# ENHANCED POTENTIAL FOR THE ANALYSIS OF ARCHAEOLOGICAL FINDS BASED ON 3D MODELING

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**ABSTRACT:**

In early 2007 the special research program HiMAT – History of Mining Activities in Tyrol – was established at the University of Innsbruck. It is an interdisciplinary research project dedicated to the history of mining in Tyrol and adjacent areas, sponsored by the Austrian Science Fund (FWF). At present, the Surveying and Geoinformation Unit of University of Innsbruck is completing the modelling from a three-dimensional close-range laser scan of spectacular wooden artefacts from a Late Bronze Age ore dressing installation. In this way, the fragile objects can be saved in digital form and interpreted before undergoing the lengthy preservation process. 3D-lasercanning is a non-contact and non-destructive way of acquiring geometric data of sensitive and complex objects. The high resolution of modern equipment allows an exact spatial documentation with a high resolution texture. Compared to conventional methods the speed and the reachable degree of detail is marked higher. A known problem arising during the handling and evaluation is caused by the gigantic data volume. This needs – besides a powerful hardware and a skilful software and operator – preliminary considerations concerning the proper raster-width.The spatial models resulting from the measurement- and evaluation process can be used in different – and meanwhile often described – ways. An additional aspect arose during our pursuits with the wooden artefacts mentioned above. The findings had to be inserted into a special fluid for conservation purpose within 4 days. During the needed time span –more than a year – the findings cannot be investigated further by the archaeologists. So the virtual model can replace the fragile original which does not need to be touched further more. This method could also help to solve problems of archaeological scientists working in countries which forbid the export of archaeological artefacts. Having scanned the finds the further analysis could be done at home under more even circumstances. Finally, by an additional scanning after the conservation procedure the changes in geometry caused by the fluid can be pointed out.

## 1. INTRODUCTION

In early 2007 the special research program HiMAT - History of Mining Activities in Tyrol – was established at the University of Innsbruck. It is an interdisciplinary research project dedicated to the history of mining in Tyrol and adjacent areas, sponsored by the Austrian Science Found (FWF).

Under the broad auspices of the research program, 12 university institutes, 4 of them from neighbouring countries, participate in a total of 14 subprojects. One focal point is the investigation and reconstruction of the technology, economy and social history of the alpine mining communities, from prehistory up to modern times. The central themes are the procurement and processing of the raw mineral resources, metal production and trade, as well as the influence of mining activities on societal development and the environment.

Some examples of very fruitful interdisciplinary collaboration are the use of modern laser scanning techniques for documentation and presentation of archaeological finds and features.

## 2. DATA ACQUISITION

Laserscanning replaces the a-priori point-selection of conventional tacheometry by automatic, high-speed measurement of a point-grid with extreme density. The technology used for that mainly depends on the distance of the scanner from the object and on the demands of accuracy of the results. While scanning with relative large distances (air-borne LS, architectural, industrial) the points are measured by using the time-of-flight method, in close-range applications with a demand of high accuracy exclusively the triangulation-method is applied

The used Faro Laser Line Probe scanner mainly consists of a projector mapping a spot onto the surface of the object and a camera measuring the spatial direction to the spot. The distance between the two devices is constant and known and the directions to the spot are fixed instrumentally respectively measured by the camera. This corresponds to the classic situation of spatial intersection. The spot is moved permanently with extreme velocity in a profile-plane and measured 640 times. In a one-second-interval 30 profiles are measured, following from this a measuring rate of 19.000 points per second.

The scanner is mounted on a Faro Laser Scan Arm. Moving the scanner regularly in 10 cm distance above the surface; stripes of ca. 8 cm width are measured. The fully flexible seven axis carbon arm provides the orientation online in a stable system. So there is no need to cover the object with a pattern of reference points adhered on the surface, which is timeconsuming and sometimes not esteemed by the responsible archaeologists or conservation experts.

So the resulting point-clouds consisted of a sum of measured partially overlapping stripes, representing the object-surface. The accuracy of the points is stated with 2S = 0.1mm. The raster width was chosen and preinstalled in the instrument with 0.25 mm in square. Further treatments had to be done prior to modelling: the registration of the single scan-stripes had to be refined using features of the surface and the points in the overlapping areas needed to be thinned out.

Finally the point clouds were the basis of digital surface models arising by meshing ("triangular irregular network"). In order to complete the models some editing was required to fill holes were no data was collected. The resulting models were suitable for use in further analysis. All calculations outside the scanner were performed using InnovMetric PolyWorks® software.

## 3. ANALYSIS OF ARCHAEOLOGICAL OBJECTS

In the frame of the Special Research Program HiMAT, archaeological investigations have been conducted in 2007 in a prehistoric mining landscape in the lower Inn Valley, Northern Tyrol, Austria. In this region intensive copper ore exploitation took place during the Middle European Late Bronze Age (1200 – 800 BC). From this period numerous traces of underground mining, mineral processing and ore smelting have been located by archaeological prospection.

Within a former peat-bog, currently drying up due to the drainage in the course of the agricultural land use, the well preserved remains of a Late Bronze Age mineral dressing plant could be discovered and partially excavated. On this site mechanical crushing and grinding of copper ore from a nearby mine took place, followed by an ore washing process. The aim was to produce a heavy ore mineral concentrate, suitable for smelting. Associated with the ore beneficiation process several implements could be recovered during the excavation: hammer stones (once mounted to a wooden handle) as well as a nearly completely preserved wooden trough and a wooden "knife". These finds represent parts of the prehistoric equipment which was in use for the mineral treatment and therefore are of high scientific interest with regard to the reconstruction of the whole metallurgical process chain.

Due to the wet bedding under a thick layer of peat, the wooden remains show on the one hand a quite spectacular state of preservation and on the other hand an extremely fragile constitution, once removed from their protective environment! So an immediate, cautious and longsome conservation process is necessary to preserve the archaeological objects for a long term. In this case the archaeologist highly appreciates the possibility of a digital documentation of these artefacts by 3D-laserscanning, permitting a detailed contactless analysis of the objects on the computer screen. Three examples of very valuable application of 3D-laserscanning are demonstrated in this paper.

### 3.1 Wooden trough

Compared with conventional methods to document the wooden artefact, the laser scanning technique provides essential advantages. In this case, the very fragile object could be scanned and digitized shortly after the recovery. This enabled the research team to document the original form and size of the object (as-is state) before the conservation process was started (figure 1). The chemical treatment as well as the exposure to mechanical strain during handling bears the risk of irreversible changes (shrinking) or even damages of the object.

Using the digital model, various analysis can be carried out: the documentation of the external form with cross sections in any desired order (figure 2 and 3), a determination of the volume, including the capacity of the trough, a detailed observation of surface structures resulting from the manufacturing process (woodworking), from the usage during ore processing or from alteration during three thousand years of being embedded in the peat. Damaged parts of the object can be reconstructed by digital completion. By 3D laser plots the fragile object can be reproduced in various materials in full size or any desired scale. Such replicas are very useful for demonstrations in museums or for educational purposes.

Figure 1. High resolution 3D model of the 3000 year old wooden trough

Figure 2. Photographic documentation of the wooden trough

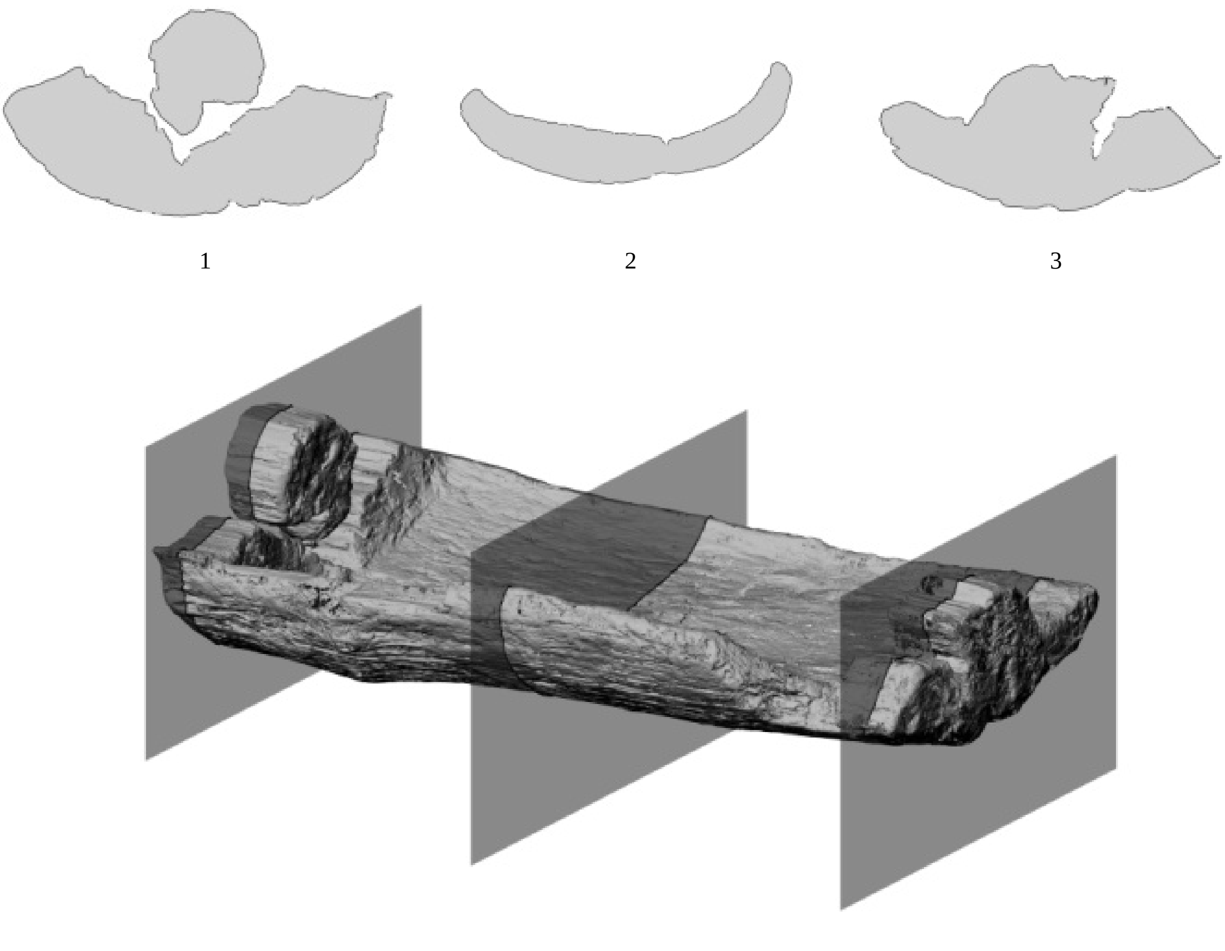


Figure 3. 3D model of the wooden trough with sections across the two edges (1+3) showing the detached core of the log (1) and traces of fissuring and deformation (3) due to alteration, and with section across the central part of the trough (2).

### 3.2 Wooden “knife”

In connection with the use of the trough mentioned above a wooden artefact in the form of a knife was also recovered from Late Bronze Age layers. This implement was probably used in order to discard the light and worthless mineral fraction from the heavy ore mineral concentrate, which accumulated at the bottom of the trough during the washing process. The laser scanning data permit detailed analysis of the external form of the object including cross sections through the working part and the handle, but also of the surface structures resulting from the manufacturing process (woodworking) as well as from usage.
The wooden implements described above represent very rare archaeological features of high scientific interest and therefore the use of laser scanning technique is a very suitable method of documentation (figure 5).

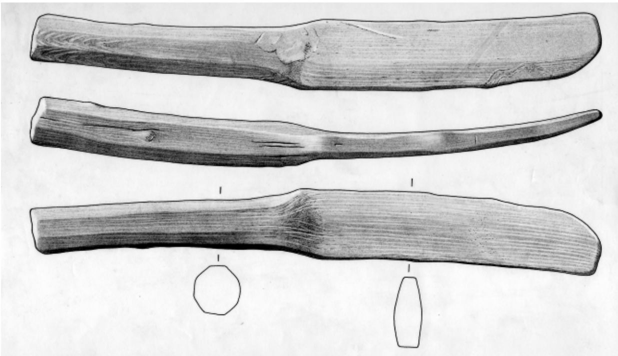

Figure 4. Manual drawing of the knife

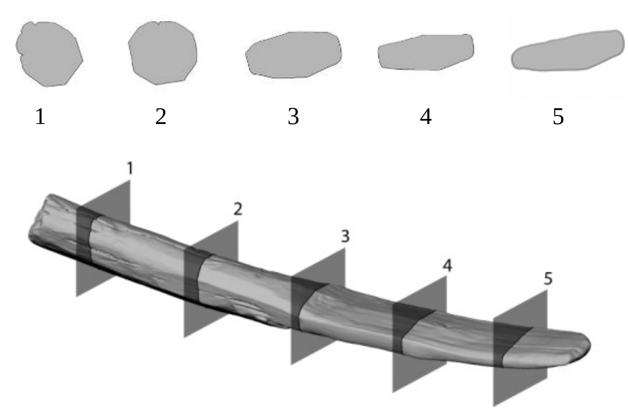


Figure 5. 3D-plot of the wooden „knife“ with cross sections showing the carved form of the tool: octagonal profiles across the handle (1+2), transition profile between handle and “blade” (3), flat hexangular profiles of the “blade” (4+5) with rounded down traces of use (5).

### 3.3 Hammer stone

In the context of prehistoric mining hammer stones represent a very common implement and are wide-spread in archaeological features. These tools were used in mining (winning) processes and particularly in the ore dressing process (crushing and grinding). Mostly they are made of boulders of various sizes, from a few hundred grams up to 10 kg and more, according to the requirement of each particular step in the process. Great importance was attached to a careful selection of stone material in order to guarantee the optimal practical use (figure6). High grade metamorphic rocks like amphibolites and eclogites were preferred material for this purpose in the region of the Inn Valley.

Hammer stones in general show two categories of manmade traces. The first comprises preparation traces in connection with the handling of the tool. Intentionally picked notches or grooves are common. The second category includes all traces of usage, such as blunted surfaces and chipping traces.

Figure 6. Photographic documentation of the hammer stone made of a well rounded boulder of eclogite.

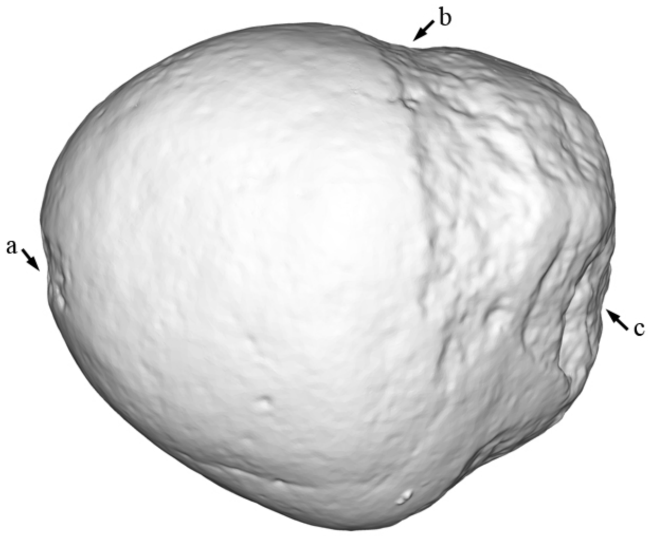


Figure 7. 3D model of the stone tool pointing out the intentionally picked notch (a) and groove (b) as well as the traces of use (c, blunted surface).

In connection with the ore dressing plant within the peat bog several hammer stones were found during the excavation, embedded in tailings of crushed minerals. One of these implements, a heavy boulder of eclogite (3.5 kg), showing a picked notch and groove and traces of usage, was documented by laser scanning technique. Detailed form and surface analysis with cross sections were carried out, enabling, amongst other things, the determination of volume and volumetric weight of the tool, which are useful features for its classification. Due to the high resolution of the laser scanning technique even surface structures become observable which are not visible to the naked eye (figure 6 and 7). This is clearly shown by the digital plot of the intentionally picked notch and groove on the smooth surface of the boulder. Thus the prehistoric technique of preparing and handling the tool can be studied in detail. Here again the laser scanning technique offers an essential advantage compared to conventional methods of documentation.

## 4. CONCLUSION

Within the framework of the special research program HiMAT (History of Mining Activities in Tyrol) at the University of Innsbruck an intensive collaboration of the participating archaeologists and surveyors arose. The outstanding findings of the excavation of a Late Bronze Age ore dressing installation have been measured using a close distance Faro scanner of extreme high accuracy. The resulting 3D – models of a hammer stone and wooden knife and trough were an extreme fruitful basis for detailed investigations. Compared to conventional methods these can be done more comprehensive and with less effort.

As examples the derivation and drawing of cross sections and the determination of volumes and volumetric weights are cited. Besides that the laser scanning technique offered essential advantages:

- The wooden findings had to be inserted into a special fluid for conservation purpose within four days. During the needed time span of six month the virtual model replaced the original for investigations. By an additional scan after the conservation procedure the changes in geometry can be pointed out.
- Due to the high resolution of the laser scanning technique even surface structures became observable which are not visible for the naked eye.
- Scanning can help scientists working in countries with rigid export rules to transfer examination work to home.

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