Computer modelling as a basic research and visualisation tool to research defunct historical mining technologies, using the example of cementation water mining in Smolník (Slovakia)

***Pavol Rybár*[1], *Ladislav Hvizdák*[1], *Pavel Hronček*[1], *Miloš Jesenský*[2] *and* *Robert Šimůnek*[3]**

In the first part of the study, we point out that it is necessary to use 2D and 2.5 (3D) computer modelling when researching defunct or inaccessible historical montane phenomena. Computer models bring new, hitherto unknown information to historic research. In order to obtain the relevant model information, the researcher must use historically-verified information in computer modelling. This can only be obtained through complex and systematic archival and field research. The resulting model delivers much information that the scientist obtains directly by accurate measurement from the models, or their critical qualitative and quantitative evaluation.

The second part of the study provides specific examples of research procedures and methodological processing of computer models, including archival research, field research, expert computer modelling, and critical model evaluation. These procedures are presented using the world's second oldest example of mining and commercial use of cementation water in Smolník. After a brief introduction to the history of cementation in Smolník, we present a 2D model of the oldest map view of cementation dating from 1696, a 2.5 (3D) model of mountain landscape with main water facilities in the second half of the 18th century, and a 2.5 (3D) model of the underground area where cementation water was mined – i.e. what the mining field looked like in the first half of the 19th century.

Key words*: computer modelling, 2D, 2.5 and 3D models, historical research, cementation, mining underground, Smolník*

Introduction

Computer technology and digitisation are now commonplace in every social sphere, touching our everyday lives. Without these technologies, the effective running of our society would be hindered. All scientific disciplines now use computer technology and computer modelling to such an extent that now many would not work or exist as independent disciplines without them. History is somewhat an exception, as it only sporadically uses these technological procedures. It is unfortunate that the trend of digitising and creating visualisations in history lags behind other academic fields. The digitisation of preserved historical collections is only now gathering pace, and methodical procedures in computer modelling in history remain largely redundant. Traditional forms of information around the world are now digitally converted, which generally makes such sources more accessible.

This paper introduces a methodical approach to computer modelling and creating new information, which has been previously unknown in (montane) history. These outputs allow us to virtually visit places that would otherwise remain inaccessible, and to see objects that might otherwise not be seen because they are unavailable or no longer exist. Digital technologies therefore clearly have a wide scope of applications in the field of tangible as well as intangible mining heritage, and in the visualisation of existing and especially defunct buildings, processes, technological procedures, etc. This digital process allows defunct buildings to be critically evaluated and explored, and to be preserved for future generations through digital heritage.

Aim of the study and methodology

This paper aims to elaborate a methodical procedure and highlight opportunities for using 2D and 2.5 (3D) computer modelling as a basic research and visualisation tool to research defunct or inaccessible historical mining objects, technologies, and facilities. The example is used of cementation (vitriol) water mining in the former free royal mining town of Smolník in historical Upper Hungary (in today's Slovakia).

[1] *Pavol Rybár, Ladislav Hvizdák, Pavel Hronček,* Department of Geo and Mining Tourism, Faculty of Mining, Ecology, Process Control and Geotechnology, Institute of Earth Resources, Technical University of Košice, Letná 9, 042 00 Košice, Slovakia, e-mail: pavol.rybar@tuke.sk, ladislav.hvizdak@tuke.sk, pavel.hroncek@tuke.sk

[2] *Miloš Jesenský***,** Museum of Kysuce in Čadca, Moyzesova 50, 022 01 Čadca, Slovakia, e-mail: jesensky@kysuckemuzeum.sk

[3] *Robert Šimůnek,* Department of the Middle Ages history, Institute of History, Academy of Sciences of the Czech Republic, v. v. i., Prosecká 809/76, 190 00 Praha 9, e-mail: r_simunek@lycos.com

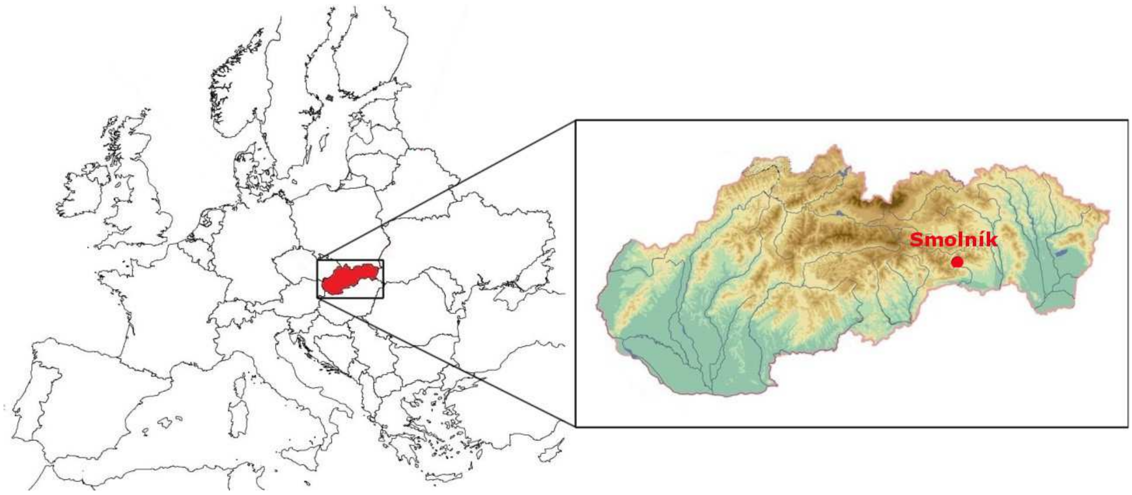

Fig. 1. Location of Smolník within Slovakia and Europe.

In order to meet this paper's objectives, it is necessary to proceed according to the following basic methodical procedures that are divided into three stages.

Archival research: To enable accurate and high-quality computerised modelling, complex and systematic historical research must be first carried out. Only methodically well-directed historical research can provide high-quality text data for the modelling of non-existing or inaccessible montane objects. A historian should proceed on the basis of methodological procedures used in historical research, with an emphasis on archival research (Gerber, 1974; Hroch et al., 1985; Eco, 1997; Best and Kahn, 1998; Dvořák et al., 2014). The gathering of written and visual documents is followed by the classification and critical scientific evaluation of the content - the final synthesis is then processed into a textual form as a basis for computer modelling. The most important historical maps and pictorial documents for the research of this issue are deposited at the Slovak Mining Archive in Banská Štiavnica in the Mining Office Banská Bystrica (hereinafter SMA BS BKBB) and Spišská Nová Ves (hereinafter SMA BS BKSNV) collections, in the so-called Moll Collection in the Moravian Library archive in Brno, and in the National Széchényi Library in Budapest map and picture collection.

Field research: Based on our practical experience with research on similar topics, we know that after finishing historical research and before starting computer modelling, it is necessary to conduct field research. Field research provides information on the development of the historical montane landscape in time and space, it verifies known information and leads the scientist to new, previously unknown historical phenomena and contexts. In field research, it is advisable to proceed according to verified methodological procedures, in particular the method of loading maps over themselves and the leader factor method (Minár et al., 2001, or in accordance with methodological procedures for the exploration of mountain landscape (Demek, 1987; Lacika, 1999; Hronček, 2014). Although an important part of fieldwork is oral history (Ritche, 2003; Veselská, 2008), it is not yet appreciated and so little used in our geographical area.

Computer modelling: In order to get all the information about mining underground, mining facilities, buildings, and whole mining sites (mines) from the old mining maps, we have to georeference them in the first step of digitisation, i.e. place them in the current coordinate system and then merge into one unit (Blišt'an, 2007; Blišťan and Kožiakova, 2008; Timár, 2004; Hlásny, 2007; Cajthaml, 2013). For this step, it is essential to obtain historically relevant map data with archival research, to have a large-scale digital map for the modelled problem or phenomenon available in a computer environment, and also to know the surveyed landscape on the basis of field research. Only once these basic conditions have been met, can the georeferencing be corrected and then used for the 2.5 (3D) modelling of historical mining objects and phenomena (most of which do not exist today).

We have used the ArcMap and ArcCatalog software included in the ArcGIS 9.1 package to georeference maps within the geographic information system (*Koreň*, 2008). The GPS coordinates of selected control points, measured in terrain, were transformed into the JTSK coordinate system using the ConvertCoord application, which is typically used by geodesists to convert GPS coordinates (latitude and longitude) into JTSK coordinates required by the GIS data processing software. With this step, the underlying maps could be placed into the correct (real) position.

When creating 2.5 D perspective models, (resp. 3D models) for the reconstruction of historical, defunct mining objects, technologies, and processes, we proceeded according to the methodology developed by L. Hvizdák and M. Molokáč under the leadership of prof. P. Rybár at the Faculty of Mining, Ecology, Process Control and Geotechnologies at the Technical University of Košice (Rybár and Hvizdák, 2009, 2010; Rybár, Hvizdák, Molokáč, Hvizdáková, 2010; Hvizdák and Molokáč, 2012; Hvizdák, 2013). A similar issue is also addressed by K. Weis and coll. (Weis, Jeleň, Bednárik, 2015). The LIDAR technology was not used because the research was aimed especially at the underground.

A brief history of copper cementation in Smolník – the first basic steps of research towards computer reconstruction

The former free royal town of Smolník lies in the southern part of the Spiš region (former Spiš County) in the eastern part of Slovakia. Smolník used to be part of Upper Hungary (until 1918), and one of the most important mining towns in Hungary. According to archive documents, we know that Smolník had the second oldest commercial copper production by cementation in the world (the first-time copper was obtained using the cementation process was in 1086 in China (Lung, 1986)).

The first written report regarding the production of cementation copper in Smolník, dated 1346, states that the market in Košice also sold cementation copper from Smolník (Juck ed., 1984). It is therefore very likely that the production of copper by cementation began in Smolník sometime during the early 14th century, and it might well have been in the late 13th century. In a contract concluded in 1497 between Matej Turzo, the owner of the ironworks in Levoča, and the chamber count from Smolník, Ján Donel (Wenzel, 1880), it is mentioned that M. Turzo will supply iron for copper cementation and pumping machines.

From the 16th century, we have many records about the cementation process in Smolník, especially the works of medieval alchemists and naturalists. These include, for example, the works of Philippe Theophrastus Paracelsus (Paracelsus, 1570), Juraj (Georgius) Wernher (In Rebro, 1996), Georgius Agricola (Agricola, 1546), Andrej Smoczký (Jesenský, 2009), anonymous encyclopaedic work from 1600 (Anonymus, 1600), Dávid Fröhlich (Fröhlich, 1639), and Luigi Ferdinand Marsigli (Marsigli, 1726).

The oldest surviving drawing of the cementation process - dating from 1748 - is in the parergon of the Clear Map of the Mining Works on Spitzenberg (Ostrý vrch hill) in Smolník by Ján Gašpar Reitzner and Ján Anton von Steinberg. The map is deposited at the Slovak Mining Archive in Banská Štiavnica, in the fund Mining Office Banská Bystrica, inv. no. 00130.

Two more cartographic documents are important for the computer visualisation of cementation water mining. One is a handwritten map of the Smolnian chamber estate (*Teritorial Plan über die zur kay*[serlich] *könig*[lichen] *Schmölnizer Kupfer Handlung gehörige privilegirte ober hungarische Berg Stätte Schmöllniz, Schwädler und Stooss*) from 1774. This cartographic work is stored in the collection of maps and pictorial documents at the National Széchényi Library in Budapest under number TK 1312. The last document is a mining map of cementation water mining underground from the early 19th century. The map shows water tunnels and shafts in Spitzen Berg - the largest mining field. It is deposited at the Slovak Mining Archive in Banská Štiavnica, fund Mining Office Spišská Nová Ves, a collection of maps and plans, inv. no. 9470.

The production of cementation copper and thus cementation water mining reached its peak mid-19th century. From that period it gradually declined, and in 1963 ended (Schenk, 1966). The complex history of cementation water mining and the cementation process in Smolník, from the very beginning to the end of the 19th century, was elaborated in a large manuscript study (Hrončišek, Rybár, Jesenský, Hvizdák, 2017).

Background, goals, and computer reconstruction of cementation water mining

The oldest digital 2D visualisations of cementation water mining in Smolník can be produced on the basis of a critical evaluation of Marsigli's 1696 map (Marsigli, 1726). The map, published by L. F. Marsigli as Fodinae Schmelnitzences, is deposited in the Moll Collection of the Moravian Library in Brno (sig. Moll-0003.128,08).

In the centre, the map (Marsigli, 1696) shows the cross-section of copper mines in Smolník for underground cementation water mining at Spitzen Berg (Ostrý vrch hill, 818 m above sea level (ASL). On the right is a cross-section of Rothenberg (Červený vrch hill, 838 m ASL), which due to the map's orientation (south to north) actually lies west of Spitzen Berg. In the left part of the map is a cross-section of a ridge (810 m ASL) that lies east of Ostrý vrch hill. In the map's top right part is a legend describing the map's individual components. The main copper ore vein of Smolník depicted on the map forms an imaginary axis of the entire underground.

The largest sources of cementation water were in the underground of Spitzen Berg. The author labelled this mining field as "southern" (de Monte meridionali). Five handpumps moved water to the collection ditch (Neu Kolben), from where it continued to the pond at the bottom of an unnamed shaft. This shaft is equipped with a water-driven pumping machine (Machina, quae attollit aquam vitriolatam), and the surface pumping machines above the shaft were powered by a water-driven wheel with raceway (Grund Wasser Fl.). If Marsigli is correct in saying that, despite inaccuracies, the map shows the actual technical state of cementation, we can assume that the lines leading from the shaft to Smolnícky creek (Vorna Fl.) symbolically depict a system of six adjacent cementation drains. The identification of Marsigli's main pumping shaft on the northeast slope of Spitzen Berg is rather problematic. Based on the archive research, it could be the Fund Schacht shaft or the Königer Kiesz Schacht shaft (SMA BS BKSNV, mining map inv. no. 9454). The map shows three circular wooden shaft towers on the ridge of Spitzen Berg, where ore was pulled up to the surface and sorted. However, these shafts cannot be identified both due to the inaccuracy of Marsigli's map and a large number of shafts (in the early 18th century there were 67 (SMA BS BKBB, mining map inv. no. 130)). In the centre of the northern slopes of Spitzen Berg is a tunnel that can be matched (Oral history. Interview with J. Fritch in summer 2014) to the historic Kalb tunnel, which was documented in 1634 (Vlachovič, 1957).

An analogous situation in the underground is also west of Spitzen Berg mining field, where there is a cross-section of the “northern” mining field called Roth (de Monte Septentrionali, Roth dicto), and also in the underground of the ridge (810 m ASL) between Ostrý vrch hill and Štósky vrch hill (865 m ASL).

Map digitisation and creation of 2D models of underground spaces for cementation copper mining in the late 17th century. To obtain historically relevant information from old maps – be it physico-geographic or mining maps – it is necessary to **georeference** them in the first step of digitisation and subsequent research, i.e. to accurately place them in the current coordination system. In this step, it is methodically necessary to draw on, for example, the works by G. Timár (Timár, 2004), T. Hlásny (Hlásny, 2007), M. Boltižiar and B. Olah (Boltižiar and Olah, 2009), J. Cajthaml (Cajthaml, 2013), M. Klaučo et al. (Klaučo, Weis, Gregorová, Anstead, 2014), and other authors.

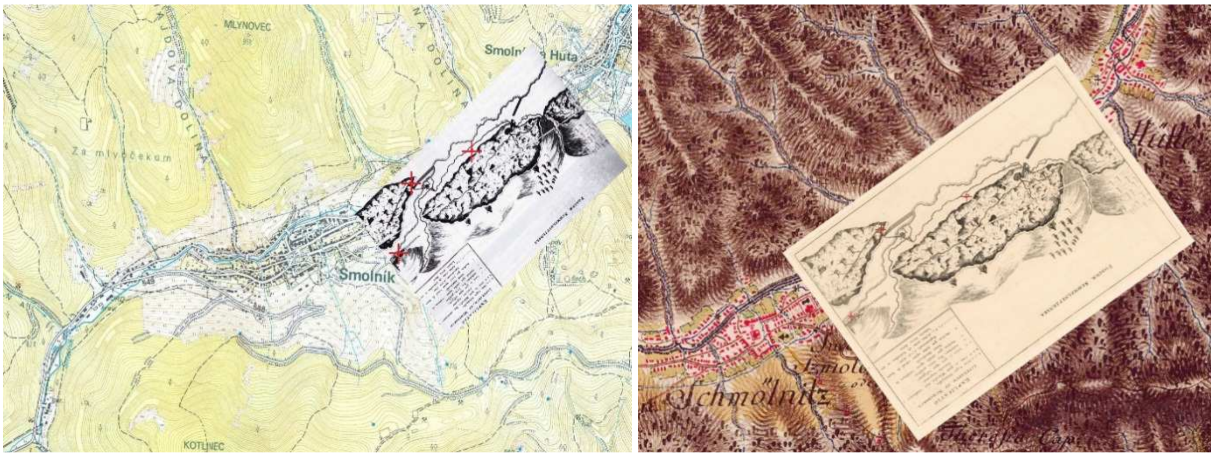

Fig. 2, 3. Projection of the georeferenced Marsigli`s map from 1696 into a contemporaneous geographical map (left) and projection of the georeferenced Marsigli`s map from 1696 into a map from the first military mapping from 1790 (right).

Fig. 4. Projection of the georeferenced Marsigli`s map from 1696 into a 3D Google Earth map. The 2D model creates a real and fairly accurate picture of the position of underground passages, underground technological facilities, and surface cementation facilities at the end of the 17th century.

The map is positioned using control points. The points must be selected in such a way as to minimise the deformation of the underlying map position, i.e. the points must be sufficiently distant, identifiable with certainty, and evenly cover the area shown on the map. Two or three points would be enough for the placement, but the more points there are, the more precise the georeferencing. When georeferencing Marsigli’s map, we used three control points. The original plan had been to identify at least six to eight points, but this was not possible due to age, map content, depiction technology used, and the preservation of suitable montane relics. The following points were identified: the shaft below Červený vrch hill (*Rotenberg*) and the *Kalb* shaft and the *Jozef* shaft at the northern foot of Ostrý vrch hill (*Spitzen Berg*). Control points must be known points in the landscape at a given time horizon and present. Their location is determined from the current map or directly in the terrain; then they are matched with a historical map and overlapped – georeferenced – in the GIS environment. These mainly include road junctions, important buildings, towers, and mining work entrances. The comprehensive identification of the three points in Marsigli's map allowed us to continue with computer modelling. We can incorporate this modified georeferenced map into the current topographic map and work with it. The next step was to insert the map into the 3D Google Earth environment using professional graphics software.

The resulting 2D model enables us to see the basic position of the underground spaces for the cementation water mining, corresponding to the actual position in the landscape relief cross-section in the late 17th century. However, in view of historical montanist research, the correct critical evaluation of the model enables the reconstruction and development of a real, relatively accurate picture of the position of underground passages, underground technological facilities, and surface cementation facilities, as we did above. The correctness of these newly-created outputs is confirmed by written archival documents from later centuries.

Reconstruction of the water management system within the 2.5 (3D) model of the landscape built in the late 18th century for the purpose of expanding the cementation. As we mentioned in the methodology at the beginning of the study, the first step in creating a 2.5 (3D) model of historical water management features created primarily for cementation purposes was detailed historical archival research. For spatial orientation and tracing individual routes in the terrain, historical mining maps were used. The most important was a map from the early 19th century showing the Úhorná water reservoir and the still functional Grom water ditch. Grom was localised in the terrain using a GPS device Garmin GPS Map 62. The measured values on the original route were transformed into an underlying map, and the results of the historical and field research were transferred to this map – a 2D model. So the first step was to create a 2D model, i.e. to georeference and digitise the physico-geographic map of the entire mining area at a scale of 1:10,000, and to record the necessary data (Hlásny, 2007; Cajthaml, 2013; Klaučo, Weis, Gregorová, Anstead, 2014). We digitised three basic and key parts of the water management system. The localisation of the preserved features – the Úhorná reservoir and the southern and northern portal of the Terézia tunnel – was unproblematic (the Terézia tunnel was localised using a GPS device). The third most distinctive and now largely non-existent line element was the reconstruction of the Grom route. Into this digital layer, we gradually added other montane elements that we localised based on historical sources and which, in particular, we identified and targeted using a GPS device during field research. The next modelling step was to transform the 2D model (digital map) into a 2.5 (3D) model using ArcScene, which is part of ArcGIS. In this way, a DRM of the montane landscape around Smolník was created from the reconstruction of the water management system in the late 18th century.

The original Grom (Graben in German), an underground supply canal, started under the Úhorná reservoir (volume of 189,870 m³), built in 1768, where the Smolnícky creek was dammed. From the dam, it continued through the right side of the Smolnícka valley, using various waterworks (tunnels, bridges). Grom supplied water to several pumping machines at the foot of Spitzen Berg (Ostrý vrch hill), which extracted cementation water. Grom also supplied some water that was pumped into the underground to increase the amount of cementation water. The canal was built in the 1850s to increase the amount of cementation water in the underground. The underground Grom canal was 7.45 km long and 0.5 m wide, and had a water depth of 0.6 m - it was dug out, paved, encased with flat stone plates, and eventually covered with soil. It is now largely destroyed. The Smolnícka valley catchment area was insufficient to meet the needs of expanding mining operations, so it was decided to make a water shaft from the neighbouring Bystrý creek basin. The digging with two headings ended in 1796, and the water tunnel (1,836 m long) was named after Empress Maria Theresa (Magula, 1977).

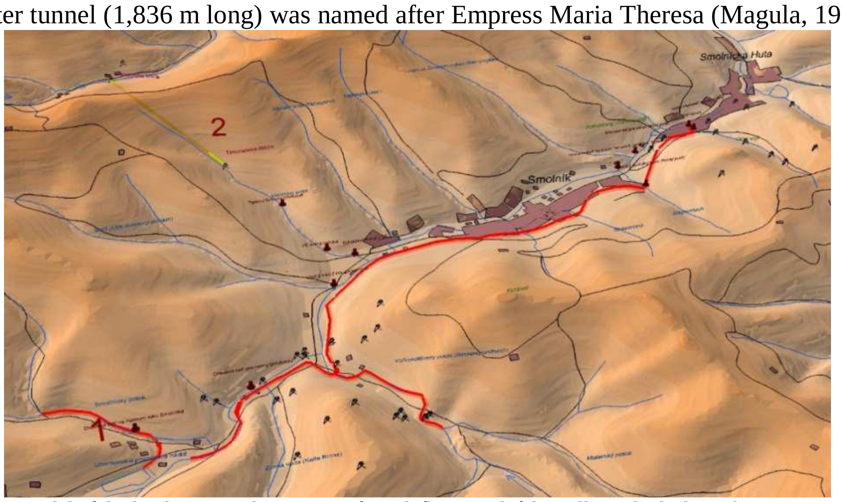

Fig. 5. Digital 3D model of the landscape in the vicinity of Smolník in Smolnícka valley, which shows historic, now defunct tunnels and shafts, as well as the reconstructions of three main water-management structures as per the late 18th century. Today's Úhorná water reservoir (no. 1) and Treziánska tunnel (no. 2). The model also includes a reconstructed route of the Grom raceway (shown with a distinctive red line), which started under Úhorná reservoir and continued through the right side of Smolnícka valley to the northeast slope of Ostrý hill. View from the southwest.

Virtual reconstruction of the defunct underground spaces and adjacent surface situation during cementation water mining in the area of Jozef shaft in the early 19th century using 2.5 (3D) modelling was carried out on the basis of old mining maps, which represented the peak of medieval and early-modern era cartography and provided accurate views of mine underground. The underground floor plan and side views allow, after a critical historical-montane assessment by a computer technician, the creation of 3D models within the displayed time horizon. Using control points, the maps can be placed into modern maps to examine the history of mining, and sometimes even to find old, hitherto unknown mining works, such as mine portals, shafts, and tunnels. In this way, we also processed the map of old cementation water mining areas in Smolník. A 2.5 (3D) spatial mine model was created to provide new presentation opportunities - the mining work can be seen from either side and from the surface to the deepest places.

The methodical procedure for creating a 2.5 (3D) model of the underground mining at Ostrý vrch hill (*Spitzen Berg*) in Smolník was carried out according to the methodology practically used for the first time by P. Rybár and L. Hvizdák (Rybár and Hvizdák, 2009):

The ground plan was georeferenced on the basis of verified relics of old shafts and subsequently placed into current maps – geographic coordinates were assigned to the old mine works. The exact scale of the old map was determined, which, according to the analysis and conversion of two graphical scales in fathoms and meters, was set at 2.07 m of one graphical scale unit. Drawing two scales on the map enabled us to work with great precision.

With the ArcGIS software, the individual mining horizons (water tunnels) were digitised, and each horizon was assigned one layer.

By side view analysis, the individual layers were assigned altitudes, giving the digitised model the third dimension and creating a 2.5 (3D) model from the 2D model.

The next step was the modelling of vertical works – shafts, where they were defined as line objects with two altitude values for their endpoints.

Similarly, obliquely inclined line works were defined in the software, e.g. corridors supplying cementation water from the walls of the underground massif, where the endpoints were assigned different altitudes and locations.

This was followed by colour differentiation of the individual parts of the mining work and their size definition so that the model was representative and had maximum informative value.

In the next step, the entire underground model was embedded in a digital relief model (DMR), creating a real underground view in the early 19th century. Based on field research, we know that the underground is currently caved in and flooded with underground water, which makes it inaccessible.

The last step was the modelling of surface technical objects on the Jozef shaft that ensured the whole process of cementation – from mining to sedimentation in ditches. We created the objects based on their preserved drawings in old maps.

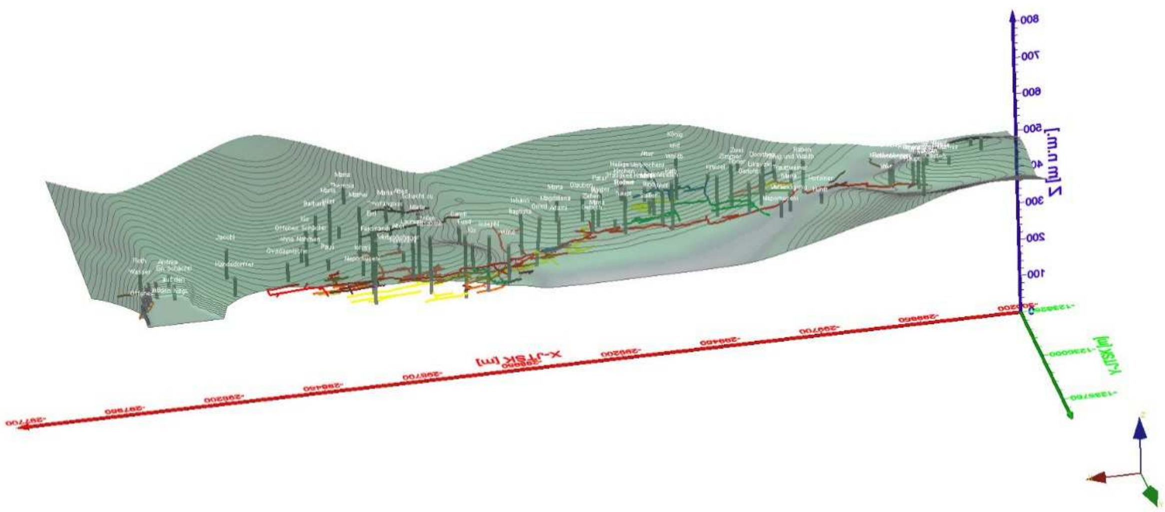

Fig. 6. Digital 2.5 (3D) model showing the mining underground of Spitzenberg hill in mid-18th century (Weis, Bednárik, Masný, 2016).

In the area of Smolník under Spitzen Berg, according to a mining map (Slovak Mining Archive in Banská Štiavnica, fund Mining Office Banská Bystrica, inv. no. 00130) dated 1748, 11,869 m of horizontal corridors were dug, amounting to 169 identifiable tunnels on nine horizons. The longest tunnel - ca. 4,480 m - ran between the Obere Rottenberger Wasser Kunst shaft in the west to the middle between the Jacobi and Kiss shafts east of the deposit. As it almost reached under the whole deposit, it probably also served as a drainage and transport tunnel. On the map, it is marked in red and was dug between 460 m ASL in the west and 484 m ASL east of the deposit. The total length of the vertical mines, i.e. shafts, is 5,053 m, representing 91 identifiable shafts. The deepest shafts are Ertl (183.5 m) and Ferdinandi (inclined length of 178.2 m, depth of 177 m) in the east of the deposit (Weis, Bednárik, Masný, 2016).

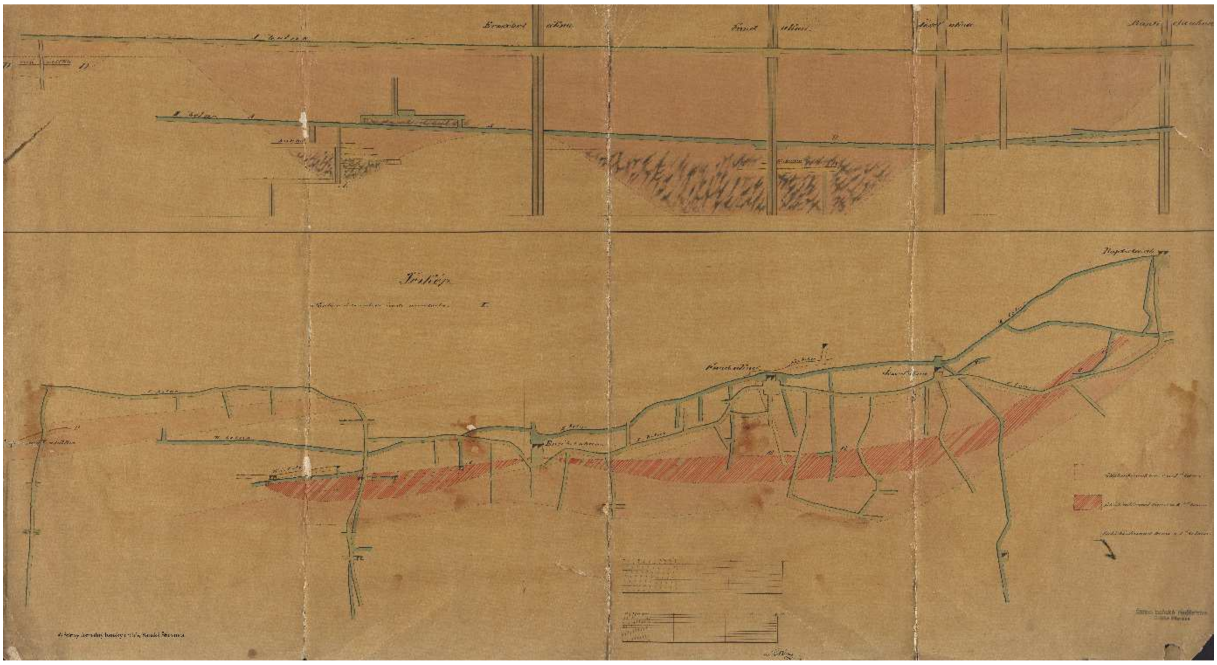

Fig. 7. Mine map from the early 19th century showing the underground for cementation water mining in the mining field in Ostrý vrch hill (Spitzen Berg) (Slovak Mining Archive Banská Štiavnica).

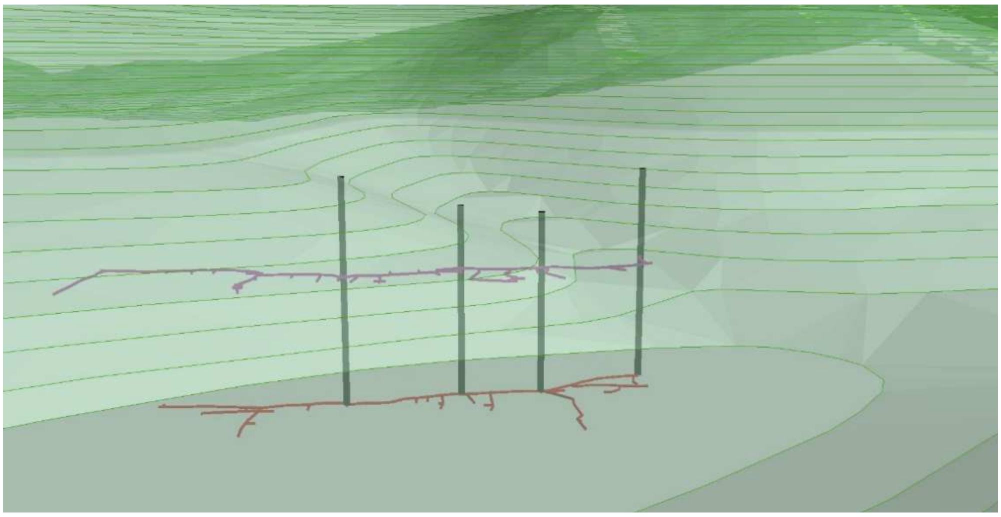

Fig. 8. Digital 2.5 (3D) model showing the underground for cementation water mining and surface cementation facilities at the Jozef shaft in the early 19th century. View from the north.

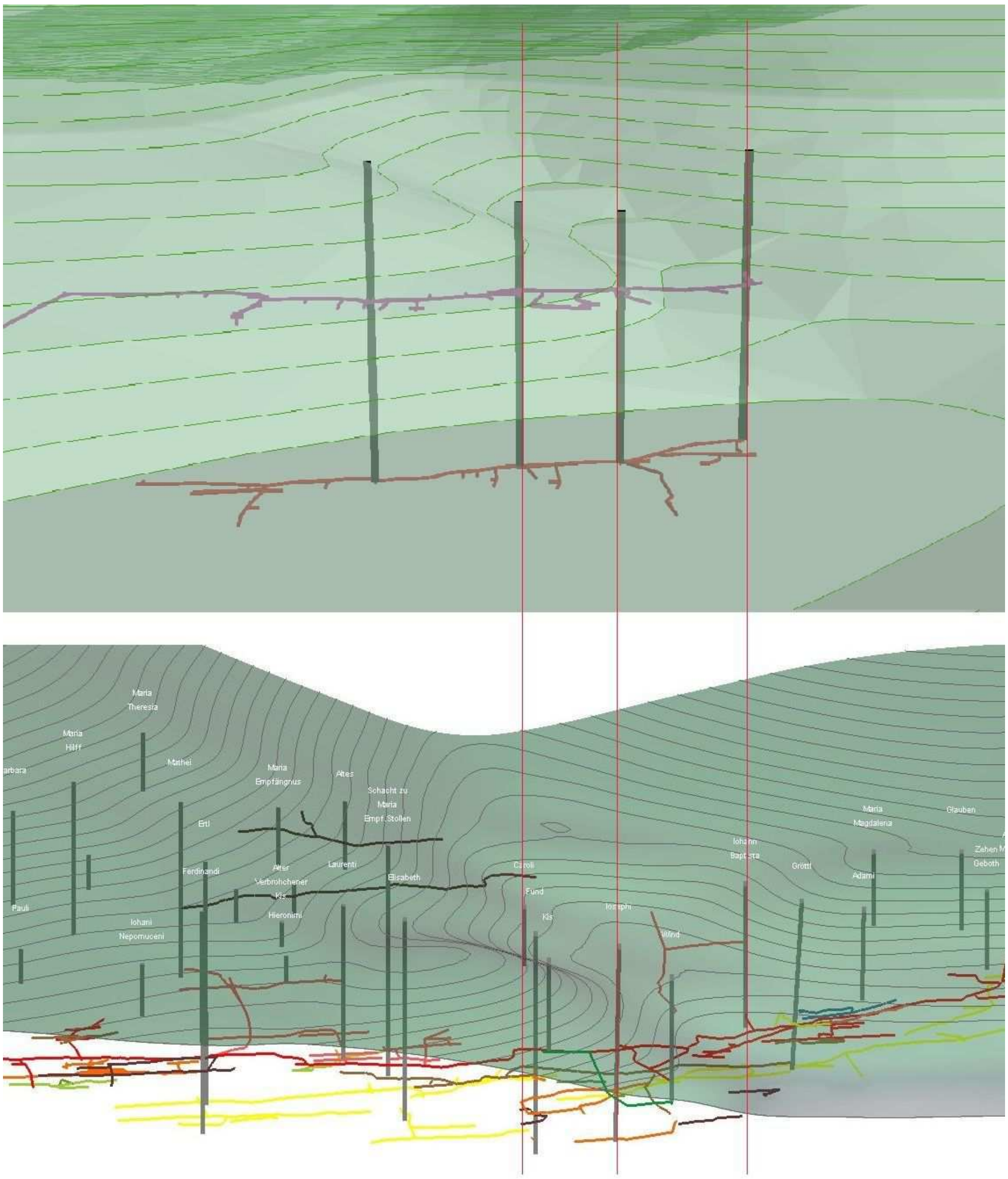

Fig. 9. A complex 2.5 (3D) model of the underground mining under Spitzen Berg in the middle of the 18th century (figure above, edited by Weis, Bednárik, Masný 2016) and 2.5 (3D) model of the new "cementation corridors" driving in the middle of the 19th century between shafts Elisabeth, Fund, Josephi a Johan Baptista (figure below). View from the north.

Conclusion

When researching the history of mining and the related technological processes (digging of underground tunnels, transport, mining water pumping, construction of technical facilities, etc.), the basic methodological process is always archival research combined with the critical analysis of written and pictorial historical sources. Based on this data, an expert in history, or history of montanism and technical sciences, can reconstruct the history of the surveyed historical, currently defunct and often forgotten, mining phenomena. These materials are necessary for the further expansion of historical research, which is now computer modelling. In modelling and subsequent visualisation of surveyed mining phenomena, it is necessary to digitise historically correct materials, because only such digitisation process can guarantee that the correct results of outputs are achieved.

The outputs created by the presented methodological procedures in the form of 2D and 3D models provide new and very accurate historical information about objects, phenomena, technological processes, and various structures. New historical information that we can accurately measure in models (e.g. areas, volumes, lengths, depths, etc.) or obtain by critical analysis (e.g. visual appearance in the landscape, functionality; we can also model period situations – slope ratios, angles of inclination, pile size, communication, underground space size, invisible historical forces, and relationships in the country and society that formed it, etc.), cannot be found in any archival documents - it can only be obtained with the appropriate computer modelling. The quality of input information for modelling in a computer environment is a basic and determining factor in the creation of new, relevant, and unique historical information.

References

Agricola, G.: De Natura Fossilium X. (Textbook of Mineralogy), Translated by Bandy Mark Chance, Bandy Jean A. 1955. *Geological Society of America Special Paper 63, USA, New York, Book IX., p. 188, 1546.*

Agricola, G.*:* Dvanásť kníh o baníctve a hutníctve, 1556. Košice : TU Košice; Zväz hutníctva, ťažobného priemyslu a geológie SR, Translate Petr, K., Petrová, M. 2006, pp. 192 – 193, 2006. Anonymus: Rerum hungaricarum scriptores varii historici, geographici: ex veteribus plerique, sed iam fugientibus editionibus revocati: quidam nunc primùm editi. *Francofurti, p. 599, 1600.*

Best, J. W., Kahn, J. V.: Research in education. Historical research. Chapter 4. *Eight Edition, Boston, London, Toronto, Sydney, Tokyo, Singapore : Allyn and Bacon. pp. 77-112, 1998.*

Blišťan, P., Kožiakova, L.: Geographic information systems - An effective implement for modelling effects of mining activity, (*2008) 8th International Scientific Conference on Modern Management of Mine Producing, Geology and Environmental Protection, SGEM 2008*

Blišt'an, P.: Geographic information systems in geology - efficient tool allowing effective presentation of data, *(2007) 7th International Scientific Conference on Modern Management of Mine Producing, Geology and Environmental Protection, SGEM 2007, https://www.scopus.com/inward/record.uri?eid=2-s2.0-84890282592&partnerID=40&md5=fd3b0d43a1bb7c641704e318e607a97d*

Archive of Moravskej zemskej knihovny v Brně, Czech Republic, Moll collection of maps and pictures.

Archive Országos Széchényi Könyvtár in Budapest, Hungary, Collection of maps and pictures.

Boltižiar, M., Olah, B.: Krajina a jej štruktura (Mapovanie, zmeny a hodnotenie). *Nitra : Fakulta prírodných vied Univerzity Konštantína Filozofa v Nitre, 148 p., 2009.*

Cajthaml, J.: Jak georeferencovat staré mapy? *In Kartografické listy / Cartographic Letters, Vol. 21, Nr. 2, pp. 3-10, 2013.*

Demek, J.: Obecní geomorfologie. *Praha : Academie, 476 p., 1987.*

Dvořák, T., Fasora, L., Chocholáč, B., Malý, T., Nečasová, D., Stoklásková, Z., Wihoda, M.: Úvod do studia dějepisu, 1. díl. *Brno : Masarykova univerzita, 257 p., 2014.*

Eco, U.: Jak napsat doplomovou práci. *Olomouc : Votobla, 271 p., 1997.*

Fröhlich, D.: Medulla geographiae practicae, peregrinantium imprimis usui, deinde historiarum et rerum hoc tempore gestarum gerendarumque pleniori cognitioni accomodata. *Kežmarok : Bartholomaei Bertrami, 453 p., 1639.*

Gerber, E. W.: Methodology in Historical Research. *In Exercise & Sport Sciences Reviews, Volume 2, Issue 1, pp. 335-356, 1974.*

Herčko, I.: Záujem o záhadnú špaňodolinskú a smolnícku cementačnú vodu. In Grecula, Pavol (ed.): História geológie na Slovensku, zväzok I., *Bratislava : Štátny geologický ústav Duonýza Štúra, p. 36, 2002.*

Hlásny, T.: Geografické informačné systémy – Priestorové analýzy. *Banská Bystrica : UMB, 102 p. 2007.*

Hroch, M. et al.: Úvod do studia dějepisu. *Praha : SPN, 304 p., 1985.*

Hronček, P.: Možnosti využitia interdicsiplinárnych výskumných metód v histórii, pri výskume historickej krajiny a historických krajinných prvkov. *In Zborník kysuckého múzea 16/2014, Čadca, Kysucké Múzeum, pp. 21 – 64, 2014.*

Hronček, P., Rybár, P., Jesenský, M., Hvizdák, L.: History of the second oldest of copper cementation process in the world in Upper Hungary (Slovakia). *Manuscript, Archiv of Department of Geo and Mining Tourism, Faculty of Mining, Ecology, Process Control and Geotechnology, Institute of Earth Resources, Technical University of Košice, Letná 9, 042 00 Košice, Slovakia, 27 p. 2017.*

Hvizdák, L.: Miningtourism and information technology. *Ostrava : VŠB, Technická Univerzita, 70 p., 2013.*

Hvizdák, L., Molokáč, M. 2012: Application of GIS to the model of the old mining objects and their exploitation in tourism. *In SGEM 2012: 12th International Multidisciplinary Scientific GeoConference: conference proceedings: Volume 4: pp. 17. – 23. June, 2012, Albena, Bulgaria. Sofia: STEF92 Technology Ltd., pp. 965 – 972.*

Jesenský, M.: An Outline History of Alchemy in Slovakia. *In The role of magic in the past. Bratislava : SAV Pro Historia society, pp. 45 – 57, 2005.*

Jesenský, M.: Alchymistický rukopis Ondreja Smoczkého. *In Zborník Kysuckého múzea v Čadci XII. Čadca, Kysucké múzeum, pp. 129 – 149, 2009.*

Juck, Ľ. (ed.): Výsady miest a mestečiek na Slovensku 1238 – 1350. *Bratislava : Veda, 169 p., 1984.*

Klaučo, M., Weis, K., Gregorová, B., Anstead, L.: Geografické informačné systémy 1. *Banská Bystrica : Vydavateľstvo Univerzity Mateja Bela v Banskej Bystrici Belianum. 71 p., 2014.*

Koreň, M.*:* Geografický informačný systém *ArcGIS. Zvolen : Technická univerzita vo Zvolene, 88 p., 2008.*

Lacika, J.: Geomorfológia – Návody na cvičenia. Skriptum. *Zvolen : TU vo Zvolene, 66 p., 1999.*

Lung, T. N.: The history of copper cementation on iron — The world's first hydrometallurgical process from medieval China. *In Hydrometallurgy, Volume 17, Issue 1, pp. 113 – 129, 1986.*

Magula, R.: Využívanie vody pre banícke účely v Spišsko-gemerskom rudohorí v minulosti. *In Zborník Slovenského banského múzea, 8, p. 80, 1977.*

Marsigli, Luigi, Ferdinando. Map: Fodinae Schmelnitzences. 1696. *Moravská zemská knihovna v Brně, Mollova sbírka, sig. Moll-0003.128,08.*

Marsigli, L., F.: Danubius Pannonico-Mysicus: Observationibus Geographicis, Astronomicis, Hydrographicis, Historicis, Physicis. *Perlustratus et in sex tomos digestus. Den Haag : Gosse, Alberts, de Hondt; Amsterdam : Uytwerf, Changuion, Tomus 2., 1726.*

Minár, J. et al. Geoekologický (komplexný fyzickogeografický) výskum a mapovanie vo veľkých mierkach. *In Geografické spektrum 3. Bratislava : Geografika, 209 p., 2001.*

Paracelsus, Ph., Th.: De Tinctura Physicorum. *Straszburg, Durch Theodosium Rihel, 483 p., 1570.*

Ponduš, I. Príspevok k dejinám alchýmie v Kežmarku. *In Historica Carpatica, č. 15/1984, Košice, p. 241, 1984.*

Rebro, A. Vzácne a obdivované vody Slovenska. *Piešťany : Balneologické múzeum, p. 88, 1996.*

Ritche, D., A. 2003: Doing oral history: a practical guide. *Published by Oxford University Press, Oxford, UK, 321 p.*

Rybár, P., Hvizdák, L.: Využitie starých banských a geologických máp pre banský turizmus prípadová štúdia Gelnica a okolie. *In Z dejín vedy a techniky stredoslovenského regiónu. Banská Bystrica : Ústav vedy a výskumu UMB, pp. 214-225, 2009.*

Rybár, P., Hvizdák, L., Molokáč, M., Hvizdáková, J.: Information technologies in montaneous tourism. *In Acta Geoturistica, Volume 1, Number 2, 2010, pp. 41 – 49, 2010.*

Rybár, P., Hvizdák, L.: Information technologies and mining tourism. *In Acta Geoturistica, Volume 1, Number 1, 2010, pp. 12-24, 2010.*

Schenk, J.: Cementové vody kyzového ložiska ve Smolníku a získávání z nich mědi chemickou úpravou v 18. a 19. století. *In Z dejín vied a techniky na Slovensku IV., p. 160., 1966.*

Slovak mining archiv in Banská Štiavnica, funde Banský kapitanát Spišská Nová Ves, Collection of maps and plans (cited as: SMA BS BKSNV).

Slovak mining archiv v Banskej Štiavnici vo funde Banský kapitanát Banská Bystrica, Collection of maps and plans (cited as: SMA BS BKBB).

Timár, G.: GIS integration of the second military survey sections – a solution valid on the territory of Slovakia and Hungary. *In Kartografické listy, 12, pp. 119-126, 2004.*

Veselská, N.: Využitie ústnych prameňov v historickom výskume. In Forum Historiae, roč. 2008, č. 1. *Internetový časopis Historického ústavu SAV v Bratislave. 2008. Dostupné on-line: http://forumhistoriae.sk.*

Vlachovič, J.: Súpis zariadení mediarskeho banského podniku v Smolníku z roku 1634. In *Historické štúdie III.*, Bratislava, SAV, p. 429, 1957.

Vlachovič, J. Slovenská meď v 16. a 17. storočí. *Bratislava : Vydavateľstvo Slovenskej akadémie vied, pp. 44 – 45, 1964.*

Weis, K., Bednárik, P., Masný, M.: Geograficko-montanistický výskum v baníckej lokalite Smolník a virtuálna rekonštrukcia historických banských diel (Geographically-montanistic research of mining site Smolník and its mining works virtual reconstruction). *In Geografické informácie, roč. 20, č. 2, s. 828-843, 2016.*

Weis, K., Jeleň, S., Bednárik, P.: 3D visualisation of old mining works in Central Slovakia and their presentation on the internet. *In Cultural Heritage in Geosciences, Mining and Metallurgy Libraries, Banská Štiavnica: Slovak Mining Museum, pp. 197-208, 2015.*

Wenzel, G. Magyarország bányászatának kritikai története. *Budapest, p. 79, 1880.*