2005).

The Terramara refers to a cultural phenomenon in the region of the lower plains of the river Po in northern Italy, where between 1650 and 1170 B. C. almost quadrangular fortified settlements with inner areas usually in excess of 10,000 m² were built (cf. Brea, Cardarelli and Cremaschi 1997). These settlements were mostly protected by wood and earth defences with ditches and inside the villages following a regular perpendicular layout were rows of houses and streets. Special entrance systems with earthen or wooden bridges allowed access to the settlements. In 2006, the experimental group of VIAS was invited to construct a portion of the fortification with an entrance as a new architectural model using experimental archaeological methods at the open-air museum of Montale (Lobisser 2008).

Archaeological evidence

In Montale, the traces of a Middle Bronze Age terramare settlement were detected with external dimensions of about 100 m to 120 m. The ditches of the fortified settlement were clearly visible in the ground and showed rounded corners and within the walls there was evidence of house remains. There were also partial wooden structural elements preserved which give an indication of the building structure of the houses (cf. BERNABO BREA et al. 1997). In several settlements from around the same period, such as the Terramara di la Braglia or the Coppa Navigata in Puglia, we are familiar with archaeological findings, which show that the entrances to the settlements may have been 3 to 4 m wide and up to 9 m long (see BERNABO BREA et al. 1997). One discovery from the 19th century at the Terramara di Castione Marchesi (PIGORINI 1883) allowed valuable conclusions to be made for the design of the fortified wooden constructions. It shows wooden cages in block design lined up so that the protuberances of the cages in turn formed their own compartments lengthways. The internal dimensions of the individual cages measured about 3 by 3 m and there were also several indications of associated tower-like structures.

In close cooperation with the Italian colleagues, as well as local architects and building experts, a blue print was drawn up for our reconstruction project in Montale for four wooden cages to form an entrance about 3 m wide and 9 m long leading into the interior of the settlement (Ill. 1). The gate itself was designed as a turnstile construction with two panels and positioned approximately in the middle of the entrance. It is closed at the top with a bridge and same as the cages has a palisade.

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Experimental archaeology questions

With the practical work in Montale, it was our goal to gain a better understanding of the technical capabilities of woodworking of the Terramara. From the outset of the project there were many questions: How do we envisage the construction of a fortification from the Middle Bronze Age? How many working hours were required? How much building material was needed? Which wood joining techniques were available to the people of the Bronze Age? How resilient were bronze tools when working on solid oak trunks? What types of tools were particularly suitable for certain types of work? During the course of the work a number of questions arose especially with regards to the wooden shafts of the axe blades, which are elaborated in more detail later. We wanted to avoid using modern resources such as cranes or hoists and bring all the design elements in position by hand with the aid of levers, pulleys, and inclined planes.

Fig. 1: The floor plan for our reconstruction was developed based on findings from several excavations of fortified settlements from the Middle Bronze Age Terramare culture; by A. Cardarelli.
It was not possible to source oak in this quantity in Italy so we purchased the poles in Austria and they were transported over 900 kilometres to Montale. The poles for the wooden cages were up to 5 m long and 20–35 cm in diameter. The heaviest poles would have weighed approximately 400 kilos. Most of the poles were straight and the diameters of the poles for the palisades were between 15 and 20 cm.

Bronze tools and wooden splices

For our experimental studies on wooden crafts in the Middle Bronze Age in Montale, we made tools of bronze based on archaeological originals. We made large and small flanged axes, chisels of different sizes, bronze daggers, bodkins and awls as well as wooden dividers with bronze tips. There were also a number of tools made of wood such as cleavers, mallets, levers and reels to be able to transport the poles. The large flanged axes weighed about 425 grams. The handles were made of angular grown beech and ash woods; the handle itself came from the trunk and the tool arm from the wooden knot. To attach the blades to this knotted part, they were equipped with a narrow chisel with slots in which the blades could be inserted so that the cutting edges were parallel to the handle. These connections between splice and metal blades were additionally secured by twine lashings. Some of the small blades which weighed around 125 grams were also equipped with handles in this way.

If we look at the development of woodworking from the very beginning of the Neolithic, we notice that adzes have played an important role from the beginning (LOBISSER 2013). Our practical experience of recent years has shown that adzes with their cutting edge hafted crossways to the handle are excellently suited to working on structural timbers of all kinds. In the late Neolithic period, we find a whole range of adze blades in different sizes, which differ significantly in shape from the axe blades. We only know bronze tools described as “axe blades” from the Early and Middle Bronze Age in comparison. If we assume that such an important type of tool type wasn’t simply forgotten at the beginning of the Bronze Age, we must ask ourselves the question: Where are the adzes of the Bronze Age? In the course of our work we wanted to find out if it was possible that we could not find these adzes because the metal blades do not differ from the axe blades. Based on that, we hafted some of the smaller flanged axes in a way that their cutting edges were crossways to the wooden handles to test their functionality as adzes.

Some chisels of the Terramara were noticeable by their particular size. With lengths of 25 cm or more and weighing around 300 grams, they indicate that grooves, slots and cut outs of considerable dimensions belonged to a common spectrum of wooden connections. Working from two sides, you could theoretically cut out rectangular holes from one side to the other in poles up to 40 cm thick. We wanted to use awls and bodkins as well as bronze tipped wooden dividers for marking wooden joints. Dagger blades were probably multifunctional tools and could have very varied uses in woodworking such as for carving wooden nails.
To get an idea of how they might have felled trees in the Middle Bronze Age, we conducted several experiments with our larger axes. We learned that oak timbers of 30 cm in diameter could be felled in just under an hour using our flanged bronze axes. In most cases we were able to make the trees fall in the desired directions by chopping notch cuts and felling cuts into the upright timbers about 60 to 70 cm over the floor level. It was important that the felling cut was slightly higher than the notch cut that would determine the direction a tree would fall. To remove the bark from the oak timbers, we successfully carried out this task using bronze axes, where the hafted angular handles provided a good grip as we could use them as a lever. One attempt to haft an axe blade on to a long straight wooden handle in order to use it as a large slick was not satisfactory because the narrow curved blade at the front slipped sideways repeatedly.

At the construction site, the first four poles were then cut to the right length with axes and positioned, whereby the first two were placed on the ground approximately 3 m apart and the other two placed at right angles on top of the first pair. Since the structure was built out in the open air, we cut out semi-circular notches at the corners of the wooden cages in the top poles, so that rain water could drain off rather than being collected in the hollowed notches and speed up the weathering process. In order to achieve perfectly fitting joints, the poles were individually customized and we used our bronze tipped wooden dividers for this. When a pole was precisely positioned, the length by which it would need to be lowered was marked with the dividers at both contact points, so that the cuts were exactly equal to the diameter of the two underlying poles (Ill. 2). Then the pole was rolled inwards and turned 180 degrees so that we could cut out the two grooves. After some practice, we managed this task very well using the large bronze axes.

Some issues arose after a while during this work because the twine lashings that connected the bronze blades and wooden shafts were affected by the sharp edges that formed at the edge of the notches of the poles. The tight lashings became loose or came off completely, so that the axe blades were not fixed strongly enough in the hafted slots. A significant improvement could be achieved concerning the lashings by leaving a thicker sections in the wood at the forked ends of the hafted joints, to prevent the lashings from slipping down on the one hand and provide some protection on the other. We have since found a preserved hafted angular handle
in the Archaeological Museum in Hannover, which has a similar thickening on the hafted prongs. Another problem with using the blades was that these were only clamped in the haftings by the edge in the middle and thereby actually only properly secured in the middle of the bronze blade. They were not supposed to fit too tightly further back, because there was otherwise the risk the blades would split the hafted joints by the high kinetic energy exerted when chopping. So there was a risk that the blades would dislodge and loosen when chopping at a slight angle. A solution was found for this too: At the top end of the known Bronze Age axe blades there are usually smelting depressions which are told to be caused when pouring the bronze blades upright as the metal cools relatively quickly externally but only slowly internally. As hot metals expand there is some loss in dimension due to the shrinkage of the material when it cools but the already cooled outer surface of the blade no longer reacts so the metal sinks in at the top. These smelting depressions were reworked on many original pieces. Through our experiments, we believe we can show that these depressions were not only due to the manufacturing process, but also played a very important role for hafting the blades. In our opinion, the slots in the wooden hafts where the axe blades were placed could in the Bronze Age only be incorporated using a narrow bronze chisel from both sides (BARTH u. LOBISSER 2002, 58). Due to the working methods used in our trials, a small ridge often remained at the base of the slot. If we left this ridge slightly larger at the end of the slot and positioned it precisely so the smelting depression could rest exactly on that, the blade was thereby fixed in place at the top end of the haft. Through this combination of double fixing the blades in the hafted joints on edges and the smelting depression, as well as the thicker areas of wood of the hafted prongs beneath the lashings, we had well-functioning bronze axes that lasted (Ill. 3).

We soon fell into a routine to work more than 200 of these notches into our four wooden cages. We were able to produce indentations about 27 cm wide and 13 cm deep on average in about 20 to 25 minutes with bronze axes. The smaller axes were not suitable for this task because they simply had too little impact weight. To uniformly build up the wooden cages, it was very important to place two approximately equally thick poles on top. We also had to alternate placing the thick and thin ends of the poles in position. The two wooden cages at the front were built up to a height of about 320 cm and the two at the rear slightly lower. The remaining gaps and cracks between the joists were sealed with split wooden wedges placed in a radial arrangement before filling the cages with earth.

Fig. 3: The heavy flanged bronze axes were hafted on naturally grown angled wooden handles and proved to be useful tools for the construction of log houses (Photo: K. Hofinger).
We found out the limits of the bronze tools working on the tree knots, which left big nicks in the blades or even bent them. The rule was to avoid these as much as possible. It was actually not a big problem to straighten bent blades again. We had cold forged our blades several times over already anyway before starting work to increase their stability. Nicks and flaws had to be laboriously ground away using the grindstone, however.

Transporting and lifting the poles was largely done by hand with the aid of levers, rollers and inclined joists, over which we could roll the poles. It became clear that the people of the Bronze Age could only build regular wooden cages with almost vertical walls, if they had a method to reproduce dimensions and distances. One might consider standardized wooden rods or cords with knots. Additionally, to be able to build vertical walls they must have had a kind of plumb line.

**Gate panels, bridge and palisade**

The construction of the gate as a turnstile design with two panels was associated with many technical problems which had to be solved. The gate panels measured about 250 by 130 cm and without using any metal parts were to be made of approximately 5 cm thick oak planks. Turnstile designs have been found in several fortifications from the Bronze Age with perforated stone foundations in the relevant places. All structural timbers of the gate panels were worked on flat. We used the smaller blades as adzes and lo and behold, they were more than suited for this work (Ill. 4). When using adzes you can achieve a much higher accuracy than with axes because of the constant, slightly stooped posture and it was possible for us to produce very smooth surfaces, without having to make changes to the “axe blade”. To begin with we squared off two approximately 3 meter long oak poles with diameters of about 25 cm at the thicker end into beams using the adzes mentioned. About 14 cm thick round pivots were then carved into both ends of each of these poles. They formed the beams of the gate panels. In the mid section and about 50 cm from either end, three rectangular mortises were then worked into each pole. We used the large bronze chisels and mallets. It was important not to drive the chisels in too deep, but to a maximum of 5 mm across the grain to separate them and then chipping away by working along the grain. Using these chisels we were able to cut out pieces 16 cm long, 5 cm wide and 15 cm deep in about 50 minutes (Ill. 5).

In these cut outs, we then put three crossbeams with the cor-
responding pivots at each end per beam. Each of these joints was then secured by two solid core wood pegs of oak. The holes for the nails were also chiselled but with smaller chisels. The pegs were cleaved from straight grown wood, so we could be sure that every single wood fibre stretched across the entire length of the peg. At each end we carved heads and they were wedged from the back. The smaller bronze axes proved to be very suitable for making the pegs and the finer carvings were made with bronze daggers. The boards of the gate panels were then secured onto the three crossbeams with wooden pegs. Additionally we joined these boards together edgeways with dowels. This is how we were able to achieve a stable join of the wooden components of the gate panels, which ultimately each weighed about 150 kg.

At the start of construction of the wooden cages, to fix the gate panels in the desired position, we embedded a strong oak timber with a diameter of about 30 cm in the ground with only about 8 cm of the top sticking out. Both ends of this timber were incorporated into the joint of the cages. When the cage was at a height of about 260 cm, another beam was incorporated between the wooden cages over the gateway that it formed a kind of gate frame together with this and with the embedded timber. By chiselling round holes of about 15 cm in diameter at the appropriate points in these two crossbeams, it enabled us to mount the gate panels. The top beam together with a second crossbeam on the same level behind it formed the support for a bridge about 110 cm wide which leads across the gateway directly behind the gate.
Oak timbers with diameters between 15 and 20 cm were then split by driving in wooden wedges. The top ends of these half timbers were pointed using large bronze axes and a palisade was built and assembled as follows: The finished wooden cages were first filled with earth to about 1 m below the top edge. The half timbers of the palisades were then spread at this level on the inside against the walls of the wooden cages. By now filling the wooden cages up to the top with the rest of the earth, the posts of the palisades were wedged between the walls of poles and earth and thereby very securely fixed. Above the bridge, the vertical posts of the parapet were fastened to crossbeams with wooden dowels and twine lashings (Ill. 6).

Considerations on labour involved

It basically seems problematic to estimate hours of labour for prehistoric conditions, because we know too little about work habits, skills and abilities of the people of the past. Nevertheless, we have attempted on the basis of the data from our studies to design a conceivable scenario for such a construction process in the Bronze Age. The individual data were only ever gathered after we had dedicated days or even weeks to a particular stage with a specific tool and had the feeling to have empirically practiced and learned this stage to an optimal level. The Terramare settlement in Montale had an overall rampart of about 440 m length, so on the basis of our practical, detailed study we can conclude that the people of the Bronze Age had to muster a total of about 1,200 m³ of timber – a huge amount of about 6000 poles. If we consider that perhaps between 300 and 400 people lived in these settlements, then it becomes clear that this kind of building project involved enormous effort and was certainly only manageable by extreme exertion of the entire village community. Based on our practical studies, we want to suggest the following conceptual model: The construction of a Middle Bronze Age fortification the size of Montale could have taken approximately 195,000 man hours to complete, with time added for providing food and equipment for the working people. If of the estimated 400 inhabitants, half had participated in the fortification, it would have been possible to complete this in three years at a level of about 41 days per person per year, which would have happened at the quiet agricultural time of year. This scenario, however, we want to be understood only as a proposal possible in practice.

Summary and conclusion

In 2006 at the archaeological open-air museum in Montale in northern Italy, a portion of a fortification with gateway of the Terramara culture was reconstructed as an architectural model by the experimental archaeological group from VIAS. The fortification itself consisted of - as can be deduced from archaeological findings – wooden cages filled with earth. Access to settlements was through a gateway.
about 3 m wide. In the practical construction of the architectural model replica tools made of bronze were used.

Four wooden cages were built with heights up to 320 cm in the reconstruction work in Montale. Overall, about 18 m of the fortification was rebuilt, for which about 50 m³ of oak wood – approximately 250 poles of different diameters - were used. The gate itself was constructed in a turnstile design with two panels and each panel consisted of eight major construction elements that were solely joined by pivots, wooden plugs and pegs. The two gate panels, each weighing about 150 kilograms are relatively easy to move on round pivots embedded in massive crossbeams connecting the two pairs of wooden cages above and below the gateway. Above the gate is a bridge with a parapet. The wooden cages were equipped with a palisade on top and filled with earth.

We used the large flanged bronze axes specifically for felling and cutting of timbers, as well as to shape the semi-circular notches at the corners of wooden cages. The smaller axes were less suited for this but finer work could be done with them, such as making the wooden pegs and dowels. Looking at the development of woodworking methods from the beginning of the Neolithic, it becomes clear that adzes – lateral hafted axes – have always played an important role. So we asked ourselves: Where are the adzes of the Bronze Age? We now believe that we have found them: It turned out that it was possible to use normal bronze blade “axes” crossways also as adzes to splice wood. The results working with these tools were convincing. We were able to hew round poles into square timbers with such adzes without problems. The “axe blades” of the Early and Middle Bronze Age were clearly multifunctional and could be used both as axes and adzes (Ill. 7). It therefore stands to reason that the two-dimensional reworking of timbers was common in the Middle Bronze Age to a considerable extent.

When hafting the blades on to naturally grown trunk and branch portions to make the angular handles, we believe we made two important discoveries. By leaving a thicker portion by the ends of the hafted prongs below the twine lashings, we were able to prevent them from slipping down or be da-

Fig. 7: Small flanged axe blades were hafted as axes, as well as adzes and proved to be multi-functional tools of the Middle Bronze Age (Photo: W. F. A. Lobisser).
maged whilst using the tool. Furthermore, we could show that the “smelting depressions” that appeared at the upper end of the bronze blades during cooling had an important function when hafting the blade. In addition to the edges, they could give the blades extra grip when placed on appropriate small pins at the end of the chiselled slots of the hafted joints preventing these from loosening in the joints, becoming unstable or coming out. We don’t think that it is coincidence that these notches in some blades of the Bronze Age had been carefully reworked.

All kinds of grooves, slots and openings could be prepared well with bronze chisels. Especially the large specimens of the Terramara with lengths up to 30 cm leave one to believe that relatively complex wooden joints from solid and probably four-sided poles were used in the Middle Bronze Age up to a wider extent. We successfully used the large chisels to create rectangular openings in approximately 15 cm thick squared poles for the gate hinges. The smaller chisels we used to chisel holes for wooden pegs and we used awls and bodkins to mark wood joints. Our bronze tipped wooden dividers lent themselves very well to transmit the dimensions of the poles for the wooden cages to the corresponding next one so that perfectly fitting notches could be cut out.

Oak timbers of all dimensions could be split using wooden wedges to obtain workable pieces for various construction elements. The arrangement of rectangular wooden cages with vertical walls also assumes that the people were familiar with specific measurement systems for transferring distances and for producing standardised poles. The use of standardised wooden rods or cords with knots spring to mind. There are many indications that plumb bobs and spirit levels were familiar tools in the Middle Bronze Age. Overall, large and small bronze blades were well suited to work on fresh oak. Attempts to work on oak dried for several years have shown that it does more damage to the blade, which you certainly would have wanted to avoid in the Bronze Age.

**Zusammenfassung**

selbst als auch aus verschiedenen anderen zeitgleichen Siedlungen dieser Kulturerscheinung. Zu den Holzaufbauten im Inneren der Wälle gibt es einen aus- 


References