Information technologies and mining tourism

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ABSTRACT
The report gives a brief account of Gelnica historical mining of European relevance thanks to precious, color, and iron metal production from the Middle Ages up to the 20th century. However, contemporary shape of the earlier works and technical equipments linked with historical mining are not as valuable as we might wish, to be able to attract tourists interested in the mining of earlier times. The authors processed old mining and geological maps of Gelnica and environs, and created a unique virtual project which can meet the goal. Moreover, having connected mining and geological data, there has been created a rare three-dimensional image of ore vein composition, pings, ping fields and historical mining works in the explored region. The chosen approach is universal, usable for various mining localities.

Keywords: information technology, mining tourism, Gelnica

MINING TOURISM

With a touch of irony, we can state: the less mining, the more mining tourism. At the present time people are getting more interested in the remnants of mining, in contrast to quite recent negative attitudes towards its activities. However, as visitors, people respect the underground space, finding mining an adrenaline sport, partly adventure or heroism, and, after all, the tourists are as well curious about the miner's underground life and work.

Mining tourism offers visitors a chance to see and get to know mining tools, devices and technologies, minerals, ores and rocks accessible in the region, technologies applied in ore extractions, as well as technologies used to enrich produced ores; historical personalities who used to secure and support mining process, just like conditions in the area after shut-downs of the operations. All this has to be administered in an utterly understandable, interesting and engaging manner. There is also a social aspect associated with mining activities; therefore it is necessary to present a miner as a free person, migrating in accordance with needs, respecting a cycle of completion and repeated opening of mining operations. Miners would establish their communities, and mining technology, often highly advanced.

The above mentioned was all included in mining, and deleting its traces could as well mean a great loss of the social memory of humankind because all these spheres of action accompanied people through centuries; in case we add more primitive aspects of mining, thousands of years would count, too. And so, salvation of mining relicts and their presentation to the present and future generations in the form of mining tourism is just natural.

VISUALIZATION SPECIALTIES OF GEOLOGICAL AND MINING PHENOMENA WITHIN THE HISTORICAL MINING TERRITORY OF GELNICA AND ENVIRONS

For the above mentioned purpose, it is possible to utilize the environment and

tools provided by the Geographical Information System GIS). In order to complete the task, we have substituted missing evidence and documents by means of our own logical presuppositions:

- "seniors" (miners living in the earlier historic times) excavated mining shafts, following the advancement of rich veins both along its run and dip.
- "seniors" did not hollow the shafts beyond bearing bodies, with the exception of drainage gallery
- lots of old mining maps were used as a historical document, unique exhibit in the private collections; however, their three-dimensional identification is questionable. By finding common locations, it will be possible to position an earlier map into the physical setting.
- field research, too, can help identify the site of the earlier mining activities through identification of the former sites, discovering pings, ping fields and searching for and finding tunnel portals or their remnants, applying previous hypothesis that the seniors excavated and hollowed a shaft according to the runs and dips. After the identification of the miner's entrance spots, we presume that continuation of the shaft tracks the ore vein progression. With the idea of average advancement of the tunnel length, which could be 10 m a year with no explosives at hand, the only direction he took, was the rich presence of ore in the reef. With help of the combination of both: data of the development of the tunnels and geological maps, it is possible to identify directions of the earlier works in the researched territory, in our case: Gelnica and the environs.
- by choosing GIS as a computing medium, taking the opportunity of using different map materials and data right from the landscape, it is feasible to process data of varied levels and qualities, while respecting our ideas. GIS guarantees interaction of historic maps without a geodetic point, demonstrated in various gauges, available from 15th up to 19th century, along with the later mining maps originally created by more precise methods; in case of Gelnica and surroundings, predominantly by means of maps and geological cuts from the 70th of 20th century.

GELNICA ORE DISTRICT

The extensive ore district contains abundance of ore reefs laid in the rocks of porfyroid series, whose filling is quite varied. (Fig. 1).

Ore veins represent a type of hydrothermal siderite and also silicious copper ores. There are two well-known vein traverses, i.e., Thick: Hrubá (siderite) with twigs and Gelnická called also Kahlehöhe, (siliceous), which in a slight angle intersect. The veins occasionally contained sufficient amount of copper. Numerous veins in the valley of Grellenseifen carried siderite ore of lesser quality, and in the vein range of Zenderling, there were mercury ores. Primary minerals which used to be the subject of the extraction were represented by chalcopyrite and tetraedritom, rich in silver that used to be, together with copper, vastly utilized in the earlier times. As to the average metal content of the veins, there are no data available. The veinstone thickness occasionally reached as much as 6 m.

It is known that copper and mercury ores were mined above all in the region of Gelnica westwards, in the basic length of about 4 km and continues further on in the area of Slovinky within 5 km range. It is the longest uninterrupted deposit traverse, or mining complex at Slovinky.

Initially, the above mentioned two main veins in the territory of Gelnica were mined through pings, later on through tunnels and shafts. There is a conspicuous great number of shafts linked with the equally great number of skilled workers (private operators, mining plants, as well as a mining exchequer), who worked independently alongside vein traverses.

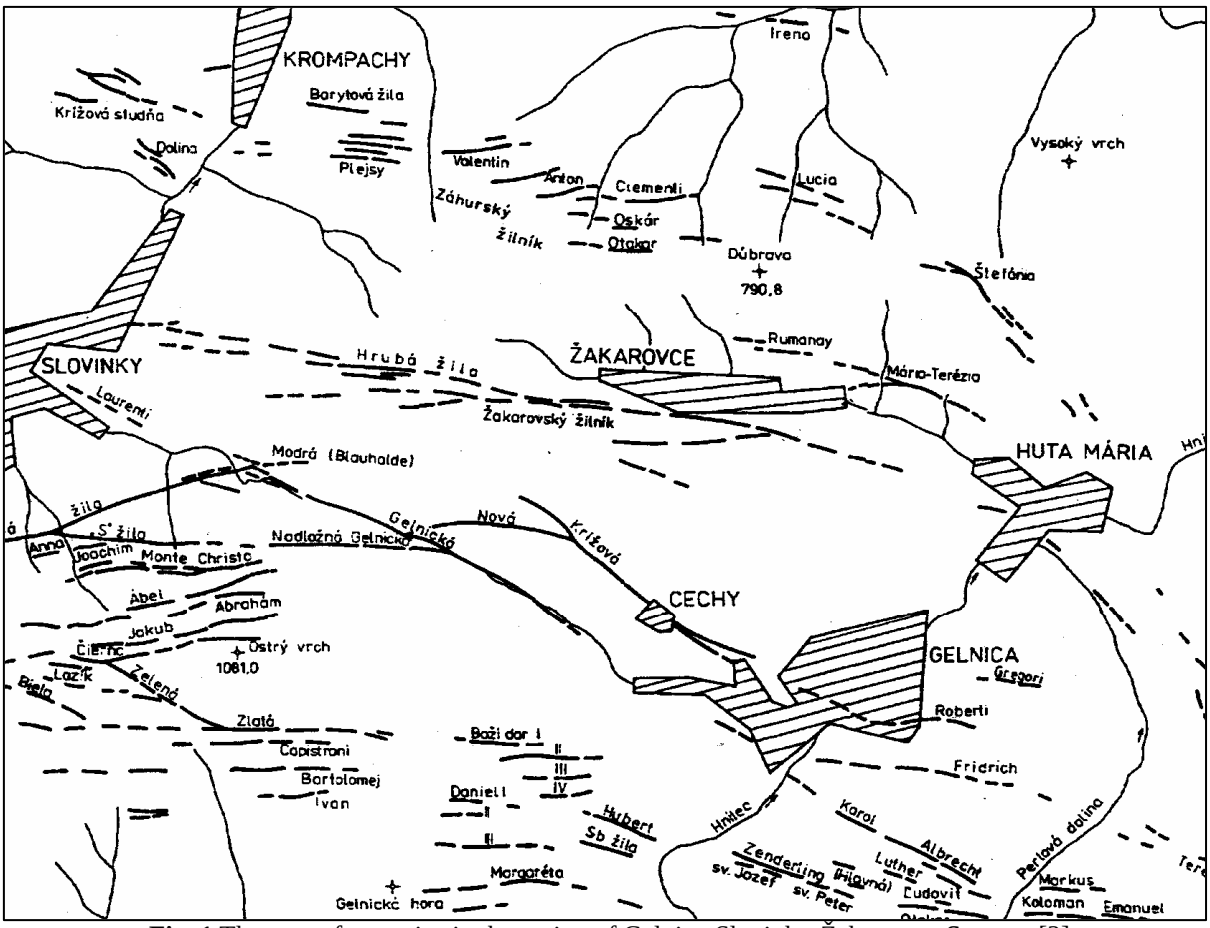

Fig. 1 The map of ore veins in the region of Gelnica-Slovinky-Žakarovce, **Source**: [3]

THE HISTORY OF MINING AT GELNICA AND SURROUNDINGS

The beginnings of mining in the Slovak Ore Mountains are impossible to trace back in detail. Some of the historians, who analyzed archeological discoveries of metal items found in the region of the Slovak Ore Mountains, have come to conclusion that they were made from metals of the local deposits. An outstanding Czech historian J.Kořan brought to attention a foreign explorer who had tested chemical composition of copper items found in the Little Asia; and based on his conclusion, the items were made in the second millennium B.C., they were made from pure copper, mined at some of the Spiš – Gemer sites. There also exists an indirect, but very valuable finding of a fireplace and pieces of iron at Jasov, traced back to Halstadt period (800-400 B.C.), and there is a presumption that these were produced from ores found in a nearby deposit. In the first century A.D., historians G. Plinius a C. Tacitus made a comment on the Celts and Kvads who produced iron in connection with iron ore extractions in the area of contemporary Slovakia.The Slavs, who replaced them, blended later on with descendants of tribes who had remained here. The Hungarians who invaded the territory of Slovakia in the 9th century, appreciated its mining and metallurgy because they highly benefited from it. More exact information on mining comes from the era of the Arpads, who sent for the colonists - craftsmen and miners, and these new inhabitants began to establish the first mining settlements in the regions of Spiš and Gemer, which is documented in the preserved records. Historians came to conclusion that mining is much older than the first mining records However, there is

still a remaining mystery regarding the very first amounts of excavated iron in the mines of the Slovak Ore Mountains [1, 2].

Direct evidence on mining in the territory of Gelnica had been preserved only from the period after the Tartar invasion over the 1241-1242ys span, during the times of forming mining settlements. The oldest existing documents are royal edicts of the mining lands and grands related to mining sites and towns of Gelnica (1264), Spišská Nová Ves (1271), Nálepkovo (1290), Smolník (1327), Švedlár a Mníšek nad Hnilcom (1337), Stará Voda (1344), Slovinky, Krompachy, Žakarovce, Jaklovce, Folkmár, Kojšov, Prakovce a Helcmanovce (1368). At the time of issuing the royal documents, mining had already existed.

In the course of time, larger mining centers had developed. In 1487, representatives of the Upper-Hungarian mining towns assembled in order to constitute a mining law and judiciary statute. At the same time they established the status of mining towns within the above mentioned Upper-Hungarian mining towns as follows: 1. Gelnica, 2. Smolník, 3. Rudabánya (contemporary Hungary), 4. Jasov, 5. Telkibánya (contemporary Hungary), 6. Rožňava, 7. Spišská Nová Ves. The listing characterized the mining and scope of mining in the respective regions in 15th century [4].

Ore and utility mineral mining used to be the right of a monarch who exercised the law himself or transferred it towards the landlords on their own estates in the forms of privileges effective as well for smaller townships as parts of mining cities.

Usual forms of mining entrepreneurship at Spiš varied. Out of secular landlords, the families of the Thurza, Čáki and Mariaši played an important role.

In the area of the Spiš-Gemer ore mountains, the association of Upper-Hungarian miners became the most significant in copper ore excavations (Oberungarische Waldburgreschaft, in Hungarian Felsömagyarországi bánya-polgárság); it was established in the year 1748 and had been in effect until its dissolution in the year 1898.

VISUALIZATION OF GEOLOGICAL AND MINING PHENOMENON IN THE HISTORICAL TERRITORY OF GELNICA AND SURROUNDINGS

In order to achieve the goal, it was necessary to choose maps as a foundation for the documentary material in time and space in the region of Gelnica and vicinity. We looked them up in the archives of Bratislava, Spišská Nová Ves, Gelnica, Banskej Štiavnica and Košice.Those were the following institutions: the public geological institute of Dionýz Štúr, Bratislava, Regional center Spišská Nová Ves, the archive of the mining museum at v Gelnica, the public central mining archive at Banská Štiavnica and the BERG college Košice.

The maps are dated in the second half of the 20th century, but there were also maps from the19th century and earlier times. Gauges of the processed maps gave evidence of different historic periods of their origin. We processed maps with the scales of 1:500, 1:2880, 1:10 000, 1:25 000, 1:5 000, 1:2000, 1:2460, 1:5760, 1:2014,1:840, 1:855, 1:2476 and 1:1240. Nowadays unusual, the map gauges are from the earlier times. Historical maps, drawn in hand, comprised another anomaly against modern practises: they were not oriented in terms of contemporary usage, i.e., the north side was not located at the upper part of the map.

In the database of used and incorporated maps of the researched area, we can find charts with basic data of the digitalized maps that became a part of documents featuring three dimensional and chronological development of mining at Gelnica and surroundings. Within the research, we also developed and digitalized other maps of the explored area, but they were not included in the final study.

METHODS OF PROCESSING HORIZONTAL AND VISUAL DATA – GEOREFERENCING

Depiction of mining works from various historical periods according to the maps of different historical times, different quality, gauge, geographical orientation, along with development of arterial veins in the researched territory, is possible through line connection of coordinate files, so called georeferencing, which is one of the GIS tools. This enables the maps to be simply rotated or shifted on condition the scanned paper maps have been vectorized into the GIS database, resulting in a set of digitalized maps depicting a situation on the surface, geological structure of the historical territory, or mining maps from the earlier periods, and recent times in the researched territory, transformed into cartesian coordinate system.

The plan also added a requirement to incorporate existing historical mining artefacts - shaft portals, pingos and pingo fields into the general image of mining operations, and three dimensional configurations of the ore veins in the explored area.

For this purpose, it was important to identify their position with tip points of the ore veins and coincide the development of historical mining works with the run of veins alongside the ore filling.

By means of georeferencing, we could demonstrate the following phenomenon:

- the course of ore veins: Gelnická vein, Lap vein, New vein, Cross vein
- setting of portals in the old, at the present time, predominantly abandoned and smothered shafts.
- location of the shafts in a part of the Gelnica ore field

We consider the ability to locate historical mining maps into the recreated ones very important, and thus help remodel historical mining territory of Gelnica and its environs.

CREATION OF 2D AND 3D MODELS, RESTORED HISTORICAL MINING TERRITORY

Reconstruction of the historical mining territory and visualization of geological and mining data in the region of Gelnica has been implemented as follows:

As a common basis of all maps, there has been chosen one Sketch-map – the Cross vein (further on only Sketch-map) situated in the coordinate system JTSK. It has been picked on the basis of a number of coordinates securing high accuracy, and on the number of mining objects shown on the map. Based on the common points on the base map and in other chosen and digitally designed maps, consequently, the earlier mining maps were attached to the base map, which guaranteed their correct placement in the map system, along with unchanged gauge.

Gelnica ore region is predominantly composed of Cross, Gelnica, Top (or Overlying) veins. Eduard Figna, the author of the research "Gelnica Cu – 1953", quotes: "*In the archive files, there is no such map that could present a precise position of the vein itself. Older maps display only mining holes, so position and development of a deposit can be remodeled to a certain extent through annotations on the maps, and from the pictured mining works.*". In addition, it is important to mention that the first mining maps appeared at the beginning of 18th century. Based on these facts, modeling of the above mentioned four veins is approximation, which in some cases, more or less, approaches real conditions.

The programming package ArcGIS is not designed to create a deposit geological model (at this point it does not matter whether we take into account ore veins or deposit bodies). With sufficient load of information and data, predominantly from the test drillings, it is feasible to design an adequate deposit model.

In order to project two and three-dimensional model of four Gelnica veins, it was necessary to create a map whose all four veins would be depicted. We have used the following records:

- **Gelnica – The New vein - Nová žila, VP**; author: RNDr. Husár M. & co..; source: ŠGUDŠ BA. The map displays a complete flow line of the New vein and incomplete courses of the remaining veins at the altitude of 560 m.
- **Geological map of the Cross vein at Gelnica**; author: Ing. Hladík ; source: ŠGUDŠ Spišská Nová Ves. The map shows only the flow line of the Cross vein's end.
- **Gelnica – Lap vein**; author: Ing. Čuj P.; source: ŠGUDŠ BA. The map displays a complete flow line of the Gelnica and Lap vein, and a part of the New vein.
- Grecula P., et al.: **Mineral deposits in the Slovak Ore Mountains.** Vol.1, Geocomplex publisher, Bratislava, 1995, map on p. 286 – 287. The map shows the flow line of all four veins on the level of horizon III, at the altitude of 340.

Tab. 1 provides basic data on four simulated veins in the Gelnica ore field.

MAPPING DATA PROCESSING METHOD

First of all, each map was loaded into the ArcMap, where it was consequently georeferenced (in the ArcMap program, the maps were allocated actual coordinates, obtained from the maps). Three maps out of four contain coordinates in the JTSK coordinate system. The map which did not cover the coordinates were georeferenced, based on the common points, e.g., the Cross Hole point, and other. After successful georeferencing, the first three maps were opened in the ArcMap program simultaneously, as it is shown in the Fig. 2. As we can see in the picture, the maps overlap each other, which secures continual transfer of the vein depictions from one map to another.

These three maps provide an overall flow line of four Gelnica ore veins at the altitude of 560 m.

Tab. 1 Gelnica veins – basic data

	Gelnica vein	**Overlying vein**	**New vein**	**Cross vein**
Total length of vein	Cca 5600 m	Cca 1000 m	1470 m	3500 m
Total vein flow line on the surface	5000 m			
Vein gradient	55 – 75° JZ	70° J	60° SV	75 – 90° JZ
Penetration depth	800 – 1000 m	50 – 200 m altitude under 340 m	70 – 130 m altitude under 340 m	Cca 500 m under surface
Vertical vein yield range	350 m			

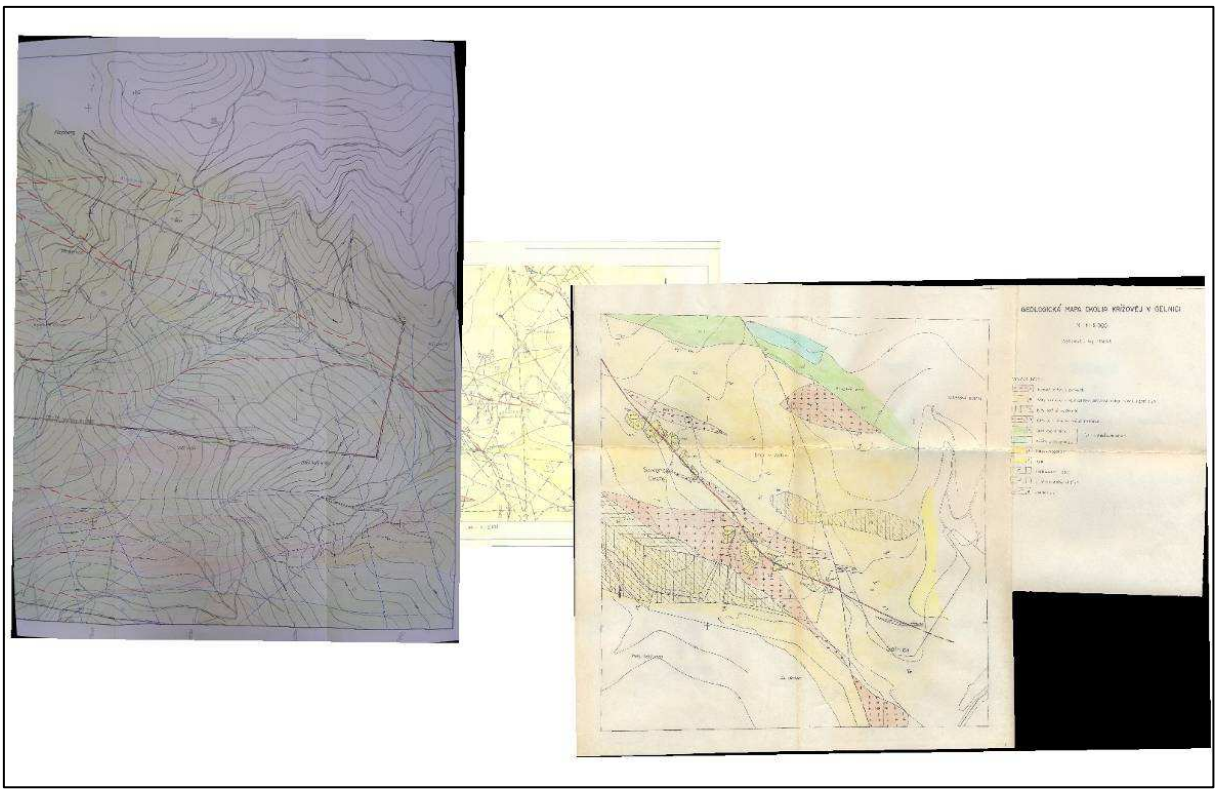

Fig. 2 Georeferenced maps overlapping one another, **Source:** Authors

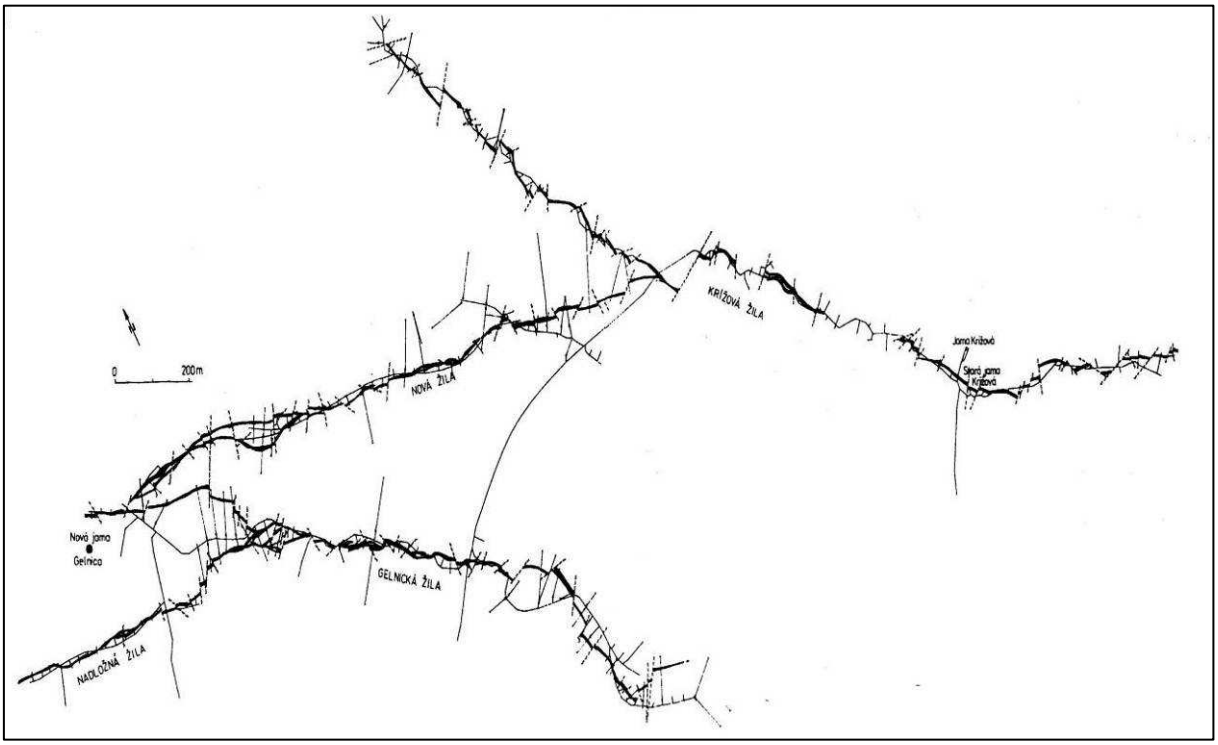

Fig. 3 The flow line of four Gelnica veins on the level of horizon III. (340 m altitude), **Source:** [3]

CREATION OF THREE – DIMENSIONAL (3D) MODEL OF FOUR GELNICA VEINS

On order to be able to create a three-dimensional image of this vein, it was necessary to accept a few conditions and simplifications:

- The vein in space will be considered a platy body,
- Penetration length, due to the lack of data, will be modeled into the depth chosen by a modeler,
- A vein surfaces in the spots where pings, ping fields and portals of the old shafts are located,
- Every vein has its characteristic gradient. All Gelnica veins have steep, up to very abrupt gradient within 60 - 90°. As the ArcGIS is not an ideal software for 3D the modeling of such structures, we adopted a simplified solution: all veins have 90° gradient.

Figures 6 and 7 are documenting 3D projection of ore veins along with mining holes in the model territory of the Gelnica ore field.

Figure 8 shows georeferencing of the former historical map with two maps obtained from ŠGÚDŠ in Bratislava, which apparently redrew older mapping data because shafts *Kaiser* did not appear on the maps approximately after 1950y.

So as to get three-dimensional image of particular horizons of the mining work *Kaiser,* as well as other mining works, we handled their vertical positioning by shifting the identified horizon upwards or downwards, the correct altitude was transferred from a historical map in the place, where the adit collar happened to occur on the earth surface; the rest of the mine was all "located" inside of the rock massive. With the exception of a few mines, where we could obtain data on the altitude or locations of exits on the surface by means of the GPS devices, we could miscalculate some of them within the range of 5 – 10 m, because of the landscape adjustments. There are no data regarding advancements of these historical works, so non-professionals and historians are given a brand new, so far unknown material.

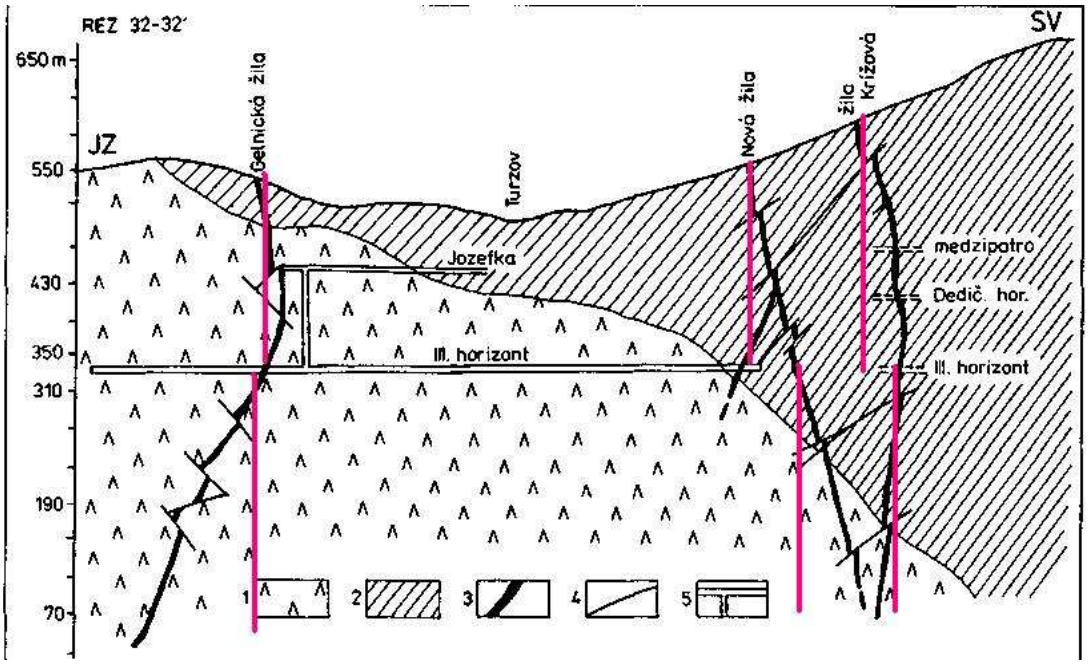

Fig. 4 Diagonal profile across the middle part of the Gelnica ore field (Piovarcsy a Husár, 1986). The view and gradient of the Gelnica, New and Cross veins. Models of veins in GIS are marked in red. **Source:** Authors after [5]

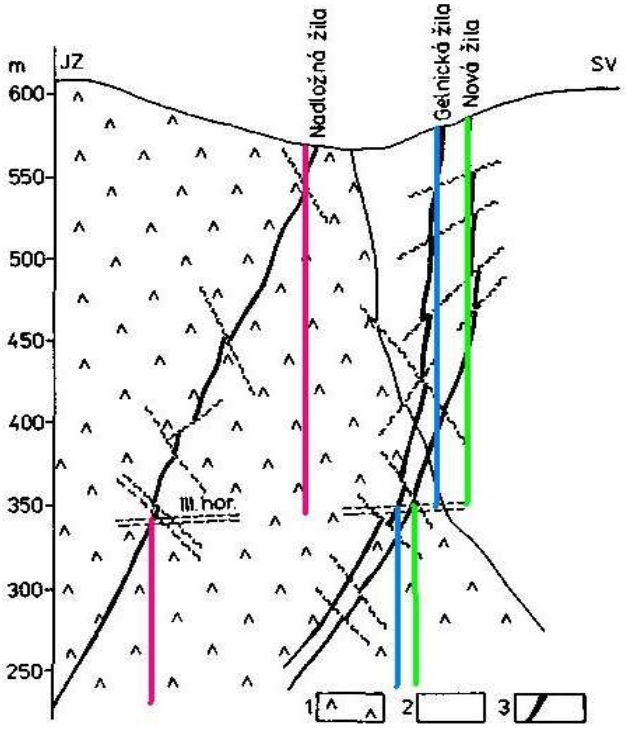

Fig. 5 Diagonal cut through northwestern part of the ore field Gelnica (Piovarcsy and Husár, 1986).Vein models are highlighted in colors of GIS (red – lap vein, blue – Gelnica vein, green – New vein), **Source:** Authors after [5]

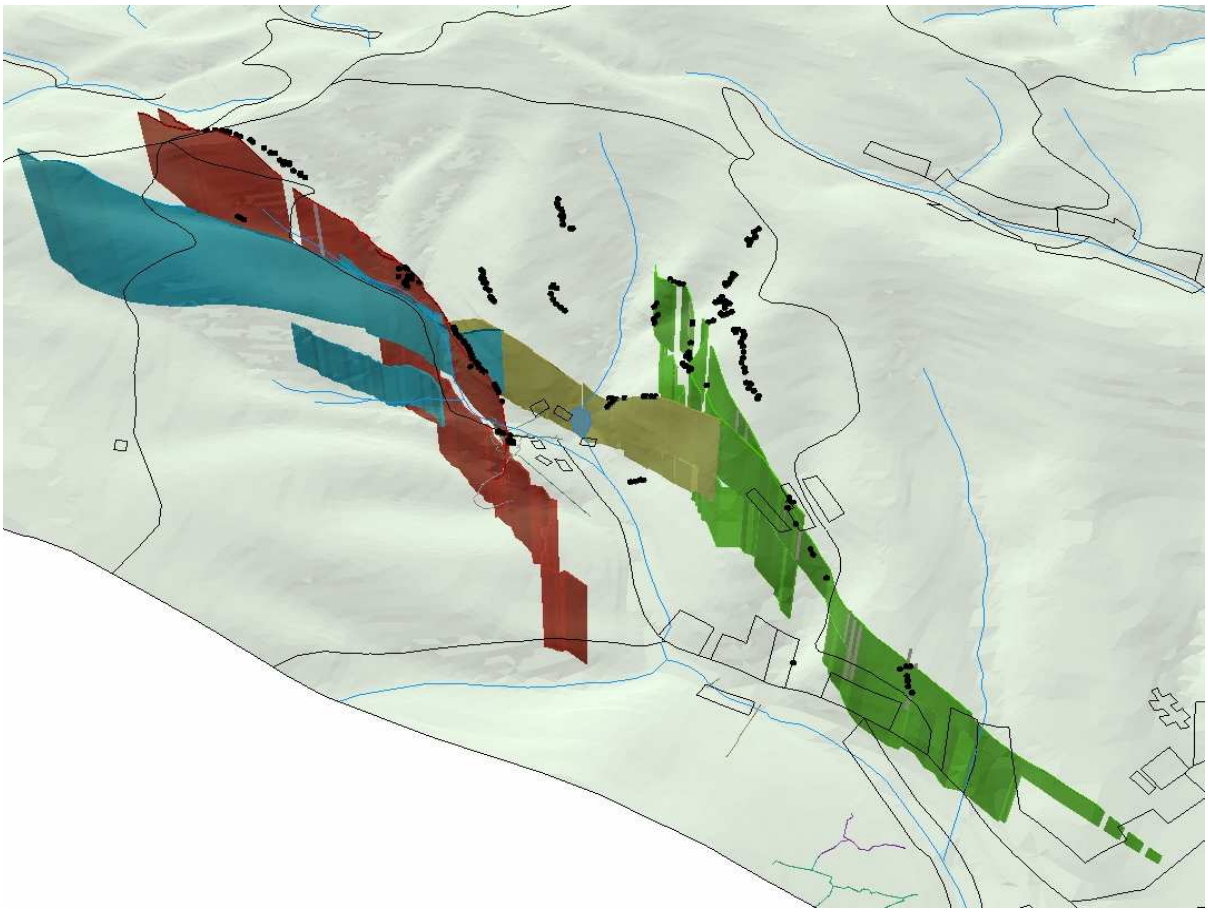

Fig. 6 Depiction of the flow line of four ore veins along with pings and ping fields, **Source:** Authors

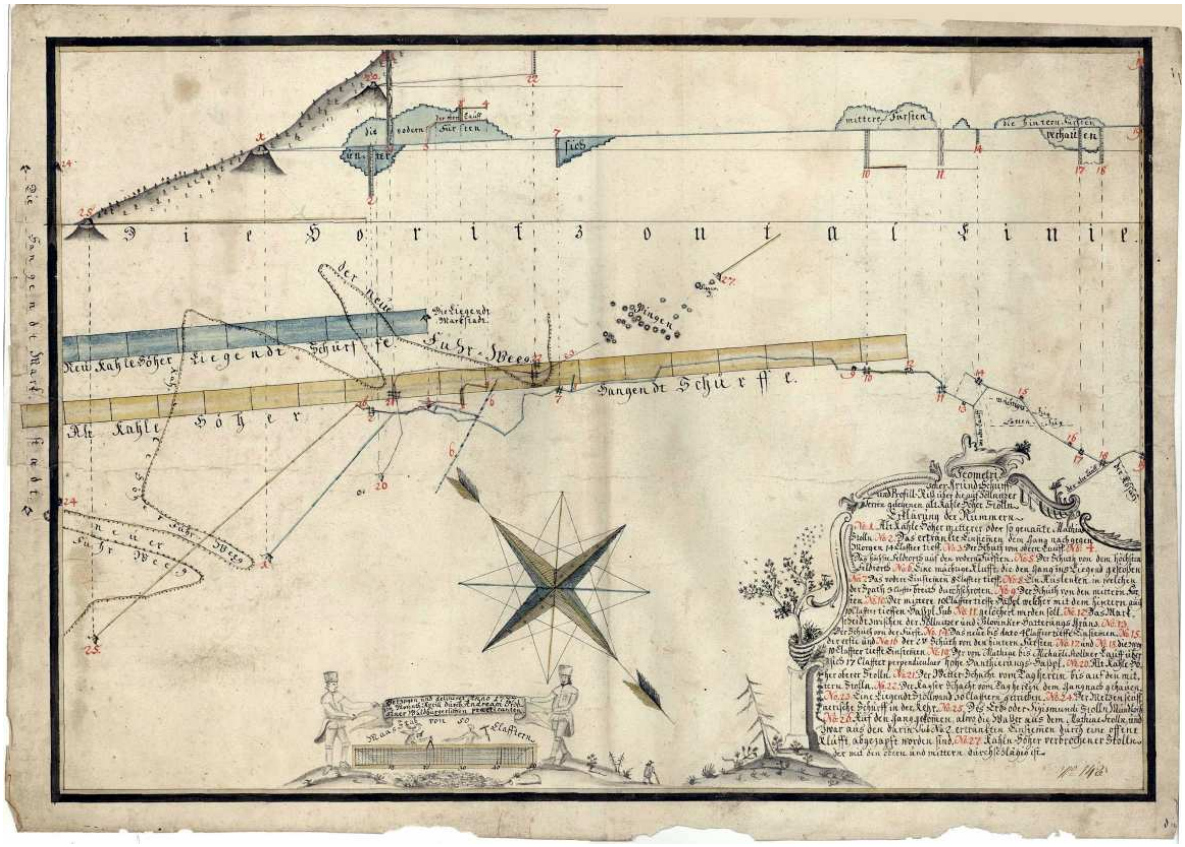

Fig. 7 Historical map from 18th century, **Source:** Mining museum in Gelnica

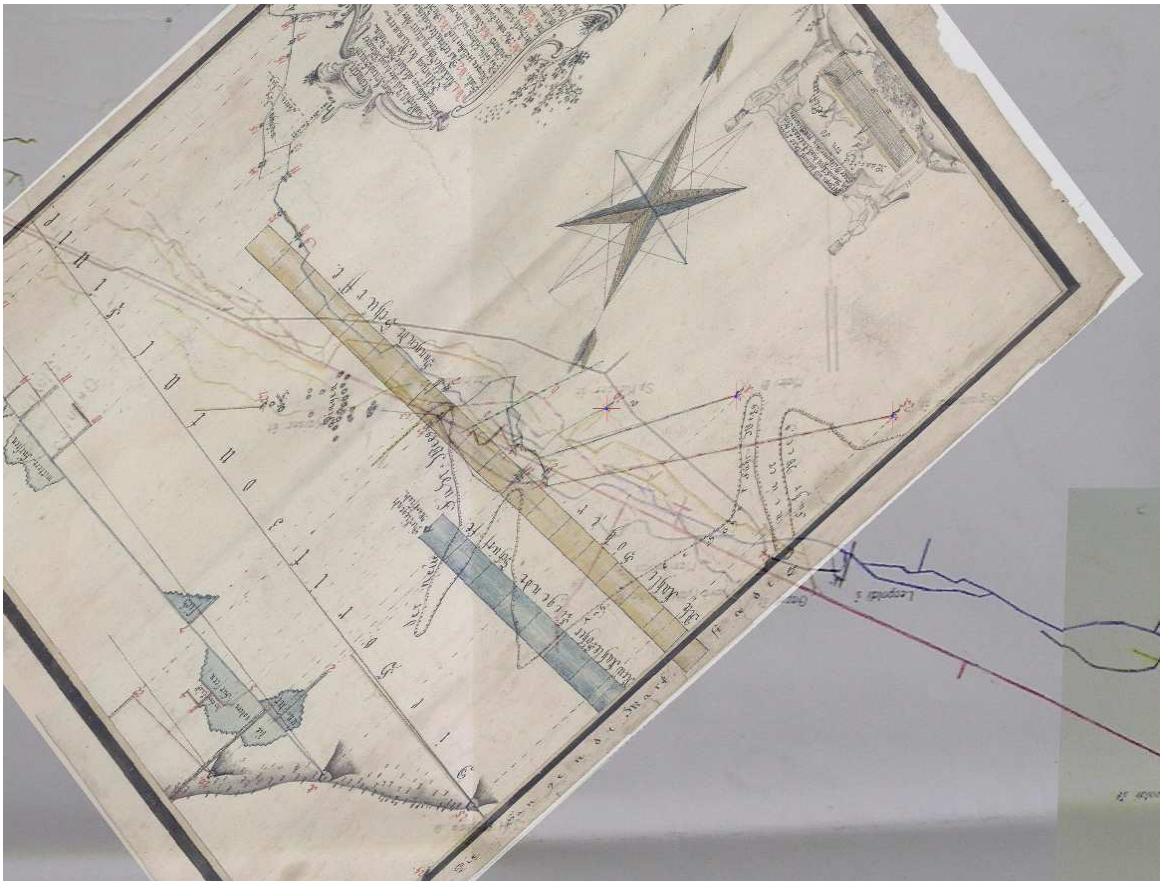

Fig. 8 Georeferenced mining works Kaiser from the historical mining maps, **Source:** Authors

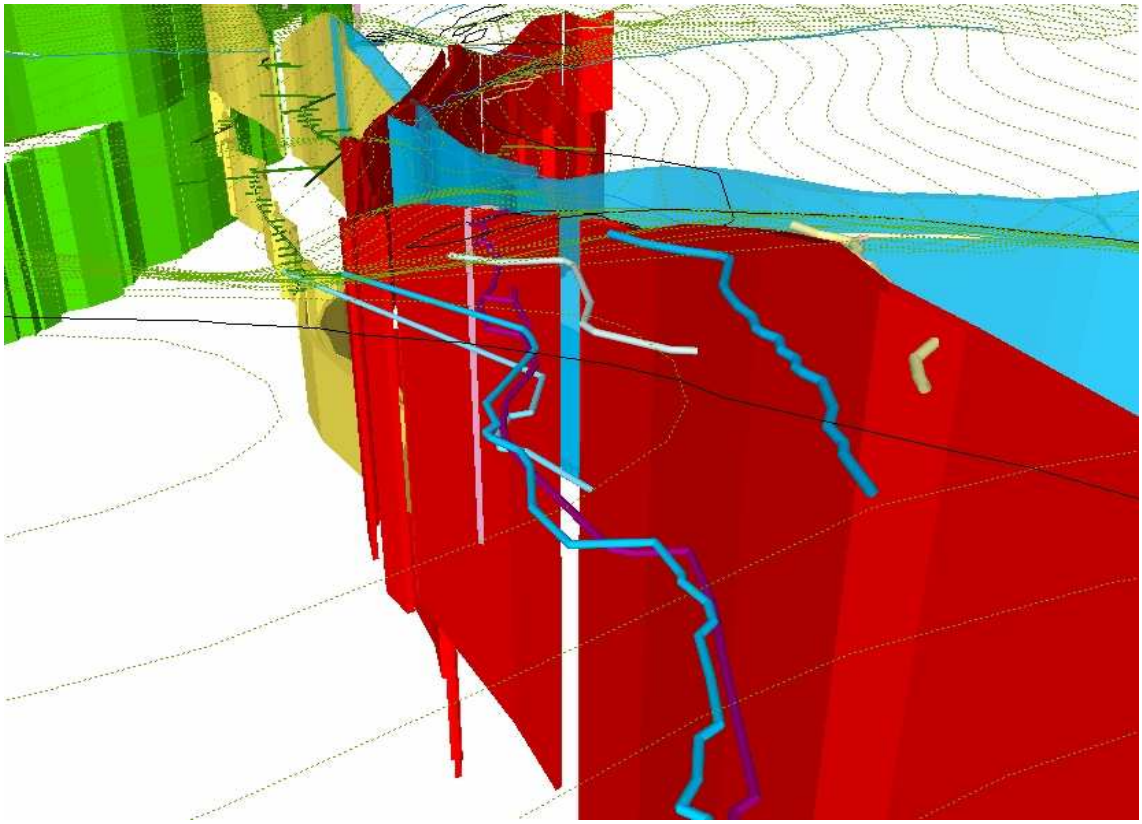

Fig. 9 The image of the mining work flow lines pictured originally on the historical map from19th century (Fig. No 7). The hole, shown on the display, is the Leopoldi hole, **Source:** Authors

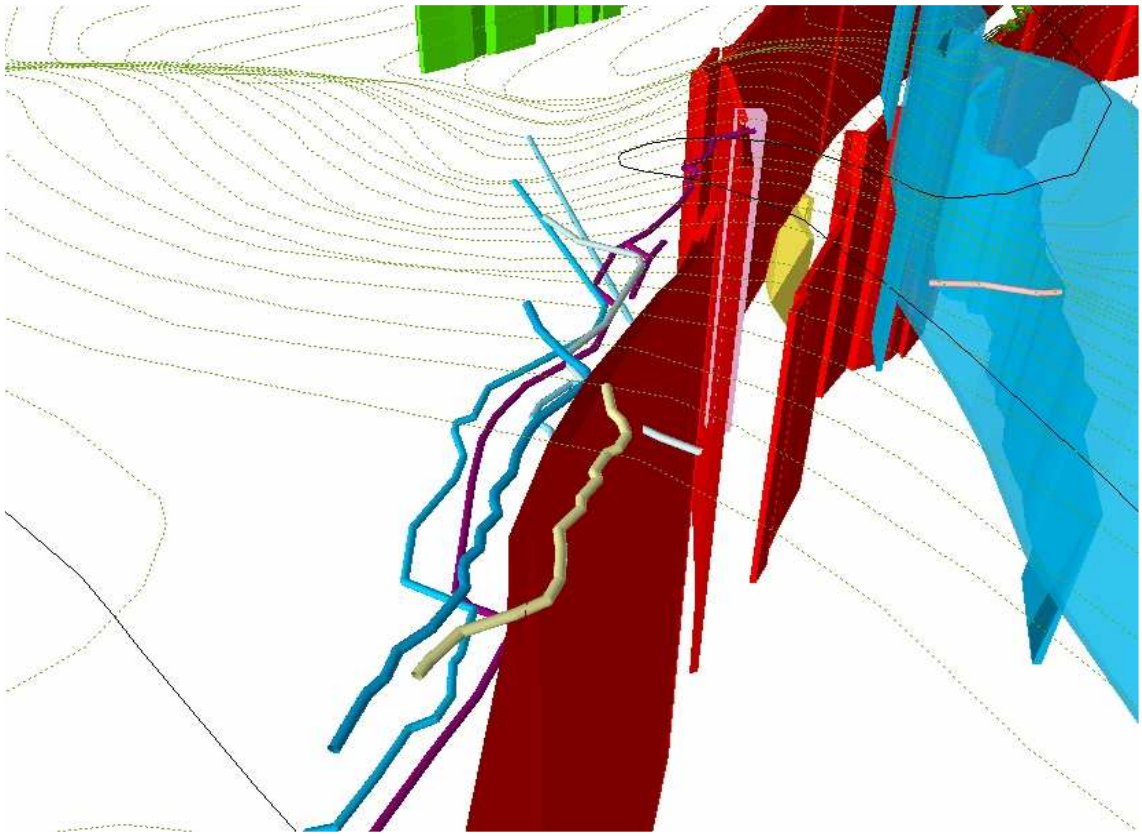

Fig. 10 The view of the Kaiser works from a different perspective, **Source:** Authors

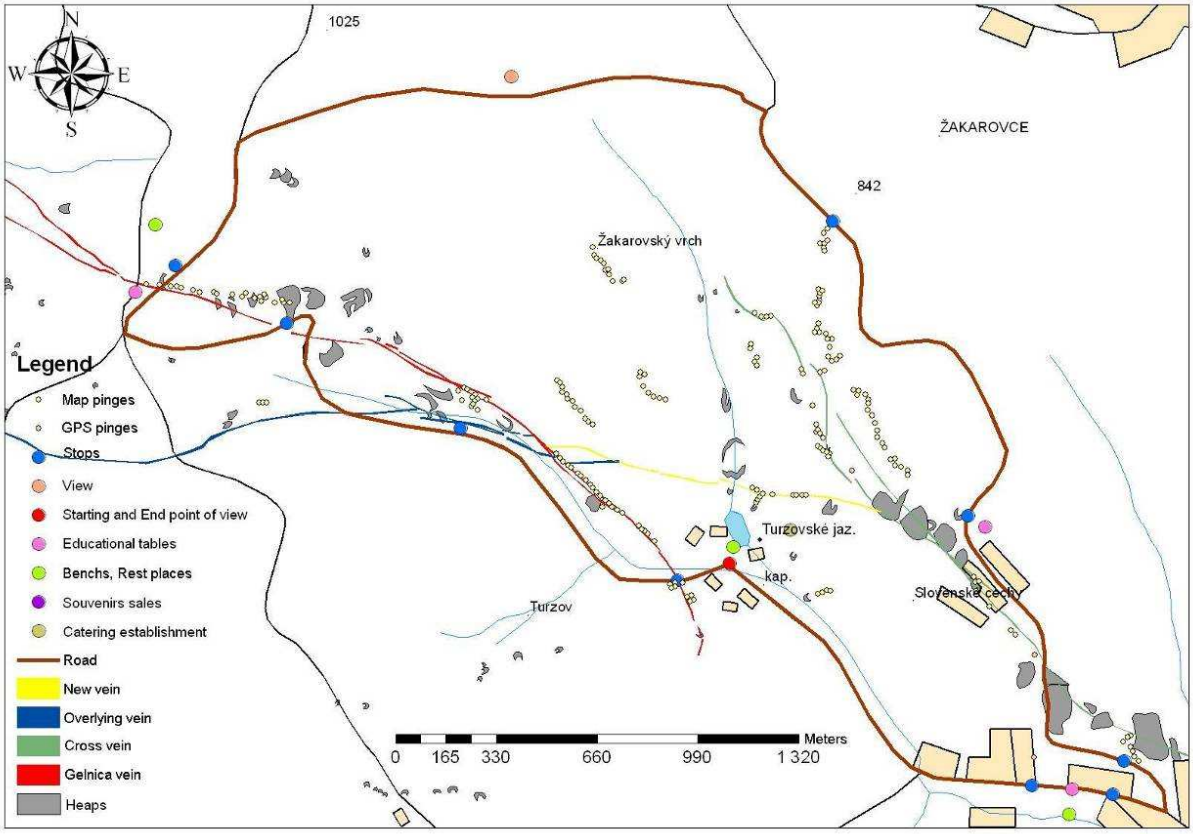

Fig. 11 The plan of mining tourism implementation at Gelnica and surroundings (2D), **Source:** Authors

THE PLAN OF MINING TOURISM IMPLEMENTATION AT GELNICA AND SURROUNDINGS

By means of mining and geological maps from different historic periods, it is accessible to create an original tool applicable for the objectives of mining tourism. Its goal to be attained is to offer a client the means which can virtually project the underground world of ore veins, and through centuries developed mining works. A tourist interested in the history of mining in the region of Gelnica and environs, will have at his disposal a chance to experience the underground world from any location on the ground surface either on foot or by various kinds of vehicle. Simultaneously we draw his attention to the landscape historical artifacts linked to historical mining activities, such as shaft portals, pings a ping fields at Gelnica and environs.

We can also offer a few hours´ trip by a special tourist vehicle, where he will get a tablet registering his travel in the terrain through the GPS system, and an earphone, providing pieces of information on the topical location, what is available to watch in the real or virtual landscape on the tablet. The combination of audio plus visual perception, the virtual world of the underground - the advancement of ore veins and historical mining works, and at last but not least, the real world surrounding us, must highly impress an eager history and nature learner. In addition to the trip to Gelnica, it is also advisable to visit the Mining Museum, and enjoy the wonders of mother nature in the area.

CONCLUSION

The created medium has got a universal relevance and it is viable to set up a virtual world showing the geological composition of a landscape, as well as progression of the

mining works underground in a chosen historical region. The medium can serve a purpose for remodeling historical mining areas. The earlier maps that had been admired as amazing historical and aesthetic documents, often without precise or even approximate position, can as well provide new information for their modern use.

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