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REFERENCE AND RECONSTRUCTION SOURCES FOR COMPARATIVE GEOVISUALISATION OF THE GIECZ STRONGHOLD IN THE 12TH AND 21ST CENTURIES

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Abstract: This article presents the process of presenting and valorizing spatial, historical and archaeological data for creating a comparative geovisualisation of the Giecz stronghold in two time frames: the 12th and 21st centuries. The aim of this work is related to the concept of protecting and sharing cultural heritage. Special attention has been paid to the presentation of spatial archaeological and historical data in a 3D virtual environment, with a possibility of presenting them in a Virtual Reality (VR) environment. From a cartographic point of view, special emphasis was placed on the proper integration of cartographic, remote sensing and graphic sources in a geomatic process for implementing the model into interactive virtual environments.

Keywords: geomatic process, cartographic sources, comparative geovisualisation, 3D modelling, medieval stronghold, virtual environments, cultural heritage

INTRODUCTION

The analysis of the variability of landforms and environmental development occurring over the years is a challenge for cartography, as it requires the use of methods appropriate to many sciences. This implies the need for a broadly interdisciplinary approach. The rise of digital cartography and advanced geomedia has made it possible to depict the geographic environment with entirely new methods, but has also led to a situation in which the creator of the visualisation must take into account the user's perceptual abilities (Medyńska-Gulij, Lis, Wielebski 2012). The design of new cartographic representations requires the implementation of principles that enable the map to be perceived freely and increase its visual attractiveness (Siwek 2000).

The application of modern techniques for the representation of terrain remains an open question, among which we can distinguish between methods based on three-dimensionality (3D) and pseudo-3D (so-called 2.5D). Pseudo-3D, is a term for a set of graphic techniques applied to two-dimensional graphics in order to create the feeling of three-dimensionality. Full three-dimensionality determines the comprehensiveness of the geovisualisation model and enables the full presentation of a specific section of geographical or historical-geographical space (Medyńska-Gulij 2021).

Researching the sources needed for the visualisation is also an important problem (Popelka, Brychtowa, 2011). The search for a suitable range of sources was made possible not only by access to digital field data, but also various archaeological and historical studies (Krysztofiak 2000, 2004, 2005; Kostrzewski 1966). Due to the historical nature of the sites under analysis, it was decided to divide the sources relating to former medieval fortified settlements into reference and reconstruction sources. Reference sources are materials preserving cartometricity, capable of being placed on contemporary map studies. The preservation of cartometricity is the overriding need of modern map studies. In the perspective of the work, the reference sources refer to the present state of the fortress and help to map its modern topography. Reconstruction sources are materials that do not meet the assumptions of cartometricity and are therefore susceptible to all kinds of distortion and require further geometric transformation (Medyńska-Gulij 2015). In the article, the reconstructive sources come mainly from archaeological excavations and studies by historians

The geovisualisation of the Piast stronghold in the two time frames of the 12th and 21st centuries requires the use of up-to-date digital data collected in official geodetic and cartographic databases (Iwaniak et al. 2011), as well as the use of analogue data derived mainly from archaeological research and historians' studies. When considering access to modern geodetic data, the possibility of using a geoportal providing the raw data used in the creation of the model appears to be important.

The use of the model in further environments, such as virtual reality environments, is not without significance (Medyńska-Gulij, Zagata 2020). Associated with the use of geovisualisation in virtual reality (VR) environments is the problem of the representation of reconstructions, as VR technology is also usually associated with providing the user with a wider spectrum of possibilities for insight into reconstructions, as well as the representation of completely different spatial relations (Zagata et al. 2021). Previous research shaping historical objects in a VR environment (Kersten 2020) shows that the creation of realistic models of historical objects cannot take place without first delving into the topography and architecture of the realized objects. Figure 1 shows geovisualisations of historical objects made in virtual environments that concern castles and palaces.

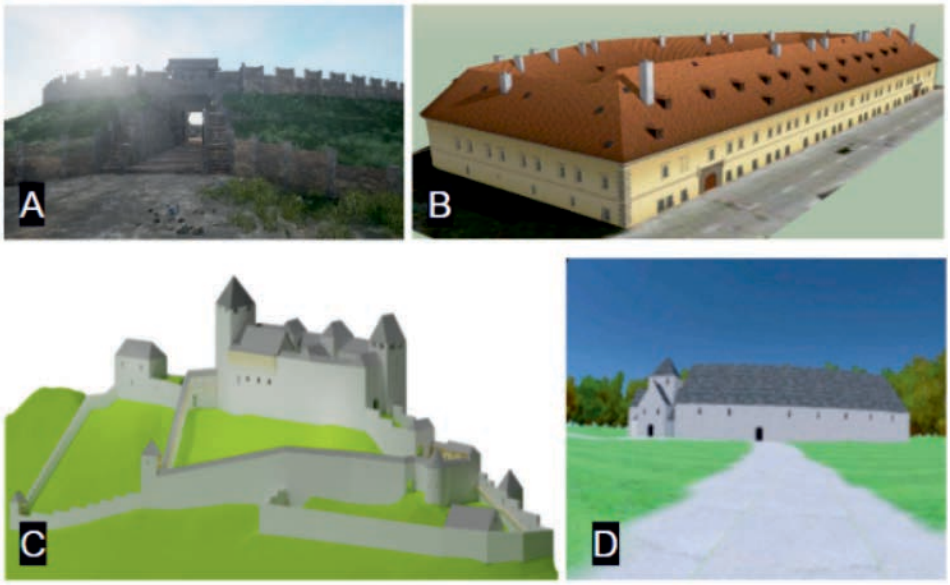

Fig. 1. Examples of geovisualisation: New Castle in Hamburg (A) (Deggim i Kersten 2022), Old Barracks in Olomouc (B) (Popelka i Brychtová 2011), Waldstein Castle (C) (Bauer 2020), Castle Palatium on Ostrów Lednicki (D) (Medyńska-Gulij i Zagata 2020)

RESEARCH AREA

The area of the present research was the site of the Giecz stronghold located in the eastern part of the Wielkopolskie Voivodeship. The stronghold's history reaches far into the past and its beginnings date back to the pre-state period, when it probably served as the forefront of the territorial organisation of the opole (vicinia) administration (Krąpiec, Krysztofiak 2003). The medieval stronghold was located within a wide plain, which during the dyluvial period was filled with the waters of a lake created from the confluence of two rivers: the Moskawa and its right-bank tributary, which does not exist today (Kostrzewski 1966). The expansion of the stronghold took place during the reign of the first Piasts. It was then that the stronghold church was extended and the construction of a ducal palace began, but this was not completed, probably due to the invasion of Bohemian Duke Bretislav. The stronghold in Giecz is mentioned in the Polish Chronicle by Gall Anonim and in the Chronicle of Bohemia by Kosmas. Both of these sources paint a picture of a significant stronghold, which played an important role in the functioning of the early Piast monarchy; from Gall Anonim's text we can read that Boleslaw the Brave led "1300 armoured knights with 4000 shield soldiers out of Poznan, 1500 armoured and 5000 shield soldiers out of Gniezno, 800 armoured and 2000 shield soldiers out of Wloclawek, 300 armoured and 2000 shield soldiers out of

Giecz". Giecz acted as a fortress that protected the crossing of the Warta River, thus protecting the then capital of the Piast state Gniezno (Wojciechowski 1952) The further history of the stronghold is connected with a decline in its strategic and political significance, which resulted in a decrease in the importance of the stronghold, although it still served as a seat of castellany in the 13th century, in reality the stronghold ceased to play a significant role in the functioning of the state with the unification of the monarchy after the division of Poland, when the centre of gravity of the Polish Kingdom shifted towards Małopolska and Kraków (Kostrzewski 1966). The current topographical level makes it possible to distinguish certain features of the stronghold. From today's point of view, the most striking features are the ramparts. Although they have been partially levelled in the eastern part of the site, they are still easily distinguishable. To this day, however, the stronghold remains a prominent feature in the local landscape, as shown in Fig. 2.

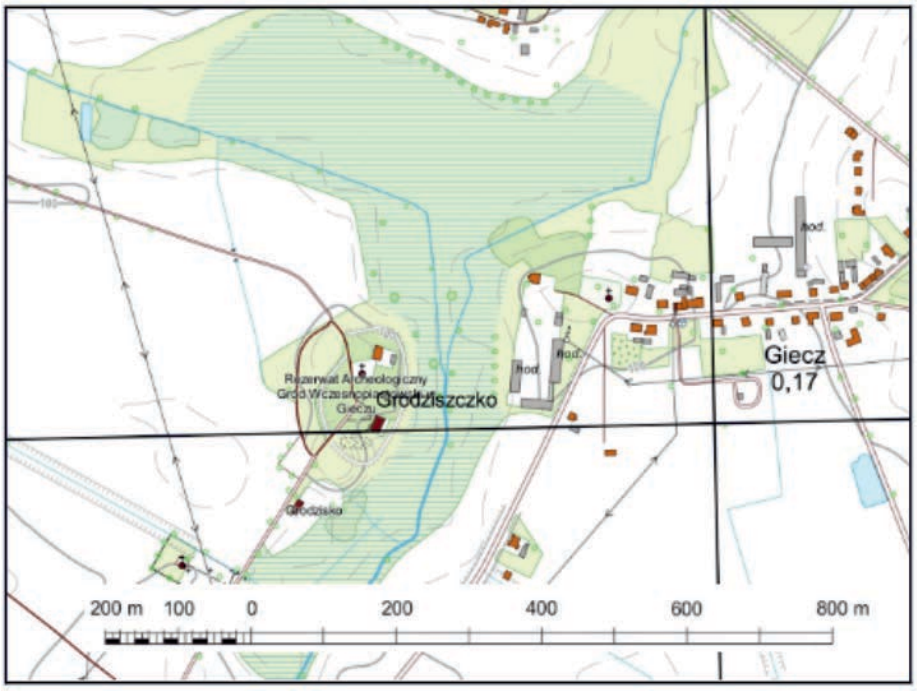

Fig. 2. The Giecz stronghold on a contemporary topographic map
Source: BDOT10K visualisation from GEOPORTAL.GOV.PL.

PURPOSE OF THE WORK

The aim of the research was to classify the sources and to examine the parameters of a virtual geovisualisation of Giecz stronghold in two time frames, one from

the 12th century and the other from the 21st century. The idea was to present the site in two spatial and temporal perspectives: a visualisation of the stronghold in its present state and a reconstruction of the stronghold in a hypothetical state from the turn of the 11th / 12th century.

In the absence of sufficient archaeological evidence of the positioning of individual elements within the fortification of the stronghold, it was decided to adopt three main architectural elements to be visualised, these objects became: The stronghold church (in the historical reconstruction) / St. John the Baptist Church (in the contemporary reconstruction); the foundations of the duke's palatium; and the defensive rampart.

The main problem, constituting a key task in the design of geovisualisation for the perception of the viewer, became the reconstruction of objects and their representation by means of appropriate geomedia attributes (Medyńska-Gulij 2022). Among these gemedial attributes, many technical aspects of the visualisation can be distinguished, such as the viewing angle, the angle of light, the colour palette and the scale of elevation gain. In the course of the research, the process of building a visualisation from raw data and modelling the parameters of the visualisation itself was presented (Medyńska-Gulij, Lis, Wielebski 2012) in order to properly present the terrain and individual objects located on the Giecz stronghold site.

METHODS

In order to realize the research objective, the main three research stages were adopted: collection and classification of sources; data transformation and comparative visualisation of the Giecz stronghold in a digital environment system. The whole process, in its assumption, is in accordance with the assumptions of the geomatics method of research (Kozie 1997; Medyńska-Gulij 2021) assuming the se of the complementarity of various digital data processing environments for their appropriate visualisation. The following software was used in the geomatics process: QGIS, CloudCompare, SketchUP and Blender.

STAGES OF RESEARCH

Collection and classification of data

The first stage involved the collection of the following data of cartographic and geomatic provenance: Digital Terrain Model, Point Cloud and Topographic Maps. Necessary for the specifics of creating the reconstruction of the Giecz stronghold, historical-archaeological data were also collected, which include: Excavation

results, Archival maps, Photographic documentation from archaeological investigations and Historical reconstructions of the stronghold and its individual elements.

The maps and sources provided were taken from the open and publicly available data (Geoportal.gov.pl) platform as raw data to be further processed in the course of the work. Historical and archaeological data were taken from excavation results and specialist literature.

These sources are mentioned in specific places in the article when referring to individual elements of the visualisation object.

In line with the problem addressed, the data were divided into reference sources, which are presented in Figure 3: a triangular grid Digital Terrain Model (TIN model) with a grid of 1m; the most recent topographic map at a scale accuracy of 1 : 10 000 from 2020; an orthophoto map from 2021 with a pixel size of 0.25 and a point cloud from 2017 with a density of 4 points per m2. Figure 4 shows the five forms of reconstruction sources: A model of the stronghold church according to T. Węcławowicz (2000), a plan of the stronghold church according to T. Krzysztofiak (2005), an engraving of the reconstruction of the entire stronghold (Kostrzewski 1962), snapshots of the archaeological survey and a cross-section of the archaeological survey (Krąpiec, Krysztofiak 2003).

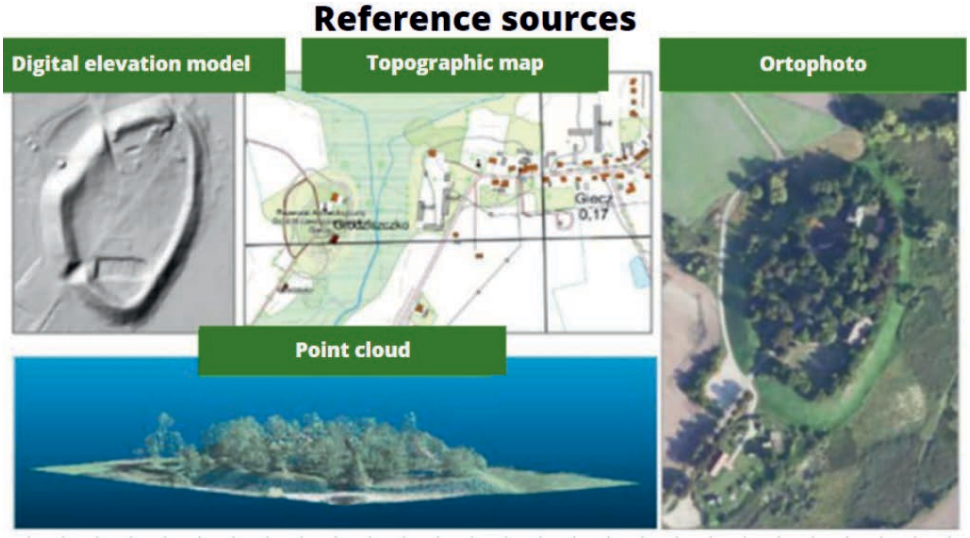

Fig. 3. Reference sources for visualisation of Giecz stronghold

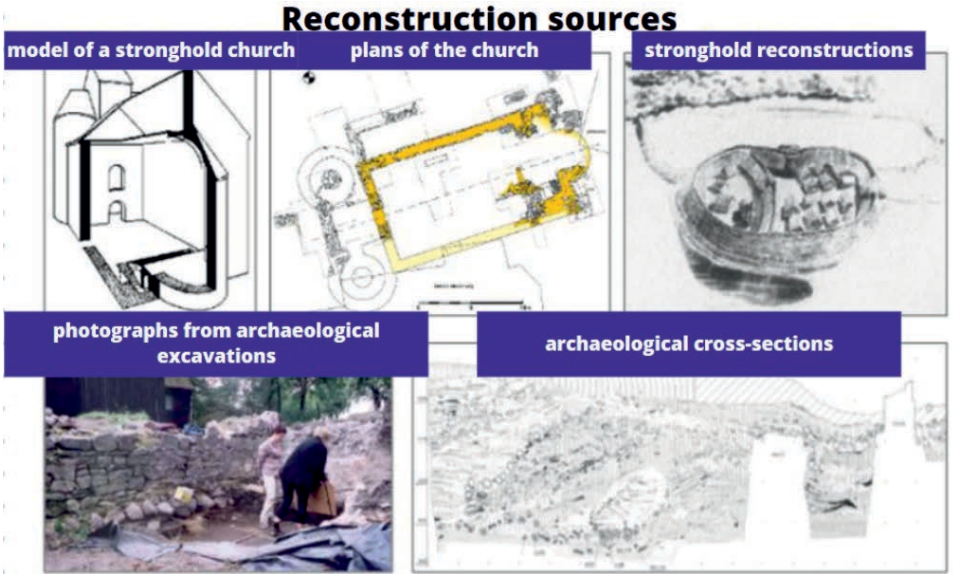

Fig. 4. Reconstruction sources for the visualisation of the Giecz stronghold (description in text)

Data transformation

In the second stage of the study, the collected data was saved in various formats. Figure 5 shows the handling of the reference data in the following digital formats: .asc (Numerical Terrain Model), .tif (orthophotomap), .pdf (topographic map) .laz (point cloud) and reconstruction sources in .jpg and .png formats.

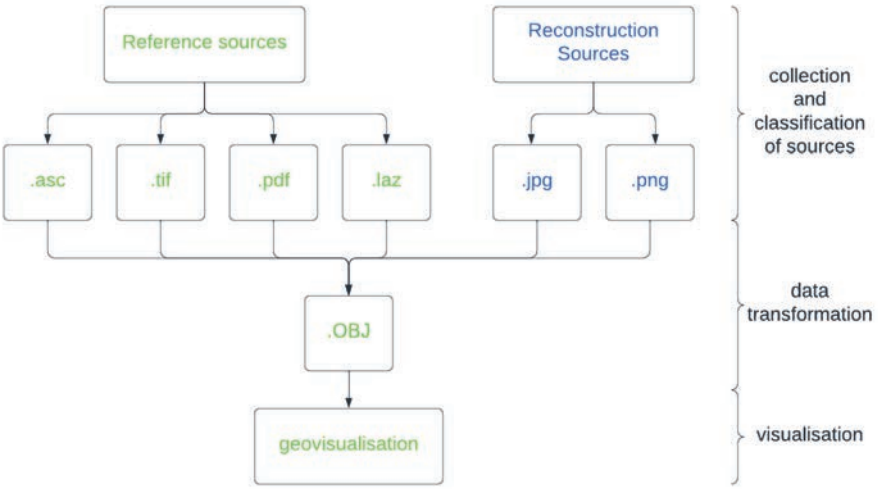

Fig. 5. Diagram of different data formats used to create the visualisations

The different steps of the study followed the adopted geomatics process for geovisualisation creation. The first step involved processing the available point cloud data in .LAZ format into a numerical terrain model (Fig. 6).

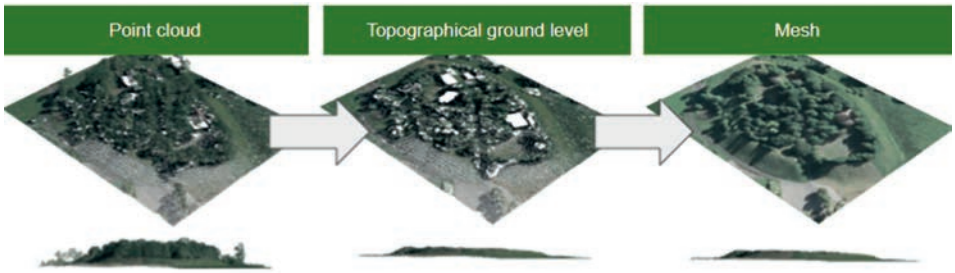

Fig. 6. Changing the Point Cloud to a mesh

The resulting model allowed further processing of the site, as well as being the basis for reconstructing the building in its present-day form. The addition of building models in Level of Detail 1 (LOD 1) format to the model, allowed an additional layer to be created, enabling the visualisation user to perceive the site more easily. Data were taken from the geoportal.gov.pl. An orthophoto map was used as an overlay on the mesh (Fig. 7).

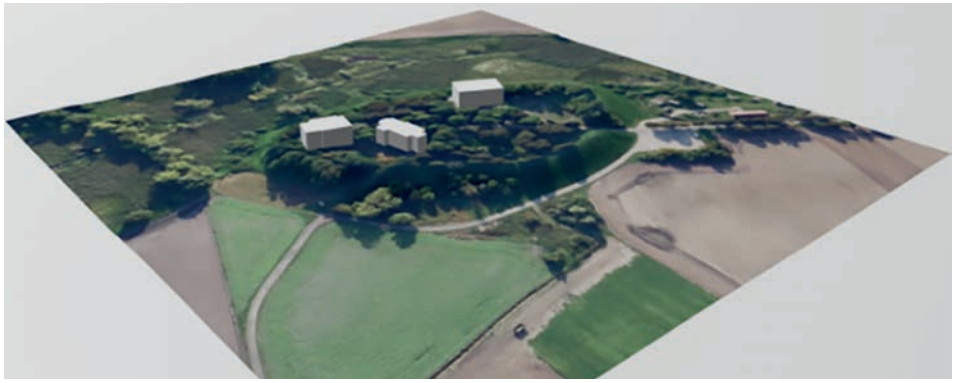

Fig. 7. View of terrain model with added 3D objects and orthophotos

In order to build a spatial connection between the state of the stronghold in the 12th century and the current state, it was decided to build a model of the foundations of the palace and place them on both visualisations of the castle. This was done in order to build a better understanding of the site in terms of the variability of the terrain and buildings. For this purpose, the available plans of the palatium foundations were used, as shown in Fig. 8. The data collected from archaeological studies (Rodzińska-Chorąży 2002) were juxtaposed in the SketchUP graphic application, resulting in a 3D plan of the palatium foundations.

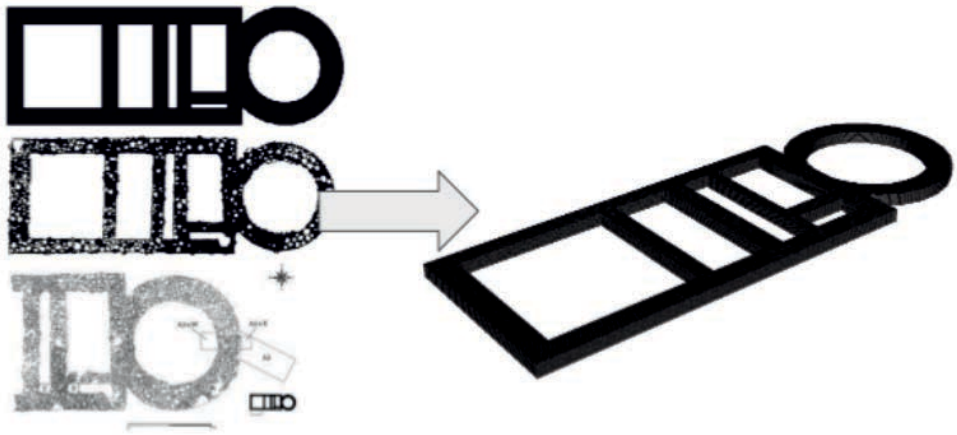

Fig. 8. Creation of the palatial foundation model

The creation of a three-dimensional object of the 10th century Romanesque church became an important part of the further study. Once the relevant materials had been collected, the creation of the church began. Unfortunately, the lack of fully cartometric materials made it impossible to accurately reproduce the geometry of the building, but efforts were made to use sources presenting the highest possible accuracy, so that the final model would match the standards of Romanesque buildings of the past period. Figure 9 shows the creation of a model of the Stronghold Church in the digital environment system from five different sources: among them, the already mentioned reconstruction sources including plans and a reconstruction of the church This Romanesque church was given a virtual form with the main nave, the vestibule and the apse from the later second phase of the church extension deliberately exposed in its mass.

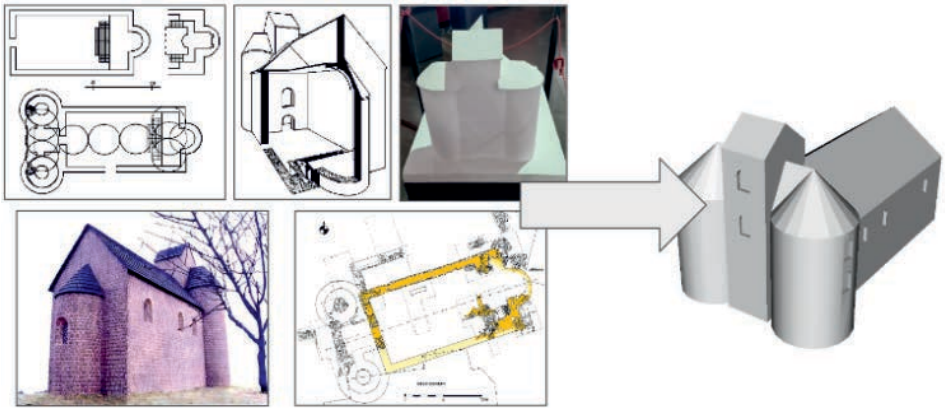

Fig. 9. Creation of a model of a Romanesque stronghold church

The construction of an overall geovisualisation of the stronghold, including the geometry of the palisade, became an open question. In the light of the archaeological investigations carried out, it has become impossible to determine the exact, scientific course of the rampart. Not enough archaeological research has been carried out on the stronghold territory. The main research carried out to date has covered the areas adjacent to the stronghold church, the cemeteries near the stronghold and single points within the reconstructed palisade. This density of research accounts for the need to use extrapolation of how the geometry of the stronghold walls ran. A hypothetical course of the defensive palisade was plotted on the basis of a contemporary numerical height model (Fig. 10).

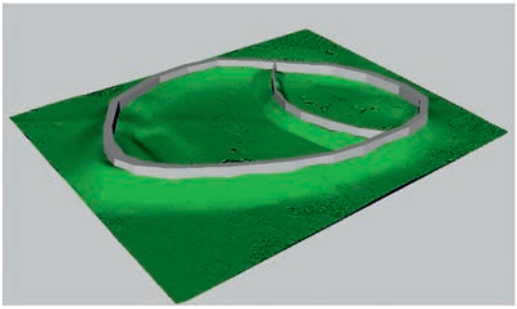

Fig. 10. Hypothetical course of the rampart

The overall geometry of the earthen rampart was also altered, with additional buttresses added to increase the defensive qualities of the settlement. The created vision of the fortress is not confirmed by archaeological research, but it is a possible reconstruction, finding common points in the general geometry of medieval fortresses existing in Eastern Europe. Figure 11 shows the difference in the level of the terrain in two colors: green representing the present state and red the hypothetical medieval state. The medieval topographic level is derived from levels taken from archaeological cross-sections, which were then extrapolated to the whole stronghold area.

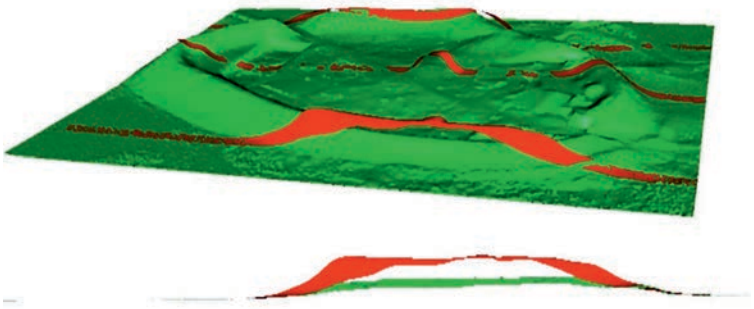

Fig. 11. Difference between the current state level (green) and the hypothetical medieval state (red)

Data visualisation

By going through all the stages of object creation, it was possible to juxtapose the two objects obtained. The resulting visualisation presents the features and objects obtained by extracting data from two types of sources. The modern visualisation retains its cartometric character in many places, as the objects were obtained by operating on publicly available geodetic and cartographic data. The medieval visualisation deviates from cartometric requirements in many places, but its primary advantage is the ability to render and change perspective views. Its final shape was obtained by processing and transforming the available partial data. The results of the visualisation are shown in Figure 12, where it is possible to compare in two sample perspective views the state of the stronghold in the 12th and 21st centuries. Above are visible projections of the modern reconstruction of the stronghold, while below is shown a hypothetical geovisualisation of the state of the stronghold in the 12th century with the course of the rampart, the situated church and the foundations of the palatium.

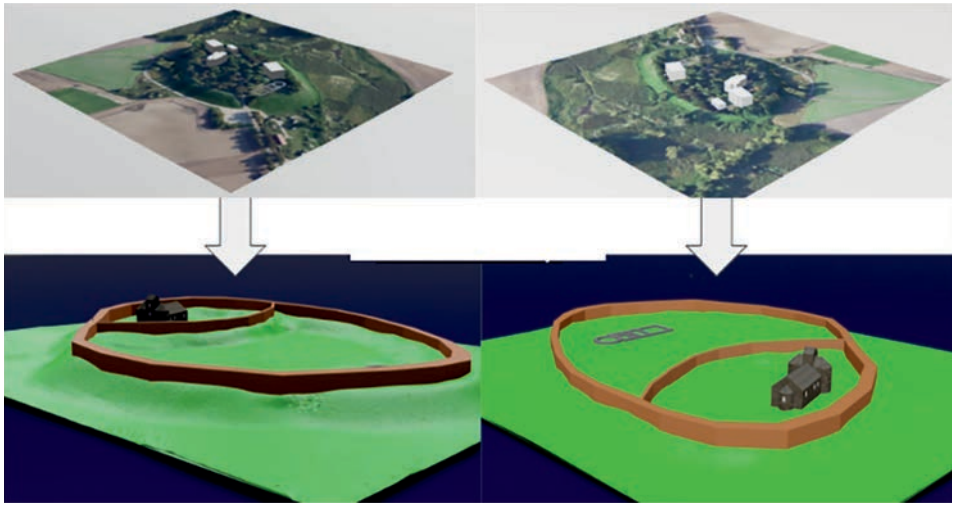

Fig. 12. Effect of comparative geovisualisation in two perspectives: above the stronghold state from 2022, below the state from the 12th century

CONCLUSIONS

On the basis of the geovisualisation of the Giecz stronghold, an attempt was made to solve the problem of sources for the visualisation of medieval strongholds in the direction of reconstruction and comparison with the present state. On the basis of the results obtained, it can be concluded that appropriate work on very

different cartometric and drawing data as well as the latest 3D digital data can contribute to a virtual reconstruction of an important stronghold. The high value of any prospective analysis of two distant states in time by means of advanced virtual geovisualisation technologies opens up possibilities for new representations of the physical features of cultural heritage objects in geographical space. However, this type of visualisation has its errors and limitations; in places where archaeological investigations have not been carried out, the data may not be completely accurate. There is also a need to continuously improve the visual appeal of the created objects by increasing the number of polygons and the quality of textures. The effect of the 3D geovisualisation may be of great importance for further research into changes in historical-geographical space and archaeological-environmental relationships.

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