Annual Report 2013

Contents

1. LBI ArchPro: Overview

1.1 Goals

Considering the massive threat of destruction and deterioration of buried cultural heritage and the need for efficient and reliable identification, documentation and interpretation methods, large-scale application of non-invasive archaeological prospection methods comprise a great potential. They are the most appropriate solution in order to provide archaeologists and planning authorities with the necessary spatial information for the protection and possible investigation of such threatened heritage at the appropriate scales: the archaeological site as well as the surrounding archaeological landscape.

Considering the state-of-the-art and the future demands for non-invasive professional archaeological prospection a consortium of European research institutes, heritage boards and public bodies supported by the Ludwig Boltzmann Gesellschaft (http://www.lbg.ac.at) established in 2010 the Ludwig Boltzmann Institute for Archaeological Prospection and Virtual Archaeology (LBI ArchPro). The LBI ArchPro (http://archpro.lbg.ac.at) is an innovative research centre for the development and application of advanced non-destructive prospection methods. It combines advanced remote sensing methods, high resolution near surface geophysics, sophisticated computer science, geomatics and archaeology. It is dedicated to the development of new and highly efficient technologies for non-invasive data capturing, data processing, virtual reality visualization and the advancement of theory and methodology of archaeological prospection. An important aim is the publication and dissemination of new developments and results of the conducted research and of exemplary international large scale case studies in professional circles as well as to the general public.

Even though the Valetta convention (Malta treaty) has not been ratified by all member states of the LBI ArchPro consortium, it is regarded by the consortium as the major basis and guideline for the future development of archaeological research and the LBI ArchPro research programme.

1.2 Partner organizations

In 2013 there were no changes in the partner consortium.

- **LBG** - Ludwig Boltzmann Gesellschaft (A)
- **NoeL** - Province of Lower Austria (A)
- **NIKU** - Norsk Institut for Kulturminneforskning (N) - The Norwegian Institute for Cultural Heritage - Archaeology Department
- **RAÄ** - Riksantikvarieämbetet (S) - UV Teknik
- **RGZM** - Römisch Germanisches Zentralmuseum (D)
- **VISTA** - University of Birmingham (GB) - The Visual and Spatial technology Centre (VISTA)
- **Uni Vienna** - University of Vienna (A) - Vienna Institute for Archaeological Science (VIAS) and Institute for Prehistory and Early Mediaeval History (UFG)
- **TU Vienna** - University of Technology Vienna (A) - Institute for Computer Graphics and Algorithms (ICG) and the Institute for Photogrammetry and Remote Sensing (IPF)
- **ZAMG** - Central Institute for Meteorology and Geodynamic (A)
- **Airborne Technologies** (A)

Collaboration Partners

Collaborative agreements for scientific research tasks and case studies exist with following organizations:

- **Uni Lund** - University Lund, Department of Archaeology and Ancient History (S): Case study Uppåkra
- **EAL** - Eastern Atlas GmbH & Co. KG (D): Magnetics
- **Malå** - MALÅ Geoscience AB (S): Ground Penetrating Radar
- **Vfk** - Vestfold Fylkeskommune (N): Case study Vestfold
- **Riegl** - Riegl Laser Measurement Systems GmbH (A): Laser Scanning
- **Pico** - Pico Envirotec Inc. (CA): AirMagnet project
- **GeoEx** - Geo Experts Research and Planning Gmbh (A): AirMagnet project
- **Uni Bradford** - University of Bradford (GB): Geophysics
- **ÖAW** - Austrian Academy of Sciences (A): Carnuntum ArchPro project
- **Uni Gent** - University of Ghent (B): Carnuntum ArchPro project
- **BOKU** - University of Natural Resources and Life Sciences, Vienna (A): Remote sensing
- **Wikitude –** Wikitude GmbH (A): Augmented Reality
- **Interspot –** Interspot Film GmbH (A): Scientific Documentaries
- **HTL Steyr –** Höhere Technische Lehranstalt Steyr (A): Hardware development
- **7reasons** - 7reasons Medien GmbH (A): Virtual Reconstructions
- **SHM** - Historiska Museet, Stockholm (S): Case study Birka

1.3 LBI ArchPro Board and Scientific Advisory Board

The LBI ArchPro Board:

- **NoeL:** Franz Humer, Gerhard Pfahler
- **ZAMG:** Sirri Seren, Michael Staudinger
- **TU Vienna :** Norbert Pfeifer, Werner Purgathofer
- **Uni Vienna :** Otto H. Urban, Gerhard Trnka
- **ABT :** Wolfgang Grumeth, Mario Rathmanner
- **RGZM :** Falko Daim, Detlef Gronenborn
- **RAÄ :** Lars Larsson, Christina Klotblixt
- **NIKU:** Carsten Paludan-Müller, Knut Paasche
- **VISTA :** Vincent Gaffney, Eamonn Baldwin
- **LBG :** Marisa Radatz, Claudia Lingner

The LBI ArchPro Scientific Advisory Board:

- Kay Kohlmeyer, Hochschule für Technik und Wirtschaft (HTW) Berlin (D)
- Julian Richards, University of York (GB)
- Joakim Goldhahn, Linnaeus University, (S)
- Maurizio Forte, University of California, Merced (USA)
- Sarah Parcak, University of Alabama (USA)

In 2013 no SAB meeting has taken place. Sarah Parcak did not follow the invitations to the two earlier meetings. SAB will be redesigned by the LBG.

1.4 The LBI ArchPro Team

The staff of the Ludwig Boltzmann Institute for Archaeological Prospection and Virtual Archaeology comprised the following fixed employees in 2013:

- Wolfgang Neubauer (Director)
- Michael Doneus (Deputy Director)
- Immo Trinks (Key Researcher)
- Alois Hinterleitner (Key Researcher)
- Nives Doneus (Key Researcher)

- Christian Briese (Researcher)
- Christina Einwögerer (Administration Manager)
- Sebastian Flöry (Researcher)
- Karolin Kastowsky-Priglinger (Administration Manager)
- Matthias Kucera (Researcher)
- Klaus Löcker (Researcher)
- Agata Lugmayr (Researcher)
- Erich Nau (Researcher)
- Matthias Nöster (Operations Manager)
- Michael Pregesbauer (Researcher)
- Vlad Sandici (Researcher)
- Elisabeth Schadek (Administration Manager)

- Philippe De Smedt (Researcher)
- Geert Verhoeven (Researcher)
- Thomas Zitz (Researcher)
- Georg Zotti (Researcher)

- Laszlo Baumann (technician, facility management Langenzersdorf, maintenance of equipment)
- Roland Filzwieser (Researcher) joined the team in 2013 with focus on the historical interpretation of prospection data and historical maps (Carnuntum).
- Viktor Jansa (Researcher) joined the team in 2013. He will work on post-processing and interpretation of geophysical prospection data (Carnuntum).
- Mario Wallner (Researcher) joined the team in 2013 with focus of data acquisition (Stonehenge, Carnuntum) and data interpretation (Carnuntum).

Staff in-kind contributions:

- Christian Gugl (Researcher) contribution from ÖAW
- Camillo Ressl, contribution from Vienna University of Technology, Department of Geodesy and Geoinformation
- Rainer Schreg, contribution from RGZM
- Lars Gustavsen, contribution from NIKU
- Christer Tonning, contribution from Vestfold fylkeskommune
- Eamonn Baldwin, contribution from VISTA
- Eduard Pollhammer, contribution from NoeL
- Pär Karlsson, Cont. RAÄ

Temporary staff:

- Manuel Gabler (Field Director)
- Jakob Kainz (Field Assistant)
- Ranko Manojlović (Field Assistant)
- Hannes Schiel (Field Assistant)
- Petra Schneidhofer (Field Assistant)
- Christopher Sevara (Field Assistant)
- Tanja Trausmuth (Field Assistant)
- Alexandra Vonkilch (Field Assistant)
- Julia Wilding (Field Assistant)

Initiative College for Archaeological Prospection

The University of Vienna installed within VIAS an interdisciplinary Initiative College for archaeological prospection (ic-archpro.univie.ac.at) at the end of 2011. Research fellows of the IC are working in the close collaboration with the LBI ArchPro staff on the archaeological analysis of LBI ArchPro case study data and various methodological data.

IC ArchPro research assistants:

- Martin Fera
- Manuel Gabler
- Jakob Kainz
- Karolin Kastowsky-Priglinger
- Michal Ruš

- Petra Schneidhofer
- Christopher Sevara
- Tomáš Tencer
- Katalin Tolnai
- Willem Vletter

Associated PhD research fellows

- Valeria Poscetti
- Joris Coolen
- Eamonn Baldwin
- Christine Markussen
- Agata Klimczyk
- Ulrike Fornwagner

1.5 Highlights 2013

AP CONFERENCE 2013

From May 29th to June 2nd 2013 the LBI ArchPro and the Austrian Academy of Sciences hosted the "10th International Conference on Archaeological Prospection" (AP13) on behalf of the International Society for Archaeological Prospection (ISAP) and the Aerial Archaeology Research Group (AARG) in Vienna. For five days the conference successfully provided a forum for 250 participants from all over the globe including renowned experts, experienced professionals as well as young aspiring researchers and students in geophysics, archaeology and computing who shared, discussed and learned about recent developments and cutting-edge research in the multi-disciplinary field of archaeological prospection (Fig. 6).

About 160 presentations (oral, poster and multimedia presentations) covered the entire spectrum of methodology and technology applied to the detection, localization and investigation of buried cultural heritage (aerial photography, remote sensing, LiDAR, near surface geophysics, data processing, visualization and archaeological interpretation) focusing on integrative approaches which exploit the diversity of all data and information necessary for the visualization and interpretation of archaeological and historical monuments, structures and entire archaeological landscapes. Extended abstracts of these contributions were also published in the "Proceedings" of the conference – a skilfully edited and richly illustrated volume presenting an excellent overview of the latest advancements in this field.

An attractive social programme (welcome party, Researchers' Pub, banquets and wine tasting) and a highly frequented conference exhibition area offered many opportunities to network with colleagues and chat with friends in a sociable atmosphere. These also included two excursions leading to the Heldenberg Museum in the Weinviertel (north of Vienna) and to the Archaeological Park at the Roman town of Carnuntum, both of which gave an impressive glimpse of the various archaeologically significant landscapes around Vienna.

Fig. 6: Virtual keynote lecture of Irwin Scollar during opening of the AP 2013 Conference (©Geert Verhoeven)

1.6 Press releases and press coverage summary

LBI ArchPro

- Aus dem All, in der Luft und am Boden – Archäologische Prospektion im 21. Jahrhundert (Dimensionen – die Welt der Wissenschaft; Radio Ö1 http://oe1.orf.at/programm/339358)
- http://diepresse.com/unternehmen/austria13/1452560/Wolfgang-Neubauer

Hornsburg

- „Spuren unserer Vorfahren“ (NÖN, Woche 30/2013)
- http://www.noe.gv.at/Presse/Pressedienst/Pressearchiv/107874_kreisgrabenanlage.pdf
- http://www.3sat.de/mediathek/?mode=play&obj=39967 (Video)

Schwarzenbach, A

- „Burgberg wurde neu vermessen“ (Bezirksblätter NÖ, 19.6.2013)

Stubersheim, D

- http://www.swp.de/geislingen/lokales/geislingen/Pickel-und-Schaufel-haben-ausgedient;art5573,1870826

Borre, N

- http://science.apa.at/site/bildung/detail?key=SCI_20130523_SCI45051703612871562
- http://www.ots.at/presseaussendung/OTS_20130523_OTS0189/wikingerzeitlicher-haeuptlingssitz-in-borre-suednorwegen-entdeckt
- http://derstandard.at/1369361932482/Im-Machtzentrum-der-Wikinger-Haeuptlinge
- http://derstandard.at/1369264145066/Oesterreichisch-norwegisches-Team-entdeckt-Wikinger-Haeuptlingssitz
- http://diepresse.com/home/science/1410665/Monumentale-Huegel-als-Wegweiser-zu-den-Ahnen?_vl_backlink=/home/science/index.do
- http://www.wienerzeitung.at/themen_channel/wissen/geschichte/548617_Radarblicke-in-die-Vergangenheit.html
- http://www.wienerzeitung.at/themen_channel/wissen/forschung/548256_Heimische-Forscher-spuerten-Wikinger-Haeuptlingssitz-auf.html
- http://search.salzburg.com/news/artikel.html?uri=http%3A%2F%2Fsearch.salzburg.com%2Fnews%2Fresource%2Fsn%2Fnews%2Fsn2421_24.05.2013_41-46987973
- http://science.orf.at/stories/1718296/
- http://www.krone.at/Wissen/Wiener_Forscher_spueren_Wikinger-Haeuptlingssitz_auf-Spezial-Bodenradar-Story-362668
- http://forschen-entdecken.at/14039.98.html
- http://www.archaeologie-online.de/magazin/nachrichten/hafen-der-haeuptlinge-koenigreich-der-toten-25864/
- http://www.bluewin.ch/de/index.php/1754,820958/Forscher_entdecken_Wikinger-Haeuptlingssitz_in_Norwegen/de/news/science/
- http://kulturarvvestfold.no/Artikkel/Forside/Nye-funn-p%C3%A5-kongssetet-Borre/10007121.php
- http://www.niku.no/no/arkeologi/geofysiske_undersokelser/arkeologer_pa_snoscooter/Arkeologer+p%C3%A5+sn%C3%B8scooter...9UFRrYWi.ips
- http://tb.no/kultur/sensasjonsfunn-pa-borre-etter-sok-med-snoscooter-1.7902531?localLinksEnabled=false
- http://redir.opoint.com/?key=PszF6qoydlYIsP2T3YOM (Tønsbergs Blad)
- http://redir.opoint.com/?key=4dMjAzBc9t5YIROCEw4J (Gjengangeren)
- http://www.gjengangeren.no/nyheter/har-funnet-47-meter-lang-bygning-fra-vikingtida-1.7902578
- http://www.nrk.no/ostafjells/vestfold/vikinggard-funn-ved-borreparken-1.11038882

- http://www.nrk.no/ostafjells/vestfold/_-ikke-grav-opp-vikinggard-1.11043010
- Fant vikingbygning i Borre (Aftenposten Innsikt 28.5.2013)
- http://www.huscarl.at/wikingerzeitlicher_haeuptlingssitz_in_borre_suednorwegen_entdeckt_und_rekonstruiert.php

Rom, N

- http://radio.nrk.no/serie/kulturnytt-radio/mnma02016013/13-08-2013#t=20m21s
- http://www.nrk.no/ostafjells/vestfold/ligger-det-et-skip-under-steinene_-1.11179490
- http://www.vestfoldblad.no/nor/Kultur/Aktuelt/AApner-gravhaug-i-Slagendalen/(39060)
- http://tb.no/kultur/graver-etter-nytt-osebergskip-1.8016967
- http://kulturarvvestfold.no/Artikkel/Forside/Gravhaug-p%C3%A5-Rom-vestre-%C3%A5pnes/10007244.php
- http://www.vfk.no/Aktuelt/Apner-gravhaug/

Norwegen

- http://nikuarkeologi.wordpress.com/2013/11/19/arkeologisk-undersokelse-magnetometer-fra-luften-2/
- http://www.niku.no/no/arkeologi/geofysiske_undersokelser/arkeologer_flyr_over_elverum_for_a_finne_ukjente_kulturminner/Arkeologer+flyr+over+Elverum+for+%C3%A5+finne+ukjente+kulturminner.9UFRvKWA
- http://archpro.lbg.ac.at/press-reports-norway/luftige-forskere-over-elverum (pdf-file)
- http://www.nrk.no/ho/dette-flyet-skal-finne-kulturminner-1.11382197
- http://radio.nrk.no/serie/kulturnytt-radio/mnma01023713/28-11-2013 (Audio)

2. Evaluation and new research programme

2.1 Evaluation Procedure

The evaluation after the first three years of operation is a regular procedure within the statutes of LBG. Independent external experts are invited to evaluate the results of the past period and to give recommendations for the future development. The LBG invited an international team of experts in order to evaluate the LBI ArchPro in Vienna at 21st and 22nd of November 2013 consisting of:

Prof. Andreas Georgopoulos, National Technical University of Athens, Greece
Prof. Fred Limp, University of Arkansas, USA
Prof. Przemysław Urbańczyk, Polish Academy of Sciences, Poland
Dr. Verena Kremling, Leibniz-Gemeinschaft, Berlin, Germany

The LBG Head Office generated a comprehensive set of questions which served the evaluation panel as terms of reference. The evaluation results as distributed in 02-2014 to all Board Members are based on the following facts and actions:

• The LBG Head Office provided the evaluation panel with the following material one month before the on-site-visit:

- *The institute's evaluation report (delivered to the Board in 11-2013)*
- *Annual reports 2010, 2011 and 2012 (public)*
- *Initial Proposal for setting up the Institute (2009)*

• The evaluation panel visited the LBI ArchPro on 21st and 22nd of November 2013 at Hohe Warte 38 and Langenzersdorf. The LBI ArchPro key researchers and directors gave a series of presentations on the motivation, results and future perspectives of the LBI ArchPro.

Together with the LBI ArchPro institute, the LBI Head Office had prepared an agenda allowing for contact with relevant staff groups on the second day:

- *Directors (Neubauer, Doneus)*
- *Key researchers and doctoral candidates*
  (N. Doneus, Pregesbauer, Wallner, Gabler, Briese)
- *Employees charged with maintenance and development of equipment and infrastructure*
- *Representatives of partner organisations*
  (Gaffney, Paasche, Rathmanner, Gronenborn, Humer)

2.2 Evaluation results

The result of the evaluation process delivered in 02-2014 is very positive.

The evaluation report of the expert team explicitly notes as cited below:

> *"In the first 3.5 years of its existence, it has created a very impressive organization, obtained a great international reputation and achieved excellent results. The evaluation panel strongly recommends continuing funding for LBI ArchPro."*

"With this original, important and very useful approach, the institute has established a unique selling point that is particularly attractive for the members of the partner consortium (see below), but also beneficial for the scientific community and the public. The LBI ArchPro is the first archaeological research institute having developed, tested and, more significantly, effectively utilized various methods in archaeological prospection. The institute's innovative approach aims for the analysis of huge landscape scales and offers many interfaces for related scientific disciplines and research themes. While the focus on large landscapes is strongly encouraged it is recommended that the LBI also develop versions of their methods that can be applied in locations with more vegetation or other impediments to the large area techniques now in use. Overall, this mission is considered to be sound and scientifically sustainable."

"In term of facilities and equipment, the institute disposes of extraordinary conditions: Equipment and facilities are cutting edge and get permanently developed further according to scientific criteria and demands. Its innovative combination of computing competence, geophysical prospection technologies, hard and software development, and archaeological expertise is one of the institute's particular strengths. One technical area that does require attention is the network accessibility of the facilities located at Langenzersdorf."

"Staff at LBI ArchPro is highly qualified and strongly motivated. There is a very good atmosphere, trustful cooperation and a positive team spirit encouraging good ideas and creativity. The flexible, effective and very efficient use of part time models and job sharing is appreciated by the evaluation panel."

"Some flagship project, such as the Stonehenge, Birka and Carnuntum prospections, have allowed for the establishment of an extraordinary scientific reputation and a highly visible public outreach across Europe. Furthermore, the findings are highly relevant in terms of national politics relating to cultural heritage. The evaluation panel recognizes that these high impact projects create a positive setting not only for the immediate archaeological investigations but also for the future by increasing the visibility and appreciation of these approaches by political decision makers and the public."

"In general, the institute's combination of theory, methodology, data acquisition, data management and interpretation is very convincing. By combining informatics, geosciences and archaeology, LBI
ArchPro has achieved an extraordinary interdisciplinary progress and methodological and technological development. The institute's knowledge transfer is very good, not only in terms of sharing technological and methodological knowledge with partner institutions, but also in terms of public outreach."

3. Results

3.1 Data acquisition

Remote Sensing data acquisition

For the task "Test flights in project areas with new camera kit" a first test-flight with the GPS/IMU solution was made on 13th of June 2013. During the 3-hour flight, the case-study area of Carnuntum was recorded twice. Using the control information available in this area, individual air-photos will be oriented and the orientation parameters compared with the resulting information (co-ordinates and attitude) of the GPS/IMU solution. The data of the test flights are currently analyzed: analysis will show the degree of accuracy and usability of the solution. A paper was prepared for the CIPA conference in Strasbourg in September 2013 (Verhoeven, G.; Wieser, M.; Briese, C.; Doneus, M. (2013)).

Geophysical data acquisition

Geophysical archaeological prospection fieldwork has been completed for the case study site Birka-Hovgården by surveying areas in the vicinity of the burial mounds at Hovgården on Adelsö. Manual GPR measurements and completing motorized magnetometer measurements on Björkö rounded up the large-scale geophysical data acquisition in the framework of this case study, resulting in a total coverage with geophysical survey methods of 73.8 hectares.

The case study Kreuttal has seen some detailed magnetic susceptibility measurements as well as repeated Caesium magnetometry and small scale GPR survey in connection with the seminary excavation of the entrance situation of a Neolithic ring ditch structure at Hornsburg.

The most comprehensive geophysical data acquisition fieldwork campaign so far has been conducted for the Carnuntum ArchPro project. After targeted information through a phone campaign and the distribution of a brochure describing the project to some 270 landowners, in July and August 623 hectares of magnetic and 167 hectares of high-definition GPR data were acquired under rather adverse measurement conditions. The freshly harvested fields and the lack of prior rain led to extremely dusty work conditions and temperatures topping 40 degrees Celsius.

In the framework of the case study Stonehenge some 180 hectares of magnetic data and 80 hectares of GPR measurements on selected areas were conducted.

Spectroscopy

The focus for the task “Systematically collect ground-based measurements using a spectrometer” was on topics like building a completely new spectrometer station: the system had to be easily deployable, stable, cost-effective, easy to transport and simple to reconfigure. In the end, a system was assembled which is based on lighting components of different manufacturers. The testing and fine-tuning of the complete system should be performed in late 2013; some VNIR and also NUV spectral measurements were also done of the excavation-area in Hornsburg, case study Kreuttal.

3.1 Data processing and visualization

Geo-referencing and data fusion

A significant amount of time was invested in the multi-temporal processing of historical images and ALS data from the study site Mølen, Norway. The results have been already presented at the AP2013 conference in Mai, but a further journal paper was finalized during the last months of 2013.

Within the task "Geo-referencing of repeated ALS test flights" the workflow for multi-temporal geo-referencing is already developed and the software package OPALS has suitable modules for realization of the workflow with practical data sets. The evaluation report, best practice guidelines and publication have to be done till 1st April 2014. Furthermore, a first multi-wavelength data set was acquired and processed. The first archaeological interpretation looks promising. In the next months the practical processing and evaluation will be finished, with a special focus on the multi-temporal data sets from Carnuntum (for radiometric comparison).

Concerning “Data fusion of AHS and ALS data” further work was done in cooperation with TU Vienna concentrating on the advanced georeferencing of the AHS data sets. The AHS georeferencing with the software PARGE is still in the test phase. As a result of the work package a workflow for the processing of the AHS data sets will be available.

For the task "Ortho-rectification of relevant aerial photography from the case study area" background orthophotomaps for the case studies have been organized. For each case study the orthophotomap and relevant DSM and DTM have been saved in one directory and ArcGIS project was build based on the data for the purpose of easier integrative interpretation

Digital terrain model generation

The Task "Advanced DTM generation for archaeological interpretation" was focused on generation of new DTM and DSM for different case studies. A special model for AIS processing (WP 1.2.4.1) has been generated. Two movies concerning the sites Kaupang and Borre have been created. In order to prepare the movies, the necessary data like models, orthophotomaps and interpretations have been gathered in one ArcScene project.

TLS measurements in the case study area of St. Anna have been done on 24th of May 2013. The aim was to compare the signal recorded from ALS and TLS systems on a free standing tree. The ALS data have been acquired on the 22th of May 2013. Finally 25 scan positions were recorded (three were repeated).

The complete Kreuttal and St. Anna data sets were processed and delivered for archaeological interpretation.

A new, refined DTM for the case study of Stonehenge has been prepared covering an area of approx. 14 km^2 (Fig. 7) The data used for generating the model was acquired in the years 2011, 2012 and 2013 (winter and autumn). Previous model had a low quality which was caused by incorrect scan alignment (the differences in height between measurement campaigns were visible in the model). In order to refine the height position of the scans OPALS software has been used.

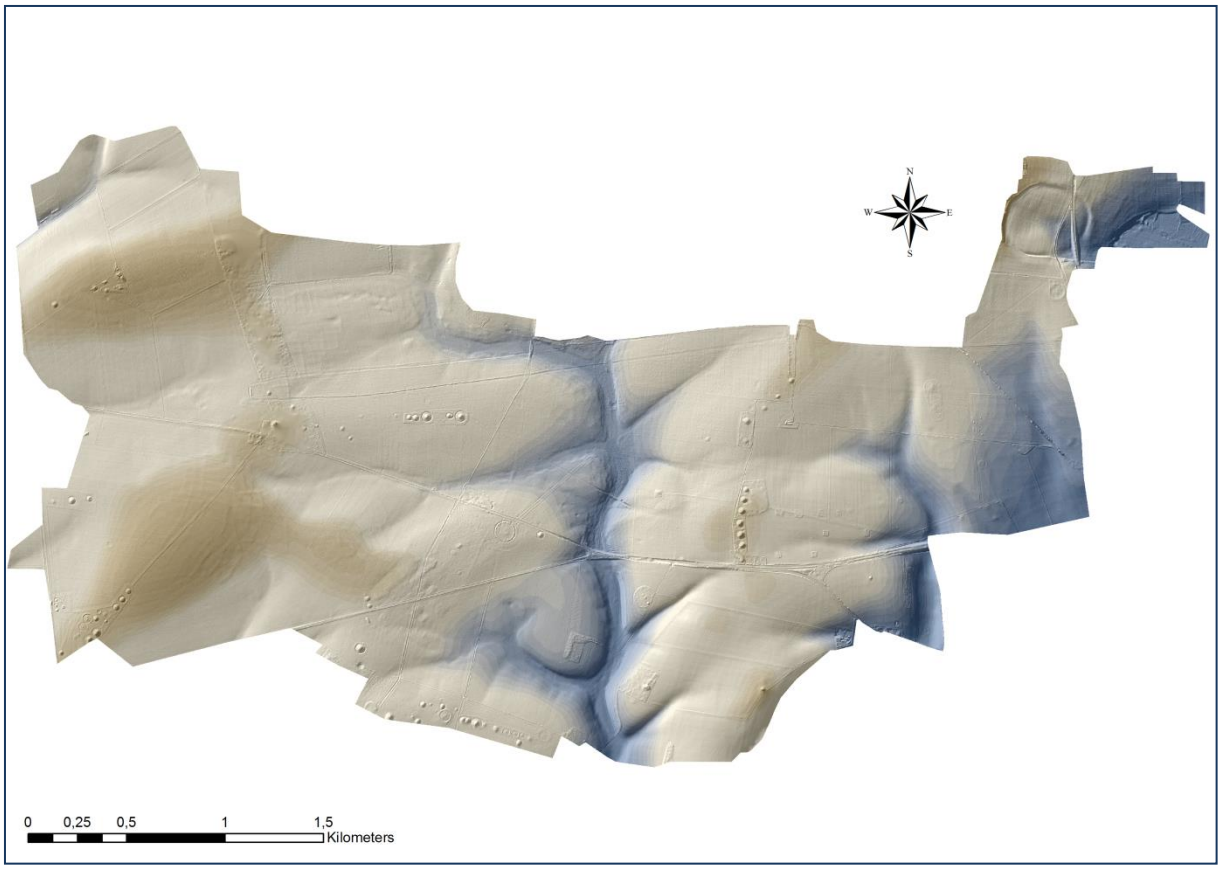

Fig. 7: New DTM model of case study Stonehenge

New DTM for case study Carnuntum has been created from the ALS data acquired on the 11th of November 2011. The time of the flight and the vegetation state allowed preparing a precise terrain model – most of the fields were already cleared.

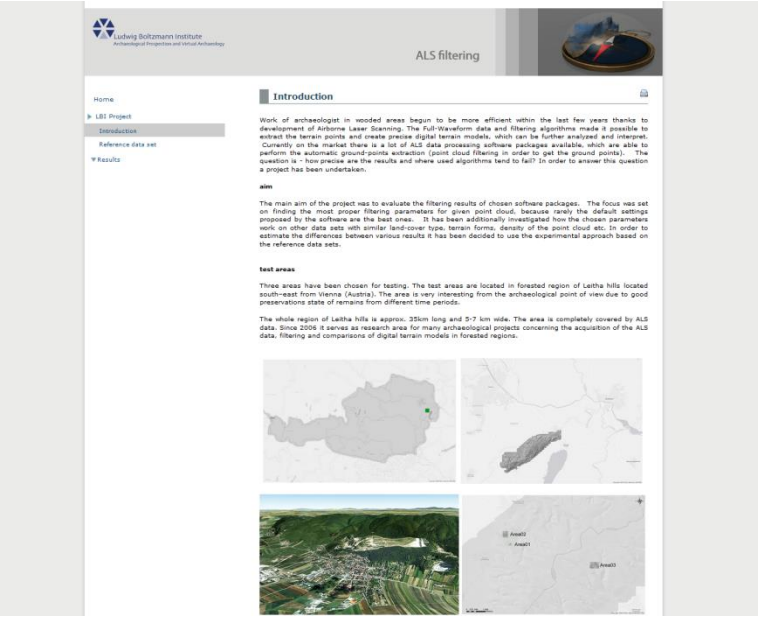

Fig. 8: Part of the ALS filtering web-page (Introduction)

The analysis of ALS attributes for the development of advanced filtering procedures is in progress. The field control has been performed on the 10th of April 2013. Advanced filter workflows have been already developed and tested on several ALS data sets, but need further testing on practical archaeological data sets. Two reports for the WP Evaluation of different software packages for ALS filtering have been prepared. The verification phase for the Scop++ and LIS Desktop software packages was performed and documented. Within this phase the filtering parameters tested before only on the area 01 have been used for bare-earth extraction of two other areas (02 and 03). The reports include some guidelines how to use the parameters in order to get optimal result. The first results have already been published at the AP2013 conference; the web-page for the project is under construction (Fig. 8).

ALS data processing

For the task "Radiometric calibration of ALS data" the radiometric calibration with the multi-temporal data sets was finished and tested within an archeological interpretation. The first interpretation results look promising and have led to the preparation of a journal paper. Preliminary results have been presented at the EARSL symposium in Gent, the AP2013, and the Riegl User Conference 2013. Two flight missions over Carnuntum with in total three different ALS-wave lengths were acquired by Riegl LMS GmbH. All the data sets were processed and the first results have been presented at the Riegl User Conference 2013. Advanced results with an archaeological interpretation were presented at the CIPA conference at the beginning of September. The CIPA paper was selected as best paper of the session and will be extended to a further journal paper.

For the task “Investigation of automatic break-line extraction and (semi-) automatic detection of archaeological structures” first tests with the software package STREX have already been performed. As part of the dissertation of one of the IC ArchPro students, the programme is also being further tested. The further investigation of automatic break-line extraction of archaeological structures is ongoing with a deadline of 1st April 2014. The evaluation of the tools in several different project areas and the archaeological analysis of the results will follow subsequently (task will be extended to the next LBI ArchPro period).

AHS data processing

For the task " Geo-referencing and radiometric adjustments" a workflow utilizing the state-of-the-art software products PARGE and ATCOR has been developed and documented. Many tests have been performed in order to find a correct way of handling the atmospheric correction in ATCOR software like if using smile versus non-smile sensor gives differences in the result or if the sequence of performed tasks influence the result – so if performing the atmospheric correction after the geometrical correction gives significant difference in comparison with the alternate sequence. Additional test concerning the influence of the flight direction on the AIS radiometry has been performed. The workflow is documented and in collaboration with the LBI ArchPro partner ABT automated; the goal is to process large volumes of data at once without manual interaction. A workshop in the premises of Airborne Technologies together with developer and owner of PARGE and ATCOR (Daniel Schlaepfer) was held to optimize the AIS data processing workflow. The guideline as a working paper is work in progress. For the case studies Birka and Uppåkra the radiometric correction for the LiDAR strips was done.

A journal paper on the evaluation of AHS toolbox is in preparation. Key point will be a novel tool within the toolbox to visualize AIS data by distribution fitting, which allows visualizing significantly

more crop marks.

Geophysical data processing

A novelty and considerable advancement in the processing of geophysical archaeological prospection data, both magnetic and GPR, is the generation of compressed GeoTiffs that combine and integrate the various earlier used output formats (Tiff and world file; ESRI FLT formatted file; ApRad Field formatted file) into a uniform, well supported file with LZW-Compression and XMP-tags for the possibility to include metadata (XMP: Extensible Metadata Platform, LZW: Lempel-Ziv-Welch-Algorithm). This advancement will permit simplified and compact data structures and the inclusion of important raw and meta information (e.g. on processing steps applied) into the results image files. User manuals have been compiled for the processing of GPS based GPR and magnetic data.

3.2 Data interpretation and spatial analysis

Remote sensing data interpretation

For the task "Archaeological Interpretation of ALS data" the ALS dataset from the case study Larvik/Vestfold was fully interpreted. After remodelling the DTM from the original data and an archaeological based filtering, the interpretation was based on negative Openness (15m Kernel), local relief model (33 Kernel) and a combination of hillshade and slope. In area 1, 131 barrows could be located, 35 of which have to be classified as insecure (Fig. 9).

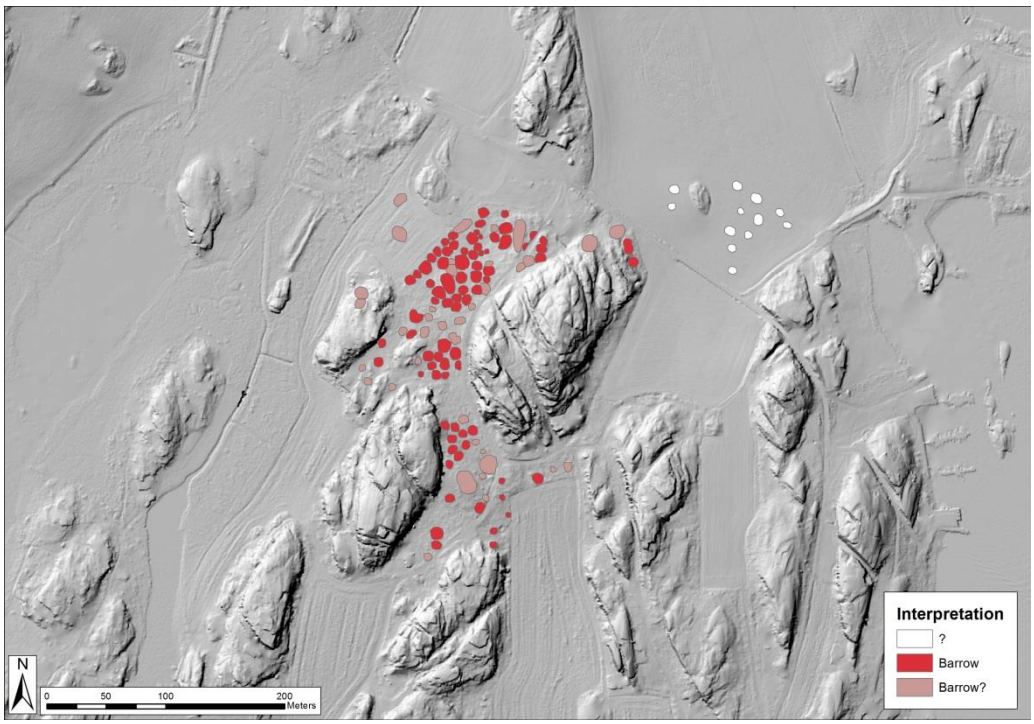

Fig. 9: Case study Larvik/Vestfold: ALS data iInterpretation of area 1

For “Archaeological Interpretation of aerial photography” a review of PCA (principal component analysis) and PCA-based image processing approaches has started to see if we can use PCA-based techniques to interpret aerial images in a better way than currently known.

Similar is the progress for the task “Archaeological Interpretation of AHS data" where a review on algorithms is finished and first tests on Carnuntum data were conducted. Some work was invested in the article of the application of the Red Edge Inflection Point algorithm and the distribution fitting. A presentation for the EARSeL Special Interest Group on Imaging Spectroscopy (SIGIS) in France was visited.

Geophysical data interpretation

Geodatabases for archaeological data interpretation have been setup for the case studies Stonehenge, Vestfold, Birka-Hovgården, Uppåkra and Carnuntum.

The interpretation workflow developed during the last decades by ZAMG Archeo Prospections® and Wolfgang Neubauer has been evaluated. Test interpretations by all respective team members have been carried out and widely discussed during an internal workshop.

For the future interpretation of all case study data a comprehensive GIS-based interpretation work flow will be developed. This work flow will be based on the ESRI Geodatabase® format (geoDB). Currently the initial geoDB design is reviewed and enhanced. The development of the work flow and the respective documentation will be done using software packages SmartDraw and Geodatabase Digrammer. The two software products provide the perfect environment for the definition of requirements, specification and implementation of GeoDB templates to be interfaced as XML documents directly to ESRI ArcMap®. All initial interpretation results will be integrated into the final GeoDB based structure until end of 2012.

In connection with the design of the geodatabase and first archaeological interpretation of the Kreuttal datasets best practice guidelines for interpretation have been considered and tested. General focus is set on redundancy concerning the workflow and practicability of used templates. The aim is to enforce a logical workflow of the interpretation of geophysical data. In a first step the structure and design of the geodatabase was defined. Once a geodatabase was defined using ESRI´s Geodatabase Diagrammer it was tested in ArcGis10.0 concerning usability. Different templates have been tested and evaluated so far. After each test the original geodatabase was again modified with the Diagrammer. The final step will be to introduce the newly designed geodatabase and workflow guidelines to the LBI ArchPro to be tested on all case study datasets.

Integrated archaeological interpretation

For the task "Data conversion and data integration of existing digital archives" several files with needed Coordinate Reference Systems (CRS) for all LBI ArchPro case studies were created. All old and new CRSs of every individual case study and lists of all their parameters were included in an Excel sheet. Additionally correct CRS files for ArcGIS were prepared and a tutorial on how to best transform CRS using the NTv2 solution in ArcGIS was made. Finally, an internal workshop was organized.

In frame of the task "GIS based integrated data interpretation" an interpretation workshop has taken place in Oslo together with LBI partner NIKU und Vfk (Erich Nau, Wolfgang Neubauer, Lars Gustavsen, Lise-Marie Bye-Johansen, Christer Tonning, Vibeke Lia, Knut Paasche).

Classification of prospection data

In the frame of the task "Classification of multi-temporal AHS data sets" the concept of multi-temporal hierarchical image segmentation is prepared to be tested. The idea is to segment the multi temporal AIS data by first decomposing original image time series in Fast Fourier Transform

component and then to perform hierarchical segmentation analogous to eCognition using Euclidean distance between FFT components of same frequency as a measure of similarity.

For the "Classification of geophysical data" different classification approaches should be running in the near future automatically or semi-automatically. Starting with the GPR data of Kaupang an object-oriented classification procedure has been developed. To allow user-interaction a so-called “Architect Solution” has been additionally developed. The big advantage is that no technical understanding by the user of the programming language is needed. Additionally to the Kaupang data set, a classification procedure for the Stonehenge set has been developed. For the future, the development and the procedure have to be formalized to make it transferable to other data sets and case studies. Further work has been done to develop an object oriented description of archaeological features for a subsequent development of object-oriented rule sets.

For the "Classification of ALS data" one of the test areas in the case study area of Leithagebirge has been prepared for the analysis and data sets were analyzed in OPALS software package based on the amplitude and echo width. It was possible to calculate a number of various parameters (rank, echo ratio etc.). Those parameters will be extended in order to find specific values for any given class. This will not be done manually since special machine learning techniques exist that are able to look for relevant values automatically. For that reason cooperation with specialists for machine learning has been initiated at partner TU Vienna (Department for Geodesy and Geoinformation).

A manuscript on the classification results for the case study Birka was completed and sent to the Journal “Archaeological Prospection”. Meanwhile the reviews are back and the manuscript is according to one of the reviewers revised. Additionally, a paper on openness – the visualization technique, which is used for image based classification of the ALS data – was published in an international peer-reviewed journal.

3.3 Methodological development

Standards

For the task "Standardizing the data acquisition and post processing methods" guidelines for the Förster magnetometer, the ATVs, the setup of JAVAD, post processing with Apsoft and the handbook of Case Studies are available. Manuals for measuring systems are currently based on oral communication since changes of the setup of systems happen quite regularly. A first best practice workflow for the setup and the work with an Eastern Atlas System (Magnetics) was introduced. The new central location in Langenzersdorf turned out to be crucial for smart logistics and therefore also forms the basis for reproducible measurement procedures. A meeting for all Case study Leaders, field directors and field workers was held on 15th of April 2013. Within this meeting documentation of most of the procedures was trained. Additionally first drafts of further guidelines and best practice papers were made for GNNS JAVAD and the SPIDAR-system. First campaigns proved that the structure of storage and logistics seems to work well.

The task “Definition of data exchange formats, geoDB and according interfaces” is in progress. The data formats that shall be used by LBI ArchPro are governed by several requirements: usability by GIS software, esp. ArcGIS, a possibility to store and retrieve Metadata (georeferencing, but also e.g. sensor information), and being a meaningful archive format which may also allow data usage by other software. Most likely variants of TIFF with GeoTIFF and some private metadata tags (to be

specified) will be used for 2D data (requiring some changes in APsoft), but there is no existing generally accepted standard for 3D data, so several options are in discussion. GeoTIFFfloat or UInt16 raster data with the addition of XMP metadata tags (to be specified) seems to be the best solution for 2D data (requiring some changes in APsoft). 3D data (Radar data) will be stored both in the previously used proprietary FLD format, and in multiband GeoTIFF or single-band UInt16 GeoTIFFs. An internal report on data formats is already available. These metadata tags (details currently under development) will have to be interpreted during raster GDB preparation and imported into according raster GDB fields.

The first GeoTIFFs with XMP-based metadata on magnetics are available from APsoft; metadata tags for GPR images still must be specified.

As a part of the task "Multi-scalar data representation" new software for the 3D visualization has been tested. Currently, 32bit software is used for the 3D visualization. This software is not able to visualize the large subterranean 3D data resulting from LBI ArchPro massive GPR surveys. Therefore some other visualization solutions have been located and tested. A test week of GeoScene3D provided rather mixed results; this program circumvents memory problems by pre-cropping the data area, thereby however preventing the whole area to be seen. On the other hand, results of a test of Voxler3, 64bit visualization solution, were very positive. After further testing, three licenses for Voxler3D have been acquired by the partner Uni Vienna. This 64bit visualization programme should be able to display larger GPR data blocks than AVS/Express. Some work has been invested in a workflow for conversion of iso-surfaces from older formats WRL or OBJ. Voxler also provides spatial filters to be applied on the voxels in their respective neighborhood, and an animation which must likewise be programmed has already been developed for the evaluation talks. Unfortunately the greyscale image data cannot be filtered meaningful enough to extract e.g. only hypocaust pillars as clearly as the human brain can do. Hopefully fused data sets (GPR and magnetics) will be able to do better.

3.4 Software development

LoggerVIS

The development of LoggerVIS 2.0 has been completed. With the beginning of the case study season and the modification of the existing measuring equipments LoggerVIS had to be adapted to the hardware changes. The software has undergone an update to encompass these changes. Further work has been carried out on the Caesium magnetometers components of the software. Extensive testing has been done in this area, resulting in improved functionality with Caesium sensors. With the resurrection of the “letter” cart LoggerVIS had to be extended to operate the new measuring equipment and also to prepare the recorded data for processing. Another implemented feature in Logger Vis is the alternative positioning using a robotic total station instead of differential GPS.

ApSoft 2.0

In the framework of the task ‘Processing software for motorized geophysical prospection’ some further development has been achieved. For GPR systems the software package ApRadar has been expanded with a possibility to read the new log-formats from the MIRA systems ‘*.cpdt’ and ‘*.cpps’. Secondly, a solution for automatically detecting and correcting SPIDAR radargrams was solved, since the recording was started late and the GPR trace top could be missing. For magnetic systems the

algorithms have been changed to account for long data outage periods in the order of seconds (can happen with Picodas systems), the program was expanded to read the 'Measuring Description' information directly from the data files (xml files). Furthermore, various magnetic and GPR output Formats (tif-world-file, ESRI-FLT-Format, ApRad-Field Format) have been changed to one uniform and well supported format in GIS-world: GeoTiffs with LZW-Compression and XMP-Tags for metadata (XMP: Extensible Metadata Platform, LZW: Lempel-Ziv-Welch-algorithm**).** All ApMag tools producing raster-output-files were changed to generate GeoTiffs with LZW-compression for greyscale images and floating-point 2D-grids.

Solutions for automatic detection and problem solving for SPIDAR systems have been implemented. GeoTiffs with XMP metadata have been completed for magnetics and started for radar.

ArchaeoAnalyst

For the task "Definition of requirements and specification of GIS Extension ArchaeoAnalyst" the exchange data formats for magnetic and radar data were agreed upon. The implementation of GeoTiffs with xmp tags for metadata storage has been finished.

"Implementation of GIS Extension ArchaeoAnalyst1.0" is in progress. The background of ArcGIS software development has been studied and an ArcGIS Extension project was created as the backbone of ArchaeoAnalyst, complete with an installer for easy distribution of the software. This extension allows ArchaeoAnalyst to be integrated in ArcGIS just like any other ArcGIS extension. Interpretation workflows were developed using an interpretation geodatabase to allow a team to work together on the same archaeological landscape, with the possibility of viewing each other's work. Therefore one focus was to implement user interfaces and software components to let the user load data out of the geodatabase into layers, hierarchically ordered based on properties of the desired datasets. Also the possibilities to store raster data in geodatabases have been explored and a database prototype to be used with ArchaeoAnalyst was developed. This geodatabase together with ArchaeoAnalyst should simplify the handling and loading of the large datasets used for the interpretation process.

The development of ArchaeoAnalyst in the autumn 2013 was particularly influenced by concurrent interpretation sessions, since important knowledge for further development of ArchaeoAnalyst was acquired during the interpretation process. The results of this parallel development procedure, is a set of tools. The first tool is the Data migration tool having the purpose to translate whole datasets semantically and structural. This tool is being used in migrating older interpretation data into the new geodatabase structure. The second tool is the Geodatabase merge tool. The purpose of this tool is to merge the content of geodatabases with the same structure detecting and reporting conflicts based on data ownership. This tool is crucial when working in a larger team, for efficient data storing and management of the results, when working with file geodatabases. It is essentially a pseudo versioning system for file geodatabases. This tool is the software representation of our interpretation collaboration workflow.
Some work was also dedicated to the development of the DBFeeder module of the ArchaeoAnalyst. This module enables the user to load data from the interpretation geodatabase and also from the raster geodatabase into ArcGIS Layers. The user interface of the DBFeeder provides a more intuitive way to build the layers and to specify the content to be loaded. There are two modes simple and composed. The simple mode loads just one layer and the composed mode creates a layer tree of geodatabase data. This tool has the built in feature to reflect the content of the geodatabase in the

user interface offering just the relevant options context based and also warning the user if data is unavailable. The software architecture of this tool is implemented and it allows fast extension implementation for new geodatabase feature classes and raster catalogs.

1.6 Hardware development

Motorized systems

For "Construction of motorized magnetometer systems" continual modifications of the existing systems were carried out mainly concerning the wheel suspensions and ball-bearings; in general all movable components that are exposed to extreme pressures. These parts need to be continuously serviced and replaced, during these replacements new parts made of different material are being tested.

The task "Design of motorized GPR systems" focused on the design of a carrying vehicle for the SPIDAR II system. Its design is based on the aluminium prototype used for the SPIDAR I system. Various modifications were based on experiences gained during the two-year use of the preceding model: the abandonment of a mounting for the odometer wheel (instead use of constant measuring frequency), the installation of mounts for voltage stabilizers (provided by Sensors&Software), the design of a cover (canvas) for the SPIDAR antenna array to provide protection against rain, dust and vegetation. several smaller modifications of smaller components (screws, bearings etc.), the adaption of the power supply cables to be used directly with the additional on-board batteries of the DinliCenthor ATV (no separate power supply for the SPIDAR system necessary any more).

Based on this design the construction of the SPIDAR II carrying vehicle was also developed further. The frame was constructed of special stainless steel, four highly durable wheel chair wheels were used on swing (pendulum) axles and the protective cover was sewed from truck tarpaulin. The NICs and Hubs were mounted in an aluminum box (ZARGES) in the front area of the vehicle; the six antenna pairs in the rear part. The construction of the vehicle took place in Mauterndorf (ZweiradSampl); it was then transported to Langenzersdorf where firmware and software updates of the single GPR components and first test surveys were carried out. The system was subsequently moved to Stonehenge for first large-scale surveys. Several smaller issues with the system could be solved during the case study Stonehenge: A main problem was caused by the GPR signal interfering with the GPS signal. A few layers of aluminum foil directly underneath the GPS receiver solved the problem. Some of the cables connecting a single NIC with a Hub needed to be replaced. After these modifications the SPIDAR system was operating satisfactorily. Some of the modifications mentioned above have also been applied to the SPIDAR I system during the case study Stonehenge.

Positioning and navigation

GPS: During a meeting in December 2012 with responsible representatives from EPOSA (RTK-GPS correction signals via GSM) subsequent tests of their service were appointed. First tests with the EPOSA system were carried out during April 2013. Our existing Javad Sigma and Javad Triumph 1 GPS systems have been modified and a separate SIM card with a data rate of 4GB was purchased. Problems with the Javad firmware led to unsuccessful results. After contact with technicians from Allsat GmbH we received updated firmware versions and a new GSM-modem was installed on our Javad Sigma Receivers. RTK correction via GSM using the EPOSA service appears to work well. First field tests in Langenzersdorf and Carnuntum have been carried out. The EPOSA service will be mainly

used for positioning of the MIRA II system to create a fully independent survey system with all necessary components steadily installed on board of the Kubota RTV.

Totalstation: In cooperation with ZAMG – *ArchaeoProspections* a survey was carried out in the center of the town of Klosterneuburg. Difficult survey conditions (rather small survey areas surrounded by 2-4 storey high buildings) made certain modifications of the MIRA array and the processing software necessary: the odometer wheel was mounted and tracking of the survey was carried out using a Leica Robotic Totalstation. In the framework of this project a new version of the MIRAsoft acquisition software was tested to define the GPS accuracy during the survey (the old software only allowed RTK-fix). Under certain survey conditions this new feature allows to carry out surveys which were otherwise impossible.

Optimization and extension of survey systems

For the task "Design and construction of non-magnetic sensor cart" the project "HELGA redesigned" (new design and construction of a manually operated magnetometer system) was planned and executed in cooperation with three students of the school HTL-Steyr. The students finished the construction of the first prototype cart. All necessary electronic components (Foerster probes, PNC digitizer, Toughbook, GPS System) were demounted from the existing motorized Foerster PNC system and mounted onto the prototype. First proper field tests were carried out in the vicinity of Steyr. Various construction faults were determined during the tests and several modifications have been carried out by the students. The system has been moved to Langenzersdorf and will be finalized there.

For the daily application of a stable Caesium sensor array during the excavation project “Hornsburg 3” the 1996 constructed non-magnetic ladder system was selected and modified (task "Improvement of manually operated Caesium magnetometer system"). The ladder system needed to be strengthened in order to span over several meters of excavated area carrying the rather heavy sensor array. Six Caesium sensors were mounted in an array with three sensors close to the ground (with 50cm sensor spacing) and three sensors used as gradients (two meters above) The design of the array was based on previous LBI ArchPro tests. Two of the PicoEnvirotec digitizer boxes and the power supply were mounted on a small cart to be placed outside the excavation trench. A Panasonic Toughbook and LoggerVIS were used for measurement control and data acquisition. Several adoptions were necessary to position the system as a RTK GPS system, mounted on the ladder system in a stable position with the Caesium sensors, should be used. The main issue was to transfer the position data to the Toughbook in real time to be recorded on the run together with the magnetic data. Bluetooth based data transfer was tested but appeared to be too instable over a distance of more than 10m. Modifications the Satel radio modems (originally provided by Malå for the MIRA system) were necessary to reliably position the whole system. A Satel transmitter was connected with the RTK-Rover on the ladder system and a receiver placed in close vicinity of the Toughbook. Several smaller modifications of the Caesium ladder system were necessary during fieldwork at Hornsburg.

Continuous tests and modifications of the motorized Caesium systems were done for the task "Optimization of magnetometer sensor arrays". The construction of a new box for the electronic components (digitizers, power supply) to be mounted on the quad has been successful; the old box had caused too many vibrations disturbing the system. The computer (SmallPC) steadily mounted on the Dinli ATV was sent back to Canada for repair. Repeated tests at Carnuntum and Hornsburg show

that the newly set up system is working reliably now. The development of these systems is therefore completed.

New sensor technologies

In August 2013 a Medasa Caesium iodide gamma ray system has been employed for first tests at the case study area in Carnuntum. The aim of a gamma ray system is to measure the natural radioactive radiation of certain radionuclides like Uranium, Thorium and Potassium. Anomalies of these radionuclides may indicate changes in the shallow subsurface. The device was mounted on a pod towed by a quad bike. Positioning was done via GPS and an inertial measurement unit. Further tests are scheduled for the next time period.

3.5 Case studies

Case study selection and documentation

The task "Case study standards, documentation guidelines and geoDB maintenance" focuses on the development of a series of definitions regarding case study workflow and should enable cost and time effective planning, conducting and monitoring of the LBI ArchPro case studies. The main focus in the last months was set upon the design and maintenance of a geodatabase. Preceding work dealt with the setup of the necessary infrastructure including the data structure, file structure, server design etc. All raw data (first step) have to be stored after each campaign according to the handbook of case studies. Post processed data (second step) have to be provided for archaeological interpretation afterwards. The geodatabase should contain these interpretation data (third step) and basic raster datasets. The geodatabase has to be designed in the way that all attributes linked to an object (point, line, polygon, etc.) are well defined. Each case study will be represented by an individual geodatabase; therefore maintenance is within the responsibility of each Case Study Leader.

Case study data acquisition and interpretation

In 2013 “SCRUM meetings” (product development strategy where a development team works as a unit to reach a common goal) were introduced into the workflow of archaeological interpretation. Next to the interpretation of prospection data from case studies Carnuntum, Stonehenge, Birka, Borre and Kaupang, different approaches for the designed geodatabases and workflows were tested. In the following text the data acquisition and interpretation for individual case studies will be briefly summarized.

- **Borre, N**

Data acquisition and Interpretation

In March 2013 the vicinity of the Viking Age burial ground at Borre was investigated with a GPR system especially developed for use on snow covered areas over the course of four days (Fig. 10). The campaign aimed at testing the possibility to use a SPIDAR system mounted on a sledge and pulled by a snow mobile in order to extend fieldwork campaigns into the wintertime. Some areas in the vicinity of royal burial site of Borre were selected to test the modified SPIDAR system. In search of settlement structures, the high-resolution, 3D-data images that were recorded west of the archaeological park over an area of 22 ha were analysed by the LBI ArchPro in collaboration with the Norwegian colleagues. In addition to numerous anti-aircraft gun emplacements and trenches from

World War II, that were visible in the radar data north of a former beach terrace, the remains of a typical large Viking Age building with several outbuildings were discovered in the subsurface (Fig. 11).

Fig. 10: Multi-antenna GPR system for measurements in the snow

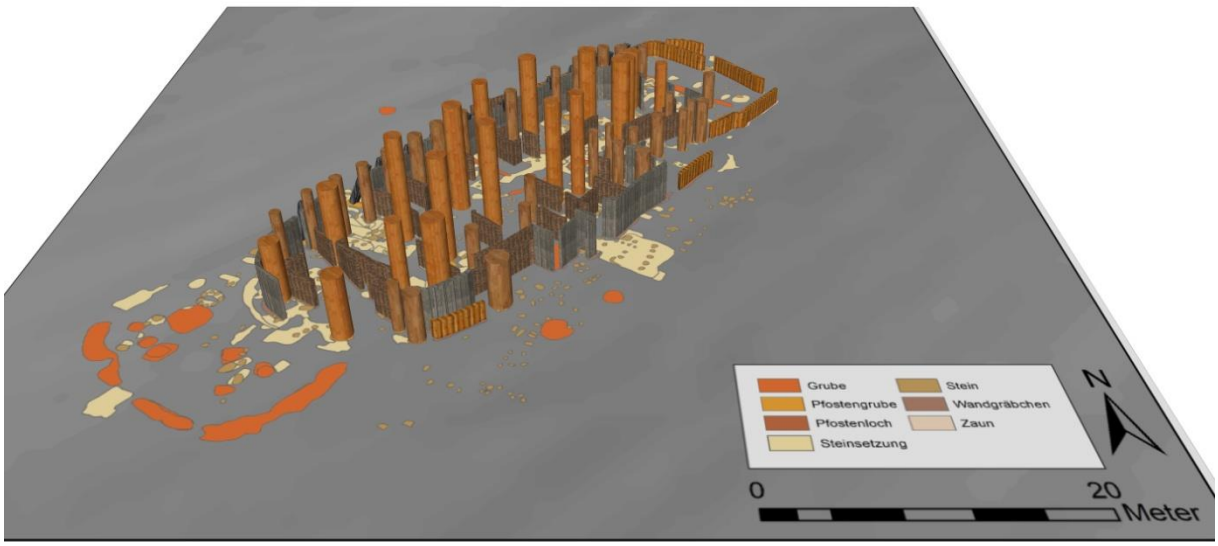

Fig. 11: Reconstruction of the late Viking Age farmstead

For the construction of that building a 1500 m^2 large terrace had been prepared. On this terrace a long house with 47 m side length and about 650 m^2 floor area had been constructed, oriented parallel to the beach. This building with three naves had a width of 12-14 m. It had a porch facing the

sea with a central entrance. The building had additional entrances from the north-eastern narrow side and the long side opposite to the sea. Traces of the central roof-supporting wooden posts can be detected in the radar data in form of the pits in which they had been placed. These postholes have diameters between 1 and 1,5m, further demonstrating the monumental character of this Viking Age building. . The typical shape of the longitudinal wall opposite the sea front with the inclined roof-load bearing posts indicates the dating of this newly discovered house. Research in this matter is still ongoing, but suggests that this building is to be dated to the period 950 to 980 AD, thus to the end of the occupation time of the burial ground. Preliminary interpretation suggests the building to be a late Viking Age farmstead, the seat of a chieftain erected right in front of the monumental graves of their ancestors.

- **Larvik/Vestfold, N**

Data acquisition

In 2013 two fieldwork campaigns have been conducted in the framework of the case study Larvik / Vestfold. The campaigns took place from March 4th to March 15th and from September 21^{at} to October 18th 2013 (Fig. 12).

Fig. 12: Larvik / Vestfold: Fieldwork autumn 2013

The main objective of the September campaign was to finalize the GPR prospection in the area of Kaupang / Tjøllingvollen. A total coverage of the same areas that have been surveyed with magnetics before, could be obtained within three weeks of fieldwork. Additionally magnetic surveys were conducted in the area of Slagendalen. Other important tasks were several smaller test excavations in order to obtain archaeological and geoarchaeological data helping to interpret anomalies visible in magnetic and GPR prospection data. These excavations have been carried out in the area of Berg / Manvik in close collaboration with archaeologists from Vestfold Fylkeskommune.

Data interpretation

On the 7th and 8th of May 2013 a workshop on the interpretation of our geophysical results as well as the overall archaeological interpretation of the site of Kaupang was held in Larvik/Vestfold. Participants of the workshop came from all major archaeological institutions in Norway and from the LBI ArchPro. As a preparation for the workshop a SCRUM meeting was held end of March in Vienna with a focus on the interpretation of the site of Kaupang and its hinterlands. A small team was working on different tasks for several weeks. The tasks included a final processing of the geophysical- and remote sensing data based on new developed processing algorithms, the set-up of an interpretation geodatabase and raster catalogues as a collection of the final images, development of automatic image classification algorithms in the eCognition software package and subsequently followed by the archaeological and geological interpretation. As a result several PowerPoint presentations showing all different stages of the survey, processing and finally the archaeological interpretation were produced. The following lectures given at the workshop in Larvik were very successful.

- **Uppåkra, S**

Data acquisition

In the framework of a seminary excavations conducted by Lund University at the site of Uppåkra in September 2013 in order to follow up prospection findings from the LBI ArchPro, measurements of the soil's magnetic susceptibility and dielectric constant were conducted for a better understanding of the relationship between observed structures in the ground and anomalies mapped.

- **Birka-Hovgården, S**

Data acquisition

Between June 7th and 27th the third fieldwork campaign of the LBI ArchPro case study Birka-Hovgården was successfully conducted in Sweden, completing the geophysical data acquisition. Areas that had not been accessible with motorized GPR survey equipment were manually measured, while simultaneously motorized magnetometer and GPR prospection (SPIDAR) were conducted at Hovgården, mapping settlement traces in the vicinity of the former Manor House Alsnöhus. Contacts with stakeholders regarding the use of the archaeological prospection data were established (Historical Museum) and plans made for a first small exhibition on the LBI ArchPro case study in Birka Museum.

- **Stubersheim/Kilianstädten, D**

Data acquisition

From the 1st to 5th of October 2012 the first geophysical survey campaign of the new case study Kilianstädten/Hessen together with the RGZM (Detlev Gronenborn) was carried out. During this first campaign the expansion of a settlement of the Linearbandkeramik culture could be determined. Due to bad weather conditions (heavy rain at the end of the survey), the short time window available and the state of some fields not being harvested, a second fieldwork campaign was necessary. This campaign was conducted in the 3rd week of August 2013. Within two days of fieldwork the missing areas and some additional ones have been prospected using one of the Eastern Atlas magnetometer systems. The outline of the settlement is now documented completely except of the not accessible parts. Most of these have already been destroyed by the new highway bypass, which initially started the investigations. The Case study Kilianstädten now covers an overall area of 35 ha.

- **Stonehenge, GB**

Data acquisition

In February 2013 a short two-week survey with TLS has been carried out in order to cover the previously not measured areas to the south, west and east of the Stonehenge triangle (Fig. 13).

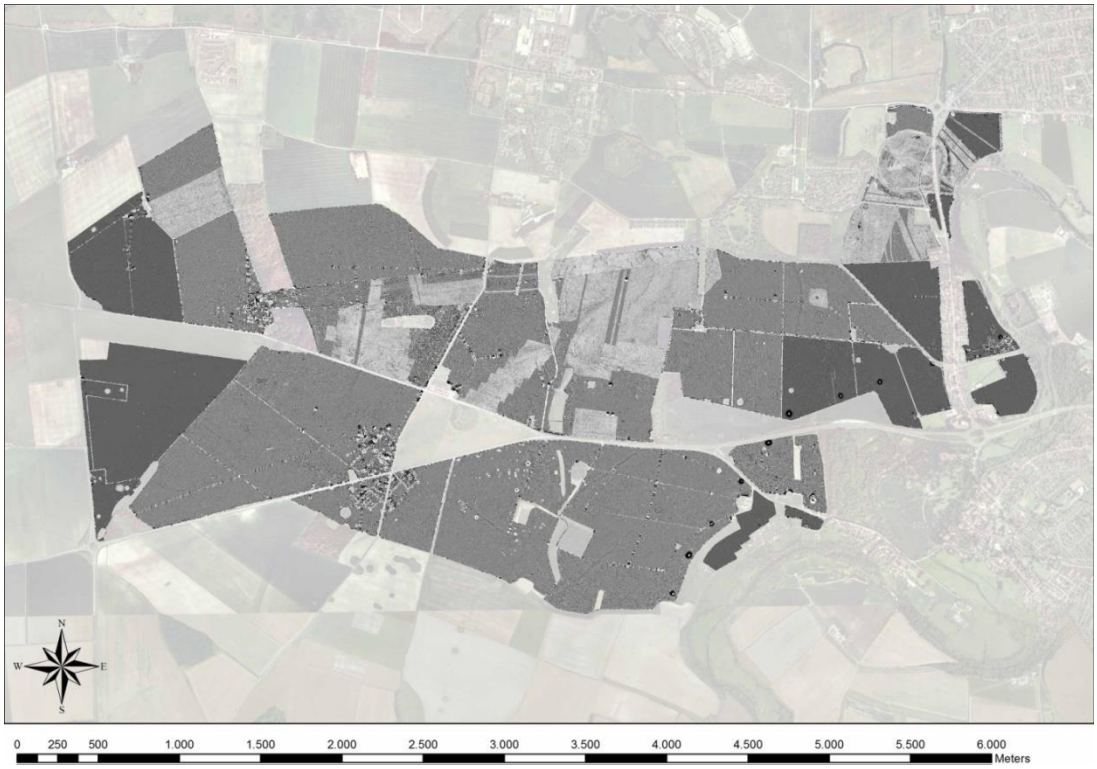

Fig. 13: Stonehenge: geophysical prospection 2010-2013

Fig. 14: Stonehenge 2013

From August 28th to September 27th 2013 a proposed final geophysical field campaign has been carried out for the Stonehenge Hidden Landscape Project (SHLP) and the accompanied LBI ArchPro case study in order to wrap up the residual rest of the unmeasured project area (Fig. 14). Except for some small areas which could not be surveyed because of growing crop and inaccessible fields the

whole project area could be covered during this campaign, producing a seamless DTM of about 12 km^2. We came back to Stonehenge with two motorized magnetometry systems, two SPIDAR systems and one of our MIRA systems. In almost four weeks of field work 1.15 km^2 of GPR data and almost 2.3 km^2 of magnetic data could be collected. The areas prospected by GPR include the Lesser Cursus field, the area between the Cursus and the Avenue and large parts of Durrington Walls and the Cuckoo Stone field. With magnetometry the residual areas east to the Winterbourne Stoke barrow group and west down to the river Avon could be surveyed. Again the newly prospected fields show numerous archaeological structures in unparalleled detail and accuracy.

Data interpretation

Parallel to the field work the interpretation of the magnetic data was continued. Until the end of 2013 more than 4.600 archaeological features were mapped. Also the TLS derived DTMs from Stonehenge were systematically interpreted (Fig. 15).

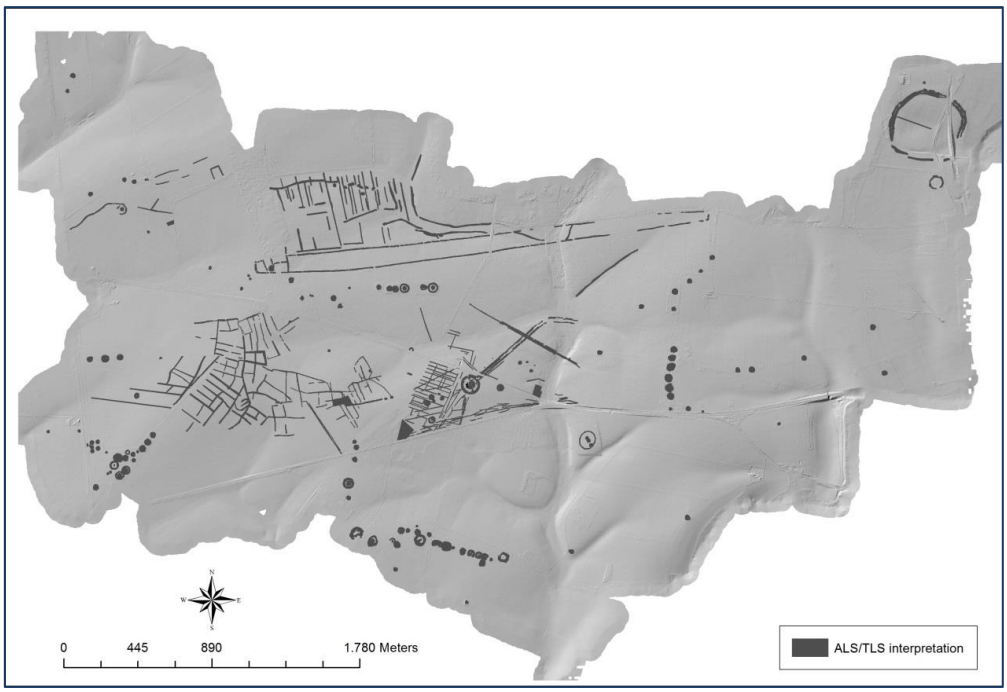

Fig. 15: TLS Interpretation Stonehenge

- **Kreuttal, A**

Data acquisition

In 2013 geophysical surveys were planned for spring but due to unfavourable weather conditions no measurements were conducted. From 1st July to 15th August 2013 excavations at Hornsburg 1 took place in cooperation with the Uni Vienna, also hosting several educational programs. From 22nd to 25th July a geoarchaeology workshop for the IC ArchPro was organized, including two days of classroom lectures and two days of field practice. IC students learned the basics of soil coring, stratigraphic description, in-situ pXRF, magnetic susceptibility and hyperspectral measurements and collecting samples for geochemistry and soil micromorphology.

The excavation focused not only on single archaeological information but also – and even more intensively – on the testing and development of newest prospection and documentation techniques (e.g.: Magnetoscanner, pXRF, SfM, geomorphologic investigations, susceptibility, GPR, coring, IR- and

UV imaginary, hyperspectral scanning etc.). Also four UAV flights were performed (visible and NIR) for test purposes (Fig. 16).

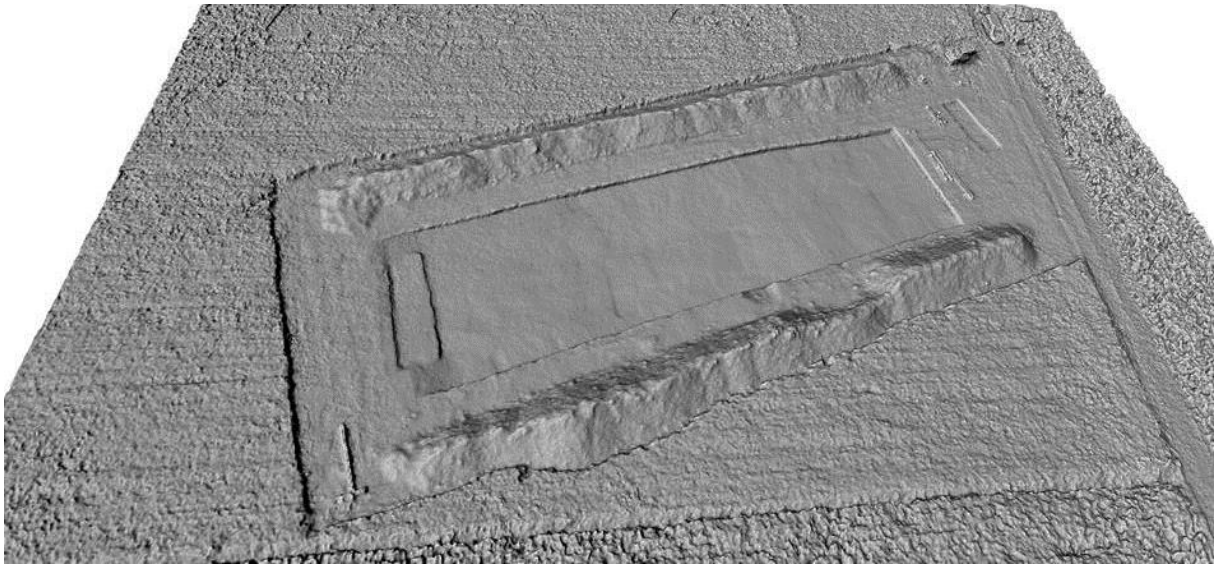

Fig. 16: DSM of the Hornsburg excavation area

Various aspects of new survey methods were investigated during the excavation. A main focus was set upon the development of the magnetoscanner, a moveable platform holding 6 caesiumgradiometers with inline-spacing of 50cm and 25cm possible. It was of main interest to scan the area of the excavation trench before and after the removal of the topsoil to gain more information of the buried features. In addition one of the ditches excavated was constantly scanned during the excavation process. Additionally a complete susceptibility survey of the excavation trench was carried out and cross-sections being documented with this technique. For the first time a pXRF was used on site to gain more information of the chemical composition of the different deposits. In April soil samples were collected and processed in May to give some indication of subsurface features prior to excavation. Additionally a 3D laser scanning (TLS) campaign was done for documentation of the south gate of the presumed Iron Age hill fort.

For soil chemistry the primary aims were to help to identify stratigraphic units, collect sediment samples for geochemical analyses and conduct in-situ measurement of soil chemistry using a hand-held X-Ray Fluorescence spectrometer (pXRF) as well as soil color using a hand held spectro-colorimeter. Analysis and interpretation of soil samples included preparation of soil samples for laboratory testing, and measurements of pH, Phosphates (Pav) and magnetic susceptibility. Spatial analyses – both vertical and horizontal – are being conducted in GIS and with PanPlot (software for presenting environmental data from soil columns). Geochemical, geophysical and sedimentary data sets are currently being combined to create a comprehensive interpretation of the Hornsburg 1 Kreisgrabenanlagen and its immediate surroundings. The first two publications are in the early stages of preparation and will be submitted to the journals *Archaeometry* and *Quaternary International* in the 2nd Quarter of 2014. An abstract has been accepted for a Special Issue of Quaternary International.

- **Carnuntum, A**

Data interpretation

In the framework of the Carnuntum-cooperation project of the LBI and the Institute for the Study of Ancient Culture (IKAnt), a focus was set on the archaeological interpretation of the areas between the gladiatorial school and a newly discovered, very large building, which was situated right inside of the town's fortification wall. By consulting geomagnetic as well as GPR data and air photography, this large, hitherto unknown zone could be mapped in detail for the first time. So far, the mapped area covers several intra-urban, insulae-like building blocks, parts of the southern town wall and the areas in front of it. During the preparation of a publication of this building, analogies of comparable building layouts have been studied. These include similar structures in Caterick, Chelmsford, Godmanchester, Wanborough and Silchester (all UK), Rottweil, Heddernheim and Ladenburg (D), as well as Augst (CH). According to these analogies, an interpretation of the newly discovered features in the South-West of the Carnuntum civil town as mansio seems very likely. After mapping of the South-Western part of the civil town in Carnuntum and the area right outside of the town wall for the first time - using geomagnetic as well as GPR data and air photography - a publication of these new results is in progress. First the research history connected with this part of the civil town was reviewed. This included old excavations done before World War I as well as scarcely published investigations of the 1930s. An important step followed in the mid-1980s, when Ewald Schedivy presented a first reconstruction of the town's street network. The new data allowed reconsidering the insulae layout in the southwest part of the town. The town wall was built after these peripheral insulae had been constructed. Thus, with the help of the GPR data, this important hiatus in the history of the town could be documented. Furthermore, the position of the mansio in the remodelled settlement layout after the fortification was built, becomes evident.

Later in the year an emphasis was put on the processing and interpretation of large data sets from Carnuntum by the LBI ArchPro team for several weeks (Fig. 17). Some 1 TB of GPR raw data were processed before the start of the actual interpretation: filtering of data with different filter algorithms and parameters to get good visual results, creation of GeoTiffs/depth slices and preparation of a map showing the areas measured with the GPR. At the same time historical maps were digitized and interpreted and a number of old excavation maps was georeferenced.

Interpretation of geophysical data focused on the south-western part of the civil town in Carnuntum and the area right outside of the town wall. GPR data from prospected areas next to "Tiergarten" and "Heidentor" are showing several structured buildings and some graves complexes. GPR data of the "western suburbs" in the area "Gstetten Breiten" include settlement features and a "grave street". Magnetic data sets of the western project area between the "Gstetten Breiten" and "Heidentor" were also interpreted; they show several temporary Roman camps, cemeteries, agricultural boundaries and drainage ditches, clay or gravel-quarries and pit houses. An outstanding building, which was situated near one of the town gates just inside the city walls, is especially worth to be noted. The building consisted of three wings of rooms which were arranged around a courtyard (ca. 30 x 23 m). It is possible to distinguish between accommodation areas and maintenance facilities. Immediately to the north, there was probably a bath building and other facilities, presumably a blacksmith's workshop and a laundry. The layout of this courtyard building as well as its position close to a gateway indicate that this was a so-called mansio, a building complex designed for housing official delegates and travellers in Carnuntum. The town wall was 1.20–1.80 m wide and included, besides the above-mentioned gateway, several towers. Very important is the observation that the

town wall was built after some peripheral insulae had been constructed. Thus, with the help of the GPR data, this important hiatus in the history of the town could be documented the first time.

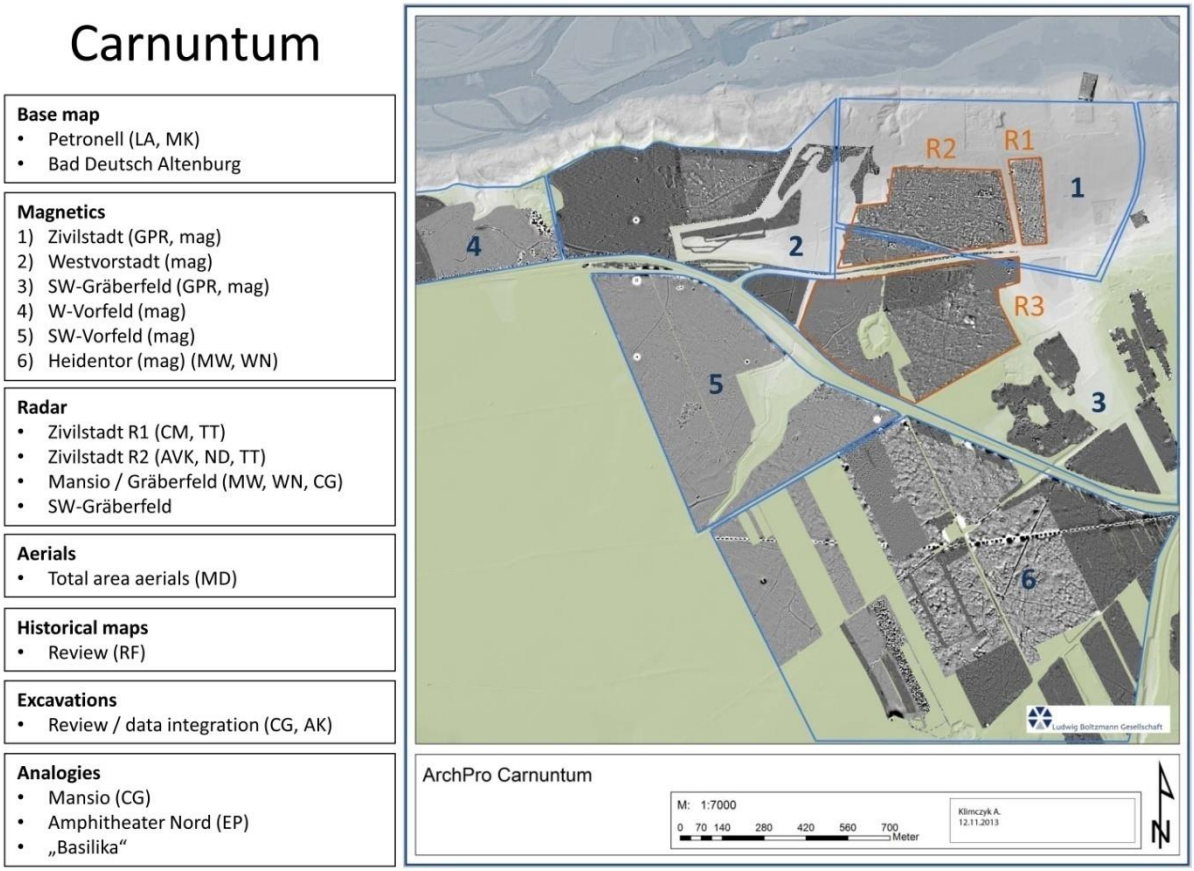

Fig. 17: Team interpretation Carnuntum

The new results will be presented to the public in 2014 together with partner NoeL.

- **Virunum, A**

Data acquisition and interpretation

Aerial photographs have indicated a densely built-up zone in the east of the Roman town of Virunum (near Klagenfurt, Carinthia), the capital of the province of Noricum since the year 2000,. These crop marks have been interpreted as Roman military camp. To gather further information on this combination of a military installation in close relationship with a civilian town, the LBI ArchPro conducted a geophysical survey on the 19th November 2013 (Fig. 18). The results will be used to start a new case study and to realize respective funding.

An area of about 2,56 ha could be examined with the high resolution ground penetrating radar measurement system MIRA II. In the northern part of the plot, numerous building structures obviously from Roman times became visible within a walled-in area. On the south side of the enclosed zone was a gateway. Apart from the southeast corner of this enclosure, it was also possible to determine the south-west corner. The western and northern side of this walled-in area should therefore coincide with the boundaries of the modern allotments being covered now by woods. Within the enclosure there are three long rectangular structures which appear to be Roman military barracks with double chambers and so-called “Kopfbauten” (officers’ billets). In the centre of the complex was a massive building, of which only the southeast corner could be measured. To the south of the enclosure connects another densely built-up area. The mapping and the interpretation is

currently underway. Even from today's perspective it is clear that these measurements will provide crucial clues about the housing of Roman troops at the governor's seat of Noricum.

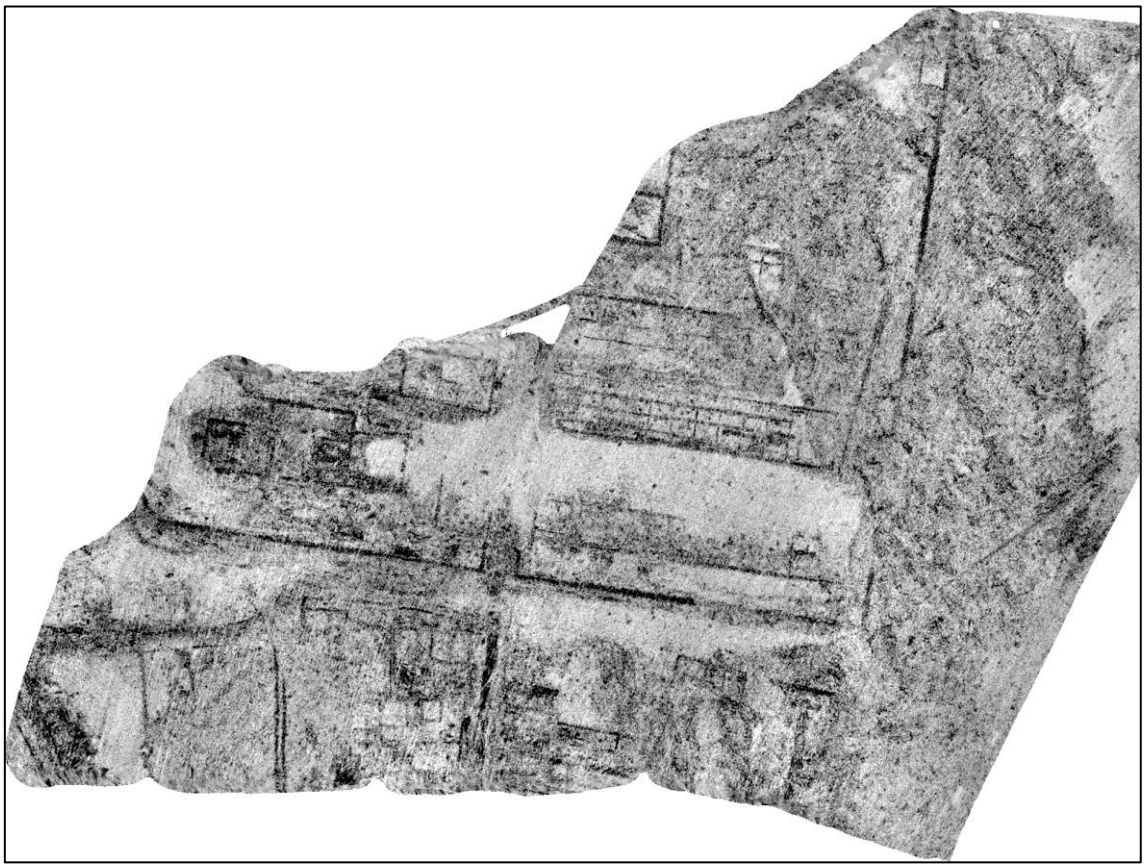

Fig. 18: GPR results from Virunum

4. Other activities

4.1 Scientific cooperation and third party founded projects

St. Stephen's Cathedral, Vienna

On the occasion of of the 500 years anniversary of the burial of Friedrich III. of the House of Habsburg (1415-1493) investigations focusing on the inner structure and construction of the royal tomb were carried out. In cooperation with the LBI for traumatology different methods were tested (geo-radar, terrestrial laser scanner measurements and endoscopy) to gain a closer insight into the grave´s construction. For the GPR survey a special unit was designed by the LBI ArchPro (Fig. 19). The investigations were done in November and December 2013. First results show the construction of the outer shell of the monument consisting of the famous relief plates and the inner chamber, which is made of green glazed tiles. Between the outer shell and the tiles is a further construction made of iron beams, which also supply the top plate of the outer shell, showing the figurine of Friedrich III., and holding two large bronze plates with inscriptions stretching close along the longer sides of the inner chamber.

Fig 19: GPR survey in St. Stephen's Cathedral, Vienna

ARAP Project

A new kind of UAS (Unmanned Aerial System) was tested: the Fotokite developed by Sergei Lupashin at the ETH Zürich (Fig. 20).

Fig. 20: Testing the Fotokite

The Fotokite is a tethered flying camera that is essentially a multi-copter connected to the ground with a taut tether to achieve controlled flight. Crucially, it relies solely on on-board IMU (Inertial Measurement Unit) measurements to fly, launches in seconds, and is not classified as a UAS, e.g. in the latest FAA (Federal Aviation Administration) UAS proposal. As a result it may be used for imaging

cultural heritage in a variety of environments and settings with minimal training by non-experienced pilots. Furthermore, it is subject to less extensive certification, regulation and import/export restrictions, making it a viable solution for use at a greater range of sites than traditional methods. Unlike a balloon or a kite it is not subject to particular weather conditions and, thanks to active stabilization, is capable of a variety of intelligent flight modes. Finally, it is compact and lightweight, making it easy to transport and deploy, and its lack of reliance on GNSS (Global Navigation Satellite System) makes it possible to use in urban, overbuilt areas.

Airmagnet

Aim of the project is to develop an airborne magnetometry data acquisition unit as well as the corresponding data processing and interpretation strategies. A focus shall also be set on the miniaturization of the airborne equipment. These advances will also lead to an increased efficiency of the archaeological data acquisition with magnetic motorized devices. First calibration flights have been conducted with very promising results: a total noise envelop of 0.1 nT was achieved whereas industry standard is 1nT. In February data for a small test survey has been acquired which is now being processed. Different processing methodologies are going to be evaluated. The evaluation of the acquired data showed that further calibration flights have to be done, especially to reduce the Lag and Heading error. After finishing a fully operative measuring platform (first milestone) a test program for the summer ’13 period was agreed on. During two weeks of August 2013 several test flights were conducted including project area “Güssing” and the LBI ArchPro case study Kreuttal. Besides the data acquisition some calibration flights to estimate heading and lag error have been performed. Additionally, two different Gamma Ray systems have been borrowed and tested during airborne operation. In the framework of the AirMagnet project time was also invested in the development of a concept for commercial exploitation of prospection services for the LBI ArchPro.

After completing a series of data acquisition missions the focus was on establishing a workflow for the processing of the acquired magnetic data as well as a diverse service protocol for the equipment. Different filtering techniques which can be applied to the raw data as well as a processing of the horizontal gradient data are subject of development. Therefore the two leading software processing products have been tested and their capabilities compared.

For the LBI ArchPro partner NIKU a very high resolution survey was flown in Norway. Therefore an Eco Dimona was equipped with a horizontal gradient configuration. The survey parameters where chosen from a very sophisticated aviation perspective: 50m ground clearance, 35m cross line spacing. Due do different technical problems the data was acquired in a two weeks mission. The data processing is still ongoing and will be finished most probably in early 2014.

4.2 Workshops

A LBI ArchPro team workshop was held on 5. November 2013 in Falkenstein, Lower Austria concentrating on following topics: assessment of the LBI ArchPro, project controlling, current team situation, dissemination etc.

ARCHAEOskills

After the host cities of Salzburg, Graz, Munich and Weimar the workshop ARCHAEOskills took place this year at University of Vienna (18.-19. October 2013). ARCHAEOskills workshops cover different aspects of archeology and were organized in 2013 by students of classical archeology and prehistory

and historical archeology in Vienna. The LBI ArchPro and the IC ArchPro have held lectures on GIS and Structure from Motion (SfM).

4.3 Teaching activities

Summer 2013

Wolfgang Neubauer, University Vienna

- 060046 LG LG Lehrgrabung II (4-wöchig)
- 060048 SE SE Integrierte Archäologische Prospektion
- 060090 PV Privatissimum

Michael Doneus, University Vienna

- 060078 SE Klima, Landschaft und Gesellschaft
- 060079 PV Privatissimum
- 060082 VO Landschaftsarchäologie
- 060086 LG Lehrgrabung 1 im Kreuttal (4-wöchig)
- 060095 UE Vermessungskunde für Archäologen (zusammen mit Wolfgang Neubauer)

Immo Trinks, University Vienna

- 060053 PR Praktikum Geophysikalische Prospektion
- 060104 VO Geophysikalische Prospektion in der Landschaftsarchäologie

Georg Zotti, University Vienna

- 060052 VO Archäoastronomie

Christian Briese, TU Vienna

- 122.428 UE Topographische Modelle
- 122.427 VO Topographische Modelle

Winter 2013/2014

Wolfgang Neubauer, University Vienna

- 060100 PV Privatissimum
- 060107 SE Integrierte Prospektion und archäologische Interpretation
- 060108 VO Ausgewählte Themen zur Wikingerzeit

Michael Doneus, University Vienna

- 060087 VO Grundlagen - Luftbildarchäologie
- 060088 UE Luftbildarchäologische Interpretation
- 060090 UE GIS-Anwendungen in der Archäologie
- 060091 PV Privatissimum
- 060097 SE Archäologie Sardiniens
- 060113 PR Flugzeuggetragenes Laserscanning (LiDAR) für ArchäologInnen

Immo Trinks, University Vienna

- 060092 VO Einführung Theorie Geophysikalische Prospektion

Christian Briese, TU Vienna

- 120.032 VU Point Cloud Processing

5. Management

An overview of the financial situation and third party project initiatives (WP 1.9.3) of the LBI ArchPro is provided at the beginning of this report.

For the project controlling a report was finalized in August 2013. The report also contains a table with a WP to be completed by March 2014. The information in the table served as an essential input for a management meeting on the future research program later in August and for the evaluation report. The project handbook was adapted.

A half-day training was organized for the LBI freelancers on 20.08.2013 in Langenzersdorf. The aim was to provide them with an overview of financial and tax aspects regarding their LBI ArchPro contracts. The training was also intended as an opportunity for freelancers to pose specific questions on their situation and to arrange for further advisory services. Feedback from freelancers was very positive.

A meeting with potential partners from Uni Vienna and TU Vienna was organized to develop a proposal for an FWF Doktoratskolleg (DK). After some discussions the project was postponed to next year for several reasons:

- The FWF provides no funding for the senior researchers (PhD tutors) causing financial problems for all involved parties.
- The industry demand at TU Vienna for paid PhD projects is so high that there are currently no tutors available.
- The LBI ArchPro who would only indirectly benefit from a DK is busy with the evaluation and has limited resources to work on the proposal.

6. Dissemination

Next to the publication activities and smaller events like “Kinderuni Vienna 2013” much effort was invested in the AP Conference 2013 in Vienna (for details please see the section on Highlights 2013).

During the months of July and August 2013 a CMS upgrade of the LBI ArchPro-website was carried out by the Ludwig Boltzmann Gesellschaft. We seized this opportunity to implement some minor but effective changes to the design and structure of the website with the objective to further improve its functionality and user-friendliness. Updates included enhanced features for image display, the reorganisation of the website menu for easier navigation and better accessibility of sub-categories and a newly customized content type for a more efficient archiving of press reports which can now be easily and fast sorted by case study area or date. Furthermore, we are currently working on the update and creation of content for the individual case study websites.

Several important meetings and lectures connected with LBI ArchPro case studies were held in the last period. On invitation a meeting with Teknikförtagen in Stockholm was used to present the potential of efficient near surface geophysical prospection methods for the investigation of waste sites, leading to a second invitation in early 2014 to participate in a departmental meeting. In regard to the case study Uppåkra an active invited participation in the two-day research seminar on future research at Uppåkra highlighted the value and importance of the results generated by this case study. Other important activities in the last quarter of 2013 involved meetings with the mother organization Riksantikvarieämbetet (RAÄ) of the Swedish partner RAÄ UV, discussing possibilities for

the use of the generated material from the case studies Birka-Hovgården and Uppåkra as well as the situation arising in January 2015 through the change of UV from RAÄ to the National History Museum (SHM). A separate meeting was held with the heads of SHM, and plans for collaboration activities concerning the Birka-Hovgården case study were worked out in detail.

Internal dissemination activities have been concentrating on following topics:
- Board meeting Halbturn (15th October 2013)
- Evaluation report (November 2013)
- LBI ArchPro personal reports
- Maintenance of LBI ArchPro bibliographical database
- Cataloguing and labeling of the LBI ArchPro library (books, periodicals, papers, CDs, etc.)
- Archiving of data on LBI ArchPro server
- Tracking of media coverage and archiving of media reports (online, print)
- Provision of information and PR material to media (i.e. Bild der Wissenschaft)
- New case study home pages: the content of the newly upgraded LBI ArchPro website was extensively updated and extended (team member information, media coverage, publication list, events); individual case study websites were created and launched.

A number of researchers visited the LBI ArchPro to transfer knowledge, exchange ideas and discuss forms of scientific collaboration. Visiting researchers:

- Jeff Welter, TU Dresden, Germany
- Guglielmo Strapazzon, University of Padova, Italy
- Lena Johansson, Riksantikvarieämbetet, Sweden
- Manfred Buchroithner, TU Dresden, Germany

6.1 Articles in journals

Articles published in journals listed in the ISI Web of Science

- Doneus, M.; Doneus, N.; Briese, C.; Pregesbauer, M.; Mandlburger, G.; Verhoeven, G. (2013): Airborne Laser Bathymetry - Detecting and recording submerged archaeological sites from the air. In: *Journal of Archaeological Science* (40), p. 2136–2151. DOI: 10.1016/j.jas.2012.12.021.
- Neubauer, W.; Gugl, C.; Scholz, M.; Verhoeven, G.; Trinks, I.; Löcker, K.; Doneus, M.; Van Meirvenne, M.; Saey, T. (2014): The discovery of the school of gladiators at Carnuntum, Austria. In: *Antiquity* (88), p. 173–190.
- Saey, T.; van Meirvenne, M.; de Smedt, P.; Neubauer, W.; Trinks, I.; Verhoeven, G.; Seren, S. (2013): Integrating multi-receiver electromagnetic induction measurements into the interpretation of the soil landscape around the school of gladiators at Carnuntum. In: *European Journal of Soil Science* (64), p. 716–727.

Articles with international peer-review published in widely circulated scholarly or scientific journals

- Doneus, M. (2013): Openness as Visualization Technique for Interpretative Mapping of Airborne Lidar Derived Digital Terrain Models. In: *Remote Sensing - Open Access Journal* 5 (12), p. 6427–6442. DOI: 10.3390/rs5126427.

- Doneus, M.; Kühtreiber, T. (2013): Landscape, the Individual and Society: Subjective Expected Utilities in a Monastic Landscape near Mannersdorf am Leithagebirge, Lower Austria. In: N. Mehler (Hg.): Historical Archaeology in Central Europe (Society of Historical Archaeology Special Publications, 9), p. 339–364.

Articles with peer-review published in national journals

- Kunst, G. K.; Doneus, N. (2013): Roman graves and rural rubbish. Animal remains from the Roman cemetery of Halbturn, Austria. In: *Anthropozoologica* 48 (2), p. 391–408. DOI: 10.5252/az2013n2a15.

Articles published in journals without peer-review

- Briese, C.; Otepka, G. (2013): Zum Einsatz von Multikoptern als Kameraplattform in der Nahbereichs-Luftbildmessung. In: *Sachverständige* (4), p. 218--223.
- Verhoeven, G. (2013): Drones: een nieuwe kijk op archeologische luchtfotografie. Archeobrief. In: *Vakblad voor de Nederlandse archeologie* (17/3), p. 16–21.

6.2 Books and book chapters

Author or co-author of books

- Doneus, M. (2013): Die hinterlassene Landschaft - Prospektion und Interpretation in der Landschaftsarchäologie. Wien: Verl. der Österr. Akad. d. Wiss. (Mitteilungen der Prähistorischen Kommission, 78).
- Doneus, M.; Gugl, C.; Doneus, N. (2013): Die Canabae von Carnuntum – ein Modell für römische Lagervorstädte? Von der Luftbildprospektion zur siedlungsarchäologischen Synthese: Verlag OAW (Römischer Limes in Österreich, 47).

Author or co-author of chapters in books

- Doneus, M. (2013): Airborne Laser Scanning and archaeological interpretation – bringing back the people. In: R. S. Opitz und D. C. Cowley (Eds.): Interpreting Archaeological Topography – airborne laser scanning, 3D data and ground observation: Oxbow (Oxbow Books), p. 32–50.
- Verhoeven, G.; Sevara, C.; Karel, W.; Ressl, C.; Doneus, M.; Briese, C. (2013): Undistorting the past – New techniques for orthorectification of archaeological aerial frame imagery. In: C. Corsi, B. Slapšak und F. Vermeulen (Hg.): Good practice in archaeological diagnostics. Non-invasive survey of complex archaeological sites. Natual science in Archaeology. Cham, s.l: Springer International Publishing (Natural Science in Archaeology), p. 31–67.

Editor of books, including editor of proceedings

- Neubauer, W.; Trinks, I.; Salisbury, R. B.; Einwögerer, C. (Eds.) (2013): Archaeological Prospection. Proceedings of the 10th International Conference on Archaeological Prospection. Wien, Austria, 29.05.-02.06 2013. Wien: Verl. der Österr. Akad. d. Wiss.

6.3 Conference proceedings

Full articles in proceedings of scientific conferences

- Bill, J.; Nau, E.; Neubauer, W.; Trinks, I.; Tonning, C.; Gustavssen, L.; Paasche, K.; Seren, S. (2013): Contextualising a monumental burial - The Gokstad revitalised project. In: W. Neubauer, I. Trinks, R. B. Salisbury und C. Einwögerer (Hg.): Archaeological Prospection.

Proceedings of the 10th International Conference on Archaeological Prospection. Wien, Austria, 29.05.-02.06 2013. Wien: Verl. der Österr. Akad. d. Wiss., p. 134–136.

- Biwall, A.; Beronius, L.; Trinks, I. (2013): Gamla Uppsala revisited - archaeological excavation and prospection in Old Uppsala. In: W. Neubauer, I. Trinks, R. B. Salisbury und C. Einwögerer (Hg.): Archaeological Prospection. Proceedings of the 10th International Conference on Archaeological Prospection. Wien, Austria, 29.05.-02.06 2013. Wien: Verl. der Österr. Akad. d. Wiss., p. 312–313.
- Briese, C.; Doneus, M.; Verhoeven, G. (2013): Radiometric calibration of ALS data for archaeological Interpretation. In: W. Neubauer, I. Trinks, R. B. Salisbury und C. Einwögerer (Hg.): Archaeological Prospection. Proceedings of the 10th International Conference on Archaeological Prospection. Wien, Austria, 29.05.-02.06 2013. Wien: Verl. der Österr. Akad. d. Wiss., p. 427–429.
- Briese, C.; Pfennigbauer, M.; Ulrich, A.; Doneus, M. (2013): Multi-Wavelength Airborne Laser Scanning for Archaeological Prospection. In: P. Grussenmeyer (Hg.): XXIV International CIPA Symposium. Strasbourg, France, 02.-06.2013 (ISPRS Archives, XL-5/W2), p. 175–180. Online verfügbar unter http://www.int-arch-photogramm-remote-sens-spatial-inf-sci.net/XL-5-W2/119/2013/isprsarchives-XL-5-W2-119-2013.pdf.
- Coolen, J.; Fera, M.; Doneus, M.; Grillmayer, E. (2013): Using barcode, tablett PC and smartphone technology for archaeological field surveys. In: W. Neubauer, I. Trinks, R. B. Salisbury und C. Einwögerer (Hg.): Archaeological Prospection. Proceedings of the 10th International Conference on Archaeological Prospection. Wien, Austria, 29.05.-02.06 2013. Wien: Verl. der Österr. Akad. d. Wiss., p. 195–196.
- Doneus, M.; Doneus, N.; Briese, C.; Pregesbauer, M.; Mandlburger, G.; Verhoeven, G.; Miholjek, I.; Daim, F. (2013): Measuring the topography of submerged archaeological sites from the air. In: W. Neubauer, I. Trinks, R. B. Salisbury und C. Einwögerer (Hg.): Archaeological Prospection. Proceedings of the 10th International Conference on Archaeological Prospection. Wien, Austria, 29.05.-02.06 2013. Wien: Verl. der Österr. Akad. d. Wiss., p. 16–18.
- Doneus, M.; Draganits, E.; Gansum, T. (2013): The Viking-age royal burial site of Borre (Norway): LiDAR-based landscape reconstruction and harbour location at an uplifting coastal area. In: W. Neubauer, I. Trinks, R. B. Salisbury und C. Einwögerer (Hg.): Archaeological Prospection. Proceedings of the 10th International Conference on Archaeological Prospection. Wien, Austria, 29.05.-02.06 2013. Wien: Verl. der Österr. Akad. d. Wiss., p. 36–38.
- Doneus, M.; Verhoeven, G.; Karel, W.; Briese, C.; Pfeifer, N.; Ressl, C. (2013): Towards an automated georeferencing and orthorectification of archaeological aerial photographs. In: W. Neubauer, I. Trinks, R. B. Salisbury und C. Einwögerer (Hg.): Archaeological Prospection. Proceedings of the 10th International Conference on Archaeological Prospection. Wien, Austria, 29.05.-02.06 2013. Wien: Verl. der Österr. Akad. d. Wiss., p. 380–382.
- Doneus, N. (2013): From point to polygon - investigating a Roman rural landscape. In: W. Neubauer, I. Trinks, R. B. Salisbury und C. Einwögerer (Hg.): Archaeological Prospection. Proceedings of the 10th International Conference on Archaeological Prospection. Wien, Austria, 29.05.-02.06 2013. Wien: Verl. der Österr. Akad. d. Wiss., p. 197–199.
- Gaffney, C.; Gaffney, V.; Neubauer, W.; Baldwin, E.; Löcker, K. (2013): An integrated geophysical approach to Stonehenge. In: W. Neubauer, I. Trinks, R. B. Salisbury und C. Einwögerer (Hg.): Archaeological Prospection. Proceedings of the 10th International

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- Gaffney, V.; Gaffney, C.; Garwood, P.; Neubauer, W.; Chapman, H.; Löcker, K.; Baldwin, E. (2013): Stonehenge Hidden Landscapes Project: Geophysical investigation and landscape mapping of the Stonehenge World Heritage Site. In: W. Neubauer, I. Trinks, R. B. Salisbury und C. Einwögerer (Hg.): Archaeological Prospection. Proceedings of the 10th International Conference on Archaeological Prospection. Wien, Austria, 29.05.-02.06 2013. Wien: Verl. der Österr. Akad. d. Wiss., p. 19–23.
- Gustavsen, L.; Tonning, C.; Lia, V.; Nau, E.; Paasche, K.; Gansum, T.; Filzwieser, R. (2013): Large scale archaeological prospection: Case studies from three years of fieldwork in Norway. In: W. Neubauer, I. Trinks, R. B. Salisbury und C. Einwögerer (Hg.): Archaeological Prospection. Proceedings of the 10th International Conference on Archaeological Prospection. Wien, Austria, 29.05.-02.06 2013. Wien: Verl. der Österr. Akad. d. Wiss., p. 218.
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- Miholjek, I.; Doneus, M.; Doneus, N. (2013): Submerged archaeological sites from the air: Case study of Kolone, Croatia. In: International archaeological symposium "Living with glass: From prehistory to the early middle ages". Pula / Zadar, Croatia, 20.-23.11.2013. Pula (Materijali, 25), p. 113–114.
- Pregesbauer, M.; Michel, R.F.M.; Kabelik, B.; Altenberger, A.; Rathmanner, M. (2013): A comparative study on new technologies for mapping glaciers and snow fields. In: Geophysical Research Abstracts. An Open Access Publication for Abstracts of the Earth, Planetary and Space Sciences, Bd. 15. 10th EGU General Assembly. Vienna, Austria, 07.-12.04.2013.
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6.4 Invited scientific lectures

- Briese, C. (2013): Aktuelle Arbeiten der Forschungsgruppe Photogrammetrie. Generalversammlung 2013 des Vereines der Grundkatasterführer Österreichs. Wien, 2013.
- Briese, C. (2013): Unbemannte Flugsysteme zur Geodatenerfassung. Innsbrucker Hofburg-Gespräch, "Drohneneinsatz im zivilen Bereich. Innsbruck, 04.05.2013.
- Briese, C.; Ressl, C. (2013): Praktische Beispiele zur Oberflächenmodellierung aus Bilddaten. Innsbrucker Hofburg-Gespräch, "Drohneneinsatz im zivilen Bereich. Innsbruck, 04.05.2013.
- Doneus, M. (2013): Prospecting Archaeological Landscapes. Keynote. Počítačová Podbora v Archeológii 12. University of Bratislava. Kočovce, Slovakia, 22.05.2013.
- Doneus, M. (2013): Beyond Field Survey. Prospecting Archaeological Landscapes. University of Groningen. Groningen, Holland, 24.09.2013.
- Doneus, M. (2013): The first and next 30 years of AARG: a discussion on AARG's past, present and future. AARG Annual Meeting 2013. AARG & Dutch Expertise Centre for Archaeological Remote Sensing. Amesfoort, Holland, 26.09.2013.
- Doneus, M. (2013): Progress, applications and perspectives on ALS. Workshop: 3D Scotland. Aerial Laser Scanning for Archaeology and Heritage Management. RCAHMS. Edinburgh, GB, 02.10.2013.
- Doneus, M. (2013): Verborgenes kartieren – Geoinformation in der Archäologie. 150 Jahrfeier der Österreichischen Geodätischen Kommission. Bundesamt für Eich- und Vermessungswesen. Wien, Österreich, 07.11.2013.
- Doneus, M.; Doneus, N.; Briese, C.; Pregesbauer, M. (2013): Airborne Laser Bathymetry – detecting and recording submerged archaeological sites from the air. Application du LiDAR en archéologie / application of LiDAR surveys in archaeology. IUPPS commission: Theory and method in landscape archaeology. Institut d'Art et d'Archéologie, University Paris. Paris, France, 06.03.2013.
- Mandlburger, G.; Hollaus, M.; Eysn, L.; Mücke, W.; Otepka, G.; Karel, W. et al. (2013): 3D Punktwolken sind mehr wert … VoGIS-Fachforum 2013. Feldkirch, Österreich, 21.11.2013.
- Trinks, I.; Verhoeven, G.; Kucera, M.; Nau, E.; Sevara, C.; Doumas, C. et al. (2013): 3D Digital Documentation of Akrotiri: Architecture, Wall-paintings and Finds. Paintbrushes. Wall-painting and vase-painting of the 2nd millennium BC in dialogue (2013). Fira, Thera, Greece, 24.05.2013. Online verfügbar unter http://www.uoi.gr/files/attach/chrosteres_paintbrushes/CHROSTERES_BOOK.pdf.

- Verhoeven, G. (2013): Archaeological Society seminar series Breaking new ground from the air - Some recent technologies for the benefit of aerial archaeology. UCD Archaeological Society seminar series. University College Dublin. Dublin, Ireland, 24.10.2013.
- Zotti, G. (2013): Archäologie einer Landschaft - Steinabrunn und mittel-neolithische Kreisgrabenanlagen. Verein Kuffner Sternwarte. Großmugl, Österreich, 12.10.2013.

6.5 Other lectures (not included in conference proceedings)

- Doneus, M. (2013): Die Visualisierung als Blackbox? Zur Bedeutung von Metadaten bei digitalen Geländemodellen. Strategien der Visualisierung in den Geisteswissenschaften: Probleme und Chancen. 4. Workshop des Forschungsschwerpunkts der Historisch-Kulturwissenschaftlichen Fakultät. Wien, 26.04.2013.
- Doneus, N.; Doneus, M.; Briese, C. (2013): Archaeological prospection: New techniques for terrestrial and submerged sites in shallow water in Mediterranean. Parcours et échanges en Méditerranée. École française de Rome. Besançon, France, 19.10.2013.
- Pregesbauer, M.; Altenberger, A.; Michel, R. (2013): New advances in airborne imaging spectroscopy for very high resolution preospection applications demonstrated on an open pit mine. 75th EAGE Conference & Exhibition incorporating SPE EUROPEC 2013. EAGE. London, United Kingdom, 10.06.2013.
- Pregesbauer, M.; Michel, R.; Altenberger, A. (2013): Fusing multi source Remote Sensing Data – selected aspects on geometric and thematic accuracy. 75th EAGE Conference & Exhibition incorporating SPE EUROPEC 2013. EAGE. London, United Kingdom, 10.06.2013.
- Pregesbauer, M.; Michel, R.F.M.; Altenberger, A. (2013): Exploiting the information on airborne imaging spectroscopy data – practical aspects to enhance the potentiality. Geoinformatics 2013: XIIth International Conference "Geoinformatics: Theoretical and Applied Aspects". EAGE. Kiev, Ukraine, 13.05.2013.
- Ruš, M.; Doneus, M.; Verhoeven, G. (2013): Current options of airborne spectroscopy for the detection of archaeological vegetation marks. Forum of young geoinformatics 2013. TU Zvolen. Zvolen, Slovakia, 02.05.2013.
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- Ruš, M.; Doneus, M.; Verhoeven, G. (2013): Evaluation of airborne imaging spectroscopy for the detection of archaeological vegetation marks in Carnuntum, Austria. AARG Annual Meeting 2013. DECARS; RCE. Amersfoort, Holland, 26.09.2013.
- Verhoeven, G.; Wieser, M.; Briese, C.; Doneus, M. (2013): ω, ϕ and κ – random Greek characters or important variables for aerial archaeologists? AARG Annual Meeting 2013. AARG & Dutch Expertise Centre for Archaeological Remote Sensing. Amesfoort, Holland, 27.09.2013.
- Zotti, G. (2013): Computerbasierte Methoden zur Archäoastronomischen Landschaftsanalyse. Tagung der Gesellschaft für Archäoastronomie. München-Gilching, Deutschland, 31.10.2013.

6.6 Data publications

- Roncat, A.; Wieser, M.; Briese, C.; Bollmann, E.; Sailer, R.; Pfeifer, N. (2013): Digital surface model, hillshade and Lambertian reflectance model of the rock glaciers Oelgrube and Aeusseres Hochebenkar. Data Provision at PANGAEA, project: C4 Austria, funded by ACRP (Austrian Climate Reasearch Program);. Online verfügbar unter http://doi.pangaea.de/10.1594/PANGAEA.816225.

6.7 Masterthesis

- Nau, E. (2013): Die Ergebnisse der interdisziplinären stratigraphischen Grabung Schwarzenbach-Burg, Schnitt 5, 2002 bis 2003. Prospektion, Stratigraphie und Fundvorlage. Unpublizierte Diplomarbeit. Universität Wien, Wien.
- Wallner, M. (2013): Die späteisenzeitliche Eisenverhüttung im Oberpullendorfer Becken. Eine quellenkritische Analyse zum Stand der Forschung. Unpublizierte Diplomarbeit. Universität Wien, Wien.