

Virtual Reality Application Keltenwelt am Glauberg

New Approaches in VR for Archaeological Sites

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Abstract: Virtual (VR) and Augmented Reality (AR) have long moved from fancy tools used to solely impress an audience to important means that enable a better understanding of archaeological sites within their environs. The VR application of the museum of the “Keltenwelt am Glauberg” aims to add a new level of information by using the technical abilities of modern VR devices to explain the route that archaeologists have taken to reconstruct different views of a past long gone in an intentionally non-photorealistic but honest style that shows different solutions for reconstructions and gives room for the users’ own thinking and interpretation. The great potential of VR in the form of immersion and conveying a feeling of presence, was also used to design new experiential spaces on a 1:1 scale that can maximally serve the communication of archaeological research, methods and results, while at the same time enabling new sensory and spatial experiences. The result – which will be made available for Oculus Quest 2 devices – will be used for entertaining educational purposes in the museum, it also is the basis for further data and models that have been on display in exhibitions, presentations, publications and last but not least in an AR app that helps to explore and understand the Early Iron Age hillfort on the Glauberg.

Keywords: *Archaeology—Celtic Settlements—Virtual Reality—Virtual Reconstructions*

CHNT Reference: Beusing, R. Grellert, M., Posluschny, A.G. and Wölfel, N. (2025). ‘Virtual Reality Application Keltenwelt Am Glauberg: New Approaches in VR for Archaeological Sites’, *Proceedings of the 26th International Conference on Cultural Heritage and New Technologies*, Vienna and online, November 2021. Heidelberg: Propylaeum. doi: [10.11588/propylaeum.1449.c20752](https://doi.org/10.11588/propylaeum.1449.c20752).

Introduction

In the field of virtual reality (VR), improved displays and the simple creation of VR worlds have inspired museums to make greater use of VR devices in exhibitions and to explore boundary conditions for their use (Shehade and Stylianou-Lambert, 2020; Grellert, 2018). Evoking a sense of space, size and embeddedness is now possible in a simple way. The dimension of a building can be grasped as if you were standing inside of it. No other interface offers this possibility. At the same time, new forms of interaction exist. For a profitable use of this feeling of presence in the context of archaeology, a careful selection of topics, spaces, buildings, or settlement facilities as well as means of archaeological (re)constructions must be made (Cecotti, 2022). Exploiting these potentials, a VR application has been developed for the museum of the “Keltenwelt am Glauberg” (KWG), that uses

modern digital forms of mediation to present the latest research to the public in an innovative way, appealing in particular to a young audience.

The Glauberg is situated approximately 40 kilometers northeast of Frankfurt am Main. It encompasses an Early Iron Age ("Celtic") hill fort featuring abundant burials on its slopes. The fortification is encircled by an extensive ditch and rampart system, covering an area of about 200 hectares (Posluschny and Beusing, 2019). The virtual reality experience primarily focuses on reconstructing and conveying the historical significance of this site from the mid-1st millennium B.C. Furthermore, there are indications of human habitation during other periods, including the Middle Neolithic, Late Bronze Age, Late Antiquity, and the Middle Ages.

Though the famous Glauberg burials present a wide range of affluent accoutrements, but scarce visible remains of dwellings and settlement structures have survived. (Re-)Constructions of the hill-fort and its environs need to respect these issues. The VR application of the KWG therefore deliberately did not want to follow the widespread trend towards hyper- or pseudo-realistic reconstructions of archaeological facts and instead set its own accents and went new ways. The aim was not to achieve unambiguity, but rather, in accordance with a fuzzy state of knowledge, to show different solutions for reconstructions (Schreg, 2013) and to present background information on the sources and the scientific path that led to the creation of these reconstructions (Miera, 2020). In this way, the viewers receive similar information that the archaeologists also used to approach this past world.

Application Overview

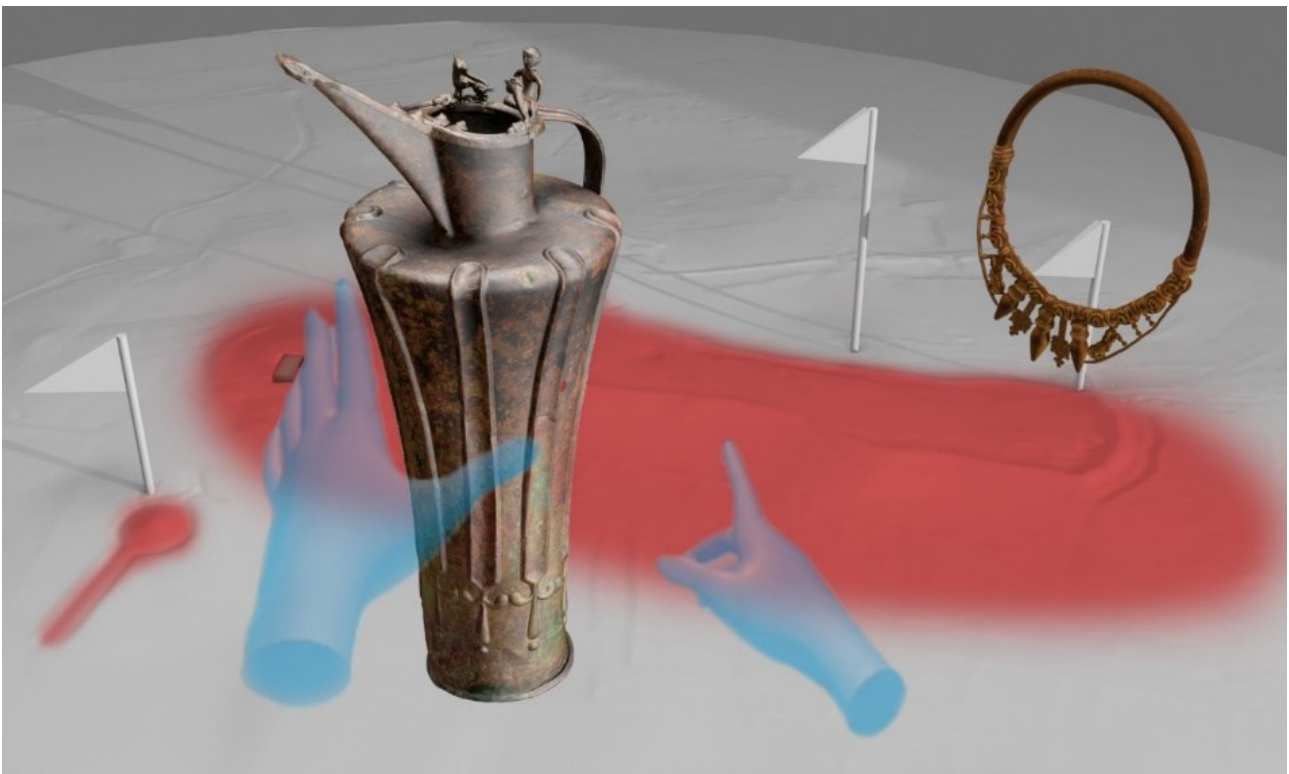


Fig. 1. Use of 3D scans created by Fraunhofer IGD in virtual scenarios. Here jug and necklace from burial 1 (© Landesamt für Denkmalpflege Hessen / hessenARCHÄOLOGIE, ALMhessen – Keltenwelt am Glauberg und Technische Universität Darmstadt, Fachgebiet Digitales Gestalten).

The VR application (available for the Oculus Quest 2) makes use of the interactive possibilities of the latest generation of VR glasses. Virtual objects can be held in the user's hands and viewed up close (Figure 1). The glasses recognise the hand movements and so it is also possible to immerse oneself in further VR worlds of the application by virtually "pressing a button".

Three levels of immersion support the use of the VR application:

1. The first level simulates the interior architecture of the real-world KWG. Users are welcomed into the virtual museum which addresses the bias between the well-preserved grave goods and the sparse information on the living world of the early 'Celts': 3D-scans of the burials' preserved metalwork are opposed to models of architecture and organic objects, which are usually less represented in the archaeological record. Moreover, the Glauberg landscapes in miniature give an overview of the local topography of the site. This first level explains the basic navigation options and the most important finds can be picked up virtually. Pictures and spoken texts explain them. In the first level, users can then select the two main virtual worlds: the plateau and the area below the plateau with the two burial mounds and a rural settlement.
2. The plateau and the area below each represent the second level. To meet the requirements of the fuzzy knowledge, a non-realistic impression was deliberately chosen for this second level of the VR world. In a rather reduced, comic-like style, users can reach the Glauberg's plateau settlement, the burial mound, or the rural settlement. In both areas the user can choose between seven sites (Figure 2). At each location they can look around and get an abstract idea of what it might have looked like in that place. Each of the seven locations has a deepening level.
3. The deepening levels are, for example, the interior of a Celtic house or a large-size archaeological laboratory room on the subject of the wall surrounding the plateau around 450 BC, in which different variants of the walls and an animation of the wall construction can be seen on a scale of 1:1. Only in the third level the user finds reconstructions that are not in a comic-like style, but appear more atmospheric, a little more realistic. But these reconstructions are only excerpts or examples and do not give the impression of being part of a complete photo-realistic world. Moreover, sources and scientific explanations are provided alongside these kinds of illustrations.

In the VR application, paradigmatic new paths have been taken in the contexts of VR, archaeology, and reconstruction (Cecotti, 2022). The great potential of VR in the form of immersion and conveying a feeling of presence, is not to be used to seemingly reconstruct a realistic-looking world (which in all honesty the archaeological sources would not be able to provide), but to design new experiential spaces on a 1:1 scale that can maximally serve the communication of archaeological research, methods and results, while at the same time enabling new sensory and spatial experiences.

Overall, the archaeological situation of the Iron Age on the Glauberg is difficult to interpret. The hilltop settlement was partially overlaid by a city in the planning phase, dating to the mediaeval Staufer period. Several of the settlement remains on the slopes of the Glauberg hill have been lost through erosion and farming and usually only the remains of very deeply dug structures have survived. For the 3D models, a basic ground plan was created based on the preserved features on site, which was supplemented by suitable parallels from other sites.

Many aspects on the Glauberg – as elsewhere – do not allow for an unambiguous reconstruction; here, possible variants were researched (e.g., for the house roofing, for the reconstruction of storage pits, etc.), which illustrate the necessary vagueness of the scientific hypotheses. The aim was not to present a staged past, but to allow the users of the application to participate in the scientific process of discovery on the basis of the data available on site and determined by analogies from other archaeological contexts. The narrative told is not the illusion of a past (Eide et al., 2019), but of the researchers trying to understand and reconstruct a past that is hard to decipher.

In a first step in 2020, the archaeologists compiled the latest research results related to the Glauberg's occupation as well as to Early Iron Age settlements in southern Germany and thus laid the foundations for the reconstruction. Several scenarios for VR on the Glauberg were conceived from an archaeological perspective and designed according to the current state of scientific knowledge.

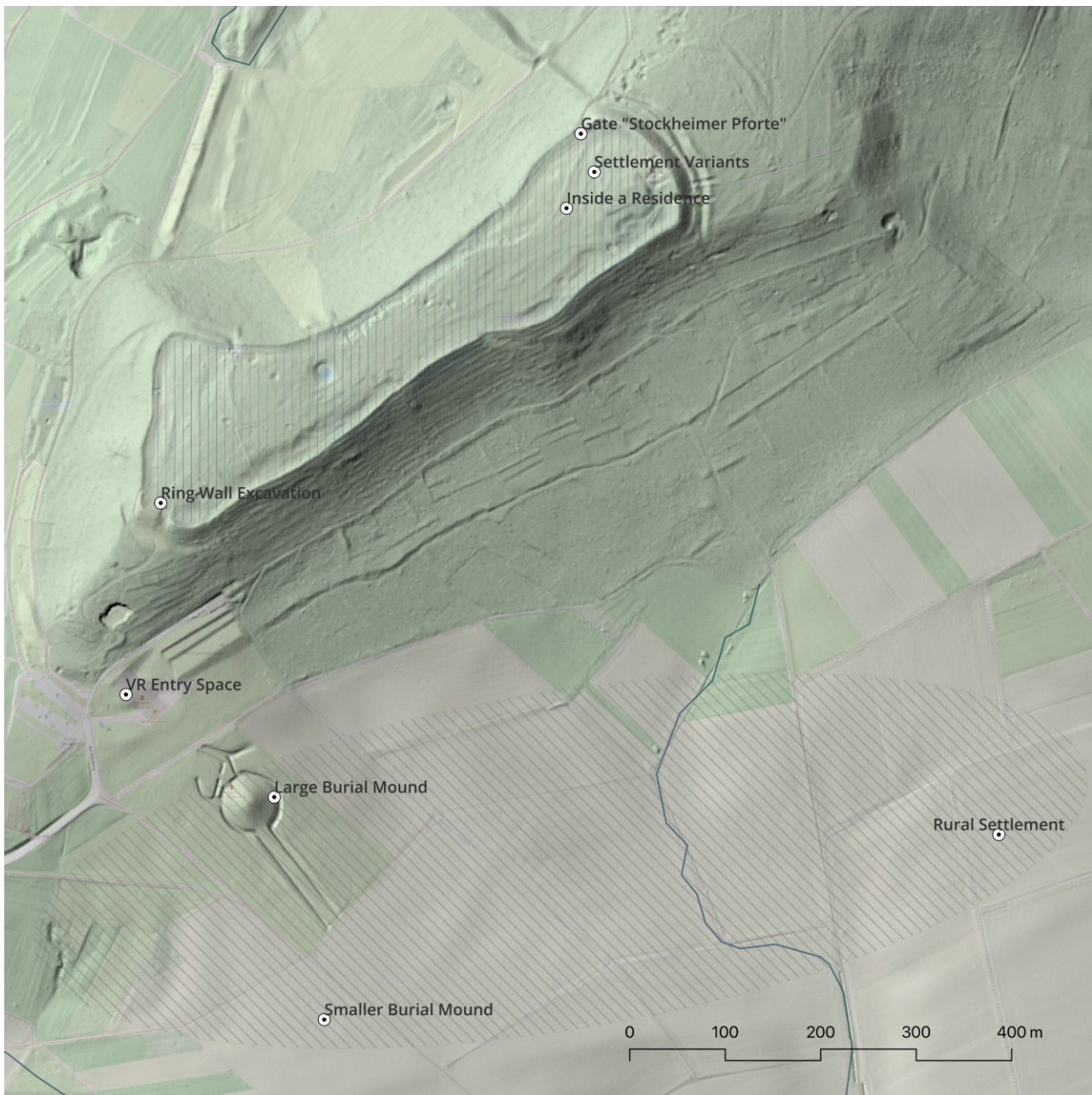


Fig. 2. Map with the location of the VR scenarios on the plateau und at the burial area. (© Landesamt für Denkmalpflege Hessen / hessenARCHÄOLOGIE, ALMhessen – Keltenwelt am Glauberg und Technische Universität Darmstadt, Fachgebiet Digitales Gestalten).



Fig. 3. Scenario “rural settlement” based on preserved local features supplemented by information from further excavated sites (© Landesamt für Denkmalpflege Hessen / hessenARCHÄOLOGIE, ALMhessen – Keltenwelt am Glauberg und Technische Universität Darmstadt, Fachgebiet Digitales Gestalten).

The archaeological findings and features on site were always at the centre of attention. Based on publications and previously unprocessed excavation and prospection documentation, the settlement and the sacred space around the main burial mound were evaluated and possible locations for scenarios were identified. From a list of suggestions obtained in this way, seven scenarios (Figure 2) were selected in consultation with the KWG Research Centre to be elaborated as 3D models for VR.

1. Circular rampart excavation (Figure 4) – in a laboratory surrounding the user can explore the results of an excavation of the wall from 1934 which give information about the construction of the wall. A simulation shows the wall’s construction and different suggestions are presented for battlement and roofing.
2. Gate “Stockheimer Pforte” – typical gate for Iron Age ring-forts in the region. The user gets an impression of the reconstructed gate, it can be compared to gates of forts in contemporary civilizations in Poland, Greece and Babylon. Moreover, a panorama view of a real-world reconstruction of the Donau-gate at the Heuneburg in Baden-Württemberg is presented.
3. Variants of hill-top settlements – The medieval settlement on the Glauberg has completely transferred Iron Age settlement traces onto the plateau. Other elevated fortifications in Germany show very different settlement patterns, from loose groups of houses to dense, city-like development. In the scenario, the user can walk through settlements of varying densities or explore the different settlement proposals from a bird’s eye view.
4. Inside a residence – The user can enter a residential house and explore different living areas such as a cooking area, sleeping area or working area. They can grab different items and retrieve detailed information about architectural details and furnishings.

5. Large Burial Mound – The scene can be the construction of the tumulus with two graves and an empty pit in the center of the tumulus. The graves and findings can be brought up and the grave goods can be examined more closely.
6. Smaller Burial Mound – The smaller burial mound shows post positions, which could indicate a processional route during the act of burial. These architectural details are discussed. Furthermore, the burial and its grave goods can be examined more closely.
7. Rural Settlement (Figure 3) – several Iron Age rural settlements in the vicinity of the Glauberg were detected, but due to slope erosion they were not very well preserved. An exception is the chosen hamlet with deeply buried pit houses. Next to the three pit houses from the Glauberg, an Iron Age village from Hesse was used as a model for the uprising houses of the hamlet. The user can enter a pit house and explore variants of storage pits.

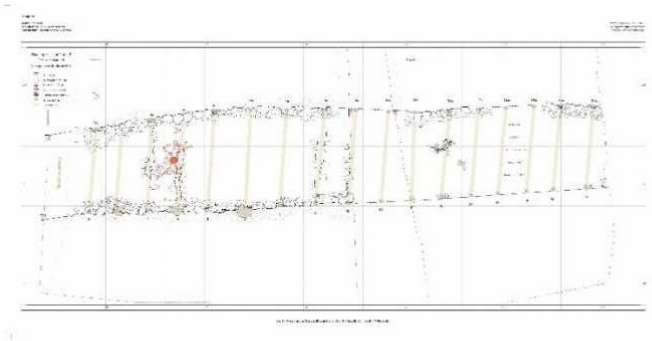
In order to do justice to the concept, it was also decided not to undertake a comprehensive landscape reconstruction, as no reliable statements can be made about this in detail. Only modern terrain was thus used as a “playing field” for the individual scenarios. For this purpose, a high-resolution LiDAR scan of the terrain had to be adapted and reworked for its use within the VR scenarios. In parallel, digital models of the enclosure wall, the settlement on the Glauberg plateau and known Iron Age building elements and settlement types were created. To distinguish the state of knowledge from the hypothesis, a search was made for practicable forms of representation for those buildings and structures whose models could be found in well-preserved features of other sites and in experimental archaeologically sound test arrangements. A total of seven scenarios (see above) could be modelled.

It is the aim to use the VR application in the museum of “Keltenwelt am Glauberg” (<https://www.keltenwelt-glauberg.de/en/>), and to also publish it for free on Oculus Quest 2 devices to not only enable visitors to emerge in the virtual world at the Glauberg itself but to also prepare their visit at home or to enhance their onsite experience after coming back home. Using VR technologies might also help to attract and inform new peer groups about the world of the Celts on the Glauberg and the archaeological research used to understand it (Mortara et al., 2014). The resulting model was at the same time also used for an AR application which is available in the respective app stores under the name “Keltenwelt AR”.

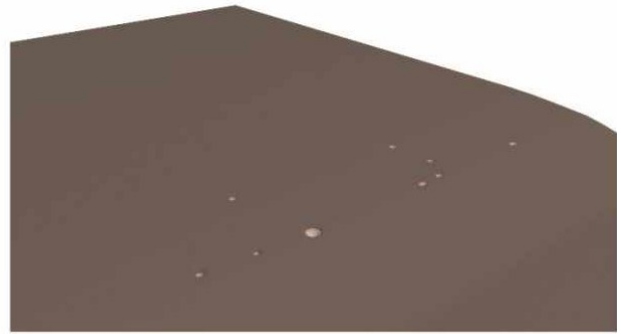
After starting the application, the users find themselves in an entrance room (Figure 5), which is designed in the architectural language of the museum and forms the transition between the real and virtual environment. In this room, the application is introduced by an intro that is both auditory and visually perceptible. It explains what can be seen in the initial room and how the users can dive into further levels of the application.

Structure of the VR application

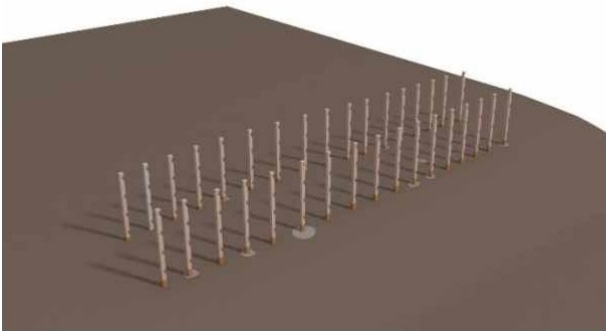
On the one hand, this room provides an overview of the content of the application. In wall niches, miniatures of reconstructed buildings can be seen, which can be visited during the application on a scale of 1:1. In addition, a room-filling model of the terrain at Glauberg extends at the feet of the users, providing an overview of the thematized surroundings. This model can be found in a scaled-down form within reach of the players. By pressing a virtual button, the user can dive into the other levels of the application.



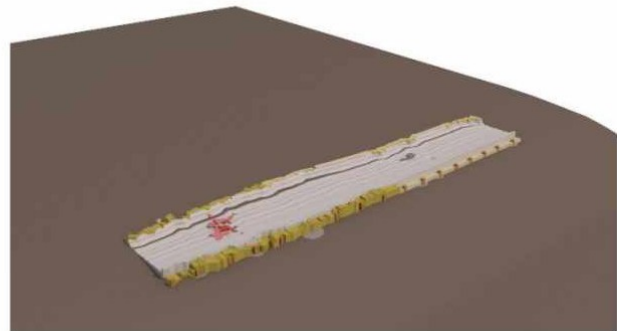
a) Archaeological documentation



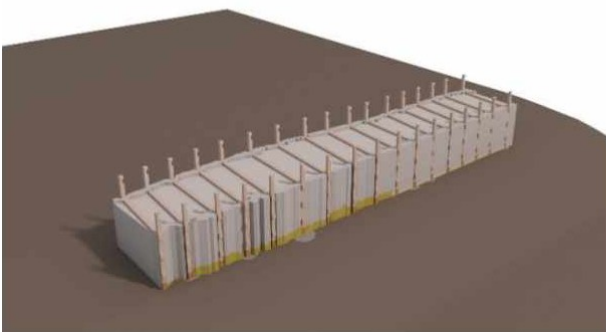
b) Modeling of the postholes as displayed in the documentation



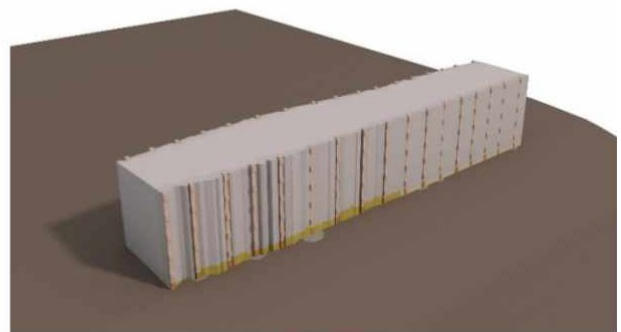
c) Modeling of posts



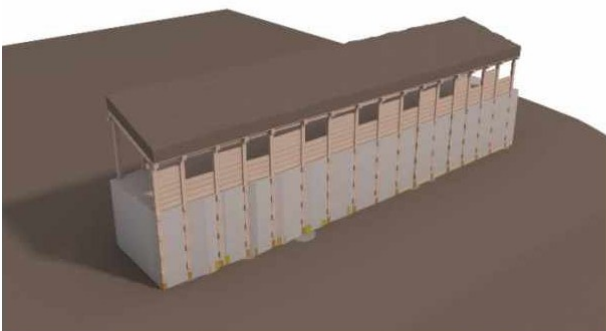
d) Modeling the wall base as documented from excavation analysis



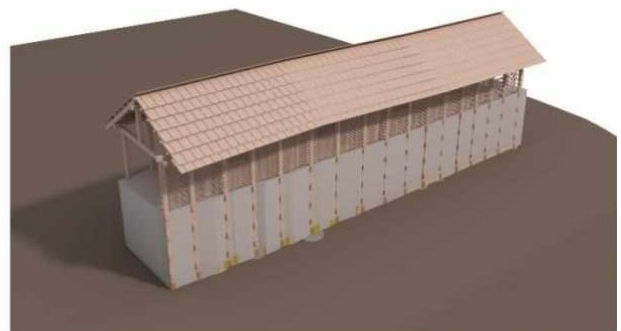
e) Structure of the wall body as found in similar walls from other archaeological sites



f) Supplementation of the wall body in different heights



g) Supplementation of battlement with chest defense in different variants – chest defense of wood planks and pent roof with reed covering



h) Supplementation of battlement with chest defense in different variants – chest defense of wickerwork and saddle roof with wooden shingles

Fig. 4. Wall surrounding the Glauberg plateau – reconstruction of the wall according to archaeological excavation (© Landesamt für Denkmalpflege Hessen / hessenARCHÄOLOGIE, ALMhessen – Keltenwelt am Glauberg und Technische Universität Darmstadt, Fachgebiet Digitales Gestalten).



Fig. 5. Top: The entrance room of the application adopting the interior design of the real world Keltenwelt museum. Middle: 3D scans created by Fraunhofer IGD – virtually exhibited in the entrance room-. Bottom: Information on the objects displayed on a virtual screen (© Landesamt für Denkmalpflege Hessen / hessenARCHÄOLOGIE, ALMhessen – Keltenwelt am Glauberg und Technische Universität Darmstadt, Fachgebiet Digitales Gestalten).

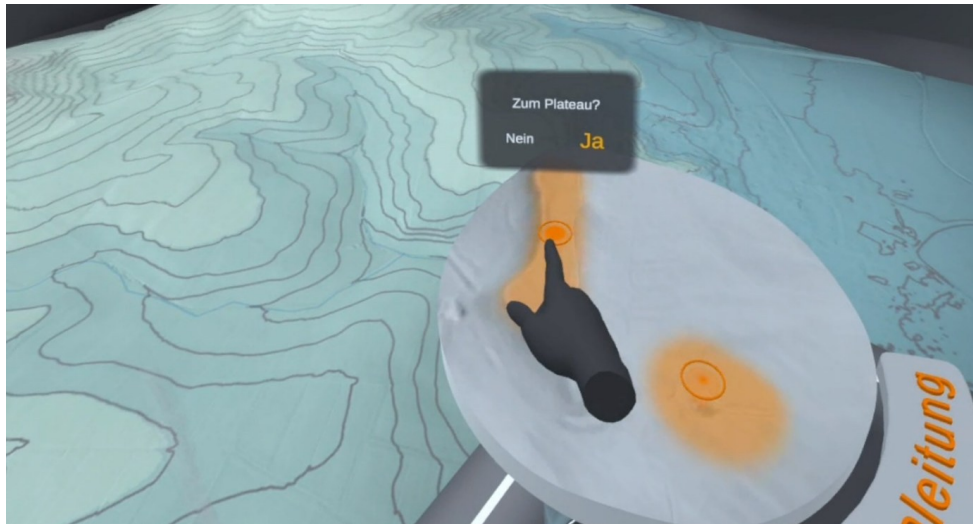


Fig. 6. Navigation via tapping the model (© Landesamt für Denkmalpflege Hessen / hessenARCHÄOLOGIE, ALMhessen – Keltenwelt am Glauberg und Technische Universität Darmstadt, Fachgebiet Digitales Gestalten).

Control is intuitive through so-called “hand tracking”, which allows users to see their hands as a 3D model in the game and use them just as they would in the real world.

On the other hand, the initial room exhibits 3D scanned reconstructed finds from the burial mounds at Glauberg. In contrast to the physical objects, visitors are allowed to take them in their (virtual) hands and look at them in detail. By placing these objects in a designated light column, information about the respective object is projected onto a surface on the wall.

The application offers two worlds of experience (Figure 6) that can be visited starting from the initial space: the plateau on the Glauberg and the district around the large burial mound. These worlds are deliberately kept in a comic style in order not to suggest any certainty about the reconstructions, as would be the case with a photorealistic representation.

The plateau shows a reconstructed Celtic settlement within the circular rampart (Figure 7). Different thematic locations are offered to the users, which can be selected by tapping the miniature model: the settlement, the wall, the gate and the dwelling house. In order to convey how the reconstructions came about with the help of archaeological finds, references and interpretations, there is an in-depth level for each of these thematic focal points, which users can immerse themselves in by tapping a button on the miniature model.

These immersion levels deliberately break the presentation style and are intended to bring visitors into the world behind the application through the look of an oversized virtual workshop.

In the circular rampart immersion (Figure 8), sections of the wall are presented with different reconstruction variants at a scale of 1:1. Information on findings and references is presented, including a view of an animation of the wall's construction phases.

In the recess level of the gate (the so-called Stockheimer Pforte; Figure 9), the references used are presented as 360° panoramic photos, alternative wall reconstructions from other locations are shown, and visitors are given the opportunity to view the wall from the battlements.

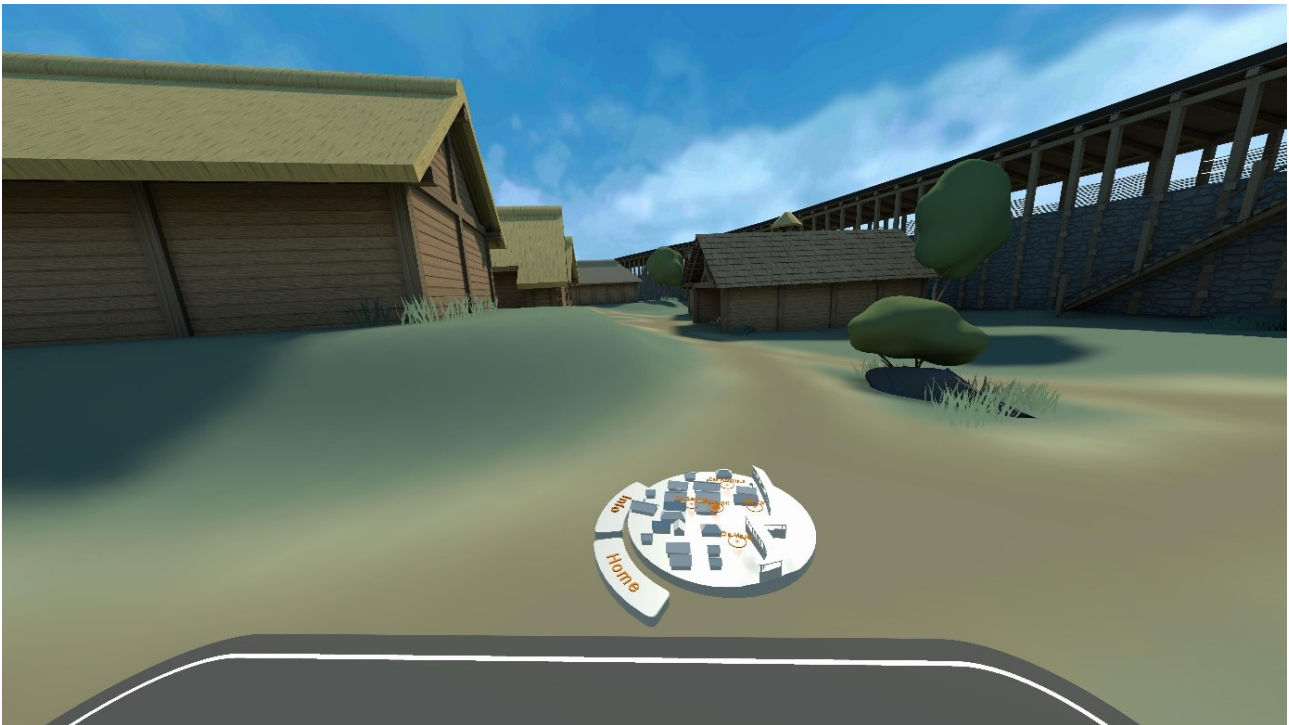


Fig. 7. The plateau: a reconstructed settlement with a circular rampart (right) in a comic-like style (© Landesamt für Denkmalpflege Hessen / hessenARCHÄOLOGIE, ALMhessen – Keltenwelt am Glauberg und Technische Universität Darmstadt, Fachgebiet Digitales Gestalten).

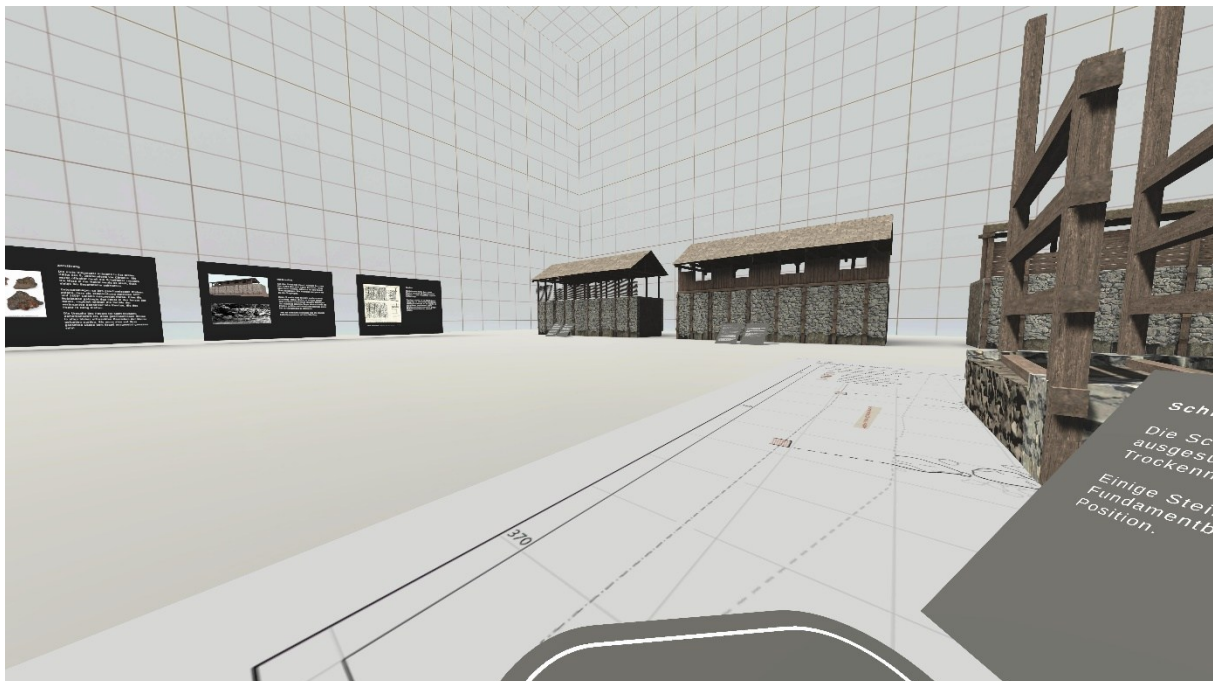


Fig. 8. Immersion level of the circular rampart (© Landesamt für Denkmalpflege Hessen / hessenARCHÄOLOGIE, ALMhessen – Keltenwelt am Glauberg und Technische Universität Darmstadt, Fachgebiet Digitales Gestalten).

The density of the buildings of the settlement (Figure 10) and the types of houses are also speculative in the case of the Glauberg plateau. Possible variants are presented at the in-depth level – as an overview and from a pedestrian's perspective. The construction methods of the houses are also discussed, and photos of references are shown. The overview presents a good possibility of comparison among the three settlement variants offered.

In the immersion on the theme of the dwelling house, the visitors immerse themselves in the atmosphere inside a reconstructed house (Figure 11). Here they can switch between daytime and nighttime atmospheres as well as getting a more detailed information about the areas within the house and its furnishings when touching different objects.

The second world that users can experience is the area around the large burial mound (Figure 12–13), which can also be visited in the real environment of the museum. Navigation by touching the tumulus on the miniature model in the initial room is done in the same way as navigating to the plateau.

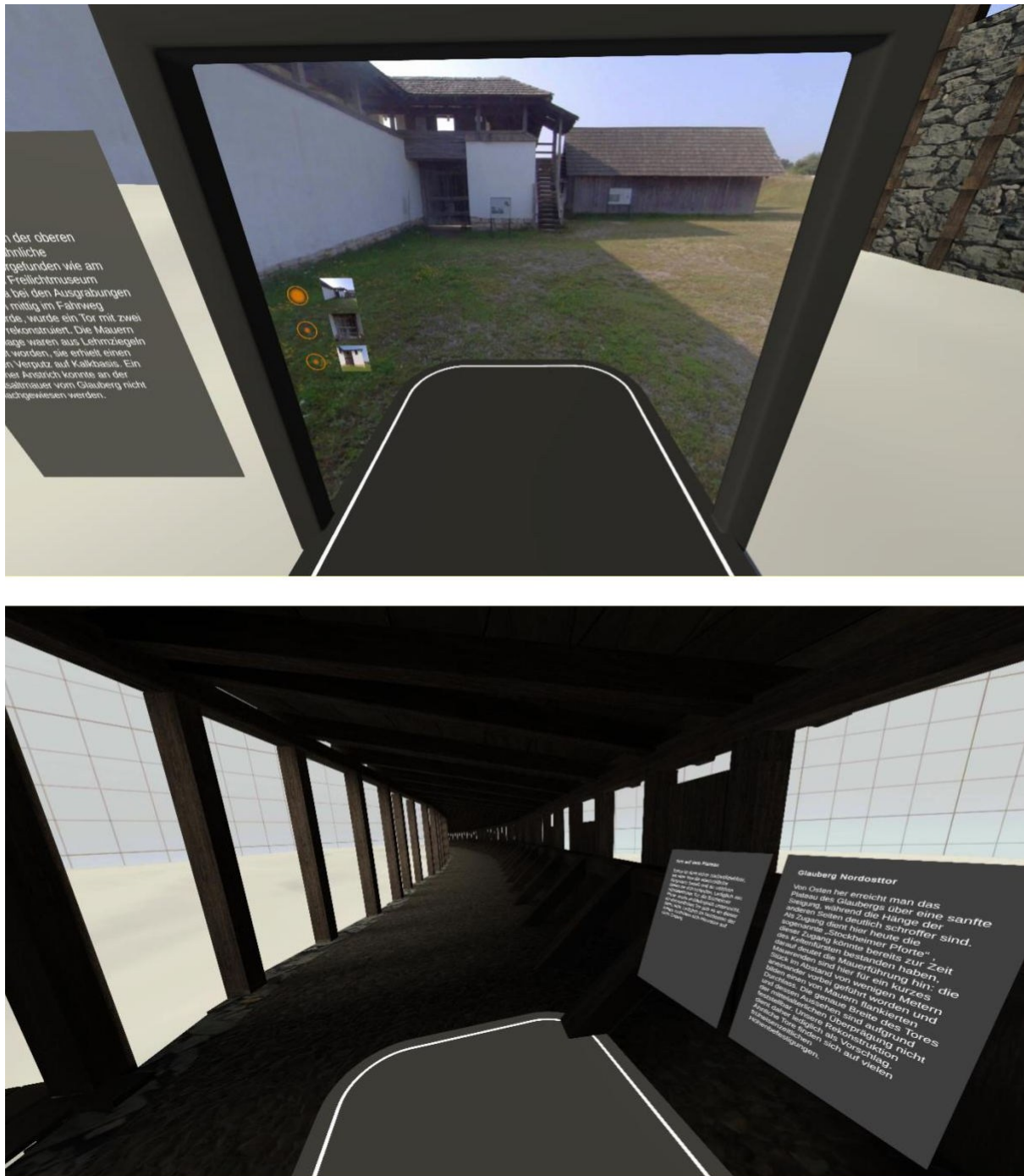


Fig. 9. Immersion level of the gate: Top – panoramic photos of references from other sites. Bottom – inside the battlement (© Landesamt für Denkmalpflege Hessen / hessenARCHÄOLOGIE, ALMhessen – Keltenwelt am Glauberg und Technische Universität Darmstadt, Fachgebiet Digitales Gestalten).

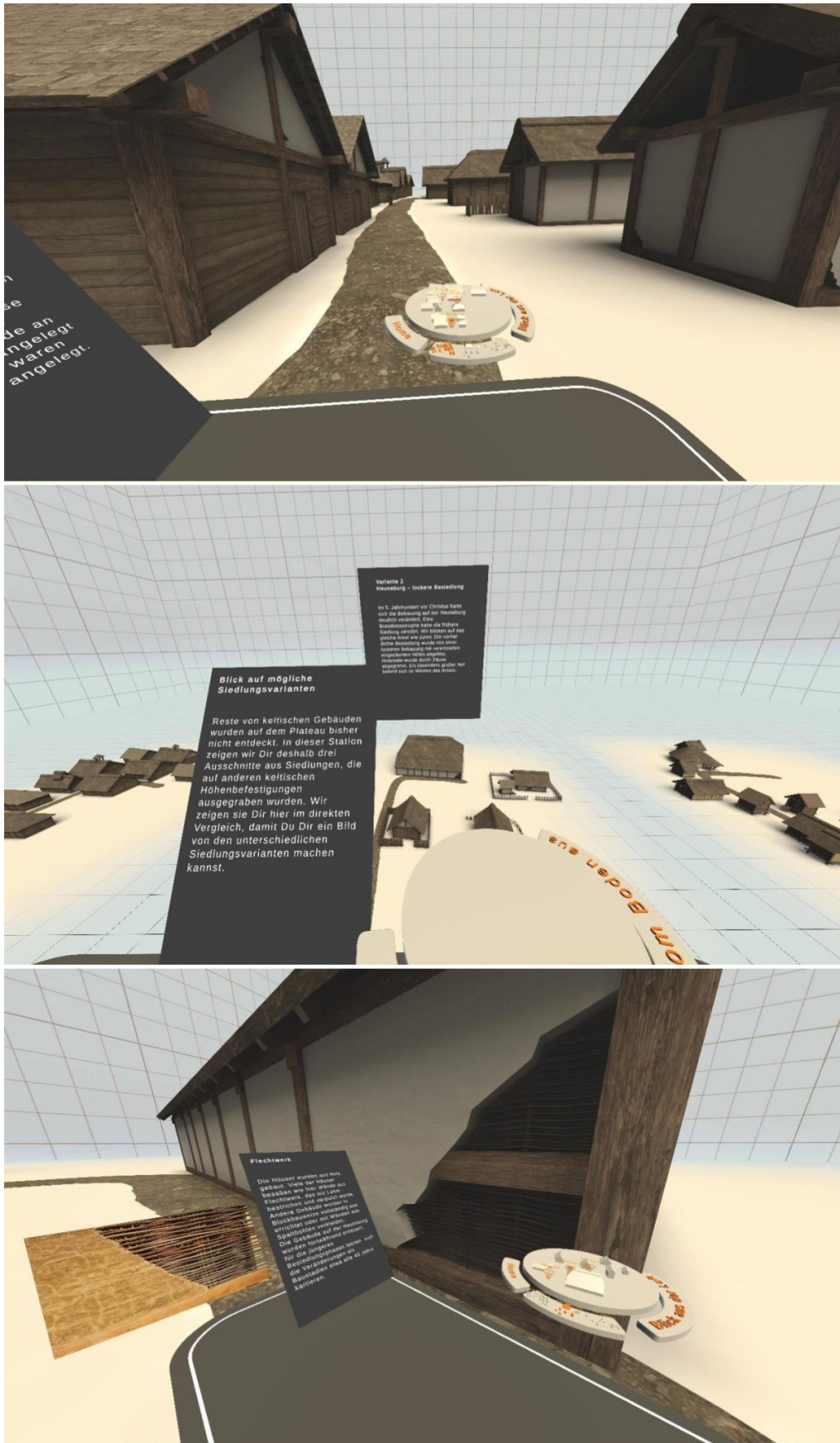


Fig. 10. Immersion level of the hilltop settlement: Top – navigation via miniature model. Middle – variants in the building density as an overview from a bird's eye perspective. Bottom – Immersion level of the settlement: house construction (© Landesamt für Denkmalpflege Hessen / hessenARCHÄOLOGIE, ALMHessen – Keltenwelt am Glauberg und Technische Universität Darmstadt, Fachgebiet Digitales Gestalten).



Fig. 11. Immersion level of the residence interior: Top – atmosphere and equipment. Bottom – Information about everyday objects (© Landesamt für Denkmalpflege Hessen / hessenARCHÄOLOGIE, ALMhessen – Keltenwelt am Glauberg und Technische Universität Darmstadt, Fachgebiet Digitales Gestalten).

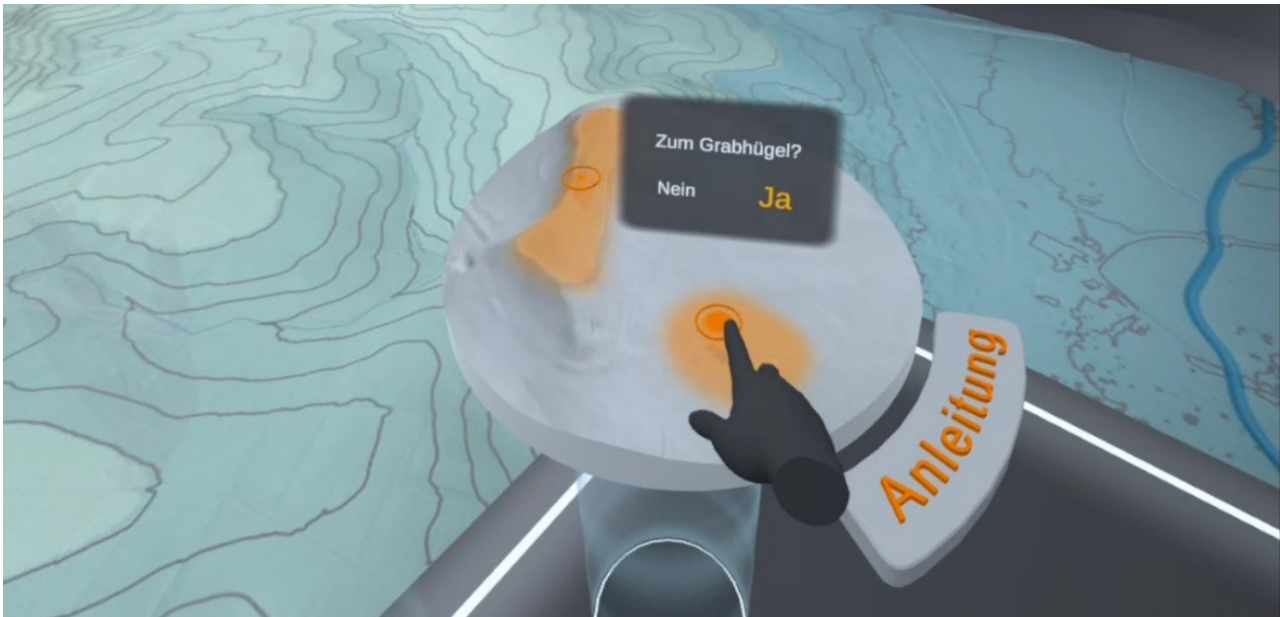


Fig. 12. Navigating from the intro room to the burial mound (© Landesamt für Denkmalpflege Hessen / hessenARCHÄOLOGIE, ALMhessen – Keltenwelt am Glauberg und Technische Universität Darmstadt, Fachgebiet Digitales Gestalten).

When the tumulus is selected as the target, the visitors will find themselves in front of the large tumulus. Looking around, they can also see the second smaller tumulus, a settlement, and a flock of sheep. Information boards are displayed for all points when looking in the respective direction. In addition, there is also the possibility of diving into a deepening level for the two tumuli and the settlement. The navigation in this section differs from the usual navigation of the application. While in the other sections navigation is done via the miniature model, here the players can dive into the respective immersion level by pointing at the locations. This different way of navigating will be used experimentally in the course of this application. The goal is to explore and comparatively evaluate the most intuitive navigation option with the help of this application.

In the immersion level for the large burial mound (Figure 14), a three-dimensional section through the mound is shown, so that the users are granted insight into the pits, which are not visible in the real environment. Like the archaeologists themselves, who explored these pits, visitors can now approach the excavation sites and recover and view the grave goods from the tombs with their own (virtual) hands.



Fig. 13. The surroundings of the tumulus: Top – the great tumulus. Middle – the small tumulus. Bottom – sheep and the settlement (© Landesamt für Denkmalpflege Hessen / hessenARCHÄOLOGIE, ALMhessen – Keltenwelt am Glauberg und Technische Universität Darmstadt, Fachgebiet Digitales Gestalten).

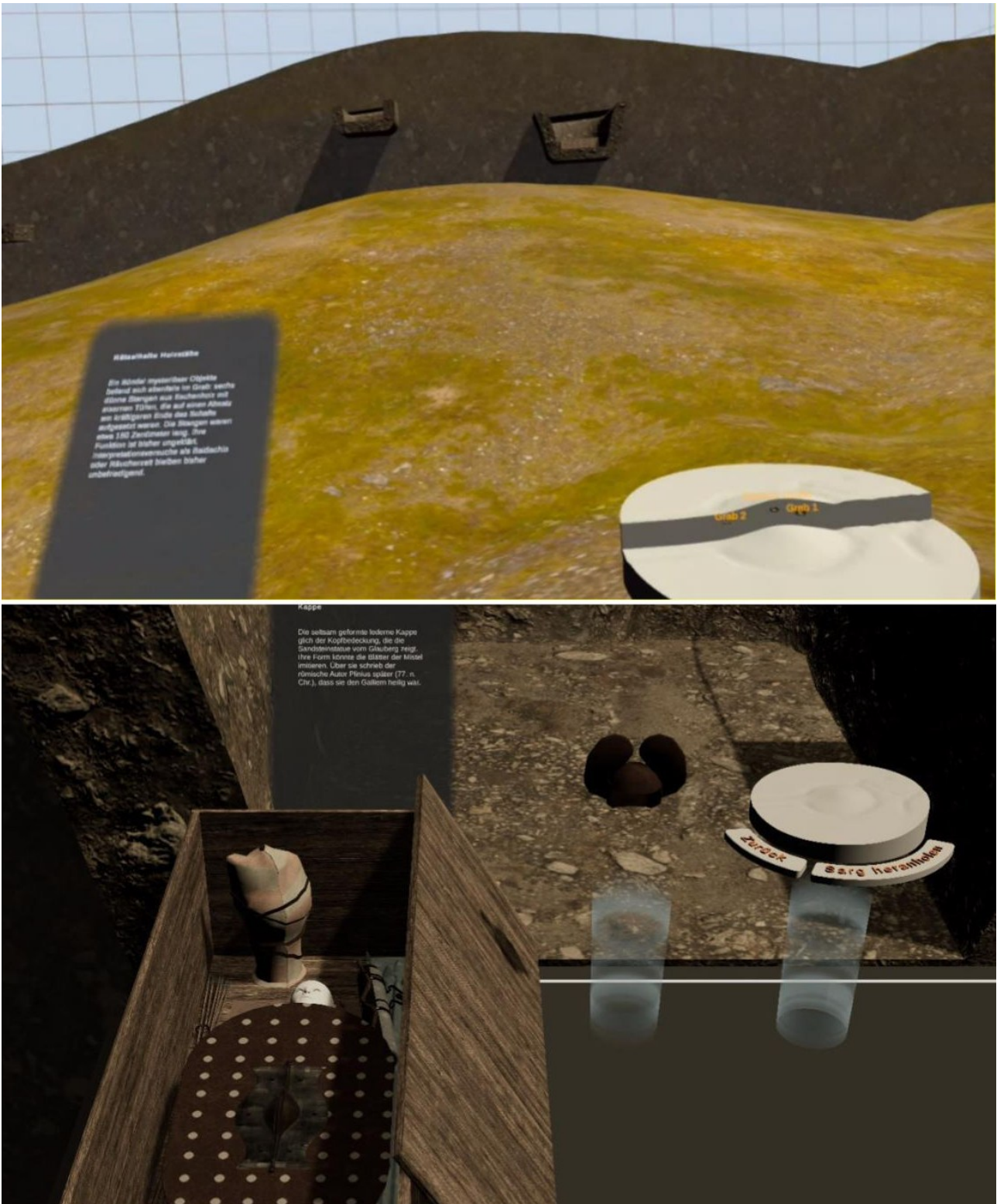


Fig. 14. Immersion level of the large tumulus. Top – Section through the tumulus with three burials. Bottom – details of the burial pit with wooden coffin and grave goods. (© Landesamt für Denkmalpflege Hessen / hessenARCHÄOLOGIE, ALM-hessen – Keltenwelt am Glauberg und Technische Universität Darmstadt, Fachgebiet Digitales Gestalten).

The recess level of the second smaller tumulus is constructed similarly (Figure 15). Its reconstruction provides visitors with a completely new insight. Here, too, the users can open the burial mound and examine the coffin and its contents more closely.

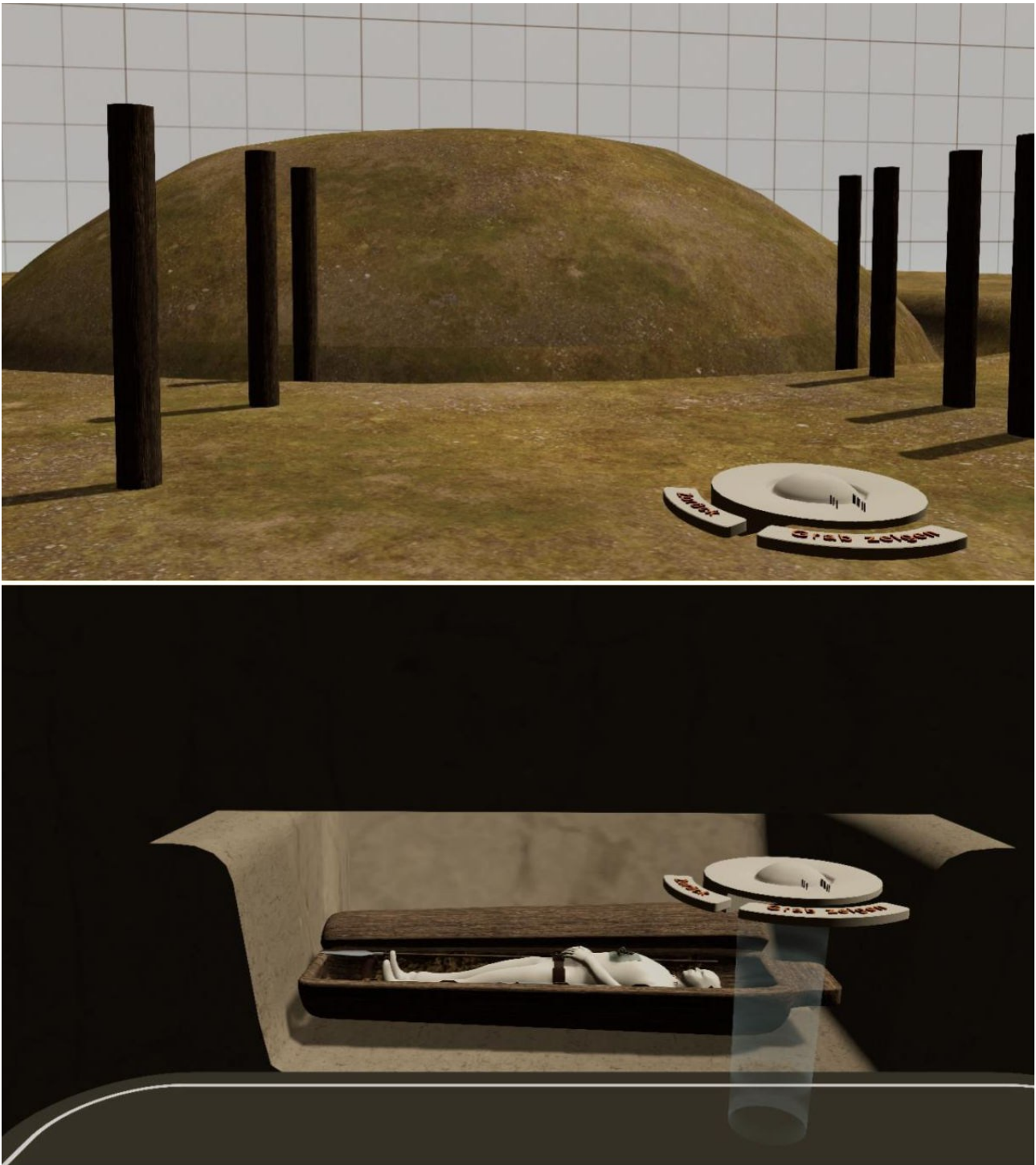


Fig. 15. Immersion level of the small tumulus: Top – burial mound with ring ditch and post alley. Bottom – burial pit with coffin (© Landesamt für Denkmalpflege Hessen / hessenARCHÄOLOGIE, ALMhessen – Keltenwelt am Glauberg und Technische Universität Darmstadt, Fachgebiet Digitales Gestalten).

There are also no visible remains of the settlement areas, which were located at the foot of the Glauberg and affected by soil erosion. Nevertheless, some features from this settlement were found during excavations, consisting mainly of particularly deep storage pits. In one of these rural settlements three sunken houses were excavated, the only house ground plans at Glauberg so far. Information on these and on the storage pits is offered to the visitors in the immersion level of the rural settlement (Figure 16).

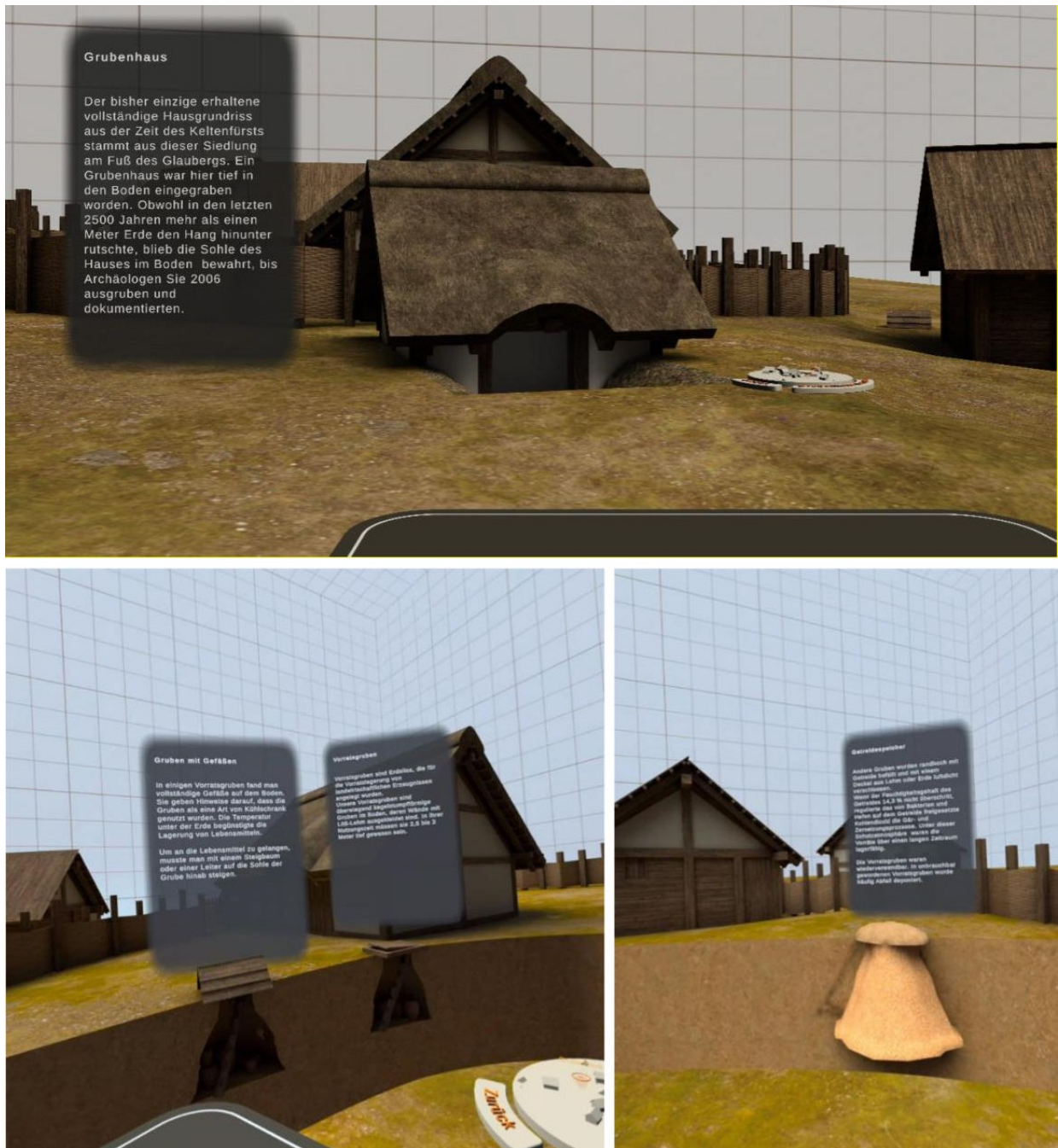


Fig. 16. Immersion level of the rural settlement: Top – house ensemble with sunken houses. Bottom left – section with storage pits. Bottom right – detail of a grain storage (© Landesamt für Denkmalpflege Hessen / hessenARCHÄOLOGIE, ALMhessen – Keltenwelt am Glauberg und Technische Universität Darmstadt, Fachgebiet Digitales Gestalten).

From the pedestrian perspective, insights are given into the possible appearance of this settlement and an animation removes part of the floor so that the normally invisible levels of the underground structures are revealed.

Usability

Evaluations of VR with visitors to the Celtic World at Glauberg have shown the fascination that immersion has in the past exerted on users. It was irrelevant that most of the environments presented were not photorealistic. Intentional breaks in the graphical output and differently designed immersion levels keep from diving too deeply into the reality of the Iron Age without seeming too instructive or

boring. At the same time, it became apparent that navigation must be simple and stringent so that users can move intuitively through the virtual scenarios. Changes in the type of navigation, as implemented in the two different areas at the Glauberg can lead to irritation and frustration, especially for inexperienced visitors. Explicit references to the change of the navigation mode are required.

The results of the evaluation will be further analysed as part of a dissertation project by Norwina Wölfel at the TU Darmstadt, Department of Architecture. A comprehensive overview of current studies in the field of virtual reality and cultural games can also be found in Theodoropoulos and Antoniou's paper (2022).

Conclusion

The VR application of the "Keltenwelt am Glauberg" enables the expansion of the existing museum space in the most diverse facets. The abstract representation offers a special world of experience and almost unlimited design possibilities. This appeals to new user groups, which can perceive the content of the VR world through different channels – even outside the museum. For example, KWG's VR stations on the Oculus Quest 2 platform will offer museum content to a clientele outside of the usual museum visitors. It is also possible to use the glasses in schools and other institutions.

The VR application demonstrates the medium's many uses beyond a cinematic representation of architecture. The developed content, which is now fully available to the museum, offers its users the opportunity to interact with archaeological objects and scenes.

The resulting VR world sets new standards in the use of VR and archaeology with the presentation of variants and the integration of the sources underlying the reconstructions. Experiencing these variants is done on a 1:1 scale, which is only possible in VR. At the same time, the potentials of VR in terms of spatial experience are paradigmatically addressed through the development and design of specific 3D spaces, so-called virtual archaeological laboratory spaces. Positive feedback from both test users in the museum at Glauberg as well as from participants of the CHNT 2021 conference in Vienna and the CAA 2022 conference in Oxford assured us that the approach chosen might be worthwhile to further develop.

Beyond their use in the VR stations, the 3D models and scenes created have already been applied in various other contexts, such as the special exhibition "The Celts in Hesse" or in an augmented reality app.

Further Steps / Prospects

As further steps, an English-language version and the integration of professional voice texts would be important. In addition, an expansion of the content to include other topics, but also the presentation of other settlement periods on the Glauberg, such as the Middle Ages, would make sense. The team is currently working on the online publication of the application in the near future.

Funding

Hessian Ministry of Higher Education, Research, Science and the Arts.

Conflicts of Interest Disclosure

No potential competing interests have been reported by the authors.

Author Contributions

Conceptualization: Ruth Beusing, Marc Grellert, Hristo Kunchev, Axel G. Posluschny, Norwina Wölfel

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