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ASTRONOMICAL AND TOPOGRAPHICAL ORIENTATION OF KREIS-GRABENANLAGEN IN LOWER AUSTRIA

GEORG ZOTTI AND WOLFGANG NEUBAUER

Abstract: *Kreisgrabenanlagen*, monumental Neolithic circular enclosures, have been recorded in many places in central Europe. Some of them have been described as having entrances pointing to solar- or lunar-related declinations (e.g., solstices, lunistices). Over 40 KGAs have been found in Lower Austria, and the current ASTROSIM project investigates their potential astronomical use. Horizon data surveyed in the field are combined with previous results from geomagnetic prospection on a digital elevation model, and the reconstructed three-dimensional sceneries and virtual models can then be investigated for their astronomical potential. In contrast to a promising overview study, results for the Lower Austrian KGA are rather sobering in general, but there are a few solar oriented entrances which can be demonstrated with newly-developed software.

Keywords:Neolithic enclosures, Kreisgrabenanlagen, orientation, topography, GIS, Virtual Reconstructions, desktop planetarium

Introduction

Since the 1980s, a large number of a certain class of Neolithic circular enclosures has been discovered by aerial archaeology in a large area of central Europe, spanning several archaeological culture groups. Geomagnetic prospection and partial excavations clarified the characteristic appearance of these *Kreisgrabenanlagen* (KGA) with 1-3 (at least approximately) circular, V-shaped ditches enclosing up to 3 palisade rings and usually broken by 2 or 4 opposing entrances. Since the 1990s, the possible astronomical orientation of entrances has been discussed (e.g. Iwaniszewski 1996; Pásztor 2008). Becker (1996) has shown orientation towards the solstices for KGAs in Bavaria, while KGAs in Slovakia have been connected to lunistice directions (Pavúk and Karlowský 2004).

Previous work

In 2003/04, 28 ground plans derived from a then ongoing systematic campaign of geomagnetic archaeological prospection of KGA (Melichar and Neubauer, 2010) had been available for a first round of astronomical investigation. From these plans and several artificial horizons derived from GIS analysis, a slight pattern of systematic astronomical orientation of entrances and gaps in the palisades also in many Austrian KGAs seemed to emerge (Zotti 2010). Besides directions connected to the sun, also some orientations towards rising and setting points of a few stars which could then also otherwise be connected by simultaneous rising and setting events seemed to manifest themselves. However, a final conclusion was not possible at that time because information deemed crucial, especially horizon elevations, were mostly not available.

Project ASTROSIM

A thorough investigation of the possible astronomical orientation of the Austrian KGA had to wait for the current project ASTROSIM which is now entering its final phase. In this project we combine the results from

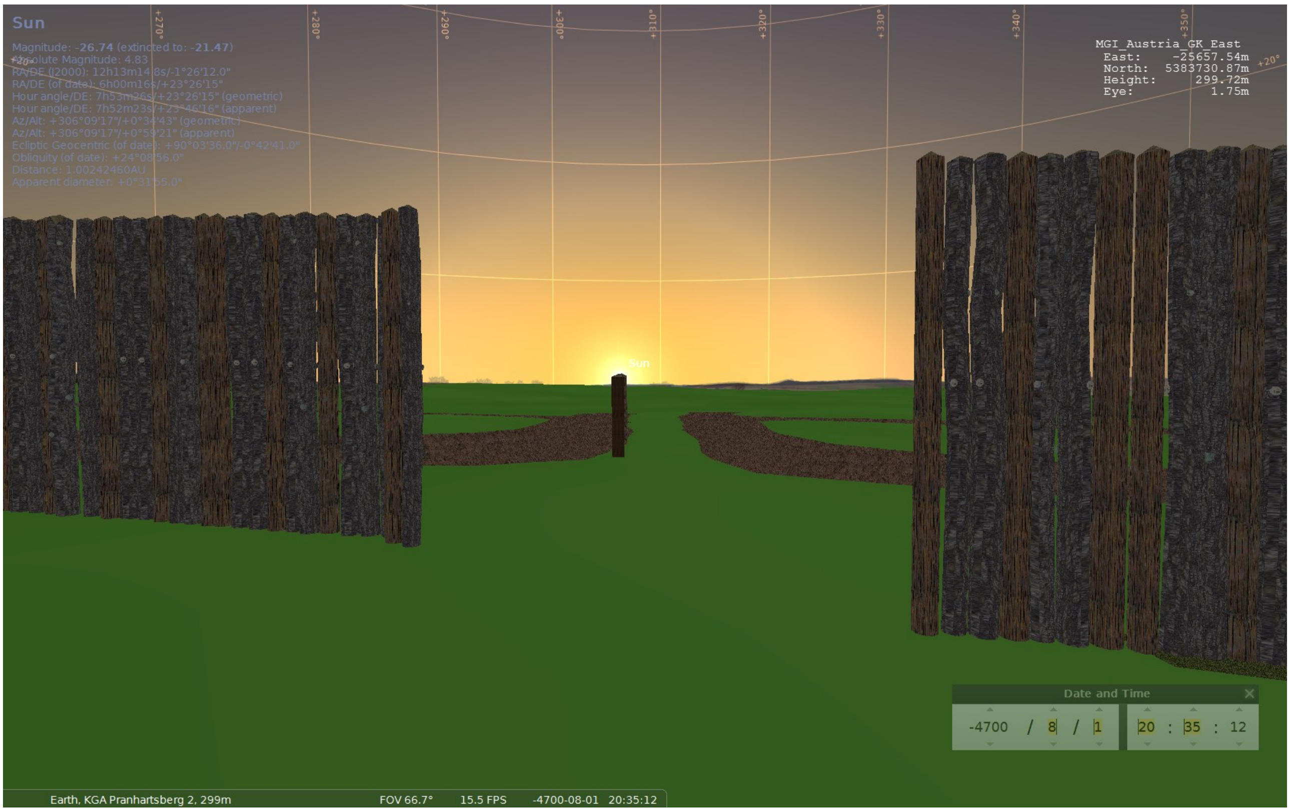

Figure 1: The northwestern entrance in KGA Pranhartsberg 2 with posts (filling posthole-like traces found in the magnetogram) just before solstitial sunset. Snapshot from the virtual walk through the 3D model displayed with the new Scenery3d plugin developed for Stellarium. The observer position in the survey grid used is displayed in the top-right corner.

the previous geomagnetic archaeological prospections, newly gathered survey data, GIS analysis, virtual reconstructions and a newly-developed three-dimensional walkthrough simulation in an advanced desktop planetarium program. First results of this project were presented at SEAC2010 (Zotti and Neubauer, in print). In this paper, we once more describe the project and then present the main results.

SURVEYS

Aside from unsharp soil and crop marks, nothing remains visible in today's landscape from these monumental structures, so there are also no physical remains like standing stones which could be analysed for their potential function as target markers against the horizon in a field survey. The only data that could be recorded in the field were accurate horizon profiles which were recorded with a total station and a digital SLR camera. The major part of the work had to take place in virtual space and required the combination of GIS and 3D modelling software and some new developments and extensions of an open source desktop planetarium program.

DATA PROCESSING

Horizon panoramas

As background for the measured horizon profile, a diagram with relevant astronomical data (azimuthal grid, declination curves, and solar tracks for solstices, cross-quarter and equinox sun as well as lunar tracks for the 4 lunistice declinations (including effects of topographic parallax) was developed. It also shows diurnal paths for the brighter stars for the epoch, with indications of their extinction altitudes for best and average visibility conditions following Schaefer (1986), and accounts for the raising effect of atmospheric refraction which appears to slightly shift all horizon intersections towards the north. The photographic panoramas were stitched with the open source program Hugin and aligned to the measured horizon line in an iterative process. The sky was then made transparent in Photoshop.

From this diagram-enhanced panorama, declinations and potential celestial targets of horizon intersections can be immediately read off, or, without the diagram, the calibrated panorama can also be used in modern desktop planetarium programs like the open source program Stellarium.

3D Modelling

A geographical information system (ArcGIS) is used to collect, manage and display all geographical data. Unfortunately, direct 3D modelling is almost impossible, requiring data export and the use of dedicated 3D modelling programs. An export plugin working in ArcGIS 9.3 allowed us to export, for each site, parts of a digital elevation model in TIN (triangulated irregular network) format, background map, georeferenced magnetogram and outlines of the main features (ditches, palisades) of the KGA into Google Sketchup. This modelling program is simple to use, available in a cost-free (but not open source) version and widely used especially to create the buildings in Google Earth. A huge advantage of this program over others is that models are georeferenced, that is, both geographical position on Earth and orientation are stored in the model file. Another plus is that it is extendable by user-written plugins. Sketchup also allows the proper simulation of shadows, but only for days past 1970, so that for solstices in prehistoric times, where the ecliptic was stronger inclined, either the geographical latitude can be carefully adjusted to achieve the required larger solstitial morning and evening amplitudes, or the scene can be slightly rotated for a single event.

In Sketchup, the maps, magnetograms and feature outlines were projected onto the TIN, and the ditches cut into the "virtual soil", and, where seen in the magnetograms, palisades were put up to provide an approximate representation of the past structures good enough for geometric evaluation. In this phase, to achieve a natural or even photorealistic look was not intended.

A loader plugin was developed for the panorama diagrams. A problem with the photo panorama is that it was taken only on one spot (the KGA centre), while in the 3D simulation we want to walk around on the terrain. If the horizon is sufficiently far away, the photo can however be used to represent a background of infinite distance. The Sketchup requirement of putting it on geometry of limited distance means this geometry, simply a part of a sphere, must be linked to the observer eye to avoid parallax shifts when moving through the virtual scene. Together with the panoramas, the actual astronomical investigation could now be performed on the models.

Astronomical Simulation

As mentioned above, we use Stellarium as desktop planetarium. It is still under active development, and during the project some shortcomings were observed and reported which must at the moment be circumvented, and should be corrected in future versions in order to create software that not only looks impressive, but also delivers correct, dependable results for its application in historical problems. However, being an open source project, everybody is invited to contribute! Effects that were contributed so far which are important to horizon astronomy were a correction of the horizon display and atmospheric refraction and extinction, available since version 0.11.2.

The biggest new development however is the still ongoing development of a new plugin which is capable of providing a three-dimensional walkable scenery. With this plugin, a landscape with building structures can be explored virtually in combination with the impressive astronomical simulation quality of Stellarium (Figure 1). Models can be exported in OBJ format directly from Sketchup or other modelling software.

Results

The first KGAs investigated in this detail nicely confirmed several preliminary results from the older study. A Deneb alignment was confirmed for KGA Steinabrunn on the measured horizon (and in this altitude also atmospheric extinction would not have impeded its visibility), and also several solar-related orientations towards the rising or setting points on the cross-quarter days (right between solstices and equinoxes) are indeed present.

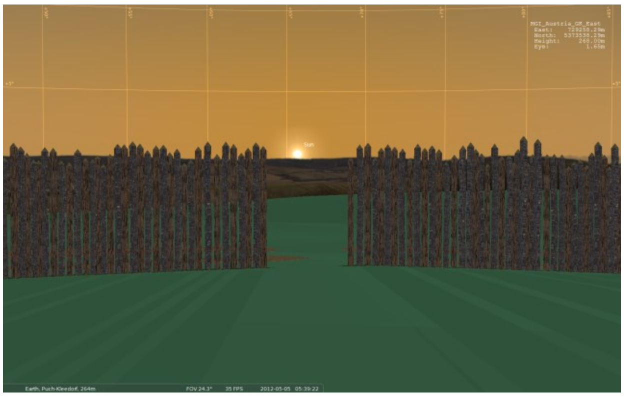

Figure 2: Summer cross-quarter sunrise at Puch, seen from the KGA centre. As satisfying as this confirmation of earlier results seemed to be at first, it could not be confirmed for many sites. In addition, this direction nearly coincides with the downward slope. Snapshot from the Scenery3d plugin developed for Stellarium.

On the other hand, from the site visits and first self-made virtual reconstructions, it became clear that the mental image of a KGA, as an enclosure providing a totally secluded space with the upper edge of the palisade wall forming the visible horizon, must be corrected. KGAs frequently, indeed almost always, have been erected on sloped ground, and so by their large diameter, an observer standing in the centre and looking down the slope will most likely have been able to see over the rim of the palisade and into the valley or counter slope, unless the palisade was unexpected high. The elevation difference between the highest and lowest point inside the area enclosed by the ditch (the inner, in case of multi-ditch KGA) is about 3.5m on average and exceeds 6 metres in KGA Friebritz 1. KGA Gauderndorf, with its two entrances outside the solar or lunar declinations, was thus immediately excluded from further astronomical consideration, when any possible stellar target of the south-eastern entrance turned out to be right in the valley, and the other direction also failed to meet the proposed bright star Deneb on the landscape horizon. In KGA Steinabrunn, the entrance pointing towards rising Deneb likewise was identified as being at the same time the entrance on the top of the slope, while the south-eastern entrance again was looking right into the valley, so that no star could ever have been observed from the KGA centre through this entrance.

Further, we had to notice that also the solar cross-quarter orientations, when confirmed with the measured altitudes, typically at least almost coincided with directions that were connected to the *aspect* (the azimuth in which the surface is oriented) of the terrain, either going up and down the slope, or following the contour of the terrain. A suspicion substantiated that we were on an unfortunate mission, and we should reconsider our classification attempts also with the simple topographic data of surface aspect and slope, data not available in the earlier study. In our 25m DEM, the slopes read off at the KGA centres average at almost 4 degrees (7%) and reach up to 6.4 degrees (11%). Of course, all the sites have been in agricultural use for centuries if not indeed millennia, and have therefore been under influence of erosive processes and also intentional changes like levelling and terracing. In a few KGA magnetograms one half of the ditch is better preserved than the other, suggesting that the terrain has eroded asymmetrically, which can also cause a slight rotation of the aspect. From our DEM we can of course only read the present value. However, we had now a second concept against which to test our azimuths.

DECLINATION DISTRIBUTION OF THE ENTRANCES

The classical result of orientation studies is usually a conversion from measured azimuths and horizon altitudes into astronomical declination, in the hope to identify a non-uniform distribution that shows a higher sample count in declinations of major significance, e.g., the solstice or lunistice declinations, or, if evidence is over-whelming and the sites can be dated, declination of stars that may then be interpreted as having been the subject of attention to the builders, for religious, calendrical, or for whichever other reasons.

Figure 3 is the "curvigram" representation (Ruggles 1999, 72) of the 87 declinations derived from the measurements of azimuth and horizon altitudes in the 32 sites. In this image, the declinations of the eastern entrances (pointing to rising declinations) are plotted pointing upwards, those for the western entrances (setting declinations) downwards. Every hump representing one declination with a slight allowance for uncertainty is plotted with identical weight, and a thick line represents the addition of all those entries.

We must observe that in fact no large groups of similar declinations can be identified, although winter and summer solstice sunrises and sunsets are represented with, in total, five entries: Pranhartsberg 2 (both), Alt-ruppersdorf (winter sunset), Stiefern (winter sunrise over

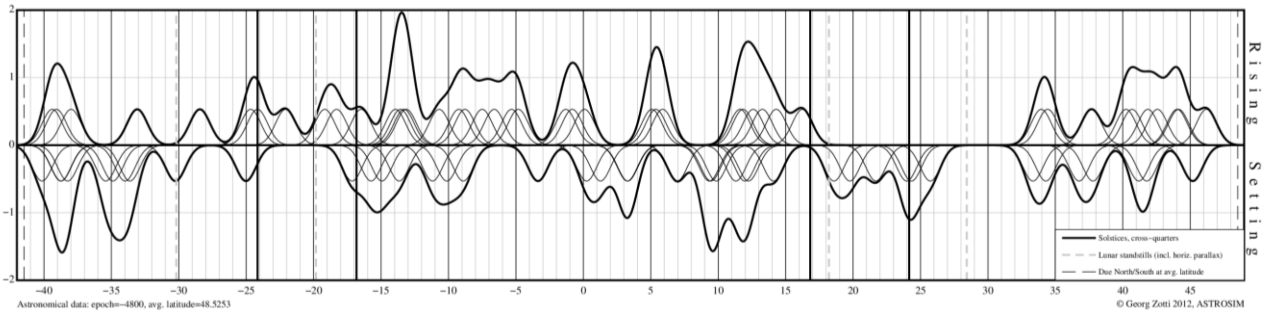

Figure 3: Curvigram plot for the declinations indicated by the 87 KGA entrances. Vertical thicker lines indicate solstices and cross-quarters, dashed lines indicate lunistices. There is no convincing evidence for systematic orientation towards any declination by more than 3-4 KGAs.

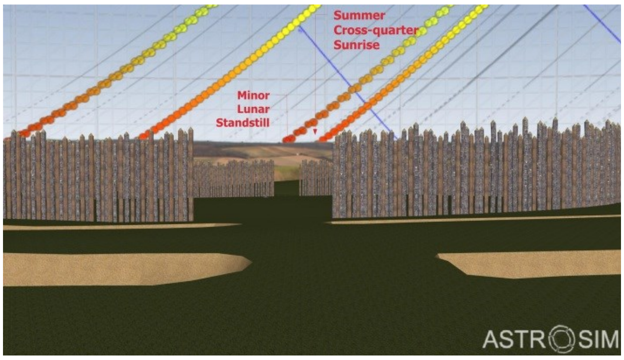

Figure 4: KGA Puch: The connection of the entrances points towards the Lunar minor standstill moonrise, but is also practically identical to the aspect, or terrain orientation.

an 11° high horizon) and Oberthern (summer sunset). In the incompletely preserved KGA Altruppersdorf in fact both solstice sunsets can be connected with entrances when observed from slightly different off-centre spots. The highest clustering of declinations seems to be present at -13.5° and +12°, which is interesting only in that these declinations are almost opposing each other. They represent otherwise insignificant solar longitudes about 30-35 degrees from the equinoxes, however with not more than 4 KGAs showing entrances towards these declinations, it seems not enough to propose any significant role for them. We must especially concede that the orientation towards the cross-quarter declinations, although impressively confirmed with shadow simulation in the virtual models for the neighbouring KGAs Puch (Figure 2) and Kleedorf and maybe KGA Pranhartberg 1 (here the sun rises over a nearby breakline which may however have eroded substantially) can only be further shown at KGAs Karnabrunn and Michelstetten if observed slightly off-centre, but at no other site, when the measured horizon is taken into account. This result represents in fact a severe defeat for any hypothesis on a connection with an observation-based solar calendar that took note of the cross-quarter days - any such observations, if performed at all, now appear to have been the exception, not the rule, for the KGAs in our study area.

Regarding lunistice declinations, the 2004 study already had turned out negative, and the only good match we could now find is for the southern major standstill moon setting at KGA Pranhartsberg 1, which however is also its top-most entrance, making its deliberate lunar connection unlikely. The south-eastern entrance at KGA Rosenburg is close enough in line with an observer slightly off-centre to suspect a connection with a major standstill moon rising over the adjacent cliffs, but is likewise entirely explainable by downslope orientation. At KGA Puch, the line connecting the entrances towards east-northeast coincides indeed with minor standstill moonrise (Figure 4), but at the same time is practically identical to the direction down the slope (Figure 5). The south-western entrances both of KGA Schletz and Michelstetten point steeply upslope and clearly miss any lunistice direction suggested by Pavúk and Karlovský (2004, 276). A sight line towards the minor standstill setting moon at KGA Kleinrötz proposed by the same authors is geometrically possible, but its intentionality in the light of the results above appears rather unlikely.

SLOPE ORIENTATION OF ENTRANCES

Only in late 2011 new Lidar (airborne laser altimetry) data of the KGA sites have been available to us for even more detailed investigation of the now-suspected slope orientation. Lidar provides a highly accurate digital surface model, with typically several samples per square metre, which means that the data even had to be smoothed with a low-pass filter or else both aspect and slope orientation are susceptible to the local roughness of plough furrows visible in the terrain data. With such high-resolution data it was possible to measure reliable data of local aspect and slope variations not just in the centre, but at each entrance, which made a significant difference in some cases. In the GIS it is possible to create a line following the local slope down into the valley (Figures 5, 6). An interesting example is shown in figure 6 for KGA Steinabrunn: Released next to the top entrance, the line runs through the central area and bends right into the direction of the opposing entrance, which always had appeared to be misaligned as seen from the KGA centre. This means, at least in today's surface, the direction of the lower entrance path exactly follows its own ground aspect, and not the line connecting it to the centre of the KGA. Similar slope line results can be seen

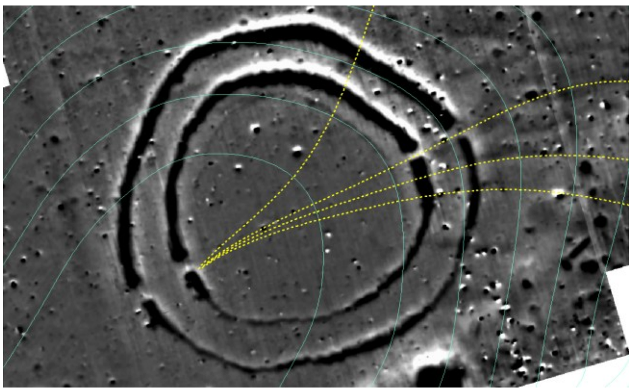

Figure 5: Slopelines, released near the „winter crossquarter" entrance of KGA Puch. According to the Lidar data this is the highest point of the KGA, and local slopes diverge, still a direct line exits through the diametrically opposing entrance. Contours are 1m apart.

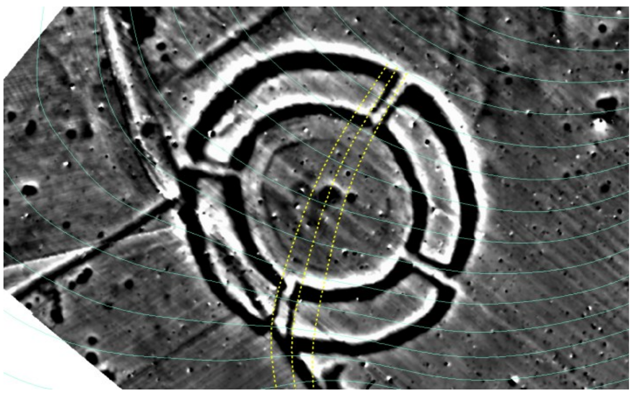

Figure 6: Slopelines, released near the northernmost entrance of KGA Steinabrunn. Again this is the highest point of the KGA, and local terrain curvature even explains the apparent twist of the opposing entrance as following the local terrain aspect*. Contours are 1m apart.*

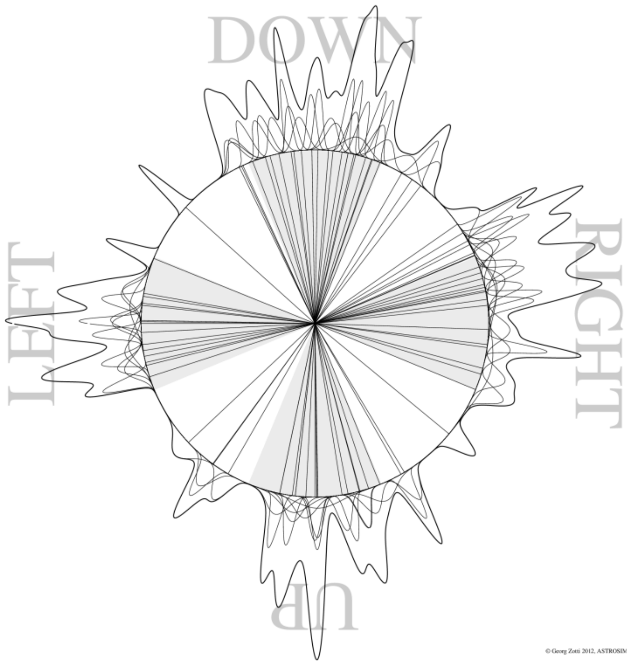

Figure 7: Circular curvigram and indicators of deviations of entrance azimuth from the downward-pointing azimuth, or aspect*, of the site's sloped terrain. The observer is standing at the entrance and looks down the local slope, facing the* aspect *of the terrain. The orientation of the respective entrance plotted here is the deviation from the aspect. The distribution is distinctively uneven and reveals a preference for entrances pointing downward, upward or along the contour line, just keeping the height of the KGA centre. The grey "Maltese cross" bars are 45° wide.*

for many of our sites, and this seems indeed to provide a valid pattern for orientation preference.

Figure 7 is a circular variant of the curvigram which shows, in the inner circle, the difference of "aspect-azimuth", while the outer curves show again single humps for each entrance and again a summary curve. The slope of the terrain influences the weight of each contributing direction, so that steeper terrain (where also the downward direction is more apparent and can be more easily determined without instruments) causes a narrower, but higher hump. The distinctive Maltese cross pattern shows that indeed, with few exceptions, there is now a general preference detectable in the orientation of the KGA entrances, although it is indeed not related to astronomical activity, but simply to the up-, downward or sideways orientations also roughly as seen from the KGA centre. The rather broad "cross bars", caused by deviations from the exact surface slope direction of today derived from Lidar data, can be partially explained, at least in the cases where the terrain is not strongly sloped, by slight local changes in the exact orientation of agriculturally used surfaces caused by erosion and deliberate levelling. There are cases like Glaubendorf 1 where one half of the KGA is more strongly eroded than the other, also indicating changes in the local topography. The sites of two KGAs, Stiefern and Kamegg, have been terraced, changing aspect as well. KGA Strögen originally seemed to follow the pattern perfectly when measured from the older 25m DEM grid; however the Lidar data also suggest a larger deviation. An interesting site is Friebritz 1 with indeed cardinally oriented northern and eastern entrances, and a far less convincing southern entrance. It turned out that this KGA lies on the end of a low ridge, so that all three entrances face downward, and the only side without an entrance is pointing up the ridge.

Conclusion

In this paper we have provided an overview and summary of our results from our thorough interdisciplinary investigation of the orientation of 87 entrances in 32 Neolithic *Kreisgrabenanlagen* in Lower Austria. We have shown that, while indeed a few cases of solar orientation can be beautifully demonstrated, in general the entrances are much clearer correlated to the aspect, or surface azimuth, of the typically sloped terrain on which the KGAs had been erected, providing "upward", "downward" and "side" entrances. Any stellar orientation pattern previously suspected has dissolved entirely.

The Scenery3d plugin for Stellarium is still being developed and will be made publicly available for similar research. A publication of the numerical results and a detailed description of the situation at each KGA are in preparation.

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