GIS based processing of multiple source prospection data in landscape archaeology

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ABSTRACT:

In a project dealing with landscape archaeology the Institute for Pre- and Protohistory of Mainz University and the Institute for Spatial Information and Surveying Technology (i3mainz) of the University of Applied Sciences Mainz have been examining the area around the Celtic oppidum “Hunnenring” in the northern Saarland (Germany) since the end of 2006. Its wall is partly preserved up to a height of 10 m, which makes it one of the largest Celtic structures of its kind. Various sources indicate that the low mountain range, which is nowadays situated peripherally, used to be a significant centre with supra-regional importance in Celtic times. Aided by various archaeological prospection methods and the use of methods of applied geoinformatics and surveying technology it is attempted to reconstruct the pre- and protohistoric habitat as detailed as possible. A special focus is made on tracking early use of resources and on the question to what extent local iron and copper-ore deposits affected economic activities of people.

However in this project we used a combination of different archaeological prospection techniques and methods of modern 3D-surveying technology to achieve this aim. A conventional method to record anthropogenic characteristics of the relief is surveying with a total station. The recorded terrain points are used for creation and visualization of a Triangular Irregular Network (TIN) in a GIS. By this means very fine characteristics of the relief, like terraces of settlement, old routings and historical mine shafts can be documented. *Airborne Laser Scanner Data* were used for 3D modelling of the complete investigation area because of their potential to capture a dense cloud of terrain points in high quality, particularly in wooded areas, where good conservation of archaeological structures is indicated. For selected regions a *Terrestrial Laser Scanner* was used to generate a *Digital Elevation Model* (DEM) of even higher resolution. A conventional archaeological prospection technique is the surveying of single finds. For this purpose a ploughed acre was paced off systematically and the positions of single finds were recorded by using *total station and GPS*. Particularly for detection of sub-surface metalliferous materials the use of *geomagnetic prospection* is a very helpful method. Recording and analysis of anomalies of the earth magnetic field yields a method to detect ditches, pits and other filled-in intrusions of the ground, but also high temperature areas e.g. caused by smelting. The surveying of such anomalies was executed by capturing data along a regular pattern in the field. The measuring values were recorded in a dense interval in a decimetre range. The values of anomaly measurement were represented as gray scale values.

The results of all measurements were integrated for visualization in a GIS and applied for further analysis. High-resolution DEM, which have been generated using Airborne-Laserscanning (ALS) data, are a core component. The information, that was generated using various methods such as geophysics, surveying of single finds, ALS and excavations, in combination with significant factors such as soil quality, geology, waterlogging, slope and water proximity, can be included well in analysis of settlement history.

1 INTRODUCTION

The reconstruction of a pre- and protohistoric habitat with its network of human settlements, sacred places, cultivation- and field areas and natural resources is referred to as landscape archaeology. For work on a landscape scale rather than excavating particular sites, a new methodology has to be established (Campana & Francovich 2003). Hence research here relies on special prospection techniques like surveying of single finds, geophysical prospection and aerial archaeology, which all aim at retrieving historical sites without disrupting their archaeological context.

In recent times landscape archaeological research increasingly uses methods and technologies of photogrammetry and geoinformatics for approximation of the prehistoric habitat. In particular Airborne Laserscanning (ALS) is applied in archaeology to produce detailed relief maps of archaeological sites (Challis 2006; Sittler 2004). High resolution Digital Elevation Models (DEMs), which can be generated from ALS-data, enable a detailed representation of the earth's surface. In particular wooded areas, which can only be prospected very laboriously and even aerial archaeology is of limited use here, reveal the excellent prospects of using ALS data for archaeological purposes (Kraus & Pfeifer 1998; Devereux et al. 2005). Still in woodlands even the accuracy of ALS-Data is sometimes insufficient, but at least smaller areas containing archaeologically interesting structures can be detected by use of Terrestrial Laser Scanning (TLS). A Geographic Information System (GIS) provides for good capabilities to visualize and combine the information gained by different methods. As an analytical tool GIS helps to identify indications for further prospection activities.

2 AREA OF STUDY

The Celtic oppidum "Hunnenring" with its fortified walls preserved up to a height of 10 m is situated on the ridge of the Dollberg Mountain *(Fig. 1)* in northern Saarland (Germany). The large amount of human resources needed for construction of these fortifications indicates that this Celtic town from the 2nd and 1st century BC used to be a significant centre of supraregional importance and also a home to the local elite. Whereas for the second and first century BC the Dollberg plateau served as a central settlement for a major community, other finds from the immediate vicinity indicate that settlement activities continued throughout the following Roman period as well (Wiegert 2002).

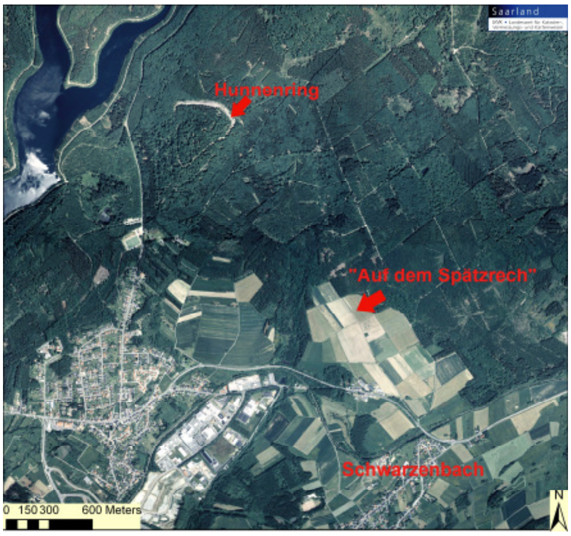

Fig.1: The Area of Study

From an archaeological point of view one important focus of interest lies on the question which economic factors influenced the Celtic-Roman settlement in this nowadays peripherically situated region. Until mid 19th century the region around the "Hunnenring" was an important centre for mining on local copper and iron-ores, resources that may also have been an important economic basis in Celtic and Roman times. Hence the intention of landscape archaeological research in this area is to find proof of prehistoric mining activities for iron and copper ore. To achieve this aim, selective prospection of archaeological sites in the region is conducted.

In 2007 prospection work concentrated on an area of appr. 20 ha, which is situated 1.2 km southeast of the "Hunnenring" close to the village Schwarzenbach *(Fig. 1)*. In this area a Gallo-Roman temple was excavated in the 1980s and only recently the remains of a civil settlement (vicus) in the vicinity were unearthed, located on the nowadays agriculturally used subdistrict “Auf dem Spaetzrech” (Miron 2000). The site is surrounded by protected spruce plantation areas and mixed forest. Towards the northeast the wooded Muenzbach valley represents a distinctive score in the terrain. Here our prospections aimed at gaining further knowledge about the expansion of the settlement.

3 METHODOLOGY AND RESULTS

A combination of different archaeological prospection techniques and methods of surveying technology was used to achieve this aim. The results were used for visualisation in a GIS and applied for further analysis. In the following sections the used methods of prospection and their results will be described and discussed.

3.1 *Laserscanning*

Recording anthropogenic structures by means of a total station is the conventional method used in archaeological prospection for documenting fine characteristics of the relief, like settlement-terraces, old routings and historical mine shafts. The recorded terrain points are used for the creation and visualization of a Triangular Irregular Network (TIN) in a GIS. In the recent past ALS-Data are used increasingly for these archaeological applications because of their potential to determine a dense point cloud (up to several points per m²) in high quality.

In our area of study some topographically interesting areas were explored in order to outline significant landscape-features. Especially the relief of the Muenzbach valley shows a multiplicity of significant anthropogenic changes like for example a recent stone pit, a footpath and some distinctive patterns of boulders. All this leads to the hypothesis of an ancient pathway connecting the “Hunnenring” to the nearby Roman settlement. In order to achieve a most homogeneous representation of the terrain with regard to detail DEM’s were generated by means of total station data, ALS data and TLS data.

The survey of the terrain by total station was accomplished by a total of 17000 points, with a point density of up to 4 points/m² in the Münzbach valley. In GIS ESRI ArcGIS a TIN was generated from the measured points. Also in ArcGIS a TIN was calculated from ALS data with an average point density of 1.5 points/m². The resulting DEMs show a clearly recognisable structure to the south of the Roman temple, which has the shape of a rampart *(Fig. 2)*. During excavation in the 1980s this rampart was misinterpreted as being the border of the Roman settlement.

The area of the recent stone pit was surveyed by means of TLS. A 1 ha size area consisting of the recent stone pit and its surroundings was recorded with the Leica Laser Scanner HDS 3000 with a terrain point accuracy of 15 cm. The single scans were registered in the program *Leica* Cyclone and thinned out by a special software-development from the i3mainz and visualized as a TIN in ESRI ArcScene *(Fig. 3)*. As a result a line structure, which slopes down into the river valley of the Muenzbach and which continues on the other side of the shore can be associated with the already mentioned patterns of boulders, suggesting a direct connection to the “Hunnenring”.

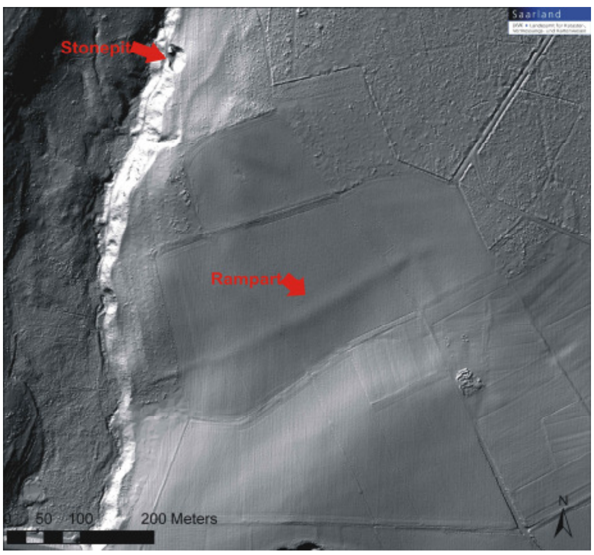

Fig. 2: Shaded DEM of the Area of Study

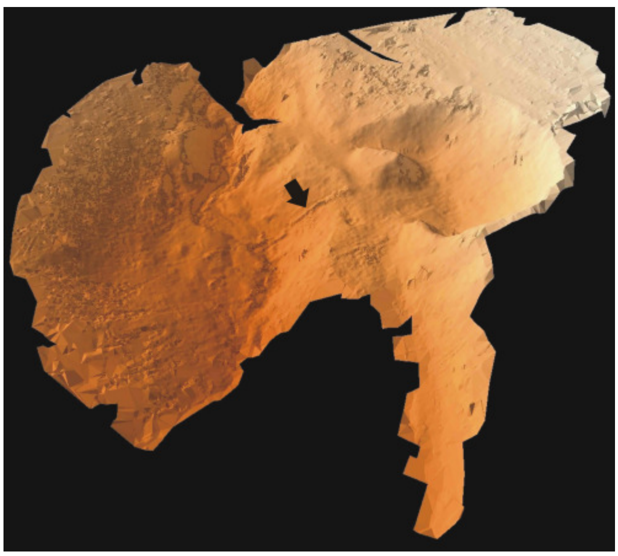

Fig. 3: The recent stone pit visualized in ArcScene

3.2 *Recording of single finds*

A conventional archaeological prospection technique is the surveying of single finds (Gillings 2006). For this purpose a ploughed acre is paced off systematically and the positions of finds are recorded by using total station or GPS. However in woodlands only selective prospection is possible. In this case soil exposures of every kind are used: waysides, lanes of forest vehicles, river beds, root plates or other places without vegetation. Typical and common soil exposures on meadows are molehills. In order to interpret the disposition of archaeological finds in molehills the position of every single molehill has to be recorded. By this means a differentiation between areas with finds and areas without can be achieved.

In our area of study single finds were recorded in the centrally located agricultural cropland and the forests northwest of the temple. On wasteland and meadows about 273 molehills were prospected and investigated for finds. Approximately 1400 single finds were categorized and visualized in ArcGIS *(Fig. 4)*. It turns out, that the major part of the finds consists of brick fragments, which concentrate clearly on an area south of the temple. Thus this area can be interpreted as the centre of the former settlement. Towards the south finds are thinning out with increasing distance. A major number of bricks was found in the forest northwest of the temple and in the Muenzbach valley. Therefore the allocation of the finds extend to an area larger than suspected before, indicating that the settlement had a greater expansion than previously assumed.

3.3 *Geomagnetic prospection*

Particularly for detection of metalliferous materials the use of geomagnetic prospection is a very helpful method. Geomagnetic prospection utilizes the property of the terrestrial magnetic field to induct every kind of material magnetism. The level of induction can differ considerably for geomagnetic sensitive materials like stone, metalliferous objects, pottery or high temperature areas (e.g. in sections of smelting) (Froehlich et al. 2003).

The geomagnetic survey is executed by means of special instruments (Caesium-Magnetometer or Fluxgate-Gradiometer) and used to locate and delimite magnetic objects by capturing the anomalies along a regular pattern in the field. Measuring values are recorded in dense interval in a decimetre range and processed by using special software programs for geomagnetics or in stand alone image processing software. Here measuring values are represented in gray scale, particularly specified by requirement and estimation of a geophysicist.

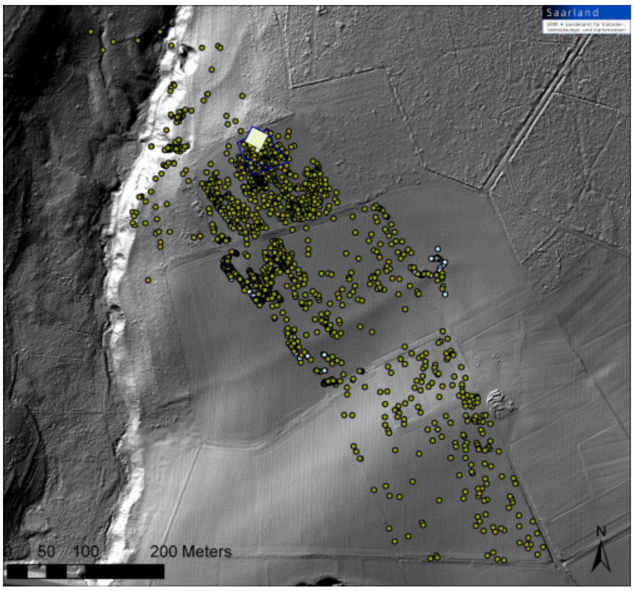

Fig. 4: Allocation of single finds on the Area of Study

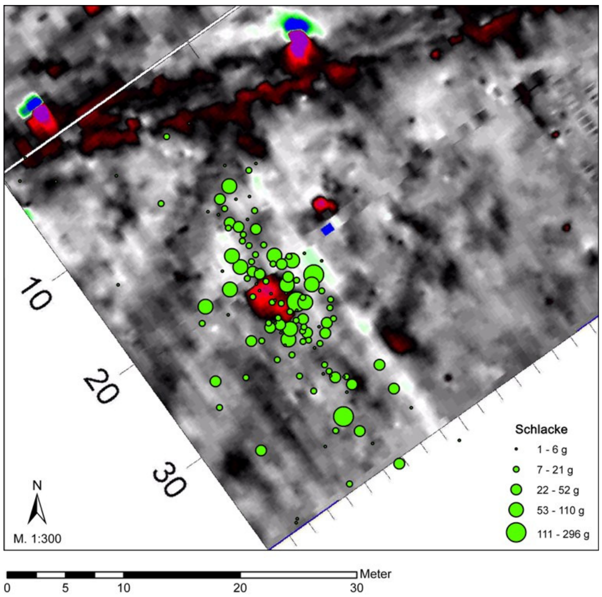

Fig. 5: Correlation between slag concentration and geomagnetic anomaly

On the Roman vicus-grounds the area adjacent to the south of the temple was prospected in a geomagnetic survey, the results of which were visualized in the program *Golden Software* Surfer. Two striking anomalies southwest of the temple can now be linked with metal-processing, since one of these anomalies was found to correlate with a peculiar high concentration of slags *(Fig. 5)*. Excavation showed a roughly 40 cm strong, thick dark grey up to black layer filling in a sewage pit and primarily consisting of slags, Roman bricks and fragments of pottery.

4 CONCLUSIONS AND FUTURE WORK

Using various prospection methods of archaeology and surveying techniques knowledge of the Roman settlement “Auf dem Spaetzrech” was improved significantly. Different methods of topographical surface recording were used to produce detailed topographical maps of the study area. The resulting DEM’s proved to be of great help to sharpen the image of the historical landscape. The results of geomagnetic prospection and of the collection of single finds were visualized in a GIS. It was shown that those single finds are distributed over a wider area than suspected so far, which means that the Roman settlement covered a larger area than previously assumed. The geomagnetic image was combined in a GIS with the distribution of slags and proved a correlation between geomagnetic anomalies and a high concentration of slags. During excavation this anomaly provided evidence of antique metal processing. An area of about 1 ha size in the Muenzbach valley was scanned with a terrestrial laser scanner to get a much more detailed image of the topography than was obtained from the results of ALS and topographical recording. The resulting DEM showed a small structure, which possibly belongs to a pathway connecting the Roman settlement with the “Hunnenring”. Processing of the TLS-data also showed that the use of a Terrestrial Laser Scanning TLS in wooded areas is a good alternative to ALS and conventional topographical recording.

Further research will concentrate primarily on the proof of mining, using ALS data as an important basis for archaeological prospection. In GIS important location criteria like spatial patterns of soil quality, geology, waterlogging, slope and water proximity will be managed and set in reference to the archaeological finds, in order to predict potential locations for further archaeological sites.

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