Wolfgang Neubauer, Immo Trinks, Roderick B. Salisbury, Christina Einwögerer
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Cover: Motorized magnetic prospection in the archaeological landscape of Uppåkra, Sweden.
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UPDATE ON THE SIMULATION OF ASTRONOMICAL ASPECTS OF MIDDLE NEOLITHIC CIRCULAR DITCH SYSTEMS

G. Zotti, W. Neubauer

1. INTRODUCTION

Since the 1980s, a large number of prehistoric circular ditch systems (Kreisgrabenanlagen, KGA) have been found in a large region of Central Europe. They were built by several contemporary culture groups in a relatively short epoch of the Neolithic (about 4850-4500 BC). The purpose of these huge monuments, which are always found close to a settlement, is still unclear, but a cultic function of some form (meeting or ceremonial place) seems most likely (Melichar and Neubauer, 2010).

The large diameters and distinct shape, usually with two or four well-defined entrances, also invite an interpretation that some form of ritual celestial observation may have played a role in their construction and use. For instance, entrances appear to be oriented towards sunrise or sunset at the solstices, as has been suggested by Becker (1996) for KGA in Bavaria, or towards the extreme lunar risings and settings known as lunistices for the KGA in Slovakia and Austria, as suggested by Pavúk and Karlovský (2004).

A preliminary archaeoastronomical investigation of 28 Austrian KGA in 2003/04, based only on interpretation sketches of the geomagnetic prospection results and a few horizon profiles created from a digital terrain model in a GIS, found a suggestive connection with a few solar dates (solstices and cross-quarter days, which are just between solstices and equinoxes, like our All-Saints day), as well as with a few conspicuous stellar objects. The stellar alignment in one KGA was presented confirmatively with a panorama image for a desktop planetarium program created from a virtual model built based on the magnetogram by an external company (Zotti and Neubauer, 2010). A presentation test in a planetarium, which seemed the natural choice for a possible demonstration to the public, proved problematic because the planetarium is only constructed to show the upper hemisphere, while our archaeological scenery should naturally also include the ground with a simulation of the prehistoric architecture (Zotti *et al.*, 2006). Therefore, desktop virtual reality seems better suited as a method for such presentations. The lack of properly surveyed horizon data called for a much more detailed study, which was performed during the ASTROSIM project (2008-2012) supported by the Austrian Science Fund (FWF) under grant number P21208-G19. Preliminary results were presented at AP2009 (Zotti *et al.*, 2009), and it is now appropriate here to present an update on the results.

2. SURVEYS AND DIGITAL MODEL BUILDING

New surveys of the horizon line have been taken in the field with a total station at all 31 magnetically prospected KGA in Lower Austria. The azimuth and altitude data were plotted into a diagram that showed solar, lunar and stellar diurnal tracks for the KGA epoch, and a panorama photograph was accurately fitted onto this measured horizon line, so that also the approximate distance to the horizon can be estimated. These horizons can be directly evaluated in a panoramic viewer, or can be imported into a desktop planetarium like Stellarium[1], which has been selected for astronomical visualization. This program offers a nice visualization of the night sky with exchangeable constellations, exchangeable horizons and ultra-wide projections, is free and open-source and therefore can be verified by studying the source code, and if necessary bugs can be fixed and extensions can be programmed as plugins.

For all KGAs, a piece of digital terrain model textured with a modern map, the magnetogram, and the outlines of the interpreted features were exported from ArcGIS 9.3 into accurately georeferenced models for the 3D modelling program Google SketchUp, where ditches were cut into the terrain and palisades were erected. SketchUp (meanwhile acquired by Trimble) can be extended with self-written Ruby plugins, and several plugins have been developed to aid in the development of virtual models for archaeoastronomical purposes. One of those directly allows the loading of a horizon panorama in the format used by Stellarium. SketchUp does not have a translation invariant skybox background node, so the panorama is applied to a spherical ring, which is linked to always surround the view camera in order to avoid parallax artefacts when the scene is viewed from different viewpoints. Looking along architectural features in the model in SketchUp, therefore, immediately shows whether an entrance as seen from another important point, like the centre or the opposing entrance, would lie in the direction of a rising or setting point of one of the celestial objects suspected to having had the attention of the builders, or to some distant conspicuous landscape feature, which also seemed to be a possibility of ritual orientation worth studying (Zotti and Neubauer, 2011). The georeferencing property could also be used for the correct simulation of solar shadows, but the Neolithic solstice positions are slightly different from those observed today and cannot be reached.

In addition, a panorama export plugin was developed, so that views from static viewpoints from any georeferenced SketchUp model can be presented in Stellarium. For a more accurate simulation of celestial positions, the atmospheric effects of refraction and extinction were also implemented and contributed to the main program (Zotti and Neubauer, 2012a). However, in the times of almost ubiquitous interactive 3D graphics, the ability of desktop planetaria to utilize only static viewpoints seemed a bit limited, and the project called for a more direct way of investigation and demonstration of the results relating to stars expected from the previous investigation. We therefore created a plugin for Stellarium that provides a 3D simulation of a foreground model, which is combined with the presentation of the night sky provided by the program. The accuracy of the simulation has been confirmed with a model of a modern astronomically oriented and motivated architecture created in Sketchup (Zotti and Neubauer, 2012b).

[1] Stellarium website: `http://www.stellarium.org` (visited 2012-10-29)

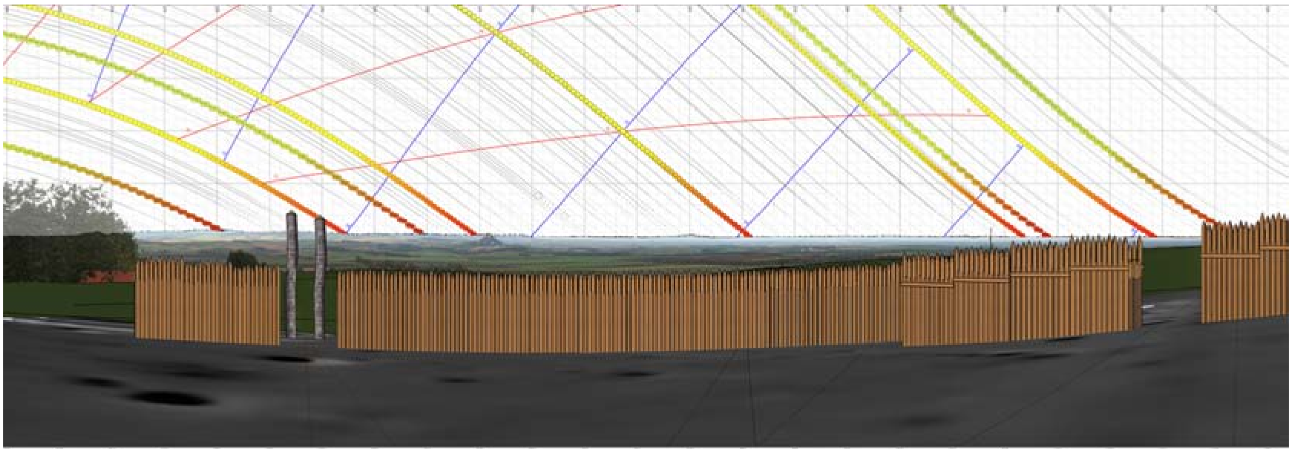

Figure 1: *A view from the center of KGA Altruppersdorf. The sloped terrain most likely allowed a view over the palisade. While the north-west entrance (right) coincides with the summer solstice sunset in this view from the KGA centre, the south-west entrance does not coincide in a similar way for the winter solstice.*

3. RESULTS

The modelling with panoramic photographs taken in the field during site visits and with a larger digital terrain model allowed the creation and investigation of KGA in their respective landscape. It also achieved a much clearer understanding of the KGA environments than was previously gained from virtual models, which only showed the earthwork itself, or of the static panoramas available previously for the desktop planetarium.

The first survey results seemed to confirm solar and stellar observations, although we also noted that the terrain may have been important as well, because often there was one entrance on the highest and one on the lowest point in the terrain. In KGA Steinabrunn, a mismatch was detected between the surveyed horizon and the digital terrain model used for the previous virtual reconstruction panorama, which erroneously had shown a nearby hill, invalidating one of the previously identified solar orientations. KGA Gauderndorf entirely failed to show the stellar pattern suggested previously, but was clearly identified as having been slope oriented, and ultimately slope orientation, and not astronomical orientation, turned out to be prevalent on almost all KGAs, with the confirmed stellar orientation in Steinabrunn likewise explicable as being a top entrance. Only in late 2011, when LiDAR based digital elevation data became available, were we able to confirm the slope orientation with even more certainty. In several cases, a slope line analysis in the LiDAR-based DEM, smoothed to get rid of the smallest visible furrows, convincingly showed slope lines connecting two entrances in the modern surface, while the very homogeneous image of the magnetogram gave no indication of asymmetric erosion which would have tilted the terrain, so the same slope should have been prevalent in the original terrain (Figure 2). There seems to be only one KGA, Pranhartsberg 2, where one entrance, maybe even emphasized by two postholes, can be shown to be perfectly in line with the summer solstice sunset, while the opposing entrance appears to be disturbed but may well have been directed towards winter solstice sunrise, and where the entrance axis neither follows nor is perpendicular to the slope line. In a few other sites, a solar connection is still suggested but coincides with the slope pattern.

While most of the 3D analysis was done directly in SketchUp, the Stellarium plugin developed in parallel clearly showed an error in the stellar orientation of the previously generated static panorama mentioned above, and when other suggested stellar orientations were ruled out by the surveyed horizon elevations it became clear that the stellar hypothesis had to be abandoned entirely. However, the summer solstice sunset entrance orientation for KGA Pranhartsberg 2 can be simulated very convincingly (Figure 3).

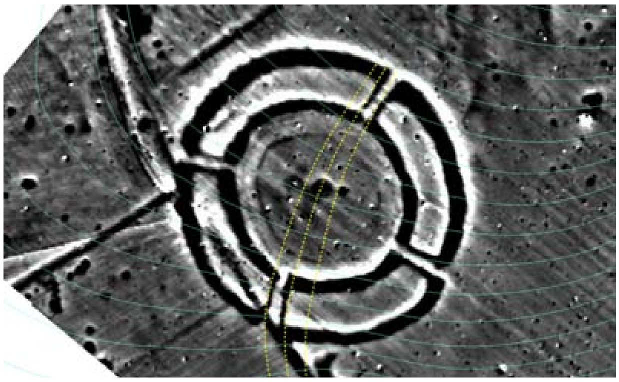

Figure 2: *A slope line analysis of a LiDAR based DEM in KGA Steinabrunn shows a very simple explanation for the layout of two entrances. The terrain slopes from the northeast down to the south-west entrance (Zotti and Neubauer, forthcoming).*

4. CONCLUSION AND PERSPECTIVE

This result, totally inverting the previous assumptions, certainly appears disappointing for supporters of widespread systematic ritual sky observation, but shows clearly the necessity of combining results from geophysical or other archaeological prospection or excavation, which is traditionally only published in flat maps, with an analysis of a reasonably large piece of high-quality digital terrain model surrounding the monument in question in order to gain a better understanding of the topographical situation.

For presentation of stellar results we had expected to confirm to a wider audience, we had envisioned the use of the Stellarium plugin with a series of SketchUp models. However, without need

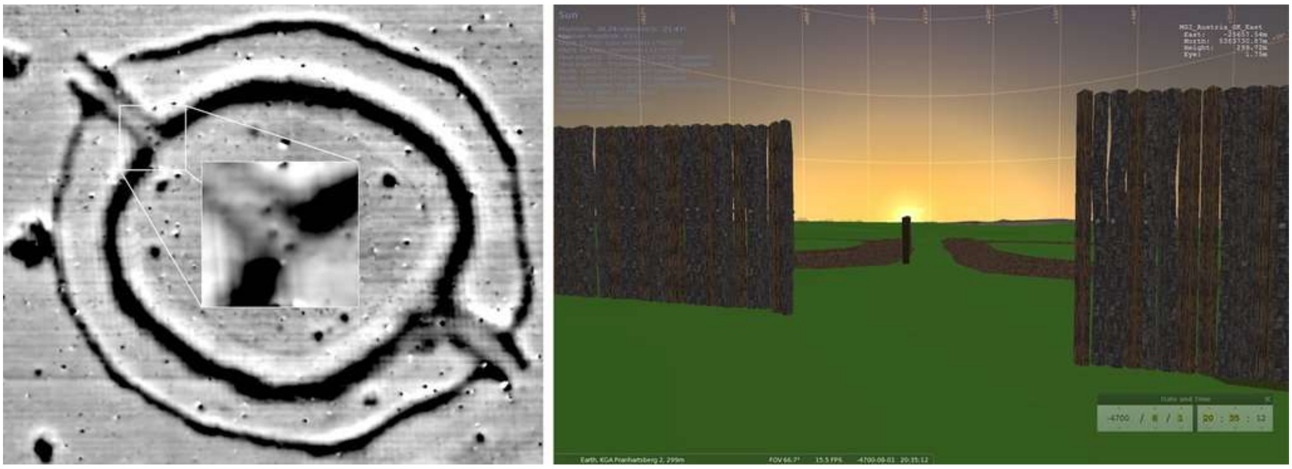

Figure 3: *Magnetogram with possible postholes in the northwest entrance, and Stellarium simulation of the summer solstice sunset in a virtual model of KGA Pranhartsberg 2.*

to simulate the night sky, we now intend to use the Unity3D[2] game engine to develop a high-quality interactive model of a considerably larger area surrounding KGAs Pranhartsberg 1 and 2, which should be based on the currently available archaeological knowledge of the terrain. Also this model will be capable of demonstrating archaeoastronomical circumstances.

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[2] Unity 3D website: `http://www.unity3d.com` (visited 2012-10-29)