Large-scale archaeological prospection of the Iron and Viking Age site Uppåkra in Sweden

First results of the LBI-ArchPro landscape archaeological case study

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Abstract—**Uppåkra in southwest Scania, Sweden, is considered to have been one of the very first proto-urban settlements in Scandinavia. Earlier archaeological excavations have revealed the presence of thick occupational layers in the vicinity of Uppåkra church and rich finds from Iron Age and Viking Age hall buildings as well as an extraordinary ceremonial house. Geophysical archaeological prospection test measurements conducted by Kiel University in 1997 had indicated good success chances for magnetic and ground penetrating radar measurements. Due to its great archaeological potential the site and its surrounding landscape were selected for the test of large-scale high resolution archaeological prospection technology and methodology developed by the Ludwig Boltzmann Institute for Archaeological Prospection and Virtual Archaeology and its partners. We present the first two fieldwork campaigns of the case study Uppåkra conducted in September 2010 and April 2011.**

Keywords: magnetometry, ground penetrating radar, terrestrial laser scanning, large-scale, high-resolution, landscape archaeology, Iron Age, Bronze Age, Viking Age, Sweden

I. INTRODUCTION

In 1934 about 5 kilometres south of the Swedish town of Lund an Iron Age archaeological settlement site was discovered during the construction of houses associated to the nearby Uppåkra church. Later minor rescue excavations and field surveys revealed the so far largest prehistoric settlement site in southern Sweden [1]. Since 1996 a metal detector survey initiated by the University of Lund [3] involving specialists from the Danish island of Bornholm resulted in a remarkable number of outstanding bronze, silver and gold objects within an area covering approximately 1.1 × 0.6 km. The distribution of metal detector finds in combination with augering, phosphate analysis and observations of changes in soil colour were used to delimit the occupation area, comprising some 60 hectares.

In 1997 the archaeological research project "*The Social Structure of Southern Sweden during the Iron Age*" was started by Prof. Lars Larsson of University of Lund with the aim to analyse the hierarchy of the settlement structure of Uppåkra [2]. Within the framework of the project a number of different geophysical archaeological prospection techniques were tested at the site, such as magnetometry [4][5], earth resistance measurements [6], ground penetrating radar (GPR) [4][7], and electromagnetic measurements [7]. In particular the magnetic survey of the team from Kiel University [4], covering an area of approximately 2.3 hectares, resulted in archaeologically interpretable, useful data.

Not only the discovery of an exceptional ceremonial house with spectacular finds made in 2001-2004 [8] but as well the excavation of a major Iron Age hall building and the absence of any substantial number of burials indicated that the sites extent and complexity has proven to be much greater than initially expected. Archaeological excavations during the fieldwork seasons have continued over the past years.

The setup of the new Ludwig Boltzmann Institute for Archaeological Prospection and Virtual Archaeology (LBI-ArchPro) and the participation of the Contract Archaeology Unit of the Central Swedish Heritage Board as LBI-ArchPro partner organization provided the opportunity to investigate the archaeologically highly interesting Swedish Iron Age site of Uppåkra and its surrounding landscape within one of the intended large-scale LBI-ArchPro case studies.

The Ludwig Boltzmann Institute for Archaeological Prospection and Virtual Archaeology (archpro.lbg.ac.at) is based on an international cooperation of the Ludwig Boltzmann Society (A), the University of Vienna (A), the Vienna University of Technology (A), the Austrian Central Institute for Meteorology and Geodynamic (A), the office of the provincial government of Lower Austria (A), RGZM-Roman-Germanic Central Museum Mainz (D), RAÄ-Swedish National Heritage Board (S), IBM VISTA-University of Birmingham (GB) and NIKU-Norwegian Institute for Cultural Heritage Research (N).

The scientific programme of the institute is divided into the three research lines Archaeological Remote Sensing, Archaeological Geophysical Prospection and Archaeological Interpretation, Spatial Analysis and Virtual Archaeology.

Archaeological Remote Sensing involves aerial archaeology, airborne laser scanning, and airborne hyper-spectral scanning. Archaeological geophysical prospection includes the development and application of motorised multichannel magnetometer and ground penetrating radar systems as well as the adaptation of satellite based navigation- and positioning solutions. The spatial and temporal analysis and visualisation of the archaeological information contained in the large and complex data sets generated by the first two research lines requires the development of novel archaeological interpretation tools based on Geographical Information Systems. The overall scientific goal is the development of new possibilities to gain new archaeologically relevant information on buried cultural heritage on the scale of archaeological landscapes. In order to test and refine the technical and methodological developments a number of selected landscape archaeological case studies will be conducted in the countries of the European partner organisations.

The second Swedish LBI-ArchPro case study focuses on the investigation of the smaller, but better known proto-urban Iron Age settlement and trading site Birka-Hovgården, a UNESCO World Cultural Heritage Site. Both sites form two of Sweden's most prominent proto-urban Iron Age and Viking Age settlements and trading places located in two different landscape types. While the UNESCO world cultural heritage site Birka-Hovgården is located on two islands in Lake Mälaren, which was subject to considerable landscape transformations due to coastline changes related to the postglacial uplift (ca. 6m since 800 AD), the prehistoric settlement Uppåkra is located in the wide open agriculturally used Scanian landscape. So far only small scale archaeological investigations have been conducted at either site.

Both sites comprise areas for settlement, workshops, tracks, communication ways and grave fields. Today only very few traces of these sites are visible above the ground surface. The mapping of Birka/Hovgården and Uppåkra and the surrounding areas using remote sensing and high-resolution GPR and magnetometer prospection is ideally suited to demonstrate an holistic, landscape archaeological approach for this type of northern European sites, as well as to generate considerable new archaeological knowledge. Terrestrial and airborne laser scanning will be valuable and powerful in mapping the forested areas of Björkö/Adelsö and small micro-topographic features in the open landscape in which Uppåkra is located, while the large open areas at Birka and Uppåkra pose ideal testing grounds for multichannel, motorized geophysical survey systems.

II. Description of Fieldwork

A. GPR and magnetic surveys in September 2010

Over the course of seven days in September 2010 in total 40 hectares of magnetic measurements and 10 hectares of high-resolution GPR measurements were conducted. The magnetometer system used consisted of five Foerster gradiometer probes (65 cm) mounted with 50 cm separation on a non-magnetic cart that was pulled by a Quad bike (fig. 1). The analogue signal is converted using a fast Eastern Atlas A/D converter, and the digitized signal is subsequently recorded using a ruggedized laptop mounted in front of the operator. Data positioning was conducted using a Leica GPS1200 real-time kinematic global positioning system (RTK-GPS) with base station established on a point with known coordinates.

Figure 1. Magnetic survey with motorized 10-channel Foerster gradiometer array mounted with 25 cm probe spacing on Sensys cart in April 2011. The RTK-GPS antenna for data positioning is visible on the cart. Data logging and navigation is implemented using custom software on a rugged laptop in front of the operator. In the background Uppåkra church can be seen.

The major part of the GPR survey was conducted using a 16 channel 400 MHz MALÅ Imaging Radar Array (MIRA) with 8 cm in-line and 8 cm cross-line trace spacing mounted in front of a small tractor (fig. 2) [9]. For data positioning a robotic total-station and a prism mounted on top of the MIRA antenna array was used. A grave mound located centrally in the area of investigation was scanned using a Sensors & Software PulseEkko^{Pro} 250 MHz GPR antenna with 50 cm profile spacing, and areas covered with lawn were manually surveyed with a PulseEkko^{Pro} 500 MHz antenna system and 25 cm profile spacing.

Both in case of the motorized magnetic and GPR surveys navigation relied entirely on the driver using old tracks visible on the ground for orientation. In case of the manual GPR surveys traditional survey lines placed on the ground between measurement tapes were used. In particular in case of harvested grainfields the visibility of tracks caused by the magnetic survey system was very weak. In stubble fields repeated measurements covering the same area can be very demanding and require immediate data processing and visualisation in order to achieve complete spatial coverage.

Figure 2. GPR measurements with the 16 channel 400 MHz MALÅ Imaging Radar Array (MIRA) with 8 cm channel spacing using a totalstation visible in the background together with a prism for automated data positioning.

Figure 3. Instant data processing in the field was performed on the ruggedized laptops used for data acquisistion, permitting data quality control and providing immediate archaeological feedback and satisfaction.

Fields with dimensions of 600 × 600 m permitted the coverage of up to 15 hectares per day with a single person operating the system. Motorised data acquisition and driving patters were optimized in order to increase data yield and reduce surface impact.

The adaptation of in-house developed data processing and visualization software to account for irregular survey geometries permitted instant quality control of the acquired magnetic data (fig. 3). Geo-referenced greyscale data images covering tens of hectares can be generated in very short time.

While the four individually suspended wheels are well suited to reduce the impact of surface unevenness did survey speeds of up to 70 km/h exceeded by far the physical limits of the instrument carrier, in particular in regard to the non-metallic wheel bearings, which had been designed for operation speeds of 7-8 km/h. After 40 hectares of surveyed area substantial repairs to wheels and bearings of the magnetometer cart were required. Both, the physical limitations of the hardware as well as issues concerning reduced signal-to-noise ratios at high sample rates of 100 Hz or above suggest currently lower measurement speed at reduced sample rate.

B. GPR, magnetic and laser scanner surveys in April 2011

In April 2011 the large-scale landscape archaeological LBI-ArchPro case study was continued at Uppåkra with the plan to cover all accessible areas surrounding the settlement site with magnetic prospection. Parallel a high-resolution terrain model of the site and surrounding landscape was to be generated using terrestrial laser scanning applying a Riegl LMS Z420i (www.riegl.com). The purpose of the latter is the future topographic correction of GPR data as well as the graphic visualisation and presentation of the archaeological prospection data and its interpretations in photorealistic 3D models.

Using two motorized Foerster magnetometer systems with 5 and 10 channels respectively more than 110 hectares of magnetic data were acquired over the course of nine measurement days. The 5 channel system consisted of five gradiometer probes mounted with 50 cm spacing while the 10 channel array was equipped with 9 probes with 25 cm spacing.

Figure 4. Laser scanning for the generation of a high resolution terrain model using a Riegl LMS-Z420i scanner mounted on top of a tripod, between scanning positions is transported with a small tractor.

In order to achieve greater data positioning accuracy precise time signals (pulse-per-second) provided by the RTK-GPS rovers were fed into the magnetic data stream and used during processing. Two identical GPS rovers mounted on the two carts were operated with a single base station.

Due to large field sizes only a small number of farmers and leaseholders were affected, which facilitated the survey preparation. Survey progress was slightly hampered by agricultural field use since exceptionally warm weather caused an early onset of the agricultural season with fields becoming inaccessible after seeding. The support of all affected farmers was exemplary and resulted in the so far largest interconnected archaeological magnetometer survey area in Scandinavia, covering in total over 1.5 km^2.

III. RESULTS

The magnetometer measurements show that the landscape surrounding the central settlement area of Uppåkra contains a huge amount of previously unknown archaeological structures, such as pits, pit alignments, postholes, hearths and over-ploughed grave mounds. Whether the detected structures, which partly differ in character, are contemporary or older than the Iron Age settlement is currently unknown. Test trenching conducted in 2000 to the east and south of the main settlement site has revealed Bronze Age and Roman Iron Age hearths, pits and postholes.

So far only a very small number of graves have been found in the area. Assuming a settlement phase of at least 700 years (200 AD - 900 AD), a population of 500 persons and three generations per century, the in total expected number of graves in the area should amount to at least 10,000. In search of some of the graves long test trenches were dug in fields to the east and south of the central settlement area in 2000. However, no substantial number of burials was uncovered. Structures of archaeological interest had been digitally recorded in 2000 using a total station. The generated shape files showing trench outline and structures of archaeological interest as polygons can be superimposed onto the new magnetic prospection data. The comparison shows very good agreement between many of the in 2000 marked archaeological structures and the magnetic anomalies detected in 2011 (fig. 5). If structures marked in the excavation are not visible in the magnetic data it is possible that the structure has been removed during the excavation process. It can as well be seen that some structures that still cause magnetic anomalies have not been marked in the excavation. A possible explanation is that the corresponding archaeological structures are located below the maximum depth of the trench. The excavated structures in this area have been interpreted as pits, postholes and hearths. The magnetic data shows that many more structures of presumably archaeological character are located in the area. One magnetic anomaly showing two branches with reversed polarisation is likely to have been caused by Lightning Induced Remanent Magnetisation (LIRM) [10].

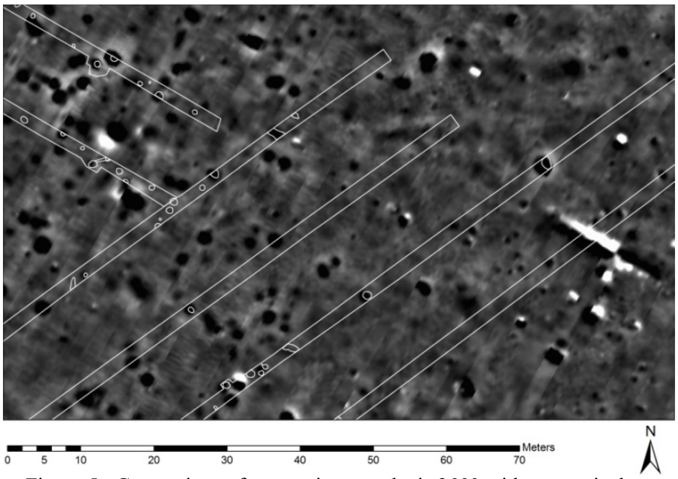

Figure 5. Comparison of excavations results in 2000 with magnetic data measured in 2011. The magnetic data is plotted with 254 greyscale values linearly plotted between -8 nT (white) and 16 nT (black). The outline of the search trenches and of the during the excavation discovered archaeological structures are shown with white lines. The strong linear anomalie in the eastern part of the image is likely to have been caused by LIRM.

Figure 6 shows the entire area covered with magnetometer measurements in 2010 and 2011. Some areas in the centre of the area of investigation were not accessible due to agricultural field use. In total 175 hectares were covered with magnetic prospection measurements during the course of 14 days of fieldwork.

GPR measurements covering over 11 hectares have revealed archaeological structures such as postholes and possible graves in great detail. In total 46 terrestrial laser scanner positions were occupied and a detailed digital terrain model generated.

I. OUTLOOK & THE ROAD AHEAD

In 2012 it is planned to complete the magnetometer prospection of the central areas and to cover selected areas with high-resolution GPR measurements. The full integration of the digital terrain model with the geophysical data is intended, both for topographic data correction and for graphic visualisation of the results.

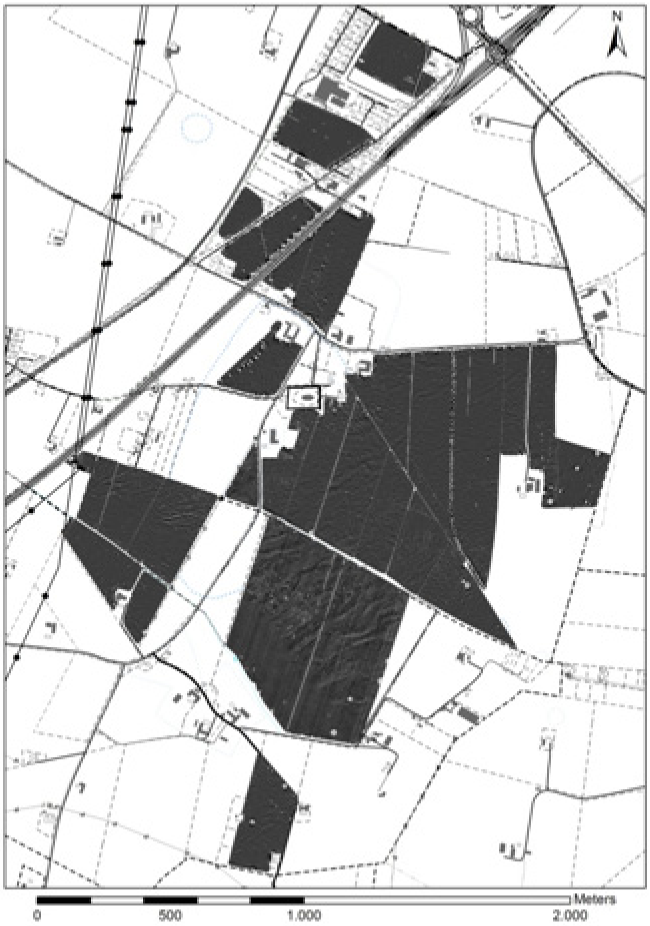

Figure 6. Overview showing the magnetic data measured in 2010 and 2011 covering 175 hectares in total. Uppåkra church is located in the centre of the map. The magnetic data is plotted with 254 greyscale values linearly plotted between -8 nT (white) and 16 nT (black).

The interpretation process has commenced by drawing of anomalies of archaeological interest in GIS and their archaeological interpretation in collaboration with local experts. The analysis and comparison of the large-scale archaeological prospection case studies of the proto-urban settlement sites Birka and Uppåkra will result in considerably new archaeological knowledge about these important sites and contribute to the advancement of state-of-the-art archaeological prospection technology and methodology.

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