Relics of manual rock disintegration in historical underground spaces and their presentation in mining tourism

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The article chronologically and methodically describes relics of the manual underground excavation preserved on the walls of the Slovak underground works. The analyzed relics a manual excavation may be used as geotouristic objects. These attractive micro shapes hardly identified in the underground by visitors, are presented only in Banská Štiavnica Mining Museum. We offer examples of relics after the manual disintegration of rocks in the underground, according to the development of the technology of the disintegration and hardness of rocks. As a result of our long-term studies of the underground, in the main part of this article we describe examples from Slovak territory. Presented can serve as a basic guide for geotourism reason, while visiting underground. Furthermore, it makes easier the identification of historical technology used for the rock disintegration and explains the various genesis of relics to experts, tourist guides and visitors.

Key words*: Manual rock disintegration technology, historical anthropogenic underground space,* relics *a manual disintegration of rocks, geotourism, mining tourism, mining heritage*

Introduction

All historical underground relief shapes excavated and built by human are identified in current terminology by the expression "underground". The term underground covers both -underground spaces created by human activity and/or natural caves and spaces under the surface. Anthropogenic underground spaces, in regard to its areal scope, mouth to the surface only by small holes - tunnels, pits and winzes.

Non-mining underground spaces are underground objects and shapes used procedures employed in mining, but the purpose of their origin was different than the extraction of mineral resources. We can thus state, that they were created using mining procedures - digging of bore holes, shafts, chambers or other shapes, but they were intended for sectors of industry other than mining itself. The Slovak linguistic equivalent of non-mining underground shapes of anthropogenic relief is the term "non-genuine mining relief shapes created by man" (Hrončeka 2013).

Underground non-mining (pseudo montaneous) anthropogenic forms are very often several times larger than shapes created by mineral extraction, or for mining purposes, referred to as montaneous anthropogenic landforms. Anthropogenic relief shapes are essential for the functioning of technical progress of modern contemporary human society.

The first a targeted created subsurface anthropogenic forms of relief in the world was created around 4000 BC on the island Malta. Underground space - Hypogeum, was built for all - a cult, religious and funeral center. Further development of subsurface anthropogenic forms of relief continued in the second millennium BC, in the Middle East

The first water tunnels, which were the predecessors of traffic tunnels, were minted, for example, in both - Petra, Jordan and Jerusalem, Israel.

Rock-cut underground spaces reached their peak in western and southwestern India, where between second century BC and 9th century AD, have created extensive underground monastic complexes. These underground spaces were carved by Buddhist, Hindu and Jain monks for example in all - Ajanta, Bahaja, Kanheri, Bedse, Ellora, Elefnthia, Karla, Padavleni, Mandapeshwar and in dozens of other locations.

For many centuries carried the technological development of underground construction the Roman Empire and thus the creation of underground forms of anthropogenic relief. The medieval period is characterized by the formation of only small underground shapes. Development of building underground forms of relief occurs the beginning of the modern period. The increase was associated with the development of the industry and transport. They started to build the first shipping tunnel at the end of the seventeenth century in France, and in eighteens century in England, especially. In the modern construction of underground forms of relief plays an important role the tunneling shield, first time put in a place in 1870 during the construction of the tunnel under the River Thames.

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The oldest a targeted created underground relief forms in Slovak territory was formed in connection with the construction of Medieval castles in the thirteenth century. Into the castle cliffs were carved cellars, tunnels and wells. In the construction of the castle Lednica, in the second half of the thirteenth century, was carved the oldest transportation tunnel in Slovakia. In the fourteenth century there was carved Gergely tunnel, in the Kremnické vrchy Mountains.

An important turning point in building underground anthropogenic forms of relief, was the use of gunpowder into mining underground spaces in the rocks. The gunpowder was first realized in the underground for the purposes of the rock disintegration in Banska Štiavnica ore mine, in the year 1627.

This technique of rock disintegration gradually expanded from the mining industry to underground engineering works worldwide. The real boom in Slovak underground construction, which was connected with the rise of underground forms of relief, occurred in the second half of the nineteenth century, when they began to build the first railway tunnels in our area.

Relics of manual disconnected rocks in underground as technical monuments

The technical monument is every item or objects created as a result or consequence of human activity and its purpose is to adapt the nature and its sources to the needs of the mankind with its present historical value. It documents its activity to such an extent that it determines the need for permanent preservation of the particular monument as a cultural property (Lednický 2004). According to the nature of technical monument, they are divided into movable and immovable

According to our research we can state that the relics a manual rock excavation process is currently very little valued as an important technical monument of historical mining technology. Archaeological findings of hand tools for excavation of rock - especially hammers, picks, chisels, drills, antlers and bones, served as very important information of manual rock disintegration in underground. But big information value have also relics of disconnected rocks in situ. Therefore it is necessary to protect these micro-forms as technical monuments. Their protection is still ensured only in connection with the protection of the underground as a whole, for example: the castle undergrounds and wells (Slovakia has a total more than one hundred e. g. Fiľakovo, Modrý Kameň, Slovemská Ľupča, Strečno, Likava, Lednica), urban underground (e. g. Krupina, Trnava, Svätý Jur, Čachtice), wine cellars (e. g. Tokaj, Hont) and many other.

Geotourism, mining tourism and mining heritage

In Slovakia is mostly used the concept of ,,tourism trade" (cestovný ruch). According to the monolingual dictionary of tourism (Gúčik et al. 2006), is explained concept ,,tourism trade" as a set of activities that focus on satisfying needs related to travelling and stay of people outside their permanent residence and usually in their leisure time. Their aim is rest, knowing, health, amusement and fun, cultural and sports usage, business trips, i. e. gaining a complex experience. Term "tourism" (turizmus) was not defined yet nor in the monolingual (slovak) dictionary of tourism and even at this term does not exist in the dictionary. So far on the Slovakia term "tourism" was narrowed to sports activities connecting with physical activities and stay directly in the countryside to know something about the home country, its natural beauties, as well as its cultural heritage (Chorvát 2006, Kompasová 2010).

In our geographical area is also frequently used the term created by the World Tourism Organization (UNWTO) in 1991: "Tourism comprises the activities of persons travelling to and staying in places outside their usual environment for not more than one consecutive year for leisure, business and other purposes not related to the exercise of an activity remunerated from within the places visited." (downloaded on 7. October 2012, available online:http://www.linkbc.ca/ torc/downs1/WTOdefinitiontourism.pdf).

Nowadays in the more and more globalized world, where the main communication expressions are in the English language, this term is increasingly used also in Slovakia. Slovak specialists in the field of geotourism (e.g. Rybár, Baláž & Štrba 2010) consider the terms "tourism trade" and "tourism" to be synonyms. They perceive the term tourism as an international one and therefore they prefer it in their works.

According to National Geographic, geotourism can be characterized as follows: ,,Geotourism is defined as tourism that sustains or enhances the geographical character of a place, its environment, culture, aesthetics, heritage, and the well-being of its residents. Geotourism incorporates the concept of sustainable tourism, which destinations should remain unspoiled for future generations, while allowing for ways to protect a place's character. Geotourism also takes a principle from its ecotourism cousin, that tourism revenue should promote conservation and extends it to culture and history as well, that is, all distinctive assets of a place." (downloaded on 25. October 2015, available online: http://travel.nationalgeographic.com/travel/sustainable/about_geotourism.html).

The first definition of geotourism published Thomas A. Hose ,,The provision of interpretive and service facilities to enable tourists to acquire knowledge and understanding of the geology and geomorphology of a site

(including its contribution to the development of the Earth sciences) beyond the level of mere aesthetic appreciation" (Hose 1995).

At the beginning of the 21st century is increasing a number of geotourism definitions. One of the best comes from pencil D. Newsome and R. K. Dowling (Newsome & Dowling 2010) ,,A form of natural area tourism that specifically focuses on landscape and geology. It promotes tourism to geosites and the conservation of geo-diversity and an understanding of Earth sciences through appreciation and learning. It was achieved through separate visits to geological features, use of geo-trails and view points, guided tours, geo-activities and patronage of geosite visitor centers". These authors also present a new approach on geotourism ,,Looking at the environment in a simplistic manner, we see that it is made up of Abiotic, Biotic and Cultural (ABC) attributes. Starting with the „C" or cultural component. We note that from these three features it is this one which is the most known and interpreted, that is, through information about the built or cultural environment either in the past (historical accounts) or present (community customs and culture). The ,,B" or biotic features of fauna (animals) and flora (plants) has seen a large focus of interpretation and understanding through ecotourism. But it is the first attribute of the ,,A" or abiotic features including rocks, landforms and processes that have received the least attention in tourism, and consequently is the least known and understood. This is the real power of geotourism, in that it puts the tourist spotlight firmly on geology, and brings it to the forefront of our understanding through tourism".

Mining tourism is the part of tourism where the visitor is offered to see and get to know: mining technologies, factors clarifying raw material extractions, its processing, business activities leading to the output, the former technical devices and facilities, the importance of significant historical personalities and families who importantly influenced mining operations, events that forever changed the entire region by establishing new technologies, etc. All the above mentioned is supposed to be explained in the language that is understandable, interesting and engaging to visitors.

Paradoxically, attenuation of mining activities has brought about greater importance and popularity of mining tourism. At the end of the 20th century mining had a worse reputation than in fact deserved due to ecological organizations, media and part of the population that was out of touch with mining activities. The interest to exploit resources and public priorities are not the same even at present. Environmental organisations are still fighting against new mining works, require restrictions on current mining activities and call for the restoration of nature after previous mining activities.

After stopped of mining activities in developed countries at the end of 20 century, mining work removal, as well as standard technological procedures of reclamation brought removal of unique mining works and machinery, and abandonment of former mining settlements. These solutions were correct, for they put an end to hard work and unsuitable living conditions in mining settlements.

By doing so, we have exultantly lost unique technological and technical works created and used by miners, and hundreds-, or maybe even thousands-years old specific social aspects of communities and social mining structures. After this manner we have destroyed a large part of technical, technological and social aspects of mining heritage, including the heritage of miners as human beings within existing regional communities, which invested their properties and lives into specific mining conditions.

We would like to point out, that since there is an effort to preserve biological diversity in order to save natural heritage that has developed over millions of years, then we should also understand the effort of technical intelligence to protect socio diversity, techno diversity or any other kind of diversity, that marks the contribution of humans to the development of mankind, in respect to thousand-year old mining activity. (Rybár & Gómez 2014).

In historical mining countries, like those in central Europe, mining tourism is based on mining artifacts that define this special type of tourism – mining tourism. It is surprising, that even the part of public that contributed to the termination of mining activities, is interested in historical mining, its interpretation and promotion. It may sound odd, but with the decline of mining activity, acceptance of its historical meaning and willingness to recognize social, economic and technological relations of mining increases (Rybár & Gómez 2014).

As visitors respect the underground space, finding all - mining, 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 a folows: 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 (Rybár & Hvizdák 2010).

While using the mining technical monuments in geotourism (mining tourism), the most important factor is the authenticity that in today's high-technology world, is becoming more and more important. The current generation of young people is losing the real concept of our ancestors´ life. They do not know the meaning of a lot of terms and they do not differentiate the meaning of particular terms connected with mining.

In the current tourism, and therefore also in the mining tourism, we use mainly the so-called staged authenticity. There is a danger that we do not see the real historical reality but only mediated and customized

pictures, impressions and images in the way they suit the tourism industry (Chorvát 2006). It is typical of various festivals and mining days and celebrations, e. g. Salamender's procession at Banská Štiavnica, Mining Day and Mining offertory at Smolník, Rudňany's šachtag at Rudňany, Minig Day at Ľubietová, St. Barabara's celebration at Pezinok, Feast of St. Barbara and jump through the leather, Faculty BERG, TU Košice, and many other events. The visitor can see different shows and the life and work of people and miners in the field of mining in the past that have become a routine part of these events.

We can conclude that the application of authenticity is very important in mining tourism in the presentation of relics of the manual excavation in non-mining underground objects.

Mining heritage in Slovak terminology forms a part of the category "technical monuments". But term mining heritage has a much wider meaning and incorporates all: natural, historical, architectural, technological, technical, artistic, documentary, geomorphologic, and other aspects. Thus mining heritage includes, in great part, the heritage of the miner as a human being within the mining communities that had invested their possessions and lives into specific mining conditions.

Definition of mining heritage is complicated because of association with all: geological, geomorphologic and natural heritage. Another time is mining heritage related to cultural heritage - historical, architectural, archaeological, industrial, technological, technical, and other attributes. Mining heritage can also cover the territory, which has long depended on mining. In territorial terms, we may assign mining heritage in different categories. In general, the concept of heritage can be defined by cultural, natural and mixed categories (Tab. 1), what is a case that covers the most areas where mining existed for a long time.

According to the classification of mining heritage made by Javier Carvajal Domingo Gómez (Gómez 2010), we have modified this classification in a way we usually understand and use (Tab. 1). All subsets shown in the table, as natural heritage, geological heritage, etc., relate to mining or geo heritage.

In a subset natural heritage (Tab. 1) we understand species of fauna, flora and minerals, which were not present previously in the micro-region, respectively wilder area, before mining. Abandoned mines, underground or surface ones, provide conditions for the existence of a new biotic and abiotic species.

Within the subset geological heritage (Tab. 1) there are allocated such aspects, which belong to geosites defined in geotourism (Rybár et al. 2010a, 2010b).

Within the subset mixed heritage (Tab. 1) we follow the broader view of a country affected by mining activities. These changes caused by abandoned quarries, or mines reclaimed by water surfaces, or otherwise differently reclaimed mines (terraced gardens, recreational areas, etc.). Dumps after underground mining usually remain like scars on the appearance of the landscape.

By the help of cultural heritage (Tab. 1) we can study and describe mining prehistory and history. Also architectural elements in the mining region and artifacts of mining technologies create part of cultural heritage. Migration of skilled miners and metallurgists into the areas with rich natural resources, meant not only the spread of know-how, but also the occupation of mining areas and transfer of cultural habits by colonists. Interesting and important part of mining heritage is the presence of King houses or Comorian yards (Kammerhof) and Mints in the mining territory. Also important families associated with mining and metallurgy are part of mining heritage. Mining heritage associated with the mining education is formed by school buildings and prominent personalities who worked at the school (Rybár et al. 2001). Mining museums and archives are establishments whose primary mission is to save and preserve the mining heritage. Another interesting area of mining heritage is the preservation of customs, and mythology associated with mining.

Tab. 1. Mining heritage structuring (by Gómez, 2010, processed by Pavol Rybár).

Mining heritage			
Natural heritage	Geological heritage	Mixed heritage	Cultural heritage
Fauna	Paleontology	Landscape	History
Flora	Mineralogy	Ecology	Prehistory
Minerals	Petrography		Ethnology
	Geomorphology		Architecture
	Structure geology		Technology
	Hydrology		Technical objects
	Hydrogeology		Mining school
	Vulcanology		Development of science
			Royal Institutions
			Mining museums
			Archives
			Significant families bound with mining and metallurgy
			Mining law
			Customs, manners, mythology

Relics a manual rock disintegration in underground spaces - undervalued attractions in geotourism

In the development of tourism related to relics of mining technical monuments we have to proceed also in accordance with international documents published by the International Council on Monuments and Sites that was founded in 1964 and that accepted many charters and recommendations. The most important document for our study and for the practice is the International Cultural Tourism Charter – Managing tourism at places of heritage significance, accepted in Mexico in 1999 (Dvořáková & Husovská eds. 2002).

For example L. Kudela and V. Lednický (Kudela & Lednický 2002) and V. Lednický (Lednický 2004) dealt with the usage of technical monuments in tourism but only on a general level.

We can mention the long-term research of mining technical monuments in Slovakia as an example of a complex research of technical monuments for touristic needs. Historical mining monuments processed in this way have become the main attraction in the still developing of both - geo and mining tourism in Slovakia. Here we have to mention the most important works in this field that we used in the methodological part of this article. They are studies that deal with geotourism and mining tourism written by C. Schejbal (Schejbal 2005, 2011), P. Rybár (Rybár 2010), also Rybár and corporate authors (Rybár, Baláž & Štrba 2010, Rybár & Hvizdák 2010, Rybár, Hvizdák, Molokáč & Hvizdáková 2010, Rybár, Molokáč & Kovács 2012).

Research of non-mining underground objects must be based on all - methodology, anthropogenic geomorphology and mining. The given issue is addressed in the works of Czech authors, such L. Zapletal (Zapletal 1968, 1969), K. Kirchner and I. Smolová (Kirchner & Smolová 2010). In the Slovakia matter in question studied, for example P. Hronček (Hronček 2002), P. Hronček, P. Rybár, K. Weis (Hronček, Rybár & Weis 2011), P. Hronček and K. Weis (Hronček & Weis 2014) and V. Čech and J. Krokusová (Čech & Krokusová 2007, 2013 and Krokusová & Čech 2014).

Methodological issues, research, grading, modeling and characterization of non-mining underground anthropogenic shapes in terms of anthropogenic geomorphology were focused only works of P. Hronček (Hronček 2013, 2014, 2015a).

To research of underground and its use in the mining tourism is important 3D modeling. Methodically are applicable e. g. works P. Rybár and L. Hvizdák (Rybár & Hvizdák 2010), P. Rybár et al (Rybár, Hvizdák, Molokáč & Hvizdáková 2010), D. Kubinský, M. Lehotský and K. Weis (Kubinský, Lehotský & Weis 2014), K. Weis and D. Kubinský (Weis & Kubinský 2014) and P. Hronček (Hronček 2015).

The deal with relics after the manual excavation of rocks in the underground was not fully used in geotourism by now. Exact identification, description and time classification of the particular relics can establish the underground adventure tourism. The dark, unlighted, often narrow underground space makes associations of time travelling of the visitors during the past centuries and for a moment creates an atmosphere of what people do, move or live in the Middle Ages or even in the early Modern Age. Drafts, cold and humidity reinforce the experiences and feelings of visitors what is especially intensified in the historical mines and galleries. The study should serve as the initial, basic guide that could be used by individual visitors mainly in non-mining underground objects.

Manual rock disintegration

To mark the main anthropogenic morphological process, which leads into the inception of non-mining underground anthropogenic relief shapes, it is proper to use the expression „perforation“ and not mining. Mining is a process connected with the extraction of raw material. It is a set of preparative and mining works realized in underground according to predetermined mining and technological sequence for a time. Over-break and poor quality mined rock is considered as tailings. Quality suitable mined rock is considered as raw material. But the term perforation means the set of processes leading to creation of underground spaces and these spaces having industrial, social and cultural purposes. Disintegrated rock is not considered as raw material. In the case of big constructions might have its secondary application.

The most important thing to create non-mining underground relief shapes was, similarly to mining works, the activity related to disconnection of the rock. For centuries the rocks were disconnected manually. In prehistory, soft rocks were disconnected by using flake tool, wooden, stone and antler tools, later also bronze and iron ones. For softer rocks grub-hoe and mattock and for harder rocks picker with a hammer, eventually chisels and claw bars were used.

The picker and hammer were for centuries considered to be the most important elemental operation in the process of creating non-mining anthropogenic relief shapes (Fig. 1 and 2). The irreplaceable position of picker and hammer lasted until the age, when gunpowder was carried into practice. For the first time was gunpowder used for disconnecting of the rock for mining reason on Banská Štiavnica' dike Bíber (Slovakia), in 1627. The pickers and hammers, despite the gunpowder and hand drilling application, were used until the second half of 19th century.

The picker evolved from bone or horny cline which was used from Stone Age. The clines were made continually from harder materials and already in Ancient times were clines and pickers made of iron.

The body of picker had its flat part (head) on one side, which the miner hits. On the other side of the picker was the bit. The body shape, length and width of the picker depended on the ground character into which disconnection picker was used. In the middle part of body there was a hole for free handle attachment. Free attachment of the wooden handle was inevitable to prevent the miner from shakings after hammer strokes. The handles were direct or easily bended and were used to chip the deteriorated ground. The drifter (right-hander) holds the picker by left hand with the bit towards the rock and hits the flat head by the hammer.

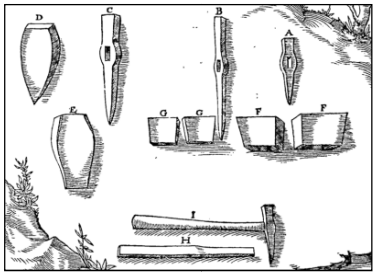

Fig. 1. Chisels and picks, 16th century (Agricola 1556).

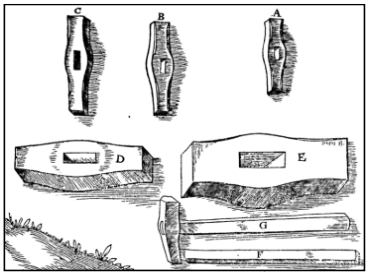

Fig. 2. Hammers, 16th century (Agricola 1556).

In the face of the trapezoidal profile tunnel the parallel lines/marks (horizontal, vertical or bevel according to the ground structure) were consistently dug. An additional set of parallel lines (grooves) had been carved out perpendicular to the direction of the formed grooves, which together with the first ones formed a network of square protrusions on the face surface. The distance and the thickness of the lines depend on the hardness and the structure of the rock. (Fig. 3). The drifter strokes off juts (eventually chipped by the picker handle), what again created a smooth-surfaced wall and the operating procedure was repeated (Faller 1868, Gindl 1969). Details of relics a manual disconnecting rock by picker and hammer are presented in Fig. 4.

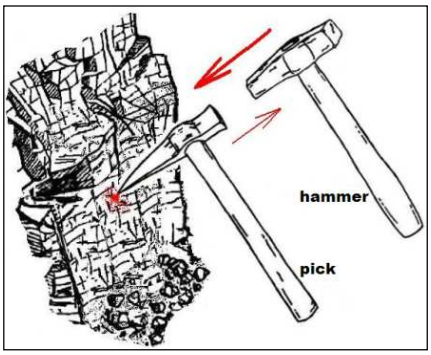

Fig. 3. The scheme of works with hammer and pick (compiled authors).

Fig. 4. Details of relics by manually disconnecting with hammer and pick.
Adit Upper Johan in the mining region Ľubietová, locality Podlipa. The nicks on the wall are cca 1,5 cm wide, cca 40 – 50 cm long and cca 0,5 – 1 cm deep. The distance ranges of nicks are 3-5 cm (left), (photo P. Hronček).
Hodruša (district Žarnovica) - medieval mining Starovšechsvätých. Mining symbol – hammer and pick with Latin wrote the year 1510, manually disconnecting with a hammer and pick (right), (photo K. Weis).

The daily advance of mediaeval miners used for rock disconnection picker and hammer, was about 7 cm. This means approximately 22,5 m per year. This figure refers the medieval hand-mined tunnel - "kresanica". „Kresanica" has mainly trapezoidal profile, 170 cm high and 50, resp. 60 cm wide (in upper, resp. lower part), allowing movement of miners. The area of the benk was usually only around 1 m^2 (Gindl 1969). For better idea we are presenting photos from underground tourist routes (Fig. 5 and 6).

Fig. 5. Visualization of the size of „kresanica" – medieval mining tunnel of the urban underground tourist route in Znojmo, Czech Republic. Body height is 160 cm, (photo P. Hronček).

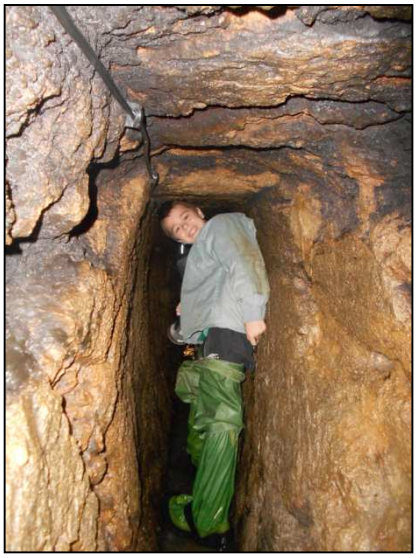

Fig. 6. „Kresanica" – medieval mining tunnel of the urban underground tourist route in Slavonice, Czech Republic. Surrounding rocks are gneiss. Body height 145 cm, (photo P. Hronček).

The following figures present manually excavated medieval mining tunnels („kresanica") made by hammer and pick technology in the mining region Ľubietová, locality Podlipa. Tunnels are excavated in rocks of terigen Perm of Ľubietová crystalline, which consists of shale and conglomerates. Some of the passages of mining tunnel were partly enlarged in the 18th and 19th centuries (Fig. 7 and 8).

Fig. 7. Manually excavated medieval mining tunnels („kresanica") by hammer and pick technology in the mining region Ľubietová, locality Podlipa. Adit Lowest Johan (left) and adit Middle Johan (right), (photo P. Hronček).

Fig. 8. Manually excavated medieval mining tunnels („kresanica“) by hammer and pick technology in the mining region Ľubietová, locality Podlipa. Adit Upper Johan (left) and adit Uppermost Johan (right), (photo P. Hronček).

On the next figures there are mediaval mining tunnels "kresanica" manually excavated in ming regions Brezno (Fig. 9) and Hodruša (Fig. 10), respectively.

Fig. 9. Manually excavated medieval mining corridor („kresanica“) by a hammer and pick in the mining region Brezno, locality Skalka, excavated in dolomite (left). Underground spaces after manually mined of limonit deposit at locality Skalka (right) (photo V. Paprčka).

Fig. 10. Manually - by a hammer and pick excavated medieval mining tunnels („kresanica“) in Hodruša (district Žarnovica). Upper adit Ján (left) and Mine Starovšechsvätých (right). Relics after the ventilation space on both sides of the tunnels near ceiling. (photo K. Weis)

More frequently used and more efficient was the disconnection of the rock using the fire. So called - fire disconnection was present since younger Stone age. The nature of this procedure was in lighting a fire near the benk of the tunnel (Fig. 11). The fire heated up the rock, which was disrupted by high temperature change of physical and chemical properties of minerals. The heated rock cooling by water was more an exception than a rule (Fig. 12). The fire disturbed rock with temperature 200 °C nd mining with soft instruments became easier. The temperature gained by special technological burning of different kinds of wood has reached max. 600 °C. The rock disconnection using a fire, whether in the benk or on the floor, depended on many factors which had to be respected by miner (digger). The deepness of disturbed rock reached from few centimeters up to 1 m. The disadvantage of this technology has been the necessity of a large amount of atmospheric oxygen, what allowed its using only in small deeps of underground. (Lynn 1994, Lynn & Weisgerber 2000, Bartoš 2004). The fire disconnection is documented in a 16th and 17th century in every important Slovak mining locality (Fig. 13 and 14).

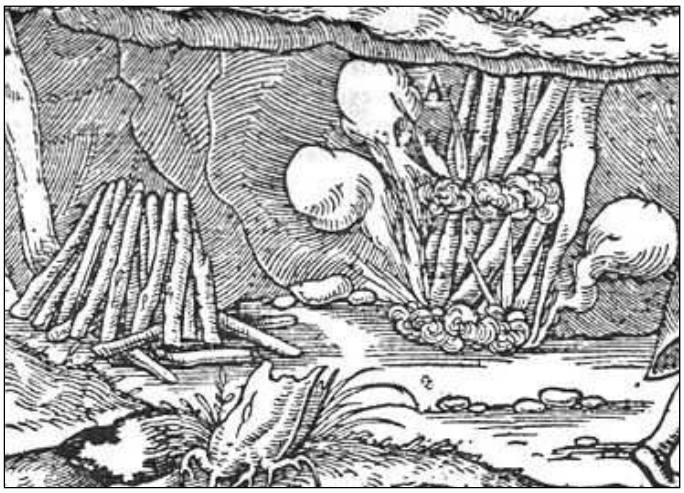

Fig. 11. Firesetting in the 16th century (Agricola 1556).

Fig. 12. The exposure of firesetting in Slovak Mining Museum Banská Štiavnica (photo P. Hronček).

Fig. 13. Medieval adit Darius, Rožňava, probably excavated using fire disconnection and subsequently hammer and pick a technology (left), (photo V. Paprčka).
Hodruša (district Žarnovica) - medieval mining in Mine Starovšechsvätých. On the walls and ceiling are visible relics of the manual excavation by hammer and pick, (right) (photo K. Weis).

Fig. 14. Underground spaces excavated with the help of fire. Subsequently the vein was disconnected with a hammer and pick or chisel. Brezinka gold-mine on Veľký Gápeľ, Nízke Tatry Mnt. (left). (photo M. Budaj). Hodruša (district Žarnovica) – drainage adit, mining field Rabenštein, (probably13th century) (right). (photo K. Weis).

On the beginning of 17th century, has a digger of underground non-mining anthropogenic relief shapes, at his disposal except the picker and hammer, also the mattock, the hoe, different chippers and crowbars and first manual drills (Vlachovič 1961).

The diggers made the manual disconnection of hard rock easier by using the trenails, which rammed into dug holes in the rock. In our territory trenails were made from beechen and hazel wood. These trenails were constantly watered, what increases their size, consistently corrodes the rock and creates cracks on the benk (von Born & Ferber 1774) (Fig. 15). The special method, used in eastern Slovakia, was breaking the rock by water. The water flowed into the bevel or vertical holes and by hammering the wooden sticks into the holes, diggers created the pressure which breaks the rock.

Fig. 15. The manual disconnection of rocks with trenail. Brezinka gold-mine on Veľký Gápeľ in Nízke Tatry Mnt. (photo M. Budaj).

The hand disconnections of rocks were constantly replaced by blasting operations (shot firing). First rock blast made by blasting powder was held by Gašpar Weindl on 8th february 1627 in tunnel Horná Bieber, Banská Štiavnica mining locality. It took almost a whole 17th century to expand this technological process in mines across Slovakia (Gindl, 1975). After that, this process started to be also used in other mining purposes.

Hand to hand with blasting operations in half of 17th century started the expansion of ground boring. From the beginning it was no mechanical, but only hand blow cutting of the holes for blasting powder charges. The deepness of these holes in those times was up to 30 cm (Fig. 16) . The next big expansion of this technology and of application of drillers with bigger power and much deeper bores came into being during the 18th century (Gindl 1981, Sopko 1971) (Fig. 17).

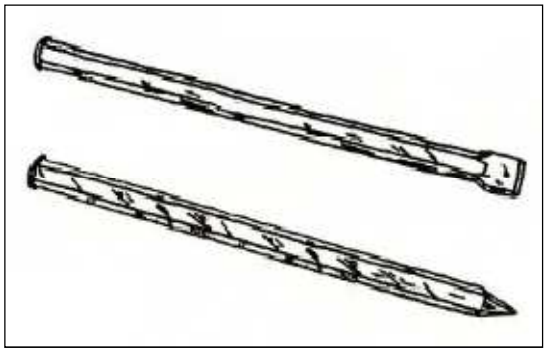

Fig. 16. Mining drill and chisel, instruments for hand drilling (Botík, Slavkovský 1995).

Fig. 17. Underground spaces created with black blasting powder (photo P. Hronček).
Left: underground corridor under Ľupča castle, dolomites (18th century). (Body height - 145 cm).
Right: Name-less adit, location Skalka near Brezno, dolomites (half of the 20th century).

Conclusion

The study describes the fundamental examples of relics on manual disintegration of rocks in the underground. They are chronological according to the development of techniques and hardness of rocks. Pursuant to our long-term studies of the underground in the main part of this article we describe basic examples from Slovak territory.

Presented article is a valuable research paper, which serves for all: documentation of historical manual technology of disconnecting rock massive in underground across the historical mining area – Slovakia, for

documentation of manual disintegration technologies of rocks in underground mining development, for further research work in situ, and also is the basis for systematically oriented mining tourism associated with cognition of historical mining technologies and increase level of individual interested persons on the subject. By this is fulfilled one of the objectives of the article, to create something like a basic guide for individual participants of geotourism, while visiting of the underground. The structure of the article facilitates visitors the identification of relics in underground spaces. It also explains the formation of them. When visitors of the underground observes these relics, they will be able to determine and identify approximate time of underground excavation spaces.

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