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3D-scanning at the Archaeological Research Laboratory
2006-2009

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<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTRODUCTION</td>
<td>5</td>
</tr>
<tr>
<td>BACKGROUND</td>
<td>5</td>
</tr>
<tr>
<td>EQUIPMENT</td>
<td>6</td>
</tr>
<tr>
<td>THE JARLABANKE RUNE STONE</td>
<td>7</td>
</tr>
<tr>
<td>GOTLAND PICTURE-STONES (c. 400-1100 AD)</td>
<td>11</td>
</tr>
<tr>
<td>RUNE STONE FRAGMENTS FROM KÖPINGSVIK, ÖLAND</td>
<td>16</td>
</tr>
<tr>
<td>CUT MARK ANALYSIS OF NEOLITHIC HUMAN BONES FROM JETTBÖLE, ÅLAND</td>
<td>20</td>
</tr>
<tr>
<td>CERAMICS FROM THE PITTED WARE CULTURE</td>
<td>21</td>
</tr>
<tr>
<td>THE RUNIC SYLLABARIUM FROM 11TH C. SIGTUNA</td>
<td>22</td>
</tr>
<tr>
<td>COMB FRAGMENT FROM THE WARRIOR’S HALL ON VIKING AGE BIRKA</td>
<td>23</td>
</tr>
<tr>
<td>THE GOLDEN FINDS FROM VITTENE</td>
<td>24</td>
</tr>
<tr>
<td>WEIGHTS AND WEIGHT SYSTEMS</td>
<td>26</td>
</tr>
<tr>
<td>SUMMARY</td>
<td>26</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>27</td>
</tr>
<tr>
<td>PERSONAL COMMUNICATION</td>
<td>28</td>
</tr>
</tbody>
</table>
Introduction

The Archaeological Research Laboratory (AFL) at Stockholm University uses an ATOS II optical 3D-scanner from GOM Optical Measuring techniques for a variety of applications, ranging from small metal objects (10 mm) of the Viking Age (750-1050 AD) via Neolithic bones up to rune stones and picture stones (up to 4m). Materials include bronze, iron, stone, ceramics, bone and wood.

The aim of this report is to show the variety of applications in Archaeological research, not only for documentation but also for sophisticated analysis. The 3D-scanner has been used, and is still being used, in several research projects. Some of these are mentioned in brief in this report, but for detailed information the reader is referred to other publications. Unless otherwise stated, photos and illustrations have been made by the author.

The 3D-scanner has been financed by a generous grant of the Swedish Research Council in 2005.

Background

Documentation and analysis of Archaeological micro topographies were introduced at the Archaeological research laboratory in the 1980's by engineer Henry Freij. After laborious pilot studies with manual recording of the micro topographies of various artefacts, Freij demonstrated the high advantage and informational value of non-touch recording of micro topographies. In 1989, AFL purchased a laser scanner specially constructed for Archaeological use. At that time, 3D-scanners were not available in the market but parts could be laser probes and mechanical parts could purchased separately and combined into an equipment for recording of topographical structures. This was made possible by a grant from The Knut and Alice Wallenberg Foundation (according to decision 1989-10-10). This laser scanner has been employed in studies of Bronze Age rock art (Freij 1993; Lindqvist 1994), Viking Age rune stones (Freij 1986, 1990a; Kitzler Åhfeldt 2002), bronze mounts from the Vendel period (Arrhenius & Freij 1992, 1994; Hedenstierna-Jonson 1998, 2002), Byzantine stamps, coins, weights and other objects (Freij 1990b). A method for groove analysis of Viking Age runes stones by laser scanning and statistical analysis, with the object to distinguish between individual carvers, has been developed at AFL (Freij 1986; Kitzler Åhfeldt 2002). This method has been used for example within the project Similar but different: The rune stones in and around 11th century Sigtuna as a reflection of urban-rural relations (The Swedish Research Council, Dnr 2002-3655), run by professor Anne-Sofie Gräslund and Dr Linn Lager at Uppsala University and the author of this report (Kitzler Åhfeldt 2008a).

This first laser scanner at AFL had its limitations though. The measuring volume was 200x200x12 mm, which means that the depth of field was 12 mm only. Micro structures could be recorded, but no larger objects. Overlapping measuring areas were difficult to handle due to poor software. The equipment was sensitive to humidity and the mechanic parts very heavy, which in practice made it impossible to use it in the field on vertical surfaces. In the late 1990’s/early 2000’, the old equipment was outdated by fast running technical development and improvement. However, studies had made it evident that 3D-scanning had an extensive use in Scientific Archaeology. Internationally, 3D-scanners became more frequently used in the fields of art preservation, reconstruction and management of cultural heritage. In December 2005 the older laser scanner was replaced by an optical 3D-scanner. This report present some, but not all, applications for which 3D-scanning has been used at AFL in 2006-2009. Originally, this report was written as an introduction for non-specialists (neither in Archaeology, nor in 3D-scanning) to show the flexibility of the equipment and the variety of objects and materials.
Equipment

The large variety of materials and in size, places certain demands on flexibility of the measuring equipment. It was essential that it could be used within several research projects. To meet these demands, AFL has chosen an ATOS II from GOM Optical Measuring Techniques, in Sweden sold by Cascade Computing AB. This scanner is adapted to the different tasks by changing the measuring volumes according to the size of the object and the demanded resolution.

The equipment is portable and can be used in the field as well as in the laboratory or in museums. In Archaeology, this is essential. As for rune stones and rock art, there is no possibility to bring them to the laboratory. If the measuring equipment cannot be brought to the site, the researcher is limited to making casts – a procedure which of course causes loss of data and furthermore is not advisable on very fragile objects. The access to metal objects and other artefacts in museum collections most often are limited by rigorous security restrictions. Therefore it is of great advantage to be able to bring the 3D-scanner to the museums.

Fig. 1. The 3D-scanner packed for a week’s work in a museum.
The Jarlabanke Rune Stone

This rune stone is one of the most famous and most discussed in Sweden. The reason is that a property owner named Jarlabanke claims in the inscription on one side of the stone that he owned the whole village of Täby – which is reasonable – and on the other side that he owned the whole “hundare” - which is not reasonable in this period because this word denotes a large region. The discussion concerns the word “ati”, i.e. “to own”. The two inscriptions probably uses ati in to different senses, ownership proper of an estate and ownership in the sense to govern or to have the authority in a more pictorial sense (Gustavson & Selinge 1987; Andersson & Källström 2008). Were the two inscriptions carved at the same time or has some time elapsed between them? Does the second inscription mark that Jarlabanke has reached a higher position in his career? To investigate this question, it was desirable to make an analysis of the cutting technique in order to see whether the inscriptions have been made by the same carver or not.

A tent was used to enhance the light conditions, but this was not enough. The wind caused that the light continuously changed on the stone surface. Since the rune stone is placed near the church walls and on a hill, the wind is ever turbulent on this site. Another difficulty was that small clouds changed the lighting as they moved across the sky. A first attempt was made with the 800x640x640 mm measuring volume, but to enhance the light intensity on the stone surface the measuring volume was changed to a smaller one, 350x280x280 mm. The use of this smaller volume has the effect that the measurement needs more time, due to the large number of overlaps needed. Another consequence is the large amount of data. The second day, measurement was continued early in the morning but by noon the sun appeared strong, healthy and disturbing. Next time, we returned in the night. Everything had to be prepared in darkness, but we were rewarded by easy and successful measuring.

The analysis of the groove data was a success. The results show very clearly that the two inscriptions have been carved by to different teams of rune carvers, each including two or three carvers in the group. This means that some time probably elapsed between the two inscriptions.

This study was done in connection to a publication about Archaeology and ancient remains in the region instigated by the National Road Administration Board (Vägverket) and the Stockholm County Museum (Gräslund et. al. 2008; Kitzler Åhfeldt 2008b).
Fig. 2. The Jarlabanke Rune Stone at the church in Vallentuna (U212).

Fig. 3. The back side of the same rune stone, with the equipment in the background.
Fig. 4. The cut mark analysis demands a high resolution. In spite of the considerable size of this rune stone, the 350x280x280 mm volume has been used.
Fig. 5. Variables used for analysis of cutting technique on rune stones.

Fig. 6. The result of the analysis shows that the inscriptions have been carved by different groups of carvers. This result has an impact on the interpretation of the historical situation when the rune stone was made in the 11th C. AD.
Gotland Picture-Stones (c. 400-1100 AD)

Fig. 7. A picture stone from Väskinde, c. 400 AD, the Great Migration period. The sun symbol has parallels on contemporary grave slabs in Spain. Archaeologist Per Widerström to the right.

The Gotland Picture-Stones belong to the most spectacular and informative artefacts of the Iron Age and Viking Age in Sweden. This treasure of images illustrate myths and cultural phenomena in the Icelandic sagas. Still, there remain questions unsolved. The origin of the picture-stones is unknown, just as the well of inspiration. Technical analyses are next to completely absent. The overall aim with this project is to clarify basic facts about cutting technique, the organisation and preconditions for this handicraft, iconography and dating. This will help us to a better understanding of the cultural context.

Documentation by 3D-scanning loose the ties to earlier paintings of the pictures, thus the scientist can be more independent of tradition. The 3D-scanner is a useful tool for close iconographic studies, since the visual impression of the topographical map is not disturbed by colours. Without touching the stone, even less removing paint, we can study the picture-stone as a new find, without prejudices about what we are going to see. The point of departure for present interpretations is the paintings made in the 1940s or even earlier. But the carved lines of the motives are very tiny and earlier interpretations can be very much debated. This is clear for example in the case of a picture stone found in 2002, where analysis of the carving by 3D-scanning yields better results than traditional side light (see fig. 15).

Another outcome of this project is that it could be shown that the motifs on several of the picture stones had been transferred to the stones by means of templates. On some picture stones, the very same templates had been used. This has some further implications, namely that this was an accepted method within this handicraft. It might imply the use of some sort of pattern books, which is known to be an integral part of the Continental...
handicraft tradition (Kitzler Åhfeldt 2009a, 2009b). As a part of this project, Anders Silenius Larsen wrote a master thesis about motifs on the earliest picture stones. By aid of the 3D-scanning, motifs could be reinterpreted and new parallels found (Silenius Larsen 2009).

Fig. 8. Preparing for scanning of a Viking Age picture-stones in the County Museum in Visby, Gotland. Placing of reference points.

Fig. 9. Picture stones in the museum magazine. The scanner has to be crammed into narrow corners.
Fig. 10. A Viking ship and a mounted warrior.

Fig. 11. The picture stone fragments are stored in shelves and have to be moved with a truck.
Fig. 12. A rather anonymous picture stone (left) becomes of high interest when the ornament appears in the 3D-image (right).

Fig. 13. A man with a sword on the 11th C. AD grave cist from Ardre.
Fig. 15. Left: Interpretation of the carvings on the picture stone found in Bro 2002 by a 3D-scanning in 2007. Right: Interpretation of the same carving by traditional side light (After Norderäng & Widerström 2004, p.87, Bild 6).
Rune stone fragments from Köpingsvik, Öland

In the church in Köpingsvik on the Baltic island Öland, a large number of fragmented rune stones are kept in a room in the church tower. Many of these appear to be parts of grave slabs and possibly of so called Eskilstuna cists, or more properly pre-Romanesque grave monuments (Wilson 1995). Besides the fragmentation, the rune stones are extremely well preserved, so well that traces of original colour can still be observed. Many of these fragments were found by the destruction of the Medieval church, but most of them were built into a new church in 1805. However, this church was turned down in 1953 and the rune fragments were recovered under the supervision of Ragnhild Boström of the National Board of Antiquities (Jansson 1954). Some of these have disappeared by theft in later times, which stresses the need of a thorough documentation.

The main concern for this study is the relation between the Eskilstuna cists and "ordinary" rune stones, as we know them usually free standing in the landscape. The question is whether the carvers of the relief-ornamented Eskilstuna cists had a different competence and thus background to the carvers of the normal-wise contour-incised rune stones. Other issues for this study are to group the rune stone fragments according to their cut marks as to judge which fragments belong to the same original rune stone or grave slab and, if possible, to judge how many carvers were engaged in the whole group of rune stones found in Köpingsvik (Kitzler Åhfeldt 2009c, 2009d).

Fig. 15. Rune stone fragments in the church Köpingsvik on the Baltic island Öland.
Fig. 16. A rune stone fragment.

Fig. 17. The workmanship of the stone cutter can clearly be seen on this fragment. Notice the fine striation.
Fig. 18. The ornament enhanced by the Select by Curvature function in the ATOS software.
Fig. 19. This detail show the thin sketch lines drawn by a sharp tool before the relief was done.

Fig. 20. Cross-section of relief carving.
This study is a part of a research project initiated and supervised by professor Milton Nuñez at the University in Oulu, Finland. Professor Nuñez’ intention is to compare the cut marks and scratches on these human bones to a reference material, in order to see whether they have been caused deliberately by human tools, by animal teeth and claws or accidentally by taphonomic factors. If they have been made deliberately, this may be a case of Neolithic cannibalism, possibly in connection to intricate burial customs. The scanning was made with ATOS SO and our smallest measuring volume 35x28x28 mm, to catch the tiny scratches hardly visible by the naked eye.

Fig. 21. Cut marks on human bones from the Neolithic site Jettböle on Åland.
Ceramics from the Pitted Ware Culture

This fragment of a pot of the Pitted Ware culture settlement at Ottenby on the Baltic island Öland was found in 2004 at a research excavation supervised by Dr. Ludwig Papmehl Dufay. The Pitted Ware culture is generally dated to 3300-2300 BC. This particular settlement at Ottenby was carbon dated to 3100-2900 BC calibrated, by carbon content in a hazelnut shell and a food crust respectively (Papmehl-Dufay & Reuterdahl 2005). Concerning 3D-scanning, the complicated thing about this object are the deep holes. It is difficult to catch data in the base of the holes due to shadows. However, the surface structure and the colour makes ceramics a rather easy task to scan.

*Fig. 22 a) Potsherd of the Pitted Ware Culture, b) Detail of ornament.*
The Runic Syllabarium from 11th C. Sigtuna

A syllabarium is a tool for learning to read and write. This object is unique because it shows that runic reading and writing was widespread and well-established in the Early Medieval town Sigtuna, so well-established that implements to make learning easier were used (Gustavson 2006, 2007). But has the object been used for other things too? Have runes been added on several occasions?

Fig. 23. The Runic syllabarium from Sigtuna.
Comb Fragment from the Warrior’s Hall on Viking Age Birka

The Birka Warrior of the 10th C. AD used combs and comb cases made of antler from elk and reindeer as a part of their dress. When the Warrior’s Hall in the Garrison at Birka was excavated under the supervision of Dr Lena Holmquist Olausson in 1998-2000, a large number of comb fragments were found. In a deposition in one of the major postholes, pieces of c. 40 comb cases were found together with a Thor’s hammer, spear heads, silver coins and other objects. The deposition has been interpreted as a building sacrifice made when the hall was built. Since the hall later was attacked and put to fire, many objects have been more or less deformed by the heat (Holmquist Olausson 2001; Holmquist Olausson & Kitzler Åhfeldt 2002; Hedenstierna-Jonson 2006).

The 3D-scanning was made with our smallest measuring volume 35x28x28 mm. To enhance the microtopography in the cut marks, an STL-file was produced and the surface was analysed in the software Geomagic. It can be noticed that the ornament on the comb case was produced by a pointed tool.

Fig. 24. Comb fragment of antler from the Warrior’s house on Birka. The width of the incised lines are 0.3mm.
The Gold-treasure from Vittene

Within the project Digital Time Travels, run by Gothenburg University, Chalmers and Lödöse Museum, the gold finds from Vittene in Västergötland were 3D-scanned in 2008. The aim was to produce tactile copies, as authentic as possible but in other raw materials, in order to make these objects more accessible to museum visitors and to increase the value of the visit (Stenborg 2007; Stenborg et. al. 2008). These unique and valuable objects were scanned at the Historical Museum in Stockholm under the supervision of the staff. The object was placed on a rotation table by an antiquarian and the reference points were placed around it, to ensure non-touch documentation (Kitzler Åhfeldt 2008c, 2008d).

The manufacturing of the tactile copy posed some special problems. The end knobs of the necklace are hollowed. In each endknob, there is a hole which is a part of the lock mechanism. The 3D-scanner cannot render this deep hollow, neither could the tactile copy be produced with completely hollowed end knobs. Still it was desirable to give a notion of the lock mechanism. The solution to this was to create a cavity deep enough for the tactile copy to look real.

Fig. 25. The golden torques (necklace) from Vittene, Västergötland.
Fig. 26. End knob of the torques. The hole is a part of a lock mechanism.

Fig. 27. The cavity in the end knob was manually created in the 3D-software.

Fig. 28. A bracelet, originally twisted several turns around a wrist but now unwinded.
Weights and weight systems

In his Master thesis *Devaluing the mitqal: Inherent Trading Fees in the Metrics of Birka* (Schultzén 2009), Ph.D. student Joakim Schultzén used the 3D-scanner to reconstruct corroded weights from Viking Age Birka. By doing this, he could also calculate the original masses of these objects and thus compare them to known weight systems. Schultzén’s aim was to investigate an earlier observed discrepancy in the weight system of Birka. This discrepancy is not random, but suggests the existence of a metric that was employed locally and probably developed for some specific reason (Schultzén 2009). This work continues within a Ph.D-thesis preliminary titled *The Connecting Waves – An Archaeometrological Study of X-XIII Century Trade Around the Baltic Sea*.

*Fig. 29. Reconstruction of a corroded weight from Viking Age Birka. By courtesy of Joakim Schultzén (Schultzén 2009).*

**Summary**

This report is a presentation of various applications of 3D-scanning within scientific archaeology at the Archaeological Research Laboratory (AFL), the Department for Archaeology and Classical culture at Stockholm University in 2006-2009. Materials analysed cover stone, wood, bone, antler, bronze, gold, ceramics and clay. The size of the objects ranges from tiny scratches on bone up to rune stones and picture stones. The analyses may be exemplified by analyses of grooves and tool marks on rune stones and grave slabs; bones and comb fragments; reconstruction of corroded objects; digital and tactile replicas of precious artefacts; analysis of template use and moulds and enhancement of obscure ornament. There are still more studies that have not been mentioned here. The ambition is not only to document, but to use the digital 3D- documentation for further analysis. Two master theses have been produced using the ATOS-scanner (Schultzén 2009; Silenius Larsen 2009). At present, there are two PhD-projects running at AFL, using 3D-scanning for analysis of Viking Age weight systems (Joakim Schultzén) and handicraft traditions (Björn Gustafsson Ny) respectively.

Several other institutions and departments have been involved, including Gothenburg University, Uleåborg University, Chalmers, The Royal Technical University (KTH), The Royal Academy of Art (KKH), The Royal Museum of Economy (Myntkabinettet), The Vasa Museum, Lödöse Museum and Sigtuna Museum. We have also had a rewarding cooperation with Cascade Computing AB. Thus, the equipment has been of use for a number of research projects covering archaeology, runology, osteology, numismatics, engineering, pedagogy and art projects.

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References


Personal communication
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