Society of Economic Geologists Student Chapter University of Miskolc

Short course –

Industrial minerals in the NE part of Hungary

Telkibánya

November 5–8. 2018.

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11.15–15.00: Visiting the Rudabánya ore mineralization and barite exploration
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Important details

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Glossary

English	Hungarian
yes	igen
no	nem
Good morning! / Good afternoon! / Good evening!	Jó reggelt / Jó napot / Jó estét!
goodbye	viszlát
Thank you!	Köszönöm!
please	kérem
How are you?	Hogy vagy?
good	jó
bad	rossz
pardon	bocsánat
Do you speak English?	Beszél angolul?
I do not speak English.	Nem beszélek magyarul
Can you help me?	Tudna nekem segíteni?
I am sick.	Beteg vagyok.
My name is…	A nevem…
Where is / Where are….?	Hol van / Hol vannak…?
Right / Left	Bal / Jobb
straight	egyenes
I would like a	Szeretnék egy…
Coffee / tee / beer / wine / water	Kávé / tea / sör / bor / víz
Bless you! / Cheers!	Egészségedre!
Where is the toilet?	Hol van a WC?
I love you!	Szeretlek!

Geology of Telkibánya

Geology of the Tokaj Mountains

(The geology of the Tokaj Mountains and Telkibánya based on Hartai and Németh, 2012)

The Tokaj Mountains is situated in the northeastern part of Hungary **(Fig. 1.)**. It is built up mostly by Sarmatian volcanic rocks. Older (Early Paleozoic and Late Permian) rocks can be found only in the northern part of the mountains, in minor outcrops. Mesozoic formations (marine sedimentary rocks) were identified only in two boreholes. Right on the Mesozoic rocks we can find the first volcanic units intercalated with marine sediments. The volcanic activity started in the Early Badenian with a submarine rhyodacite-ignimbrite flow. These volcanics and the overlying sediments were found only in boreholes, similarly to the following Late Badenian andesitic-dacitic lavaflows and subvolcanic bodies. Late Badenian rhyolitic tuffs outcrop in the northeastern part of the mountains. (Gyarmati, 1977).

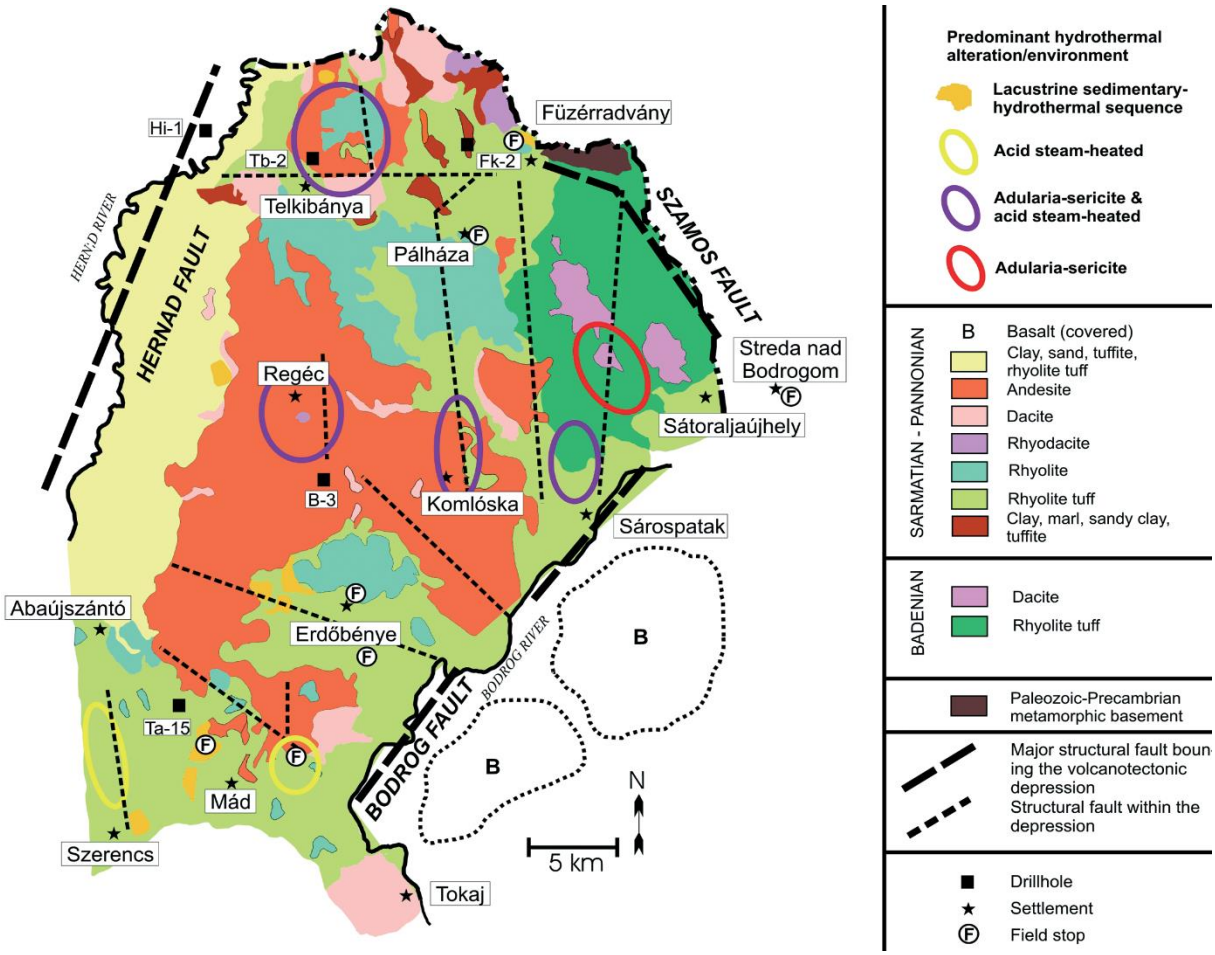

Figure 1. – Generalized geological map of the Tokaj Mts., Northern, Hungary

While in the Sarmatian the shallow marine sedimentation continued, large masses of rhyolitic pyroclasts were accumulated on land. These rocks occur both in the southern and northern part of the mountain. In the pyroclastic sequence beside the subareal tuffs ignimbrites and tuffites appear, and rhyolitic lavadomes were also formed. In the central part of the mountain andesitic lavaflows and subvolcanic bodies are dominant. Their chemical character varies from the basic pyroxene andesite to dacite. In the subvolcanic andesites the columnar jointing is frequent, which is revealed in several quarries (Gyarmati, 1977).

There was an intense post-volcanic activity in the Late Sarmatian, which produced quartz veins and silica bodies. The latter ones were formed at the base of the steam-heated alteration zone, along the paleo-groundwater table. In the hot-spring basins industrial minerals like kaolinite, bentonite, illite, diatomite and limnic silica were formed (Molnár, 1993).

Following the volcanic activity, tectonic movements fractured the mountains and the peripheral parts gradually moved downward. Along the fractures valleys and basins were formed.

Ore mineralization

The ore mineralizaton is of typically epithermal low-sulfidation type. It is concentrated in the northern part of the Tokaj Mountains at Telkibánya village where the dominant outcropping rock is Sarmatian rhyolitic tuff overlain or intercalated with shallow marine and fluvioclastic sedimentary rocks, stratovolcanic andesite-dacite-rhyolite, and late rhyolite domes and andesitic lava flows and dikes (Molnár, 2009).

NNE of Telkibánya, two N-S oriented andesite caldera-like structures can be identified **(Fig. 2.)**. The majority of mineralization is limited to the southern caldera, which contains an approximately 700 m thick sequence of hydrothermally altered andesite. Within the calderas, rhyolite and rhyodacite domes and lava flows were formed, which also underwent intense hydrothermal alteration. Following the rhyolite domes, a subvolcanic andesitic body emplaced in the caldera, and now it is exposed at surface. The latest stage of the Sarmatian volcanism in the region is represented by younger pyroxene andesite, which is unaltered and forms dikes in the strongly mineralised subvolcanic body (Gyarmati, 1977).

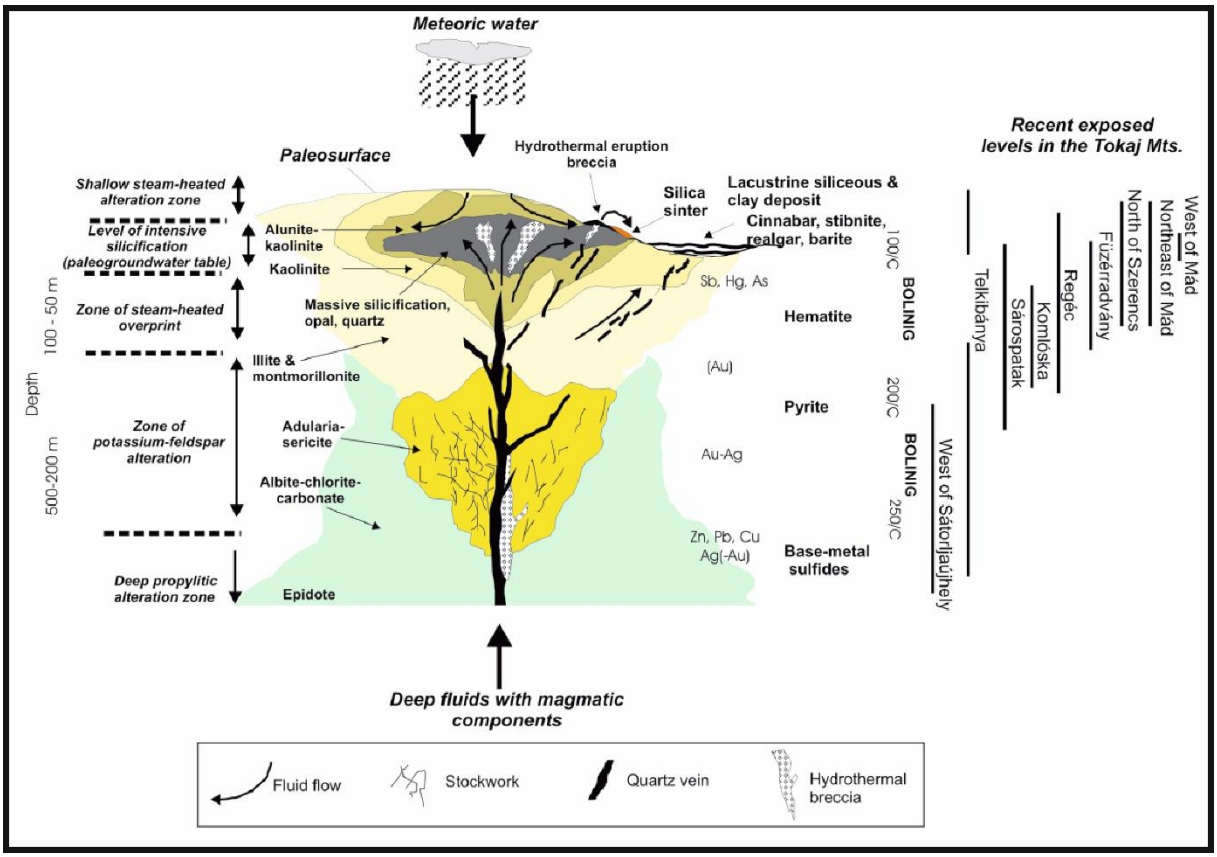

Figure 2. - Generalized model for the shallow levels of the low sulphidation type epithermal systems of the Tokaj Mts.

In the Telkibánya area, there was a two-phase mineralization. The older phase is not significant and was recognized as a polymetallic assemblage in one borehole and in the Csengő-adit. The younger phase of mineralization were formed near the surface. The host rock is Sarmatian subvolcanic andesite, which underwent a strong K-metasomatic and propylitic alteration. The alteration was concentrated along the veins. In the near-surface zones the K_2O content reaches 8–14 wt%. The main K-bearing minerals are the potassium-feldspar and adularia. Due to the intense alteration the original rock features can hardly be recognized. Propylitic alteration is characteristic in the peripheral part and the deeper zones of the mineralization (Széky-Fux, 1970, Molnár, 1993).

The number of ore veins exceeds 20. Their strike varies between NNW–SSE, NW–SE and NNE–SSW. The major veins are 0.5–1 km long; their width varies between 0.1–1 m and they are known down to the depth limit of the mining activity (200 m). On the hanging wall side of the veins, reaching to 3–5 meter thickness, hydrothermal breccia zones are present. With increasing depth, quartz, chalcedony, opal, then kaolinite and smectite, finally calcite fill the veins.

During the explorations in the last decades the highest Au concentrations (7ppm) were found in chimney-like structures with dense pyrite disseminations along the strike of veins. The Ag content in these structures is up to 320 ppm. Most of the gold is probably linked to the pyrite, but some base-metal rich infillings have also gold concentrations up to 20 ppm. Native gold occurs as 5-10 μm large grains in the cavities of sulphides and quartz. Higher gold content (up to 14 ppm) is typical in montmorillonite-bearing vein infillings.

Ag is enriched in the hydrothermal breccia bodies, as well as in association with the fewer amounts of polymetallic ores in which the concentration is up to 750 ppm. The silver content of gold grains is highly variable up to 45 wt%. The most frequent Ag mineral is the achantite but sulphosalts also occur (Molnár, 2009).

Mining History – gold and silver

The gold and silver mining in Telkibánya goes back to the 14th century. At the beginning, mining took place on surface, in open pits. The pits were deepened along the veins, which were harder than the surrounding rocks and formed outstanding crests. Several thousands of pits in the mining area reflect the intensity of the open-pit mining.

Telkibánya was given a rank of "Mining Town" by King Károly Róbert in the 14th century. That time it was on the fifth place in the order of mining towns in the Western Carpathians.

The underground mining started about two hundred years later, as the near-surface parts exhausted. These days we know about 80 adits in the area. The ventillation in the adits was solved by vertical shafts.

The excavated ore was processed in ore mills, the remnants of which also can be found in the mining district. The flourishing mining was interrupted by a catastrophe: probably due to an earthquake the largest shaft collapsed causing a large number of fatalities.

After the catastrophe the mining was suspended, then started to prosper again in the 18th century, during the reign of Empress Maria Teresa. That time the adits were made by explosions. The prosperity was ended soon after the discovery of the huge silver deposits in Mexico and thus the price of silver considerably decreased. Finally, the mining was ceased in

the 1850's. The amount of precious metals exploited from the Telkibánya ore deposit is not known due to the lack of mining documentation from the Medieval Age (Benke, 2001).

After the 2nd world war and even at the beginning of the 2000s ore exploration started again in order to open the gold and silver mines. However, the ore reserves haven't proved to be economic.

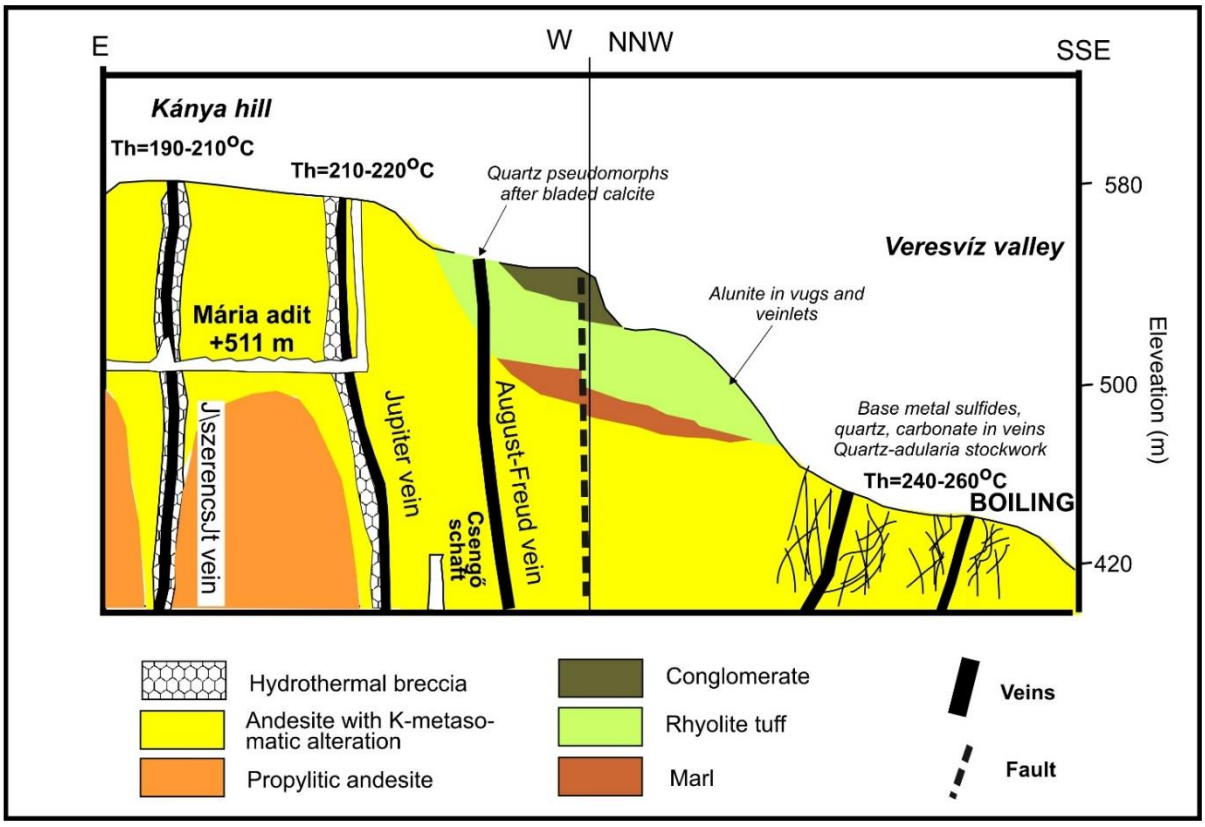

Figure 3. - Theoretical W-E sectionof the Kánya Hill (Molnár, Zelenka & Pécskai, 2009)

Mexikóvölgy quarry

The Mexikóvölgy limestone quarry is located at 5 km to the east from Miskolc. Blasting is typically used by miners to loosen stone for quarrying. The mine is situated between 300 and 600 m above sea level over an area of 1.23 km^2 (**Fig. 4.**). The slope faces have an average dip between 75° and 85° at the area. The average height of slopes is 14 to 16 m. The elevation of the mining area is between 330 m and 345 m.

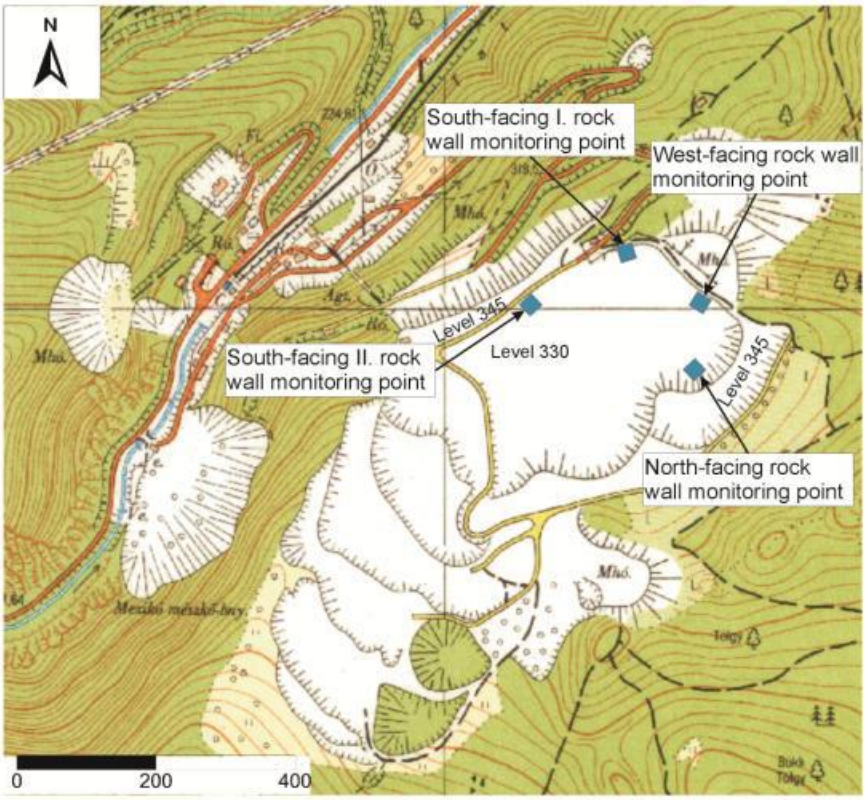

Figure 4.- Overlooking map of the Mexikóvölgy quarry

The rock material of the quarry is heavily fractured, grey Triassic limestone with well-developed cleavage and white-yellow calcite veins. The rock material belongs to the Bükkfennsík Limestone Formation. The dolomite content of the formation is minimal, it is represented as a few pelitic dissolution residuals. Clay-red clay cavity fillings are significant. Typical accessory vein minerals are gypsum, calcite, manganese oxides, marcasite, pyrite and iron-oxides.

Tállya andesite quarry

History

Baron György Majláth opened his first quarry in 1861 after finding pyroxene-andesite at the southern part of Kopasz-mountain in Tállya. The produced stone was sold as rubblestone or building material. From 1927 the Kopasz-hill quarry was operated as a large-scale mine under the management of the Sághegyi Basalt Mine Ltd. recommended by Lajos Jugovics. The first crusher was built in 1929 as well as the cableway connected to the railway loading area. In the 1930's the factory became one of the most significant quarry and since then it plays an essential role in Hungary's aggregate mining industry. Thanks to Lajos Jugovics after nearly 30 year-long research, we were able to produce an excellent amount of andesite.

In 1991 the french company Colas has privatized the North- Hungarian Mining Company and the name of the mine name was changed to Colas- Északkő Ltd. Through the years many research was conducted and the mineral resource of Kopasz-hill in Tállya (**Fig. 5.**) were found to be excellent in both quality and quantity all across Central-Europe. In 2008 the company invested nearly 1 billion HUF to establish a new 1. and 2. crushing and screening line to improve the capacity of production.

Figure 5. – Aerial photo of the Tállya andesite mine

Geology

The Kopasz-hill in Tállya is part of the volcanic Eperjes-Tokaj (Zemplén) Mountains.

Lajos Jugovics was the first geologiyt who studied the geology of the Kopasz hill at the first part of the 20th century. After that the Hungarian National Geological Institute made surveying exploration in the 1960's all around the Zemplén (Tokaj-Eperjes) Mountains and figured out

the formation condition of the Kopasz-hill. The andesite was identified as a subvolcanic body between the layers of rhyolite tuff which formed through Miocene Volcanism 12-13 million years ago. The eruption centre of the supervulcan was about 20 km in diameter and can be found near the Szerencs-hill and it is surrounded by rhyolitic domes with andesite-layers. About 9 million years ago a new volcanic event caused a magmatic intrusion to the rock body which can clearly visible in the walls of the mine.

At the present there is approximately 17-20 million metric tons of andesite in the mine which explored and exploitable.

Production / Marketing

The exploitation starts with a series of blasting, then the trucks carry the material to the crushing and screening machines. The compeny produce 15-20 different products according to the demand of the market.

Tállya Quarry produced and sold around 1000000 t/a (allowed by Mining authorities: 1,5 million tonnes) andesite aggregates in the last years mostly on domestic market.

The products are used mostly for asphalt-material, road and railway ballast and buildings.

Protecting the nature

CÉK pays special attention for the protection of environment and nature. In the area of the quarry Uhu-owls (Bubo Bubo) nests can be found, and nearby of the Dorgo-hill rare and strictly protected Stipa and Iris population are living.

Zeolite deposits in the area of Mád, southern Tokaj Mts., Hungary

General geology of the southern Tokaj Mts.

The exploitation of kaolinite, bentonite, zeolite and pure silica deposits started before World War II in the area around Mád, in the southern part of the Tokaj Mts (**Fig. 1**.). State owned mining was most active between the 1950s and 1970s; nowadays private companies exploit these raw materials. The formation of clay deposits is related to steam-heated alteration zones of low sulphidation type epithermal systems near Király, Bomboly, and Diós Hills (**Fig. 6.**).

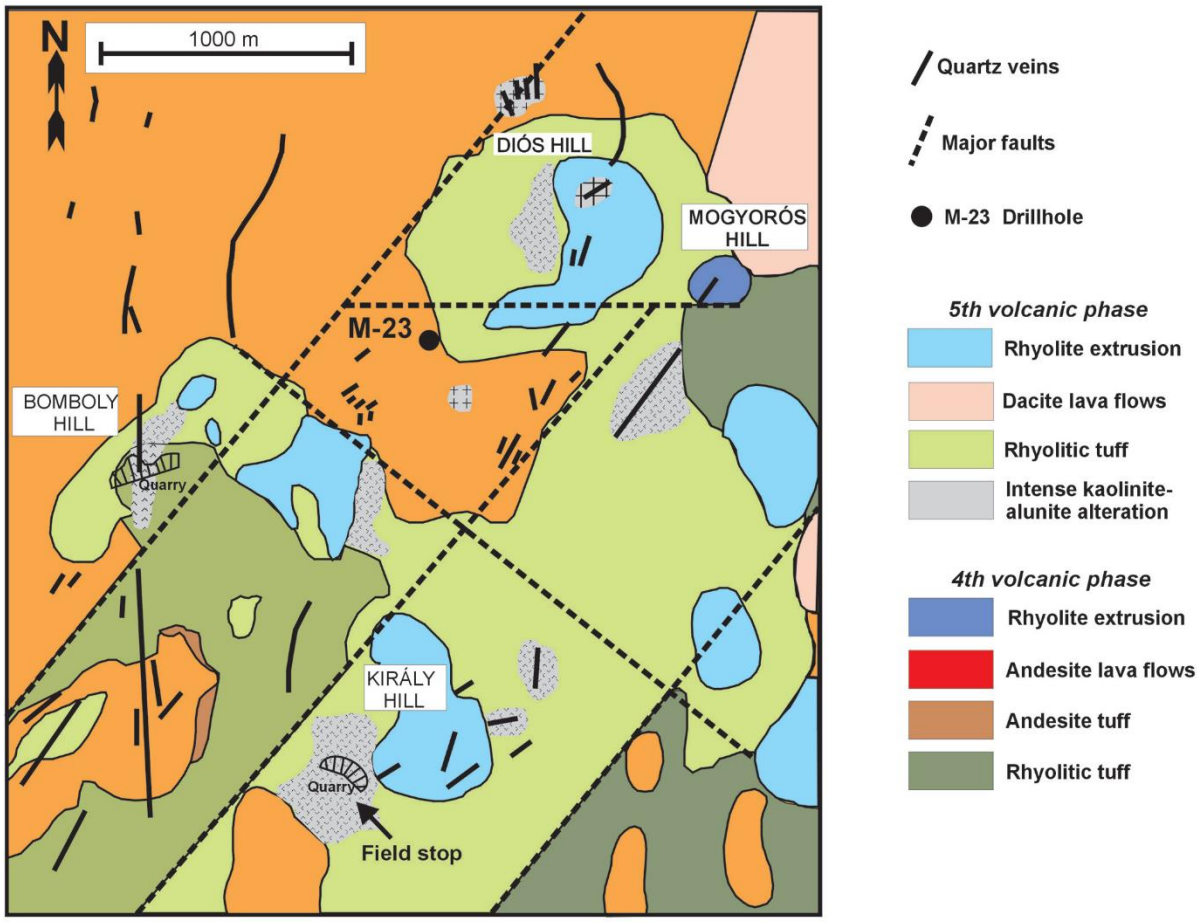

Figure 6. - Geology and hydrothermal alteration zones in the area around the Király Hill at Mád, Tokaj Mts.

Diagenetic alteration of glassy rhyolitic tuffs resulted in formation of clinoptilolite and mordenite deposits. Bentonite together with kaolinite and pure silica, which were deposited in local fresh-water basins fed by palaeo-hot springs (distal environments of hydrothermal systems) also form important deposits 1.5 km west of Mád (**Fig. 1.**) The products of the Badenian volcanic cycle of the Tokaj Mts. are not exposed in the area around Mád. The 1200 m deep Tállya-15 (Ta-15) drillhole (see its location on **Fig. 1.**) reached the Badenian rocks (14.2 Ma K-Ar age; Pécskay & Molnár, 2002) at 900 m depth below the present surface. The Mád-23 drillhole in the center of the mineralized area northeast of Mád (**Fig. 6.**) found only Sarmatian– Pannonian volcanic and sedimentary rocks (11.5-12.2 Ma K-Ar age, Pécskay *et al.*, 1986) to a depth of 712 m. According to Zelenka (1964) and Mátyás (1974), the major part of

the Sarmatian– Pannonian volcanic sequence is composed of five rhyolitic tuff units around Mád (**Fig. 7.**). Each unit reflects the variation of local, subaerial or subaqueous conditions of accumulation and they are locally intercalated with shallow marine clay and marl beds. The pyroclastic units are predominantly pumiceous glass tuff and lapilli bearing pumiceous tuff with subordinate crystal tuff as well as ignimbrite. The explosive tuff accumulations are associated

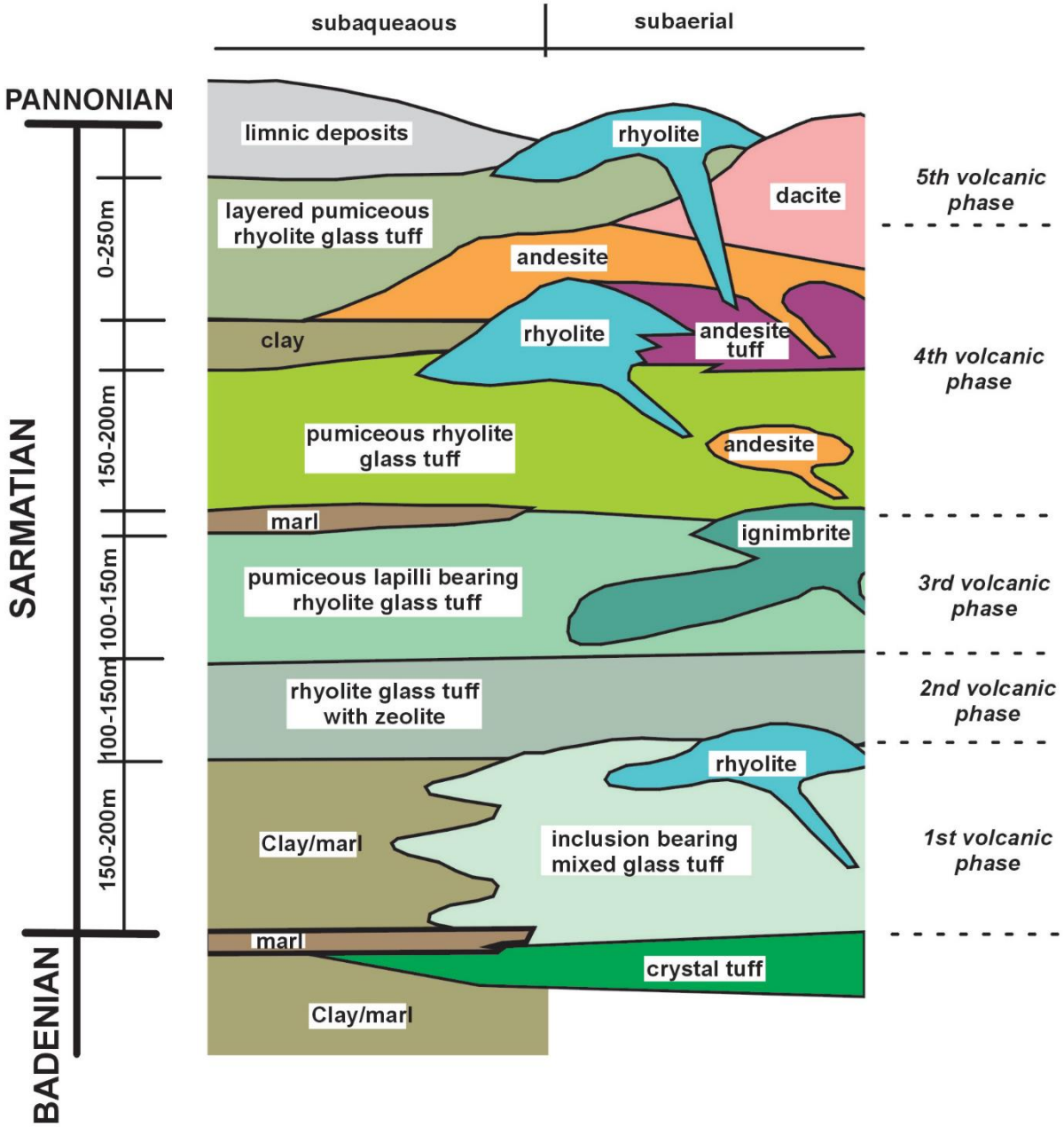

Figure 7. - Volcanic units in the southern part of the Tokaj Mts.

with extrusive domes and pumiceous lava flows. In the mineralized area northeast of Mád, the rhyolitic tuff and associated domes of the fourth explosive phase can be found on the surface (**Fig. 6.**). This phase was followed by andesitic volcanic activity producing lava, tuff and agglomerate beds deposited in shallow water and terrestrial environments. Deposition of the pumiceous rhyolite glass tuff (ignimbrite) of the fifth volcanic phase together with subsequent rhyolite domes and dacitic eruptions (9.8–10.8 Ma K-Ar age; Pécskay *et al.*, 1986) represents the last stages of volcanism in this area. Rhyolite extrusive domes now form the Király Hill,

Bomboly Hill and Diós Hill (**Fig. 6.**). The major faults of the area have NE–SW, N–S and E–W directions. The N–S and NE–SW trending faults were active during the hydrothermal processes, indicated by the predominant strike of siliceous veins (**Fig. 6.**). The E–W trending faults were also active after the volcanic-hydrothermal stages, resulting in block tectonism of the volcanic and sedimentary sequences. The mineralized zones and quartz veins of this area occur in various host rocks including rhyolite and rhyolitic tuff as well as andesitic rocks. K-Ar ages of alunite from the rhyolite of Mogyorós Hill (**Fig. 6.**) are 11.7 Ma, whereas alunite from the ignimbrite of Király Hill has an age of 10.9 Ma (Pécskay & Molnár, 2002). These data suggest protracted hydrothermal activity in this area and are in the range of K-Ar ages for volcanic rocks.

Zeolitic tuff of the Suba quarry at Mád

The Suba quarry (Geoproduct Ltd., Hungary) at the southwestern foot of the Király Hill near Mád exposes the glassy/pumiceous rhyolite tuff of the second and third eruptive cycles of the southern Tokaj Mts (**Fig. 7.**). The fine-grained matrix of the tuff contains around 1 cm large the tuff have slightly greenish colour and the matrix appears to be silicified at some places, but it generally has rather fresh appearance. However, XRD analyses by Nemecz & Varjú (1963) proved the high zeolite content of the rock. Recent investigations on the zeolitic tuff of this quarry by Kratochvíl *et al.* (2008) found 25% zeolite (18% clinoptiloite and 7% mordenite) content beside opal-CT and smectite and some samples providedthe high K-feldspar content, too. Tiny tabular crystals of clinoptilolite with around 10 μm size are associated to smectite either in the groundmass or in the altered pumice fragments. Nemecz & Varjú (1963) have already shown that K-feldspar (adularia) is authigenic (e.g. diagenetic) in the tuff and their μm -sized crystals had grown on the surface of pyroclasts. Strongly adularized parts of the tuff contains up to 10 wt% K2O. The distribution of K-feldspar and zeolites in the rock is determined by the original composition of tuff layers. Adularization preferably developed in the highly potassic glassy tuff layers whereas formation of clinoptilolite together with Nasmectite preferred the more crystalline, plagioclase bearing units. In addition, formation of clinoptilolite released potassium from the volcanic glass and supported formation of adularia in other layers. Thus the alteration of the rhyolitic tuff is related to subaqueous deposition (hydrogenetic argillitization) followed by diagenetic zeolite and adularia formation.

The pyroxene dacite laccolith at Erdõbénye, Hungary

Geology and petrology

An Upper Miocene (Sarmatian) pyroxene dacite laccolith is exposed by the Hubertus quarry of the Mulató Hill at Erdőbénye (**Figs. 1 and 8.**). The shape of the igneous body is ellipsoidal in plan view and its known extension is 1.4–0.5 km. The laccolith intruded a fossiliferous Lower Sarmatian rhyolitic tuffite and tuff sequence and crystallized at shallow, possibly a few hundred metres depth only. Due to the volatile enrichment and spectacular vesicles with up to 20 cm diameter have been developed in the dacite and these vesicles contains “pneumatolytic” and hydrothermal mineralization rich in SiO_2 and carbonate minerals among other silicates. The main mass of the laccolith consists of micro-porphyritic dacite with plagioclase phenocrysts

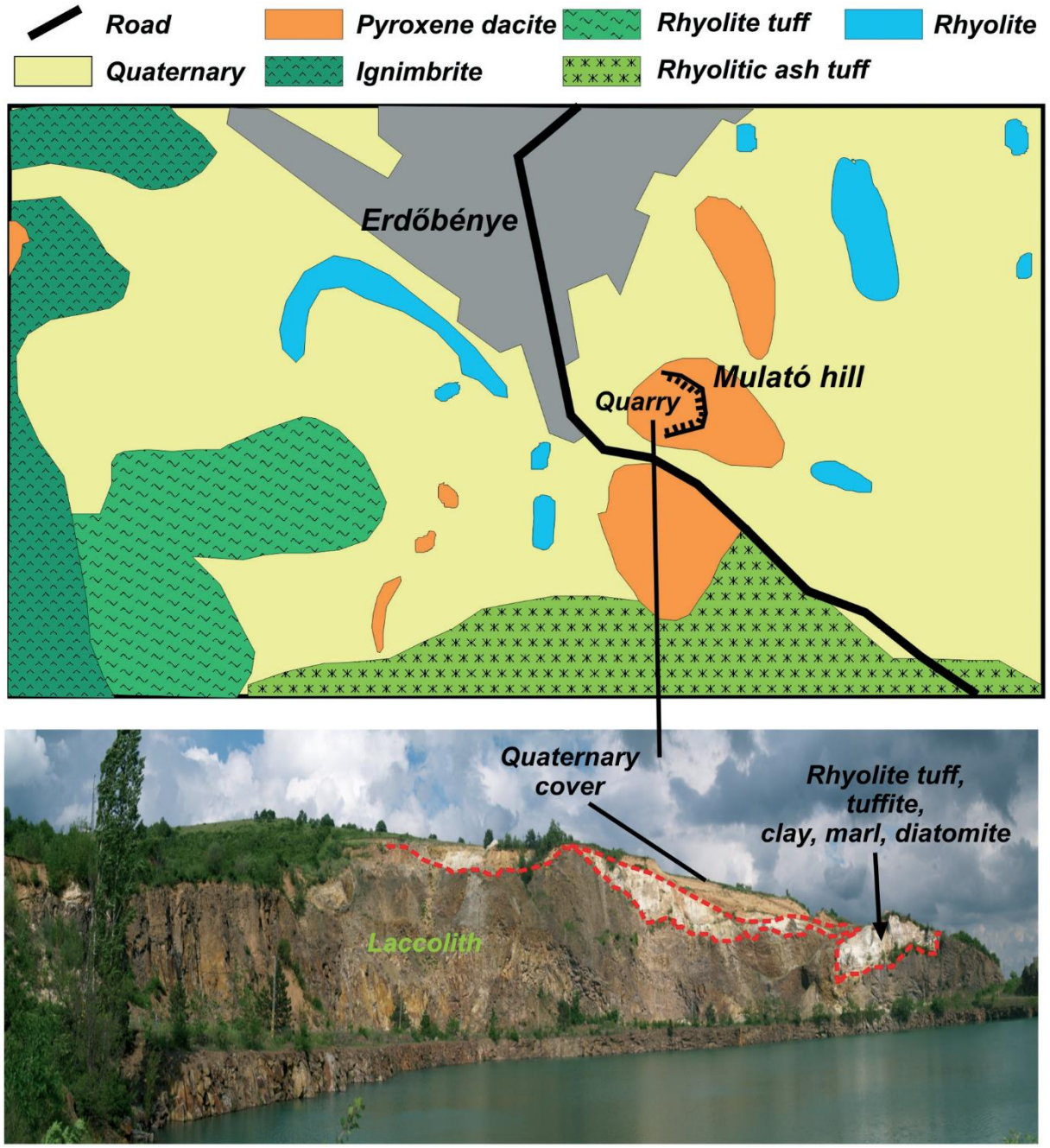

Figure 8. - Geology of the Mulató Hill near Erdőbénye, Tokaj Mts.

(An35–56, 1–3 mm) included in the pilotaxitic-microholocrystalline groundmass (Kulcsár & Barta, 1971; Gyarmati, 1977; Rózsa, 1993). The amount of ferroaugite-pigeonite phenocrysts is subordinate (2–3%) and olivine, ilmenite and apatite are rare accessories. The groundmass/ phenocryst ratio is around 75:25. Representative wholerock chemical composition is shown in Table 4. The Hubertus quarry exposes E–W and N–S oriented sections with approximately 800 m total length across the centralupper zones of the laccolith and contacts to the host tuffite (**Fig. 8.**). The central zones of the igneous body are characterized by spectacular columnar joints as the result of relatively slow cooling, however, these features gradually disappears towards the contact with the host rock. Also, vesicles are more common and larger in the zones with columnar joints and they are almost absent and very small (max. 1-2 mm) close to the contact. Along the contact to the host tuffite, the groundmass of dacite is more glassy (hyalopilitic) and

intrusive breccias containing angular and resorbed fragments both of the porphyritic dacite and host rock in the glassy igneous matrix are also common. The glassy-brecciated zone is up to 3–5 m wide. The host tuffite also shows brecciation and partial meting features along the contact in an up to 0.5 m wide zone. Development of perlitic texture also characterises the partially melted contact zone in the host rock (Kulcsár & Barta, 1971). The original contact is highly irregular with lobe-like protrusions of dacite into the tuffite. However, there also are tectonic contact zones due to the superimposing faulting.

Mineralization

The vesicles of the dacite laccolith obviously were formed at the late stage of crystallization when the pressure of segregated volatile phases was able to blow up gas cavities in the still ductile igneous body. The first stage of mineralization was formed under these "pneumatolytic" conditions and are represented by small (max. 3–4 mm) euhedral crystals along the walls of cavities (Molnár & Takács, 1993; Szakáll & Kovács, 1993). The most common mineral in the "pneumatolytic" assemblage is tridymite: some of the cavities contains rather spectacular triple twins of hexagonal tablets (**Fig. 8A.**). HRTEM studies showed that the ordering of tetrahedral layers in the structure of tridymite resulted in formation of superlattices with different periodicities. Most common is the polytype consisting of ten tetrahedral layers with 41 Å

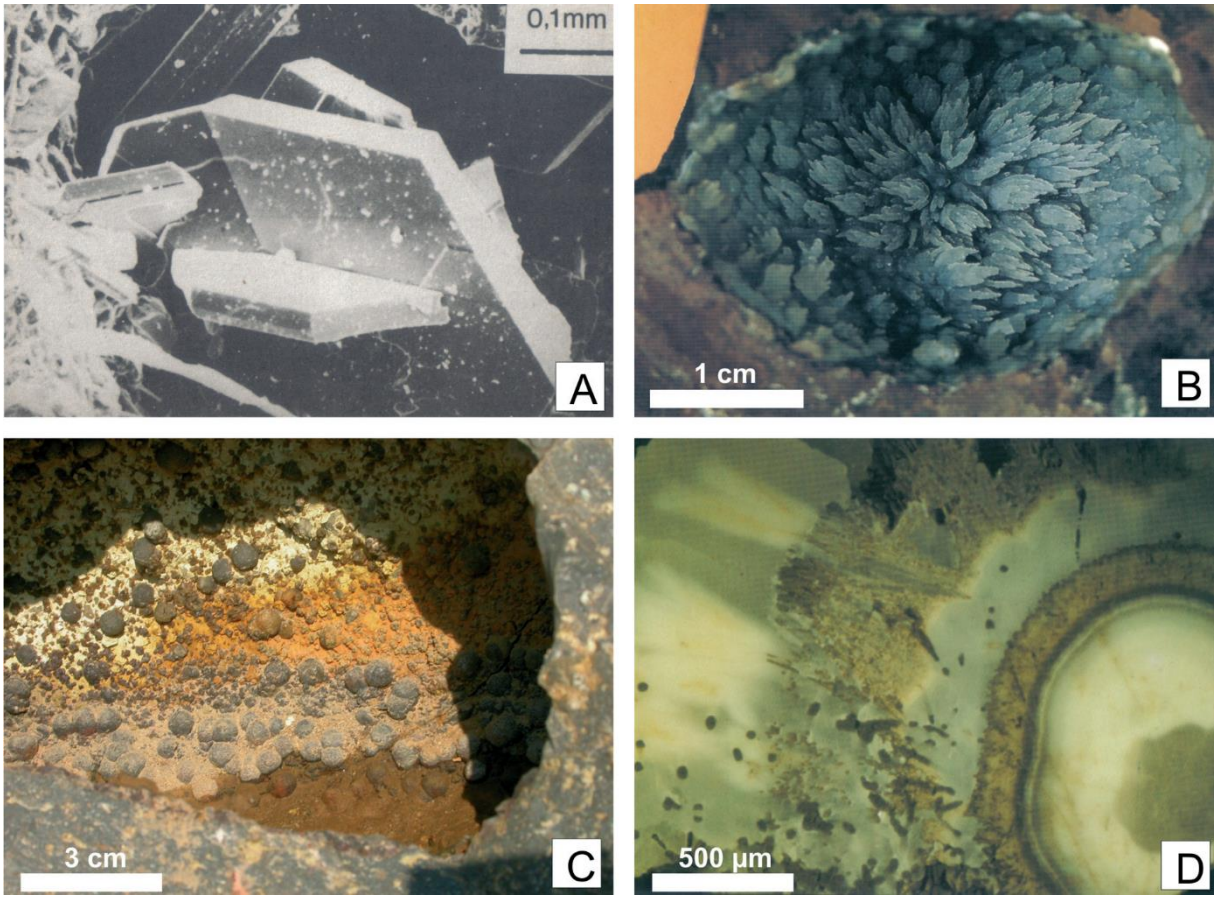

Figure 9. - Minerals from the vesicles of the laccolith at Erdőbénye, Tokaj Mts.; ***A*** *– tridymite, twinned tabular crystal (SEM photograph);* ***B*** *– opal;* ***C*** *– sphaerosiderite globules;* ***D*** *– cross section of a sphaerosiderite globule.*

periodicity. In a few cavities, occurrences of small (< 1mm) cristobalite octahedra, as well as quartz with short primatic hexagonal habit were also detected in association with tridymite. Among the silicates, the most common "pneumatolytic" minerals are the sanidine and

plagioclase. Less common is the occurrence of prismatic hornblende crystals. Rare accessories are octahedra of magnetite, which show oriented intergrowth with ilmenite at some places and needle-like prisms of apatite. Mineralization of hydrothermal origin also occurs in the vesicles of dacite and it forms the most spectacular paragenesis of the locality. The most common hydrothermal minerals are the carbonates with globular-sphaeroidal habit (**Figs. 8C and 8D**). These brownish "sphaerosiderite" precipitations reach several centimetre diameters on the walls of cavities. Most commonly they consist of minute rhombohedral crystals of siderite but their compositions are often transitional to rhodochrosite and calcite depending on the amount of Mn and Ca in the structure. The Fe/Mn/Ca ratios are variable according to the banded internal structure of "sphaerosiderite", however, the outher zones and fibrous-elongated masses of carbonate grown on the surface of sphaeroids often have calcite or rhodochrosite compositions (Weiszburg *et al.*, 1993a). It is interesting that the Mg content of carbonates are insignificant, however, it is understandable considering the strongly depleted MgO content of the host rock (**Table 1.**). The "sphaerosiderite" precipitations are often associated with a rather specific clay mineral which was described as "mauritzite" (after Béla Mauritz, professor of mineralogy and petrology), a new mineral species by Tokody *et al.* (1957a,b). See also Tokody (1962), Kákay Szabó (1983) and Papp (2004). This mineral forms blackish-brownish grass-like aggregates and encrustations on the walls of vesicles and on the surfaces of "sphaerosiderite" and consist of fine, up to 1–5 mm long, 0.1–0.2 thick vermicular-elongated bodies. These vermicular precipitations are built up by very small (0.001 mm) platelets, which show bluish colour under microscope. X-ray and electrondiffraction studies proved that the peculiar mineral has smectite structure and considering the chemical composition it can be classified as a Fe-rich saponite (Weiszburg *et al.*, 1993b). Repeated Mössbauer-spectroscopic analyses carried out periodically on the same sample during the past 15 years proved that the Fe(II)-content of the mineral is continuously oxidizing under atmospheric conditions thus the composition is gradually changing into ferrisaponite (T. Weiszburg, personal discussion, 2010). Silica minerals also occur in large variety in the hydrothermal paragenesis (Molnár & Takács, 1993). Among them opal-C and opal-CT encrustations, leaflike plates and aggregates (**Fig. 8B.**) of tubular forms are common as coloured wax, liver and milk opal, as well as bluish hialite along the walls of cavities or on the surface of carbonate sphaeroids. Precipitation of opal varieties was followed by encrustation of chalcedony and quartzine (chalcedony with positive optical elongation) at many places. The final silica precipitation is short prismatic quartz with up to 5 mm long crystals. Less common minerals in the hydrothermal paragenesis are native sulphur, marcasite, cassiterite, hematite,

Table 1. - Whole-rock chemical composition of the pyroxene dacite, Mulató Hill, Erdőbénye, Tokaj Mts.

	wt%
SiO_2	63.62
Al_2O_3	16.06
Fe_2O_3	1.85
FeO	3.41
MnO	0.12
MgO	0.14
CaO	3.05
Na_2O	4.04
K_2O	3.11
TiO_2	0.62
P_2O_5	0.04
CO_2	1.28
$^{+}H_2O$	1.05
$^{-}H_2O$	2.06
Total	100.45

barite, gypsum and sylvite (Szakáll & Kovács, 1993). Secondary minerals are goethite and Mn oxides.

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Perlite quarry at Pálháza, Tokaj Mts., Hungary

(The description of the Pálháza area based on Molnár *et al.*, 2010)

The Tokaj Mts. is a rather unique area within the Carpathian Volcanic Arc considering the volume of rhyolitic rocks. The Tokaj Mts. consist of two large rhyolitic volcanic fields, each of them cover more than l00 km^2 area. One of them is located in the southern part of the mountains between villages of Erdőbénye, Mád, Szerencs and Abaújszántó, whereas the other large rhyolitic field is located in the northern part of the mountains, between villages of Telkibánya and Pálháza **(Fig. 1.).** The most typical K-Ar ages for the southern rhyolite field are around 11 Ma, whereas rhyolite appears to be older with most common K-Ar ages around 12-13 Ma in the northern field. Rhyolite occurs mostly in terrestrial dome-flow complexes in the southern Tokaj Mts., whereas the northern rhyolite field also contains subaqueous dome, cryptodome, hyaloclastite breccia and lava flow complexes.

An economically important feature of the northern rhyolite field of the Tokaj Mts. is the common occurrence of perlitic rocks. Perlite is a valuable raw material due to its expansion during heat treatment. The perlitic rhyolite glass contains up to 5 wt% H_2O. Heating up grinded perlite to about 700°C causes partial melting (temperature of this process depends on K and Na contents) and releasing of structurally bonded water from the volcanic glass particles: this process – like making popcorn – blows up the semi-molten glass fragments into particles with extremely high specific volume. Expandability of perlite is between 1:10 and 1:20 depending on the composition of the material and also the heat and duration treatment. The expanded perlite has high absorption capacity and therefore can be used for filtering chemicals and blotting of oil pollution from water. Modern building industries use expanded perlite for preparation of light concrete blocks due to their excellent heat insulation and soundproofing properties. Agriculture also uses expanded perlite for soil treatment. Hungary is among the top perlite producers of the world and almost all of the perlite production of the country is from the quarry at Pálháza owned by the Perlit '92 Ltd.

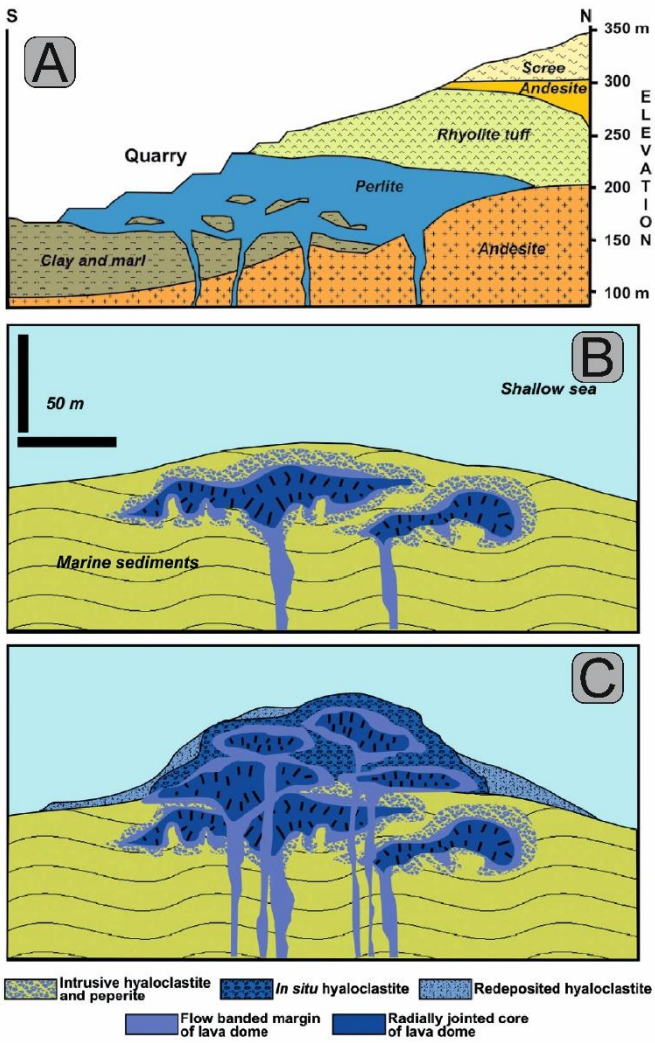

*Figure 10. – **A:** Simplified geological section of the perlite deposit at Pálháza, Tokaj Mts.; **B,C:** Evolution of the intrusive-extrusive rhyolite cryptodome complex at Pálháza, Tokaj Mts.*

The quarry on the Gyöngykő Hill (i.e. „Pearlstone Hill") exposes a part of a subaqueous rhyolite intrusive and extrusive dome-flow complex in a more than 200 m thick section above the Lower Sarmatian andesite and marine sediments **(Fig. 10/A)**. According to Németh *et al.* (2008) the section represents coherent submarine cryptodomes sourronded by hyaloclastite breccias with local occurrences of peperitic facies around intrusives **(Fig. 10/B,C)**.

The lower part of the section exposed in the quarry of the Gyöngykő Hill reveals that the rhyolitic cryptodomes and endogeneous lava domes partially intruded into the wet unconsolidated pelitic sediment and thus jigsaw-fit breccia zone containing mixed igneous and sedimentary material (peperite facies) developed along these contacts **(Figs. 11/A and 11/B)**. The contact of the magmatic bodies to the underlying sediments is highly irregular and undulates over tens of metres. The proportion of marine sediments in the breccias increases with distance from the rhyolite body. Muddy sedimentary dykes also penetrate into the jigsaw-fit breccia zones. In lower levels of the sequence, boudinage-like sedimentary clast-trains up to 5 m in length are common. The deformed sedimentary clasts are both compressed and sheared to form highly irregular-shaped lensoid or frame-like megastructures.

Up-section the magmatic bodies are more coherent but laterally pass into fragmented volcanic rocks **(Fig. 10/B,C)**. Branches of coherent cryptodomes form „cauliflower-like" complex bodies; the individual cryptodomes are lensoid-mushroom shaped with several tens of metres thickness and extension. Columnar jointing **(Fig. 11/C)** and flow-banding is typical for the inner part of domes and some of the flow bands built up by obsidian. In general, the texture of rhyolite is porphyritic (K-feldspar, quartz, biotite), aphanitic and vitriclastic. The unevenly distributed perlitisation characterizes even the inner parts of the domes, however, it is more

pronounced towards their fragmented margins, where vesiculation is also more common. Perlitisation is also characteristic to the volcanoclastic units.

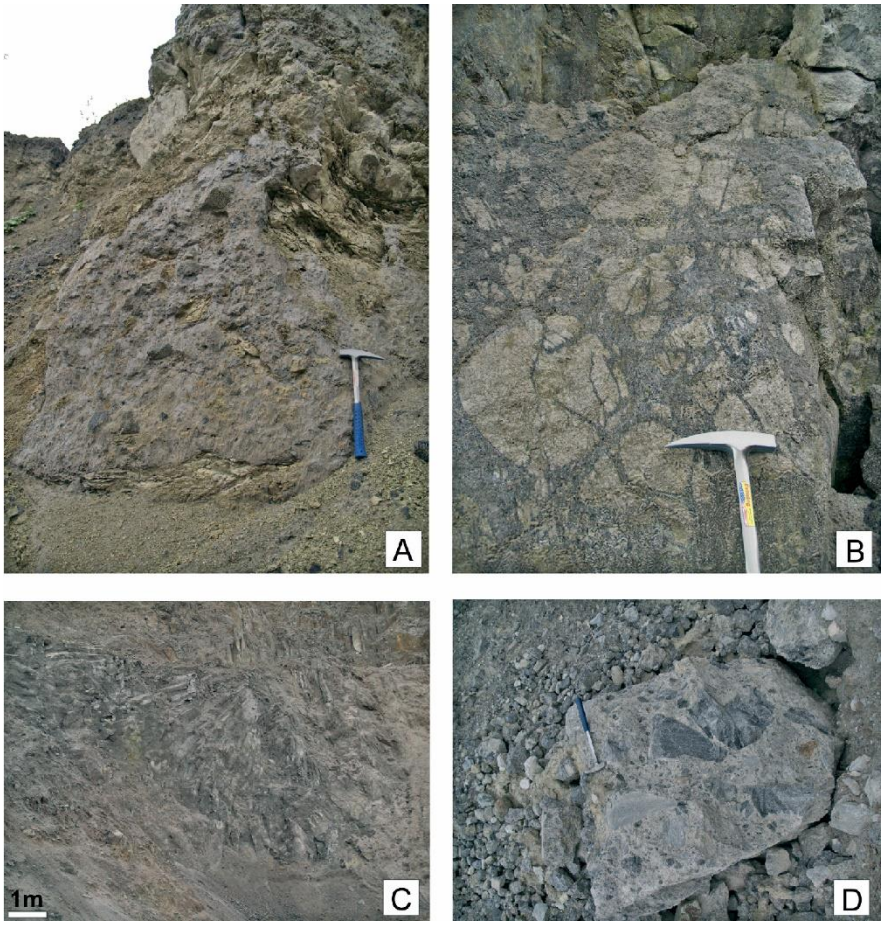

Figure 11. – Facies of the rhyolitic dome-cryptodome complex at Pálháza
A: *contact zone of argillic sediments and rhyolite intrusion;* ***B:*** *peperite at the contact between rhyolite and sediments;* ***C:*** *radially joined core of a rhyolite dome;* ***D:*** *hyaloclastite breccia.*

The fragmented caps of the cryptodomes consists of monomict breccias which are interpreted as their autoclastic carapaces, however, laterally they grade outward into jigsaw-fit, hyaloclastite breccia **(Figs. 10/B,C and 11/D)**. This breccia is rich in glass shards with ash-grade matrix-supported texture. Hyaloclastite domains are locally also present within the flow banded coherent rhyolite bodies. The hyaloclastite breccias are finer grained with increasing distance from the contact with the coherent rhyolitic units. Clasts in both the matrix-poor and -rich breccias range between 1 cm and up to 2 m. The fragments are generally angular, and show glassy textures with common flow-banding enhanced by alternation of perlitic and obsidian bands up to 2 cm thick. The hyaloclastite breccia mantle of the domes reach up to 100 m width and weak bedding appears away from the coherent magmatic bodies. Fine-grained volcanoclastic „tuff" also forms the cover of the cryptodomes **(Figs. 10/A,B,C)**. The uppermost part of the volcaniclastic succession also contains large, plastically deformed, slightly thermally altered mud clasts up to 10 m in diameter.

ln summary, the volcanological characteristics observed in the section exposed in the Gyöngykő Hill reveals that rhyolite intrusions invaded and partially encapsulated marine mud, forming peperite along the contact. The low-volume, but sustained and pulsatory magma supply

led to the unsteady growth of a network of several cryptodomes which broke through the sedimentary cover to form a lava dome complex with an associated hyaloclastite pile around the network of feeder zones **(Fig. 10/B,C)**.

The chemical composition of the perlitic rhyolite is as follows: SiO_2 68–75%; Al_2O_3 10–15%; $Fe_2O_3$0 l.0–2.5%; CaO 1.5–2.0%; MgO 0.2–1.5%; K_2O 3.2–4.5%; Na_2O 2.8–4.5%; LOI 2.0–5.0%. There is no significant chemical difference between strongly perlitic and less perlitic rhyolite except of H_2O and Cl contents (Németh *et al.,* 2008). Rhyolite contains 1.4 wt% H_2O only, and the Cl content (460 ppm) is also lower than it is for perlitic rhyolite (676–740 ppm). The darker perlite shows slightly higher H_2O and Cl content that the light one.

K-Ar ages for the perlitic rhyolite are between 13.37 and 13.94 MA (+- 0.4 Ma). The K-Ar ages are also concordant with the biostratigraphic Lower Sarmatian age for the sediments (Pantó, 1968; Székyné Fux *et al.,* 1981) mixed with the volcanic material.

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Rudabánya ore mineralization, Hungary

(The description of the Rudabánya area based on Földessy, 2017)

Introduction

Rudabánya is one of the most historic mining sites in Hungary (**Fig. 12.**). It is known for its iron and silver mineralizations since the ancient times. It was an industrial siderite iron ore operation between 1880 and 1985. Base metal explorations discovered widespread Pb and Cu anomalies since 1970, and the presence of significant barite enrichment. Small scale copper ore mining operated in the last five years of the iron ore mine. In 1995 a sampling campaign (Vörös, 1995) revealed geochemical anomalies of Au and Zn.

Modern mineral explorations started in 2007 and continued intermittently until 2015. The works aimed at localizing the enrichments of base metal and precious metal ores as well as barite on the surface and at shallow depth.

The works proceeded to outline important lead, zinc, silver and copper anomaly areas. The results are sufficient to assess the type and areal extension of the enrichments, but does not allow to make a safe assessment of geological and grade continuity and estimate mineral resource yet. At present the explorations continue under the permit to explore barite.

Figure 12. – The Rudabanya iron-ore mine at the end of the 19th century

Accessibility, Climate, Local Resources, Infrastructure and Physiography

Rudabánya (3000 inhabitants) is one of the oldest mining towns in NE Hungary, Borsod-Abaúj-Zemplén county, near the Slovak border. It lies 50 km from Miskolc, which is the 3rd largest city of Hungary. It is the most backward industrial region of the country.

Besides Rudabánya, the area covers three more smaller townships: Felsőtelekes, Alsótelekes and Szuhogy. All settlements of the area are connected with paved roads. Nearest national main highways are at Szendrő (road 27, 11 km) and Kazincbarcika (road 26, 15 km). Miskolc, the

county capital is in 36 km distance, where there is connection (M30) to the national motorway netwrok. There is a 15 km maintained railway line between Rudabánya and Kazincbarcika, used for freight transport only. Public transport is supplied by bus lines (Borsod Volán) connecting the villages with Kazincbarcika and Szendrő, the regional centres. Nearest public airport is at Košice-Barca, Slovakia (70 km).

The site is located in the Aggtelek-Rudabánya Mts, a SSW-NNE striking chain of hills from Rudabánya village to the Slovakian border, the elevation of the hills range between 180 to 363 m asl. The gently sloping hills and downs are divided by wide-floored valleys. Steep scarps were formed by the mining in pits and on waste dumps only.

Due to the northern position this is one of the coldest regions of Hungary. Annual median temperature is 9,1°C. Winter period is long, frost may occur from October to April. Annual precipitation average is 570 mm, slightly less than the Hungarian average.

The site belongs to the watershed of the Sajó river. Major runs of the surroundings are the Ormos creek, the Szuhogy creek in the southeast and the Telekes creek in the north (running into the Bódva). Inside the mining site several small and one large in-pit lake was formed; its average water level is at 230 m asl. Despite of being near to the Aggtelek Karst, connected karst water is not formed here as carbonate rock bodies are fragmentes, and the blocks are isolated by argillaceous matrix.

The natural vegetation (according to the climate zone) is deciduous forest, mostly in the Querco petraeae-Carpinetum (oak and hornbeam) or in the Quercus cerris (Turkey oak) zone. Local differences occur due to the exposure: on north facing slopes beechwoods may be present. On the carbonate rocks calcophile, on other rocks' surface acidophile associations were formed. On valley floors, at rills alders and other humidity-liking species form associations.

A considerable part of the surface around the villages is used for agriculture either as plough-land or as pasture. The southern part of the recultivated pits at Rudabánya also is a pasture. Waste dumps and pit walls are either bare or sparsely covered by pioneer weeds and bushes. The exploration area is close to the Aggtelek National Park. As lower level of protection, there is a 2 ha Natural Protection Area inside the exploration area boundaries: that is the Hominid Site of Rudabánya, founded in 1977, located in the NE part of the Vilmos pit, controlled by the Aggtelek National Park. Archaeological monuments are at Csorbakő, ruins of a medieval castle. Natura2000 areas partially overlap the exploration licence blocks.

History of mining and explorations

The historic combined iron ore production of the Rudabanya iron ore mine was 35 million tonnes 32-42 % average Fe_2O_3 grade. The main customers of the ore were the nearby iron smelters at Ózd, Diósgyőr, as well as Vitkovice/Bohemia and Kosice/Slovakia.

Four types of iron ore were traditionally known: (1) brown iron ore – limonite, (2) carbonate iron ore – siderite, (3) dolomitic iron ore – ankerite, (4) siliceous iron ore – siderite in sandstone. Of these four types, the brown iron ore and carbonate iron ore was produced in commercial quantities.

Sulphide mineralization (mainly copper ore) has been recognized, and finally exploited towards the end of the life of the mine, since 1970. Since sulphide ores were non-desirable components of iron ore, the mining operations tried to avoid involving sulphide rich zones.

Nevertheless, the discovered rich underground copper orebodies triggered surface explorations and finally led to copper ore production in the last decade was in the range of 10,000 tons per year, totalling at 125,000 tonnes of copper ore. The silver bearing lead ore has not been mined. Neither barite was produced in commercial amounts.

The exploration area is centered on t he historic ore mine of Rudabánya. On the area small copper and silver mines, adits worked in the years between 1300s to 1500. Later, from 1880 to 1986 it was in operation as an industrial scale iron ore mine.

Geological setting, structural evolution

The deposit complex is hosted in Lower Triassic platform carbonate rocks, siltstones, shales. Their present state is brecciated, folded and transgressed during the Alpine structural activity in the Jurassic and Cretaceous. Further fracturing and brecciating has subsequently taken place, since the mineralization is positioned in a major shear zone, with main activity period in the Tertiary.

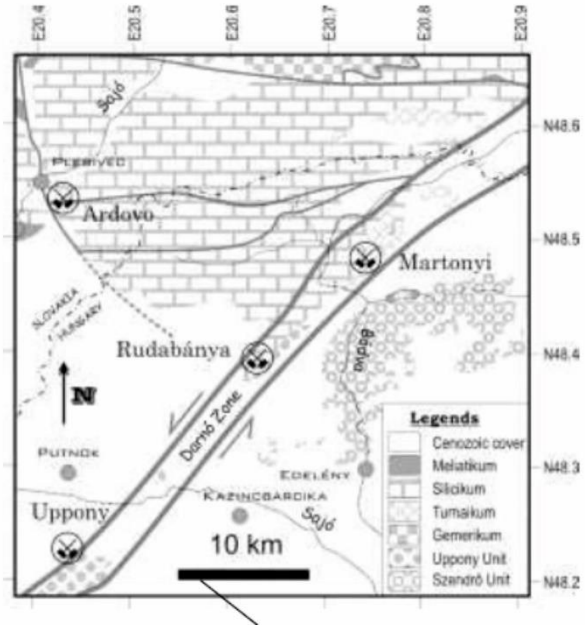

Figure 13. - Geological scheme of the surroundings of Rudabánya. Uppony and Martonyi are two similar smaller siderite metasomatic iron ore mineralizations. The Szendrő Unit is devonian, the Meliatikum, silicikum, Turnaikum and Gemerikum are different Mezozoic formation groups, from Triassic to Jurassic age.

This major shear is the most prominent and controlling structural feature of the regional geology, called the Darnó zone. According to widely accepted tectonic models, this zone is bifurcation of the regional scale fault system, a cca. 600 km long so-called Mid-Hungarian Tectonic Zone. The shear zone represents multi-stage tectonic deformation (rifting, brecciation, strike-slip faulting, overthrusting, normal faulting etc.) from the Paleozoic to the Late Tertiary. Along the SE flank of the shear zone a Paleozoic block is in contact with the Triasssic sediments, also showing anomalies of precious metals, base metals. On the NW flank the are is unexplored, although base metal geochemical anomalies are numerous, extending beyond the border to Slovakia, where the nearest Pb-Zn mineralization is at Ardovo (Grecula *et al.*, 1995).

The host rocks belong to the Silicikum stratigraphic superunit which is widely distributed North from Rudabánya in the Silica Nappe (**Fig. 13.**). The succession starts with Permian

evaporite series (anhydrite, shale). The Lower Triassic comprises a transgressive succession of littoral sandstone and aleurolite, shallow water marl and laminar or nodular limestone. The Anisian rocks are dark, euxin facies, thick-bedded or massive limestone and dolomite followed by gray, platform facies limestone and dolomite. In the further Middle and Upper Triassic part of the succession carbonate platforms and reefs alternating with basin facies rocks were developed. In the vicinity of Rudabánya basin facies formations occur up to the Middle Jurassic. A typical cross section of the Rudabánya deposit is seen in **Fig. 14**.

The Paleogene formations are subordinate, and present as tectonized fragments in shear zones. The Neogene formations unconformably overlie the older rocks in form of shallow basin sediments, lignite, clay, sandstone.

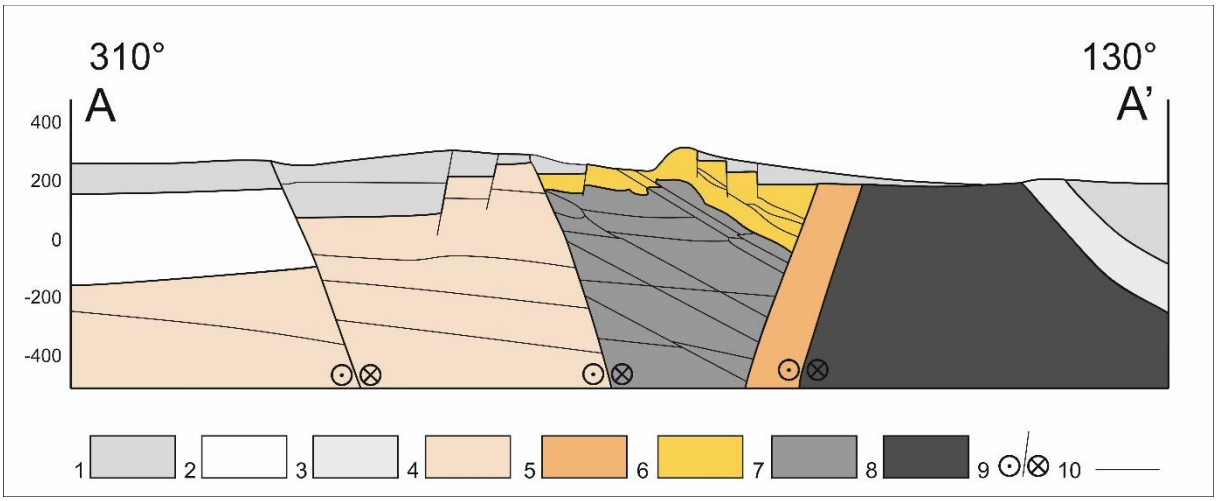

Figure 14. - Geological profile across the Rudabánya iron ore open pits. Legends: 1. Pannonian sediments (sand, silt, clay, pebbles, lignite), 2. Miocene siltstone, sandstone, 3. Miocene conglomerate, 4. Upper Triassic cherty limestone, marl. 5. Middle Triassic platform limestone, cherty limestone, marl. 6. Lower Triassic iron ore bearing complex (dolomite, siderite, limestone, marl), 7. Permian – LowerTriassic sandstone, siltstone, shale, evaporite, 8. Paleozoic shale, siliceous shale, tuffaceous limestone, 9. Master faults of the Darnó Zone (sinistral strike slip), 10. Faults

Ore mineralogy - alterations

Since the ore mineralizations outcrop on the surface, there are supergene and hypogene varieties of the different ore types. Surface orebodies have mostly been mined out, and do not play important role in the present mine area. Since the exhumation of the mineralized rocks happened before the late Tertiary sedimentation, there is good chance to localize buried supergene paleo-gossan type mineralization on the southern continuation, and on the NE and SW flanks of the outcropping mineralized zone.

The the broader region the oldest metallic mineralization are related to hydrothemally altered Paleozoic metasediments in the Szendrő/Cserehát structural unit SE from the Rudabanya mineralized zone (Földessy *et al.*, 2012). This is essentially unexplored.

Microbially mediated syngenetic carbonate iron ore accumulation was diagnosed in the lowermost known sandstone unit of the Lower Triassic series (Bodor *et al.*, 2016). These enrichments were earlier considered as subgrade, never been exploited as iron ore commercially.

The early stage Pb-Zn-Ba enrichment is stratabound exhalative ores in carbonate and siliciclastic sediments of probably Lower Triassic age, and found now as clasts in tectonic

breccias (Nemeth *et al.*, 2013). Their dominant mineralogy is galena, sphalerite, barite, pyrite.The clasts do not form commercial size orebodies.

The carbonate iron ore, which has been traditionally mined as primary iron ore in Rudabanya between 1880 and 1985, is siderite which has been formed by metasomatic replacement of existing Lower Triassic dolomite and limestone rocks. The metasomatic replacement process took place after the Anysian, before the Cretaceous (Panto, 1956; Foldessy *et al.*, 2008; Bodor *et al.*, 2016), with highest intensity along the longitudinal axis of the Rudabanya mineralization, i.e. parallel with the Darnó zone. Important to know, that intense Au geochemical anomalies were detected in the feeding channel type siderite veins crossing dolomite and sandstone below the metasomatic siderite ore bodies (Földessy *et al.*, 2014).

The next stage brings epigenetic base metal-barite ore mineralization, with (1) Pb, Zn, Ag, Ba and (2) also with Cu-Ba enrichments. The orebodies of the two mineralizations are spacely close to each other, but almost never overlap. The mineralizations are related to fault breccias, parallel and crosscutting to the NNE-SSW running master faults of the Darnó zone. This type of mineralization may extend well beyond the Rudabanya along and outside the Darno Zone. Within the Darno Zone, similar semi-massive Pb-Zn mineralization has been recognized (Boros 2010). Re-sampling of available archived sporadic cores has resulted in the detection of Cu, Pb, Zn anomalies at Szögliget, Bódvaszilas, Szinpetri, Jósvafő until Ardovo, Slovakia (Nemeth *et al.*, 2012).

The Pb, Zn Ag, Ba ores consist of galena, sphalerite, acanthite, pyrargirite, pyrite, barite, while the copper ores are essentially of tetrahedrite, bornite, chalcopyrite, pyrite.

These two mineralizations are closely related to the borders of earlier fractured siderite ore blocks, and thought to belong to the Darno Zone faulting, which has had its strongest activity from the Oligocene through the Lower Miocene.

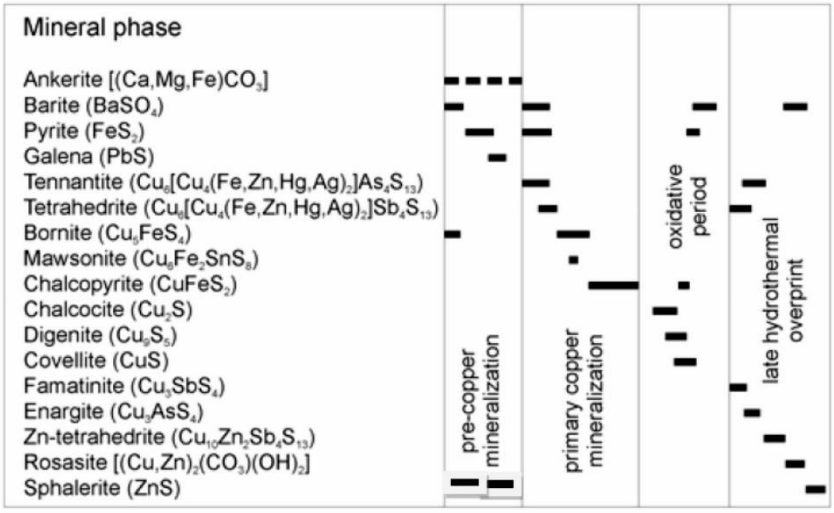

Figure 15. - The main Cu-Pb-Zn mineral phases and their paragenetic sequence

A late stage (Middle - Upper Miocene) epithermal mineralization is found in 2-3 isolated smaller vent like centers along the master faults. These epithermal mineralizations are essentially of famatinite – enargite - tetrahedrite – rosasite – sphalerite - pyrite – quartz, with high (over 100 ppm) silver content.

The ore mineral assemblages of the different stages are summarized in the evolution chart shown on **Fig. 15**.

The epigenetic and late stage epithermal mineralizations are thought to be sourced from subducted Mesozoic (Triassic-Jurassic) basic igneous complexes subsequently swallowed by the Darno Zone (Foldessy *et al.*, 2012). The copper is also originated from the adjacent, partly

outcropping partly subducted basic basalt complexes and thought to be related in this way to the base metal mineralization at Recsk, porphyry and skarn copper deposits, 80 km SSW from Rudabánya.

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Wines of the Tokaj-hegyalja region

(The description of the Pálháza area based on Molnár *et al.*, 2010)

The Tokaj wines rightly deserved their fame all around the world in the last 400 years. These wines belong to that group of wines that are strongly ruled by geological and other geofactors, in contrary of those other wines, which are dominated by viticultural and oenological technology or by the grape variety. For a brief description of the Tokaj-Hegyalja wine region see Nagymarosy in Rohály & Mészáros (2001, for more detailed information see Alkonyi (2000), Rohály, *et al.* (2003) and Botos & Marcinkó (2005). For those who are interested for constraints between wine quality and natural conditions, a short comprehension on the climatic factors influencing the wine-production can be read in Rohály *et al.* (2004).

The most important geo-factors that influence the quality of the Tokaj wines are:

- geomorphology
- meso- and microclimate
- bedrocks
- soil quality
- cellars

In this short description we focus only the soil quality factor.

Soils

The region 's basic soil mantle developed during the Quaternary. On the steeper slopes, the thin soils are typically mixed with weathered lava rocks and are quite hard to till. In the low valleys and the foothills, redeposited soils of the slope, loam, and glacially disturbed soils occur. The weathered volcanic glass, also fragments of obsidian, pumice and perlite continues to mingle with the soils today, enriching them in trace elements and minerals.

ln 1867, József Szabó, the "father of Hungarian geology" who provided the first comprehensive geological description of volcanic rocks, soils and their importance in the quality of the Tokaj wines (Szabó, 1867), distinguished three basic soil types, both in writing and on maps, from which all the other sub-types can be derived. The names of these soil types are not "scientific terms" but clearly describe the character of soils and are often used also among the workers in the vineyards.

The most widespread is the clayey *nyirok*, a red erubase soil created by weathering of volcanic rocks, particularly rhyolite and andesite, with a high occurrence of rock debris and rock inclusion (Ballenegger, 1917). ln fact, this soil variety is an *andisoil* in terms of US soil classification. When too wet, *nyirok* gets so gluey that it sticks to the spade; if it dries out, it will yield to nothing short of a pickaxe. It does not absorb water very well and has low permeability. Its red colour, from the ferric hydroxide, turns darker as its humus content increases. Yielding the most powerful and substantial wines in Tokaj, *nyirok* is the soil of the Király vineyard at Mád and Mezőzombor, the Meszes at Olaszliszka, and the Várhegy and Oremus at Sátoraljaújhely.

Of slightly lesser value is the soil type known as *yellow earth*, which forms from loess. The loess soils are confined to the southernmost part of the region. This soil variety is an *alfisoil* in terms of US soil classification. Its varieties in Tokaj are loess talus and loamy loess (both mixed

with talus, debris and fossils), as well as sandy loess on the Tokaj Hill and the hills north of Olaszliszka. Loess has good water management, good drainage, and a low to medium lime content. The loess blanket of the foothills can be traced from Abaújszántó to Tokaj and from there to Bodrogkeresztúr. The Szarvas and Hétszőlő terroirs are famous examples of vineyards with loess soil. Loess does not crop up in the interior of the mountain chain or in the valleys, but on the southeastern slope of Tokaj Hill it can be found at altitudes as high as 405 meters.

The last basic soil type is the *rock flour* that forms from intensely silicified rocks and pumice. Basically, a lithosoil produced through mechanical weathering, rock flour is finegrained debris of white rhyolite, pumice, and perlite. It is less coherent, not very malleable, and it does not retain water. Its heat capacity is inferior, so vines planted in it may easily get parched during a drought or freeze up in extreme cold periods. Rock flour is the soil type for example of the Pereshegy and Lócse terroir at Erdőbénye , the Tolcsva Hill, and the Oremus vineyard at Sátoraljaújhely.

Grape varieties

There are six officially approved grape varieties in Tokaj. Five of them are indigenous varieties occurring only in the Carpathian basin, the Yellow Muscat is a variety of French origin (Clarke & Rand, 2001):

- Furmint
- Hárslevelű
- Yellow Muscat (Hungarian: Sárgamuskotály)
- Zéta (previously called Oremus)
- Kövérszőlő
- Kabar

The two leading grape varieties in Tokaj-Hegyalja are the Furmint and Hárslevelű, often harvested, pressed, and fermented together throughout the region. This makes sense, as their time of ripening are quite close to each other, and many older plots still in cultivation are mixed plantations, containing the two varieties side by side. These two varieties cover 96-97% of the total cultivated area.

Tokaj wine types

The most famous wine of the region is the Aszú, blended with noble-rotten grapes, fermented and matured during the long so-called Aszú process. Its classical Latin name is *Vinum Passum Tokajense.* Distinct from this noble sweet category is the typically dry *ordinarium,* which is harvested *without* noble-rot grapes. Főbor ("principal wine") was the old name of Szamorodni-style wine, at least insofar as it was made by pressing the harvested fruit as is, *without separating botrytized berries from grapes unaffected by the noble rot.* From 1707 onward, Esszencia, the highest grade of Tokaji, was also increasingly referred to as *legfőbb bor,* meaning "supreme wine" (Rohály *et al.,* 2003; Botos & Marcinkó, 2005).

Nowadays, the wines of Tokaj are grouped and categorized in the following categories:

Dry wines.

- *Fresh or briefly matured wines* – Typically fe1mented dry but potentially containing some residual sugar (below semisweet category levels). With a few exceptions, they

are fermented in stainless steel tanks. These are the wines for quick consumation. *Not* a classical style in Tokaj.

- *Matured dry wines (ordinarium)* – Invariably matured in wood, with a small proportion also fermented in wooden casks. Very long lifetime and potential. As Botrytis is undesirab le in these wines, the grapes must come from high-altitude vineyards (about 250 m above sea level) calibrated specifically for this purpose.
- *Dry Szamorodni (főbor)* – Quality comparable to Beerenauslese, but fermented dry and subjected to subtle maturation (under a film of yeast). Contains botrytized grapes.

Sweet wines:

- *Sweet Szamorodni (főbor)* – Typically made in the sweet style, when the sugar content of the grapes is so high that the must will not ferment fully dry. The residual sugar of Sweet Szamorodni is comparable to a 2 or 3 puttonyos Aszú, sometimes more. It needs to be matured for two or three years, and is lightly oxidized in character.
- *Reductive sweet wines* – Ready for release in a year or sixteen months after harvest, made in stainless steel tanks plus a short barrel aging. They may contain 50 to 180 g/I residual sugar and a ratio of botrytized berries comparable to Aszú wines. *Not* a classical Tokaj style, bowever very popular.
- *Aszú (3 to 6 puttonyos) and Aszúeszencia* – Tokaji Aszú can be defined as a sweet wine with a high concentration of residual sugar that is made from hand-selected shriveled grapes affected by *Botrytis cinerea*, macerated in wine or must before pressing, and matured in oxidative conditions without adding spirits of a higher alcohol content. To our knowledge, no other wine available commercially in the world meets these manifold criteria (Rohály *et al.*, 2003). At the same time, the Tokaj Aszú yields the highest level of acidity among all wines of Hungary.

Botrytis cinerea, a species of fungus causes noble rot, and it affects the fruit in two ways: by enhancing the evaporation of the water content from the berries, and by creating special aromatic substances inside. The noble rot infection does not occur each year. It is not exceptional but quite rare. According to statistics, aszú vintages used to occur in three years per decade on the average.

The aszú berries must be picked out of the bunches one by one, by hand during the harvest, thus selecting them from the non-botrytized grapes. After harvest, crushing of the grapes follows and the aszú berry pulp will be mixed either to the freshly pressed grape juice or to young dry wine. The unit of measurement of aszú-pulp is the *puttony* (butt) and for the juice a 136-liter cask *(gönci hordó, Gönc cask* - Gönc is a village in the heavily forested northeastern Tokaj Mts. and was the place of the traditional cask production) serves as a framework for measuring concentration. The grade of the Aszú depended on how many *puttony* (a 27-liter harvester's butt) of botrytized berries were blended with a 136 1 caskful of dry wine or must. The more *puttony* aszú will be added the sweeter will be the wine.

The juice is poured on the aszú dough and left for 24-48 hours, stirred occasionally. The best growers reject the use of selected yeasts, preferring instead local wild yeasts naturally present in the vineyards to trigger fermentation. Then the wine gets into wooden casks or vats where fermentation is completed and the aszú wine starts to mature. The casks are stored in a

cool cellar. They are not tightly closed, so a slow fermentation process continues in the cask, usually for several years.

The different aszú wines must contain a minimum amount of sugar by law. The increasing number of puttonys means an increasing sugar concentration. **Table 2** shows minimum residual sugar and extract required per grade.

The Esszencia (*legfőbb bor)* is the sweetest wine of the region. The free-run juice of hand-picked pure botrytis berries accumulates, with over 450 g/l sugar (but levels of 800 g/l or more are not unheard of). Esszencia takes years to achieve a modest alcohol level of 4-5%.

2. Table - Residual sugar and sugar-free extract contents of Aszú wines

Wine type	Residual sugar (g/l)	Sugar-free extract (g/l)
3 puttonyos / 3-butt Aszú	60	25
4 puttonyos / 4-butt Aszú	90	30
5 puttonyos / 5-butt Aszú	120	35
6 puttonyos / 6-butt Aszú	150	40
Aszúesszencia / Aszú essence	180	45

Among other factors, high acidity makes a fundamental contribution to the unique character of Tokaj wines, particularly to Aszú. Having high concentration of sugar the malic acid is never a problem, but the wine will have high levels of other, more benign acids that keep the often extraordinary sweetness from being cloying. Working in a synergistic combination with the acids, these substances ca attain a perfect balance with the intense sweetness of Tokaji Aszú (Rohály & Mészáros, 2001, 2006).

The mineral and trace elements, present in the soils of Tokaj in a form that is readily accessible for the vine's roots, contribute their own flavors to the wines. This is the typical *"mineral taste"*. Due to the diversity of terroirs in the region, the wines show distinct features observable by organoleptic analysis. Wines having harvested from loess soils are less mineralic in taste, than those of volcanic soils. Different volcanic sub-soils can lend either salty taste to the wines (high level of sodium and potassium), or represent a slightly bitter palate on other terroirs (magnesium-dominated wines). Generally, wines from volcanic soils usually have a pronounced mineral taste.

Micro-oxidation in a wooden cask is a further key factor in making good Aszú or another Tokaj wine type. Micro-oxidation, which essentially occurs through the pores in the barrel's wood, is certainly not amenable to making wines that will seem 10-20 years old at three to four years of age; this can be achieved, if it must, by not topping off barrels and by frequent racking. Tokaj wines handled this way will develop rich tertiary aromas and flavors, without losing their acidity and mineral taste unmatched by any other sweet wine in the world.

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Special thanks to the following sponsors for their support

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The University of Miskolc (1735) is one of the oldest Mining Academy in the world. It was established in Selmecbánya. After the II. world war the university moved to Sopron. In the 1950's it arrived to Miskolc. The University of Miskolc offer special and unique faculties within Earth science in Hungary, which can be find only in Miskolc: geotechnical- and mining engineering, gas- and oil engineering, hydrogeology engineering.

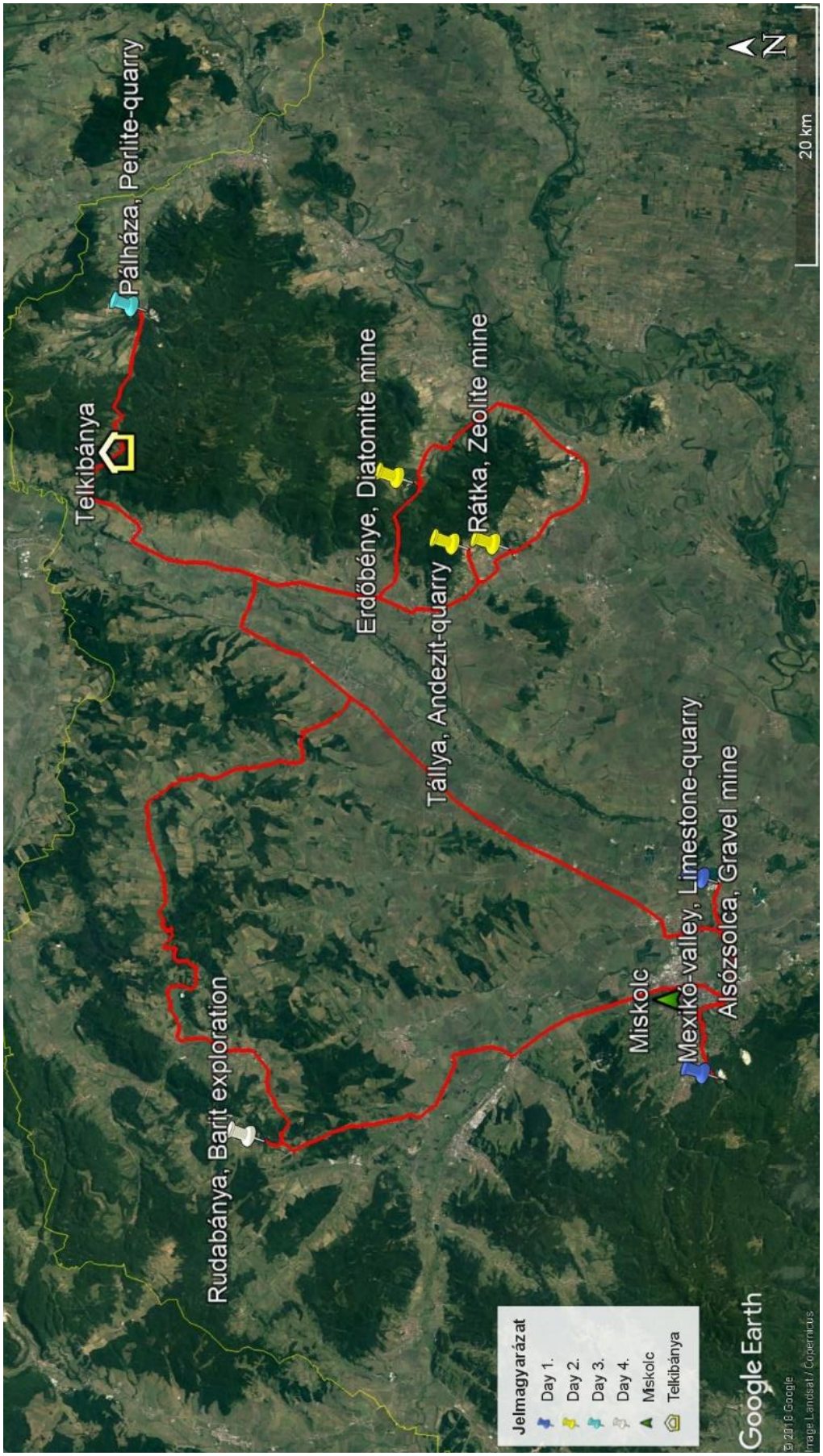
Special thank to the Institute of Mineralogy and Geology for financial support and the help during the organization.

Society of Economic Geologists

We thank to the SEG Stewart R. Wallace Fund for financial support.

SEG Student Chapter University of Miskolc

The Miskolc SEG Student Chapter was established in 2015. Near to Miskolc (In NE Hungary) there are some active and abandoned mining area, which help to our chapter. In the last two years two popular and successful GIS workshop was organized by the member of the chapter. With this international short course the chapter would like to debut in Europe and to meet and to build a good relationship with other chapters. The Miskolc SEG chapter's member worked hard for this program. We hope, that the participants will feel well, learn useful skills and get familiar a little part of Hungary.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Day 2.
Day 3.
Day 4.
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