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Mineralogy and speleology of the Szemlőhegy and Mátyáshegy Caves with an introduction to the geology and speleology of the Rózsadomb area, Budapest, Hungary

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1. Introduction

In the capital of Hungary, Budapest – which is called as 'the capital of the caves' – a lot of thermalkarstic caves were discovered under the Rózsadomb ("Rose Hill") district of the city due to the fortunate coincidence of geological–hydrological–speleological factors. To date, more than 100 caves and cave indications are known in the 5–6 km² area of the Rose Hill. The caves are hosted by Triassic and Eocene carbonate sequences.

Eight caves have more than two km length. The corridors are sometimes longer than 100 m, and their walls are often adorned by spherical niches. Total length of the caves exceeds 45 km. The galleries of these caves are situated in the Szépvölgy Limestone Formation of Eocene age. Some galleries and most of the cave indications are also hosted by the Buda Marl Formation of Eocene age. The lowest galleries of some caves extend into a Triassic carbonate sequence. Although a lot of palaeokarstic cavities and caverns exist in the territory, the age of the largest caves – according to the preliminary results of radiometric age determination of syngenetic minerals – is some hundreds of thousand years only.

The exceptional values of the caves are the more than a dozen species of minerals and especially the variety and mass of carbonates and sulphates. Minerals precipitated from warm water and aerosol, as well as recent, still developing minerals of cold water origin can also be found. The caves can be regarded as the fossil source levels of the present-day thermal springs along the Danube river. Their genesis is interpreted as a result of mixing corrosion along tectonic fractures at the level of karst water.

It was more than 100 years ago that the first hydrothermal caves in the Rózsadomb, Budapest were explored during quarry operations, and since that, about 50-60 caves and 50 cave indications have been discovered in this area. The present paper intends to summarize the results presented so far in numerous publications about those caves, however, also complements their conclusions with the observations of several hundred cave field trips and the results of the cave exploring activities of the last one and a half decades in the area. Preliminary results and the conclusions of the ongoing investigations on the mineral precipitations of the caves, more detailed than ever, will be presented here.

2. Geology and speleology of the Rózsadomb ("Rose Hill") area

2.1 Geological setting

In the mass of the Rózsadomb, the age of the oldest known rock is Upper Triassic (Horusitzky, 1935). There are three Triassic formations: the Main Dolomite Formation, the Mátyás Hill Formation and the Sashegy Dolomite formation.

The age of Main Dolomite is Carnian–Norian. In this unit, caves are very rare. The thickness of this formation is 1,500-2,000 m (Haas *et al.*, 1993, Fig. 1). This rock is strongly friable at many places. The age of the Mátyás Hill Formation is Carnian–Norian–Rhaetian (Kozur & Mock, 1991). The thickness of this formation is 50-200 m only (Haas *et al.*, 1993). The key section and the type area of the formation can also be found in this area. This formation consists of two members: limestone and dolomite. The cherty Limestone of Mátyás Hill is intensively karstified. This rock can be seen on the Mátyás Hill (Fig. 2) and in some caves, *e.g.* in the *Mátyáshegy Cave* and in a highly marly facies in the *Józsefhegy Cave* (Adamkó & Leél-Őssy, 1986).

In the cherty Sashegy Dolomite, the *Erdőhát úti Cave* and the *Táborhegy Cave* was developed. This rock is not very capable for karstification. The Triassic formations are covered by Palaeogene and Quaternary formations, thus there is a more than 150 million years long hiatus in the sequence (Horusitzky, 1935).

The first products of the Upper Eocene transgression are the few m thick beds of Upper Eocene basal conglomerate (Fodor *et al.*, 1994). This formation can be found on the surface (Látó Hill), in caves (*Zöldmáli Cave*), and is known from several boreholes. The age of the covering Szépvölgy Limestone Formation is also Upper Eocene. The thickness of this formation is up to several tens of metres. This formation can be found at many places within the area. The caves of Rózsadomb were developed mainly in this rock. The Szépvölgy Limestone Formation is usually covered by the Buda Marl Formation. The age of Buda Marl is Upper Eocene–Lower Oligocene. The thickness of this formation is less than 100 m on the Rózsadomb and it is mostly known from caves and boreholes only, because the rock is outcropped in road cuts and in foundation pits of the houses. The key section of this formation is also in a road cut. The Buda Marl has variable, but always considerable clay content, therefore it is not well karstifiable. However, several cave corridors are in these beds of the Rózsadomb, *e.g. Molnár János Cave, Józsefhegy II Cave*, some galleries in the *Józsefhegy Cave* and in *Pálvölgy Cave*. This lowest part of the Buda Marl, where some caves can be found, is called as "bryozoan marl". The allodapic limestone interbedded into the marl can also be seen in caves, *e.g.* in the *Józsefhegy Cave*, and at several places on the surface. Tuff horizons are also found, indicating volcanism contemporaneously with the accumulation of the Buda Marl Formation (Báldi, 1986). Other Tertiary rocks, which are known from the surrounding area (*e.g.* the Tard Clay and the Kiscell Clay) are devoid of caves. Furthermore, at many places, between the 160 and 220 m a.s.l. horizon, freshwater limestone of Pleistocene–Holocene age also occurs on the surface (Scheuer & Schweitzer, 1989).

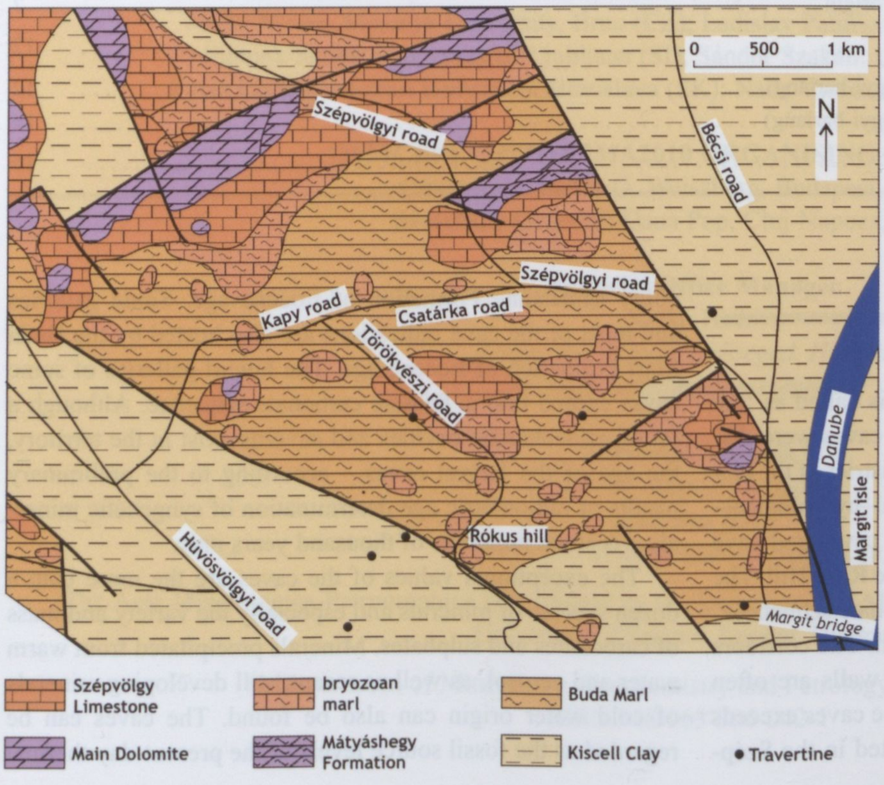

Fig. 1. Geological map of the Rózsadomb area.

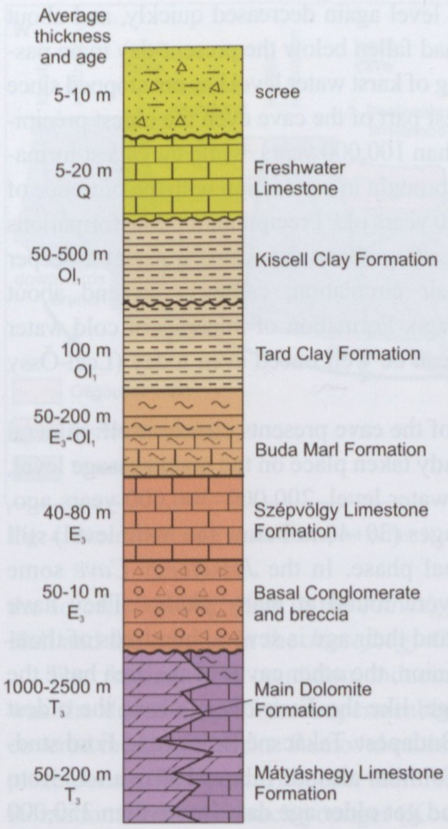

Fig. 2. Lithological column of the Rózsadomb area.

2.2 Structural geology of caves

Concerning the formation of the caves in the Rózsadomb, tectonism had played a very important role. The directions of the most often repeating tectonic lines are NW–SE, WNW–ESE, E–W, NE–SW and N–S, as it can be seen on the cave maps. Generally, several tectonic directions could play role in the genesis of caves, *e.g.* in the case of the *Józsefhegy Cave* the direction of the main galleries is E–W, but some other corridors are ESE–WNW and N–S oriented.

On the basis of our observations in the *Józsefhegy Cave*, the evolution history of the cave can be outlined as follows. During the Oligocene–Early Miocene, NW–SE oriented compression and NE–SW extension existed and tectonic effects formed an ENE–WSW trending shear zone. In this zone, the second-order Riedels (E–W trending dextral faults) and the direction of NW–SE tension fractures opened the way for descending meteoric water and for ascending thermal water, and gave possibility for corroding cave galleries. The main corridors of the cave follow this second order Riedels, therefore their geometry is en-echelon (Fodor *et al.*, 1991).

Between the Middle Miocene and Quaternary, N–S to NE–SW trending normal faults were formed by ESE–WNW extension. The Pleistocene tectonics did not modify the earlier en echelon geometry of the galleries, however, faults were rejuvenated and dilated. N-S oriented neotectonic faults can be seen at several places (Ruszkiczay-Rüdiger *et al.*, 2005) In the *Józsefhegy Cave*, the neotectonic fault broke the popcorn type precipitations, too, thus the fault is younger than the mineral deposition. The uplift of the territory was different in place and time, therefore the orientation of the galleries in different blocks are also dissimilar to each other.

The dip of layers in the host rocks also played an important role in the genesis of some caves. The galleries of the *Mátyáshegy Cave* are deeper and deeper towards to the South, because they follow the layers of the Szépvölgyi Limestone. This phenomenon may also be recognized in the *Szemlőhegy Cave* and *Pálvölgy Cave* (Fodor *et al.*, 1991b, Fodor *et al.*, 1994).

2.3 Age of the caves

In the Rózsadomb to date we know 45 km cave passages, which, belong to 8 large, and a few dozen small caves (Fig. 3). Before the formation of the recent caves, there have already been several palaeokarstic phases in the area (Müller, 1989; Nádor, 1992). In several caves (*e.g.* in the *Mátyáshegy Cave* and in the *Józsefhegy Cave*), natural vugs older than the cave occur (Kraus, 1982; Nádor, 1992). These are palaeokarstic holes, but they can be found in their original setting only very seldom, because the palaeokarstic forms have been eroded together with the rocks, or have been buried. Palaeokarstic forms having preserved by the burial are often filled up with marine sediment containing fauna elements: this gives opportunity to determine the minimum age of their genesis.

In the case of the Upper Triassic, Cretaceous–Eocene and the Oligocene palaeokarstic forms of the Buda Hills, it is impossible to prove the role of thermal effects in their formation. The Upper Eocene palaeokarstic holes of the *Mátyáshegy Cave* have been filled up by fine-grained sediment. Their diameters usually vary between 0.5 to 2.0 m and have a lentil-shaped form. These holes, which haven't been completely filled up in the course of newer transgressions, are product of the karstification, which had taken

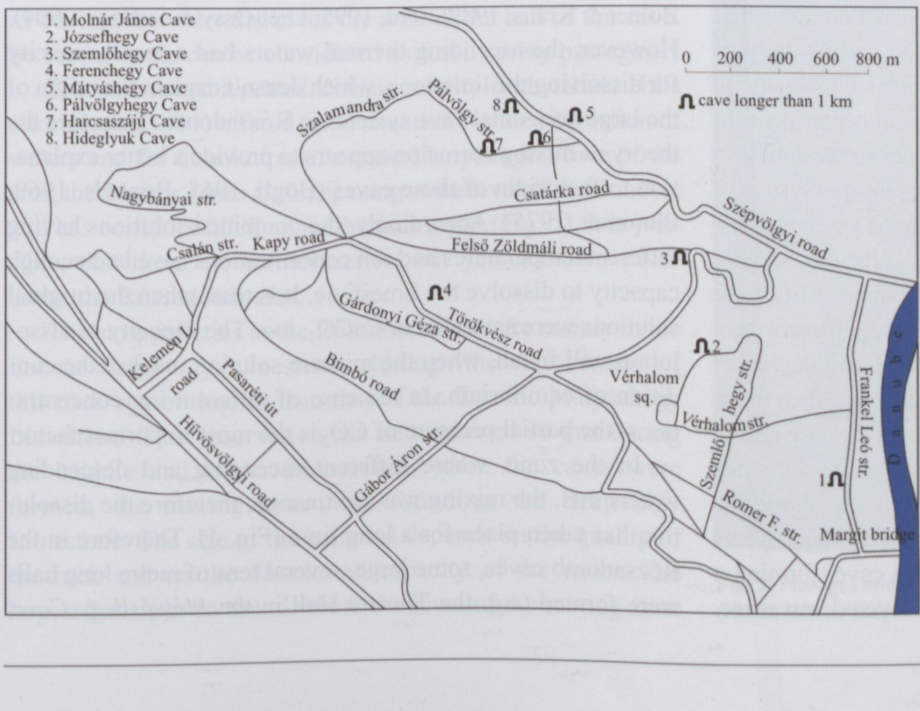

Fig. 3. Location of the caves of the Rózsadomb area.

place during the Eocene regression. Similar palaeokarstic vugs in the *Szemlőhegy* and *Pálvölgy Cave* are presumed to have been formed by dissolution in a locally uplifted reef at the border of fresh and salt water. Their age corresponds to that of some other palaeokarstic holes, usually filled up by sediments, found in the *Ferenchegy Cave*.

In connection with the Upper Eocene–Lower Oligocene or to the Miocene (Middle Badenian) andesite volcanism and postvolcanic hydrothermal activity in the vicinity of the Buda Hills, barite crystals precipitated on the walls of sphaericel niches (Fodor *et al.*, 1991). The most striking products of the volcanic effect are the siliceous veins in the caves of Rózsadomb, which have an important role in the formation of the galleries (Takácsné Bolner, 1989). The width of these veins that can be found in many places, *e.g.* in the *Mátyáshegy, Pálvölgy* and *Szemlőhegy Cave*, are between 0.5 and 2.0 m.

Palaeokarstic forms can be observed not only in the caves. There are many quarries and natural cliffs in the area which also contain some palaeokarstic holes (Nádor, 1992). On the basis of observations in caves and exposures, the Mesosoic–Palaeogene palaeokarsts of Buda Hills can be classified into four age groups: Upper Triassic, Upper Cretaceous–Eocene, Upper Eocene and Lower Oligocene palaeokarsts. However, the five great cave systems in the vicinity of the Rózsadomb are much younger than the paleokarstic holes. Probably, the caves having higher positions (*e.g.* the *Ferenchegy Cave*, 230 m a.s.l. in average) are older than some others situated at lower elevations (*e.g.* the *Józsefhegy* and *Szemlőhegy Caves*, 160 m a.s.l. in average, regarding to their main passage levels).

Due to the significant vertical extension (more than 100 m), the unique hydrothermal mineral precipitations of the *Józsefhegy Cave* provided good opportunity for systematic age determination. Therefore, the first uranium series dating of Hungarian cave formations was performed on samples from this cave – mainly from its syngenetic or nearly syngenetic precipitations. The first analyses were made by the author in Norway, at the University of Bergen, under the guidance of Prof. Stein-Erik Lauritzen. The work has been continued by Gergely Surányi and Gyöngyvér Szanyi in the nuclear reactor of the Technical University of Budapest, then at the geophysical and geological departments of the Eötvös Loránd University. The investigations, resulting in several dozens of age data, proved that the present-day system of the *Józsefhegy Cave*, including some paleokarstic vugs, had dissolved in two main phases. The first phase coincides roughly with the Mindelian– Rissian interglacial. The upper part of the *Józsefhegy Cave* had been formed about 500,000 years ago. About 220,000 years ago, the karst water level had decreased below the present-day main passage level of the cave, then in the Rissian–Würmian interglacial, or a bit earlier, an intense rise of the karst water level took place. This is proven by the occurrence of a 200,000 years old freshwater limestone cone above the *Józsefhegy Cave*. Afterwards, between 200,000–180,000 years ago, warm spring water discharged above the cave, forming a small lake as shown by the deposition of layered travertine. Then, the karst water level again decreased quickly, and about 160,000 years ago it had fallen below the present-day main passage level. This sinking of karst water level has not stopped since that time: in the deepest part of the cave even the oldest precipitation is barely older than 100,000 years, while the oldest formations, which might be brought in connection with the presence of warm water, are 65,000 years old. Precipitation of the formations of aerosol origin, spreading above the warm water at a deeper level and inducing air circulation, came to an end about 30,000–40,000 years ago. Formation of minerals of cold water origin continued and can be well traced even today (Leél-Őssy & Surányi, 2004).

Thus, the history of the cave presents clearly itself: mineral precipitation has already taken place on the main passage level, near the actual karst water level, 200,000–300,000 years ago, while the lower passages (30–40 m below the main level) still existed in an erosional phase. In the *Józsefhegy Cave* some older calcite veins were found at many places. They have palaeokarstic origin, and their age is several hundreds of thousand years. In our opinion, the other caves of the area have the same or a bit older age, like the *Ferenchegy Cave*, the oldest large cave system in Budapest. Takácsné Bolner and Ford studied calcite samples of similar altitude (about 160 m a.s.l.) from the *Pálvölgy Cave*, and got older age data (more than 350,000 years) than our data (Ford & Takácsné Bolner, 1992).

2.4 Origin of caves

Based on the results of the investigations presented briefly in the previous chapter as well as in the references, the formation and evolution of the caves can be reconstructed as follows:

It is generally agreed that hydrothermal processes played an important role in the formation of caves. (Pávai-Vajna, 1931; Jakucs, 1948; Leél-Őssy, 1957; Kovács & Müller, 1980; Kraus, 1982; Cser & Szenthe, 1986, Takácsné Bolner, 1989; Takácsné Bolner & Kraus, 1989; Ford, 1995; Leél-Őssy & Surányi, 2004). However, the ascending thermal waters had a small capacity for dissolving the limestone, which doesn't explain the origin of the large horizontal cave systems in Rózsadomb. Therefore the theory of mixing corrosion appears to provide a better explanation to the origin of these caves (Bögli, 1965; Runnels, 1969; Plummer, 1975). Accordingly, the combined solutions having different temperatures and ion concentrations have had enough capacity to dissolve the limestone. It is true, when the original solutions were saturated in $CaCO_3$, too. The capacity of dissolution will finish, when the mixture solution reaches the condition of equilibrium. In the case of different ion concentrations, the partial pressure of CO_2 is the most important factor.

In the zone, where different ascending and descending waters met, the mixing was continuous, therefore the dissolution has taken place for a long time (Fig. 4). Therefore in the Rózsadomb caves, some large, several tens of metre long halls were formed (*e.g.* the Theatre Hall in the *Mátyáshegy Cave*,

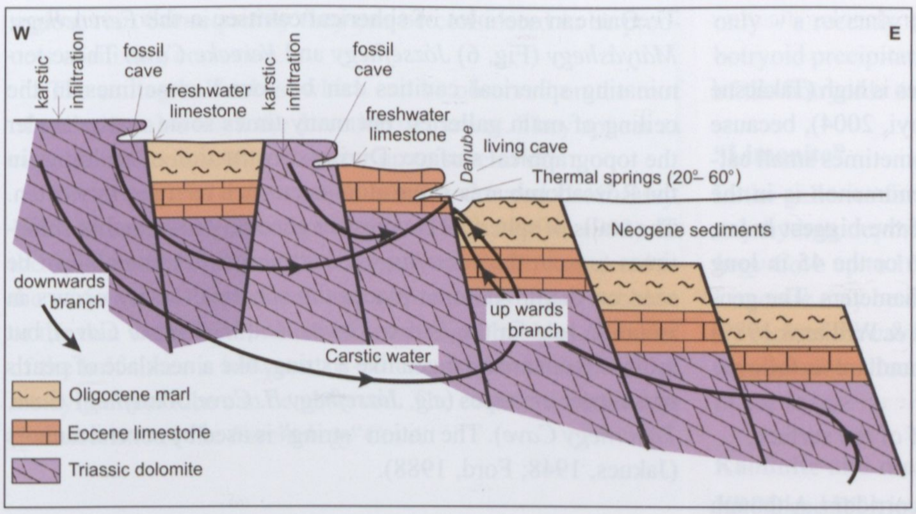

Fig. 4. Water circulation under Budapest (after Kovács & Müller, 1980).

the so-called HOSE Hall in the *Pálvölgy Cave* or the Kinizsi Hall and the Airport in the *Józsefhegy Cave*).

The fundamental condition inducing mixture corrosion was the denudation of the impermeable Kiscell Clay, which covered the karstic rocks. Removal of this formation has taken place during the Upper Miocene, therefore the cave systems in Rózsadomb must be much younger (Kovács & Müller, 1980). The uplift of the hills and the subsidence of the erosion base level depressed the zone of mixing corrosion. The dissolution of the known cave levels and formation of multi-level caves are the result of these events. A good example is the *Józsefhegy Cave,* where three cave levels (lower, middle and upper) evolved due to the differential and repeated uplift.

It is well known that CO_2 solubility capacity of cold water is higher than that of hot water, therefore cooling can continously dissolve the limestone (Ford, 1988). This process is taking place in the ascending thermal water during the circulation by mixing corrosion (Fig. 4). The thermal water having come from the deeper parts is much warmer than its surroundings. During its cooling the water dissolves the wall in the hall of the cave. So recent caves can be considered as fossil spring passages.

The intense and repeated tectonic activity in the Buda Hills (Horusitzky, 1935) offered good situation for the circulation of waters and for dissolution of caves. The youngest cave of the area, the *Molnár János Cave*, opening at the level of the Danube, still has corridors filled up by thermal water (Fig. 5). It is possible, that there are further active, but yet unknown caves under the Rózsadomb area.

The cave galleries in the Rózsadomb area are mainly in the Eocene Szépvölgy Limestone, although the clay content of this rock is a bit higher than that of the Triassic Mátyáshegy Limestone. This observation can be explained so that during the Middle and Upper Pleistocene, when the caves were formed, the mixing zone was found in the Szépvölgy Limestone. The size of the galleries depends on the quality of the rock and on the dissolution capacity of the water. The largest halls can be found where the level of the mixing zone and the dissolution capacity did not change for a longer period of time.

The minerals of the caves belong to different generations. The oldest ones (*e.g.* barite veins) were formed before the dissolution of caves; the cave formation has exposed them. The second generation of minerals (*e.g.* cave rafts) being originated from the water filling up the cave and thus were precipitated after the dissolution of the cave passages. The third generation is also connected to the thermal water circulation, but their minerals (*e.g.* aragonite needles) did not precipitate directly from the water but from the aerosols circulating above the water level. Finally the last ones (*e.g.* the dripstones) are totally independent from the hot water system and their formation is still going on.

Galleries that emerged above the water level entered to the next, destructive phase of their development (Leél-Őssy, 1957). The passages are filled up by clay and collapsed wall rock material. The clay is the insoluble residue of the Szépvölgy Limestone and Buda Marl. Minerals also precipitated from thermal water on the surface of the cave debris at some places (*e.g.* in the *Józsefhegy Cave*), indicating that the cycles of dissolution, precipitation, destruction alternated several times due to the variation of the karst water level. Its proof can also be seen *e.g.* in the *Ferenchegy Cave*, in the Törekvés corridor.

Consequently, the life of the caves did not come to an end by the dissolution. Last but not least their discovery by people may cause dramatic changes and irrecoverable damages speeding up their destruction.

Fig. 5. Passages under water in the Molnár János Cave (Photo: Sándor Kalinovits)

2.5 Morphology of cave passages

The size variability of the thermal karstic caves is high (Takácsné Bolner & Kraus, 1989; Leél-Őssy & Surányi, 2004), because between the 20–30 m long halls there are sometimes small catwalks only. The best example for this phenomenon is in the *Józsefhegy Cave*, where the "entrances" of the biggest holes, *e.g.* the 70 m long Kinizsi Railway Station or the 45 m long Airport are small passages with 20-30 cm diameters. The general marks of the hydrothermal caves (Ford & Williams 1989) are also valid for the caves of Rózsadomb, and are as follows:

i) The cave is independent from the relief of the surface.

ii) There are no fluviatile sediments in the corridors. Although the *Mátyáshegy Cave* collects the percolating waters, it is only a secondary function. We could observe heavy water flow in *Józsefhegy Cave*, but this cave lies under houses. In the caves of Rózsadomb, sometimes (*e.g.* in January, 1996) development of big waterfall was observed, however, due to a break of a discharge pressure tube.

iii) Hydrothermal minerals are generally frequent, although the *Mátyáshegy Cave* has very few such precipitation, and also in some small caves of Rózsadomb (*e.g. Áfonya Cave, Guggerhegy Cave, Korallos (Corallic) Cave* etc.) no hydrothermal minerals can be found.

The very rich hydrothermal precipitation itself is enough to prove the hydrothermal origin. The labyrinth structure – although generally significant for hydrothermal caves – is characteristic for some cold water caves, too.

The most significant forms in hydrothermal caves are the spherical cavities and corrosion niches. (Müller, 1974; Rudnicki, 1979; Kraus, 1982; Takácsné Bolner, 1989; Dublyansky, 1995). At the upper ending of the joints spherical cavities of 0.1 to 3.0 m diameter terminate the path of the ascending water.

Fig. 6. Spherical niches in the Mátyáshegy Cave (Photo: Ákos Kocsis)

One can see a lot of spherical cavities in the *Ferenchegy, Mátyáshegy* (Fig. 6) *Józsefhegy* and *Verecke Cave*. These terminating spherical cavities can be found sometimes in the ceiling of main galleries, but many times some meters under the topographical surface. During construction of buildings in the Rózsadomb area excavators open such cavities very often. The walls of spherical cavities are generally smooth, but sometimes (*e.g.* in the *Józsefhegy Cave*) beautiful minerals can be seen on them. At some places the spherical cavity occurs in isolation (*e.g.* in the *Ferenc* Caves, and in *Verecke Cave*), but most of them are arranged like a string, like a necklace of pearls or a cluster of grapes (*e.g. Józsefhegy II. Cave, Józsefhegy Cave, Táborhegy Cave*). The notion "string" is used by several authors (Jakucs, 1948; Ford, 1988).

2.6 Origin of the spherical cavities

There are two explanations for the origin of the spherical cavities.

i) Formation above the water level

The cavities are originated in those caves, where air filled space exists above the water level. The condensing vapour on the wall causes dissolution. Above the thermal spring, on the wall of a fissure, there is a temperature gradient: CO_2 and vapour escape from the water flowing downward on the wall, and condenses on the much colder wall above and dissolves the rock (Müller, 1974; Szunyogh, 1984)

ii) Formation below the water table

Spherical cavities may also be resulted from dissolution under water. This process is related to convectional currents in the hot water (Dublyansky, 1995; Rudnicki, 1989).

Corrosion niches should be distinguished from the spherical cavities. Corrosion niches form partial spheres only. Sometimes they are oval recesses on the wall and on the ceiling. Their diameter generally is several dm, and their surface is smooth. The most beautiful examples can be found in the *Mátyáshegy, Pálvölgyi* and *Józsefhegy Cave*. The corrosion niches were also formed by thermal water, by streaming up of gas bubbles, consequently, the corrosion niches are found on the convex, acute-angled walls only (Takácsné Bolner, 1989).

The contribution of other smaller dissolution forms, like convection tubes, ceiling half-tubes, scallops, to the overall form of thermal caves is small (Kraus, 1982; Takácsné Bolner, 1989; Nádor, 1992). Scallops are finger-like, 10–20 cm long niches. They are generally 4–5 times longer than their diameter. The size of the neighbouring scallops is similar, because they were dissolved in similar surroundings. Their long axis shows the orientation of the streaming and they were probably dissolved by quickly streaming water. They are frequent in the *Ferenchegy Cave*. We observed them also in normal (non-hydrothermal) caves, *e.g.* in the *Vass Imre Cave* in Aggtelek region, too. Consequently they can be considered to be products of mixing corrosion.

The ceiling half-tubes, which can be observed on the roof of galleries, also mark the direction of current. They appear as circular channels with a diameter up to several dm.

The origin of the convection tubes is debated (Leél-Őssy, 1957; Kraus, 1982; Takácsné Bolner, 1989; Nádor, 1992). In the opinion of the author, their formation can be connected to the variation of CO_2 content and upstreaming of gas bubbles, or the thin water layer, which covers the gas bubbles. The size of the half-tubes is between 10–50 cm, and more than half of the cylindrical tube can be observed. The convection tubes are characteristic to the *Ferenchegy Cave.*

3. Cave minerals of the Rózsadomb area and their origin

Some caves in Rózsadomb (*e.g. Józsefhegy, Szemlőhegy, Buda, Erdőhát úti Cave*) are very rich, but some other ones (*e.g.* caves of the *Eastern Quarry of* Mátyás hill, caves of the *Francia Quarry* etc.) are very poor in cave minerals. On the basis of our studies and data of previous publications, 15 macroscopically observable minerals (mainly carbonate and sulphate minerals) are known from these caves. There are minerals, which occur in several forms. 16 morphological types of calcite, and 6 of gypsum were distinguished. Conclusions on the origin of minerals in the caves on the Rózsadomb can frequently be drawn only on the basis of morphologic investigations and theoretical considerations. Radiometric age data, thin-section analyses and the temperature data obtained from fluid inclusion studies give sometimes additional proofs of origin of cave minerals. The paragenetic order of minerals is shown on Fig. 7.

Cinnabar

It was found in the *Ferenchegy Cave* in association with barite crystals (Nádor, 1992).

Pyrite, not observed so far in the caves of Buda, was precipitated from warm water solutions in the joints of the rocks. It might be much older than the caves.

"Manganese crust"

According to the transmission electron microscopic investigations, the thin black crust which occasionally can be found on the walls of the the *Józsefhegy Cave* consist of Mn oxyde-hydroxide minerals. Mn content reaches up to several wt% according to the spectrographic analyses. XRD studies by Nagy (2008) showed the presence of hollandite and romanechite in these encrustations. In our opinion, the Mn content of the manganese coating observed in the *Józsefhegy* and *Pálvölgy Caves* is a product of bacterial activity. It is probably not – or not only – a recently formed mineral, since it does not cover the botryoid precipitations at several places, and occurs at the foot of the botryoids only.

"Limonite"

In the galleries formed in marl, 3–5 cm large "limonite" (iron oxy-hydroxide, mainly goethite) nodules occur. In the *Józsefhegy Cave* up to 10 cm long "limonite" dripstones were found. Limonite may be derived from the pyrite contents of the country rock of the caves as well as from the finely dispersed pyrite content of the Eocene marl layers that overlie the country rock of the caves.

Kaolinite and montmorillonite

XRPD and DTA investigations detected these minerals in the clay deposits of many caves in the Rózsadomb area. The clay minerals may be derived from the rocks forming the main mass of the hill, the Szépvölgy Limestone and the Buda Marl, and they are the insoluble residue that accumulated at the bottom of the passages. These clay deposits locally reach several m thickness.

Barite

The largest barite crystals (up to 2–3 cm in size) can be seen in the *Molnár János Cave*, under water. They are covered by manganese crust. There are many barite crystals in the *Józsefhegy Cave* (sometimes covered by manganese, calcite or gypsum crust) and in the *Ferenchegy Cave.* Only a few barite crystals occur in the *Pálvölgy, Ferenchegy* and *Óbuda Caves.* Although this mineral occur in several caves, it can not be considered as cave mineral, because it formed earlier than the Pleistocene caves. They can be connected to the hydrothermal

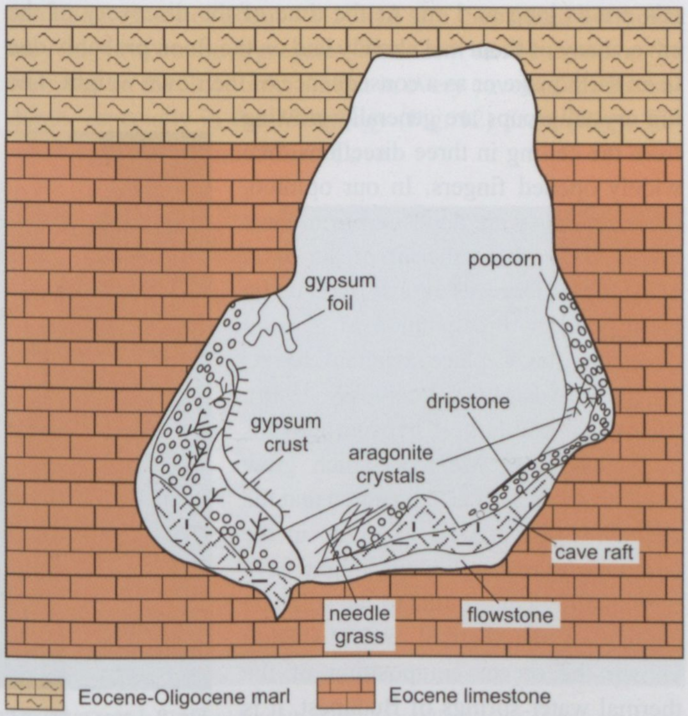

Fig. 7. Sequence of mineral precipitation in the Józsefhegy Cave.

processes followed the Middle Miocene volcanism (Müller, 1989; Molnár & Gatter, 1994; Fodor *et al.*, 1991a), or the Late Eocene–Lower Oligocene volcanism (Báldi *et al.*, 1976). Barite crystals precipitated in two stages (at around 150 °C and around 300 °C). However, the temperature of the solution from which the barite deposited, is still controversial. Probably the temperature of the solution was much lower (even by 200–300 °C) than it was presumed so far. In this case its direct connection with the volcanism taken place in the Badenian age (or still earlier) is doubtful. Though its formation may be probably linked with postvolcanic activity, it may be even millions of years younger than the volcanism. It seems to be sure that barite crystals are older than the caves, however, in the *Molnár János Cave,* barite crystals were found setting on older calcite veins from which a calcite crystal provided about 1 million year age. Consequently, some barite precipitations must be more younger than those from the pre-cave hydrothermal veins.

Fig. 8. Gypsum crystals hanging from the roof (in the foreground) and gypsum crust covering the cracked surface of clay (in the background) in Józsefhegy Cave (Photo: Szabolcs Leél-Őssy)

Gypsum

Gypsum occur in several types, listed below:

Tiny crystalline crust of gypsum is a very frequent form in the *Józsefhegy Cave* (Fig. 8), but uncommon in the *Szemlőhegy and Mátyáshegy Caves*. In the *Józsefhegy Cave*, 1-2 cm long needles of crystals were also grown up on the surface of this crust. Crystals grew around specks of dust; therefore, the surface of the crust is brown. Sometimes, there are larger gypsum crystals (up to a few cm) on these crusts also in the *Józsefhegy Cave.*

Gypsum dagger *(chandelier)*. It is the most conspicuous type of gypsum in the *Józsefhegy Cave* (Fig. 9). These crystals are very similar to but smaller than the gypsum chandeliers in the *Lechuguilla Cave* (USA, New Mexico). The largest crystals are as long as 1 m. At the time of the discovery of the cave, many of them had already laid on the floor, probably due to an earthquake or as a consequence of their own weight. The big crystal groups are generally growing from the ceiling in three directions, like widely opened fingers. In our opinion, these crystals were deposited from thermal water or from the air of the cave, when the gallery was almost filled up by thermal water. Precipitation of gypsum chandelier takes place at about 65 °C (Gatter in Adamkó & Leél-Őssy, 1986). (See the world-largest gypsum crystals in Naica Cave, Mexico, which grew under the water). It is to be noted that the decomposition process of pyrite in the overlying marly sediments might have considerably contributed to the sulphate content of the thermal water. Having known the recent composition of the thermal water springs of Budapest, it is difficult to explain the precipitation of these large gypsum crystals from the sulphate content of the ascending thermal water only.

Fig. 9. Large gypsum crystals (length of the groups is about 1 m) in the Józsefhegy Cave (Photo: Szabolcs Leél-Őssy)

Gypsum flowers were found in the *Szemlőhegy Cave* at the first time. Recently, they can be found in the *Józsefhegy Cave* (Fig. 10) only (and a few small crystals in the *Mátyáshegy Cave*). Generally they grow on the surface of clay layers or on the surface of gypsum crusts (Ghergari & Onac, 1995). These forms often stand out from the wall or hang down on the ceiling and they are twisted many times. Some crystal groups in the *Pálvölgy Cave* grew radially.

Needlegrass. The diameter of these peculiar forms is thinner than a single hair, and the crystals are moving when the visitors breathing. They lie on the floor, or hang on the wall or on the ceiling. The length of the biggest crystals is about 80–90 cm.

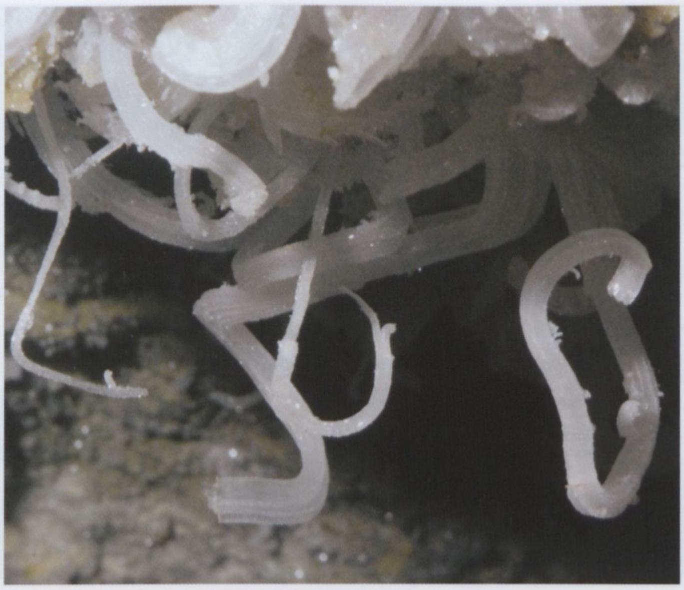

Fig. 10. Gypsum flowers in the Józsefhegy Cave (Photo: Szabolcs Leél-Őssy)

It occurs in the *Szemlőhegy Cave* and such type of crystals can be found in several places also in the *Józsefhegy Cave* (Fig. 11). They probably originated from aerosol (Adamkó & Leél-Őssy, 1986).

Dripstone form (cylindrical rim) (Klimchouk *et al.*, 1995). Only three specimens of them were found in the *Józsefhegy Cave*. The walls of these forms are very thin. The length of the smallest one is 12 cm, having an inner diameter of 1 cm, while the biggest one is 30 cm, its inner diameter is 20 cm. These forms are still developing.

Thin gypsum crust on other minerals. Thinner than 1 mm crust of gypsum occur on calcite and barite crystals in the *Józsefhegy Cave*.

Most of the **gypsum** crystals occurring in the caves of Buda may be derived from the pyrite content of the covering marl. The sulphate is transported from the covering formations by rain and meltwater. This process is proved by the high sulphate content of dripping waters in the cave, by the observation that gypsum is the last precipitating mineral, and by the fact that the dust from the air is also enclosed in the gypsum crystals, *i.e.* these crystals grow even today. Morphology of the *needlegrass* also refers to the possibility of precipitation from aerosol. However, it can not be excluded that certain large forms of gypsum (*e.g.* the *"Gypsum dagger"*) may have been precipitated already from the warm water that filled the passages. According to the analytical data of the present-day thermal spring, their sulphate concentration is insufficient for the precipitation of gypsum. However, we have no data regarding the composition of dripping waters of hundreds of thousands years ago. Furthermore, the composition of water in cave lakes may have been significantly modified and its sulphate concentration could be increased by oozing waters. However, age determination results suggest to more than 350,000 years age for a studied crystal.

Magnesite

This mineralogical peculiarity was found in a botryoid in the *Erdőhát úti Cave* (Nádor, 1992).

Calcite

It is the most common and very variable mineral of the caves of Rózsadomb. The following varieties are known:

Botryoid. Its size is smaller than a pea and has globular, concentric structure. The process of the precipitation was very unequal; in thin sections thinner and thicker layers alternate, with lots of gaps. Sometimes the originally precipitated mineral was aragonite (Nádor, 1992). The notion "botryoid" is a collective noun, as this formation has a lot of variants. The most frequent variants in the caves of Rózsadomb are as follows.

- *Common botryoid.* Small (0,5-1 cm) individual botryoids form aggregates of about 10–20 cm size. Separated botryoids may lie between the aggregates. This form can be found on the wall and on the floor only, almost in every caves of the Rózsadomb, especially in the *Józsefhegy* (Fig. 12) *Szemlőhegy, Ferenchegy, Ferenc* and *Óbuda Cave.*

Fig. 11. "Needlegrass" (gypsum hair) in the Józsefhegy Cave (Photo: András Hegedüs)

Fig. 12. Common botryoids (with aragonite needles) in the Józsefhegy Cave (Photo: Szabolcs Leél-Őssy)

• *Angular botryoid.* It can be observed in the *Józsefhegy* and in the *Pálvölgy* Cave (Takácsné Bolner, 1989).

• *Rose botryoid.* Its bottom is thicker than its top. This type exists only in the *Szemlőhegy Cave* (Kraus, 1992)

• *Coral botryoid.* Cylindric forms, aspect ratio is 1 : 5-6 (Kraus, 1991). It was recognized only in the *Józsefhegy Cave.*

• *Glass ball botryoid.* This recent type of botryoids precipitates from cold trickling water. It can be observed at several places of the *Józsefhegy Cave* and at some places in the *Ferenchegy Cave* (Leél-Őssy & Surányi, 2004) . The form is very regular, having a remarkably smooth surface.

• *Dripstone botryoid.* It is the biggest type of botryoids with up to 2-3 cm diameter, also precipitating from cold water. The name refers to the fact that this type is surrounded by dripstones, *e.g.* in the Castle Hall of the *Józsefhegy Cave*.

• *Draught botryoid.* This type is originated from aerosol (Gádoros & Cser, 1988). In our experience, the size of this form is smaller than other botryoid types. They form at the draughty places of the *Józsefhegy* and the *Szemlőhegy Cave.* During several years, botryoids up to almost 0.5 cm can precipitate from the condensing water of the draught. This form is frequent in normal karstic caves, too (*e.g. Vass Imre Cave* in the Aggtelek region, *Pierre St. Martin Cave* in the Pyrenees, etc.).

Cauliflower. This type of precipitation, 5-10 cm sometimes 10-20 cm in size, has curved and uneven surface. Perhaps it is a variety of botryoid: their textures in thin sections are very similar. There are a lot of cauliflowers in the *Szemlőhegy* and *Ferenchegy Caves*.

Calcite sponges. The white to yellow "sponges" consist of soft and crumbling fibres, 10–20 cm in length and 1-2 mm in width. They are very frequent in the *Ferenchegy*, *Buda* and *Erdőhát úti Caves*.

Dripstone. This is the most common calcite variety in limestone caves, but it is not frequent in the caves of Rózsadomb. Although in these caves there are many dripping points, the growth rate of dripstones surely depends on the clay content of the rock (it is very high, about 5–10% in the Szépvölgy Limestone), lack of ventilation, or type and thickness of the soil (Zámbó, 1993). The colour of the dripstones in the caves of Rózsadomb are always yellowish-reddish brown as a consequence of the pyrite–marcasite content of the covering strata. Beautiful dripstones (mainly stalactites, flowstones and draperies) can be observed in the *Pálvölgy, Harcsaszájú, Hideglyuk* and *Józsefhegy Caves* (Fig. 13).

Cave raft. It precipitates on the surface of hot water lakes (Hill & Forti, 1997). This process can be observed in the under-

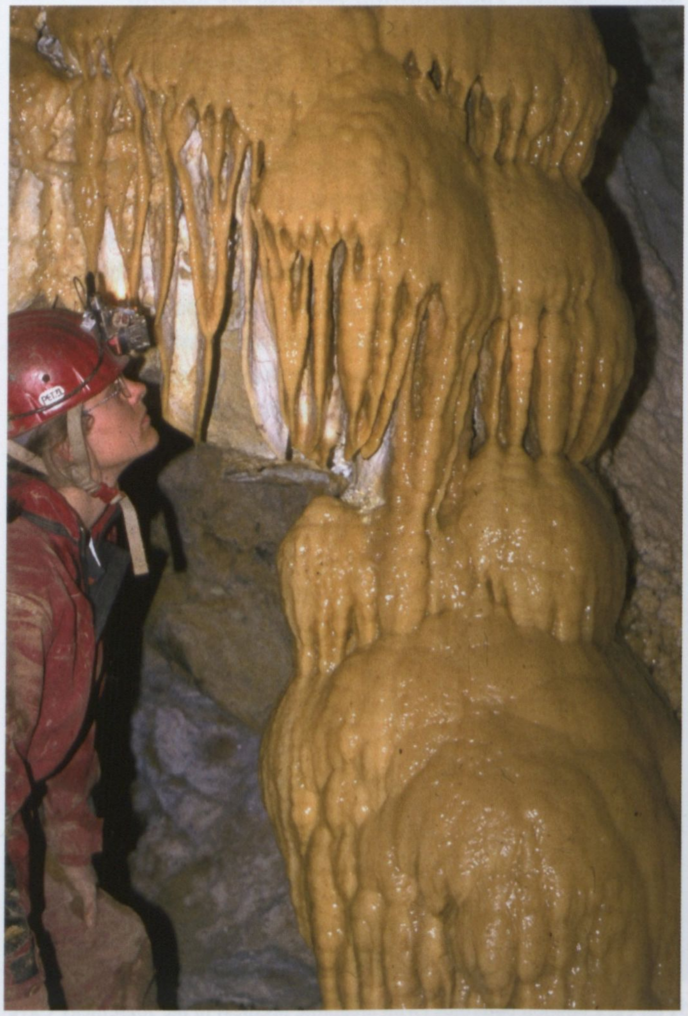

Fig. 13. Dripstone in the Józsefhegy Cave (Photo: Szabolcs Leél-Őssy)

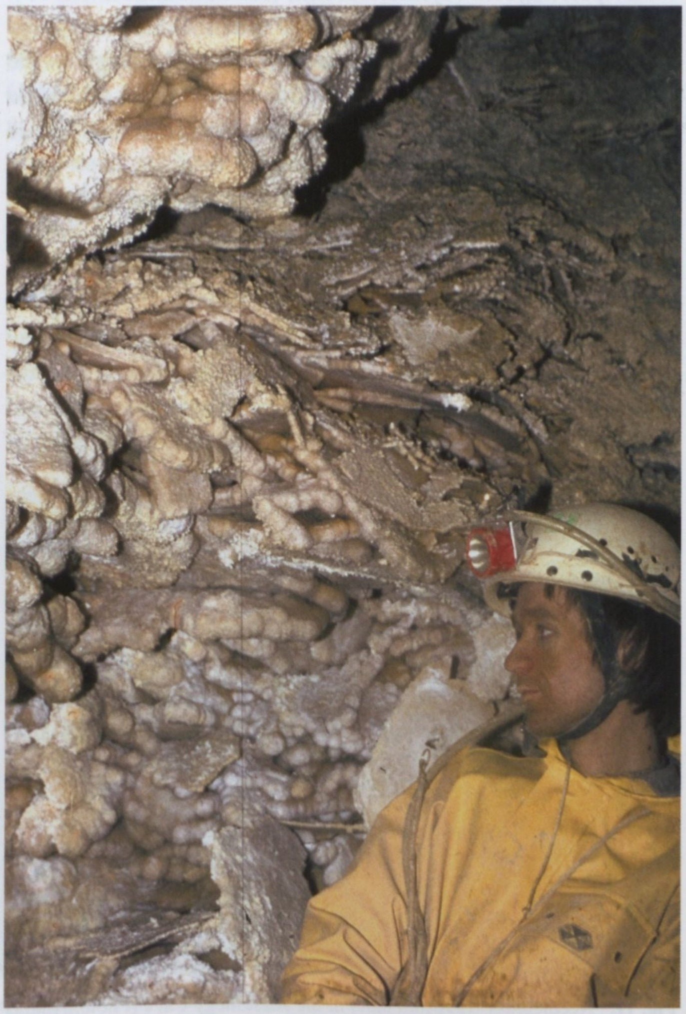

Fig. 14. Cave rafts in the Józsefhegy Cave (Photo: Szabolcs Leél-Őssy)

Fig. 15. Calcite scalenohedra in the Józsefhegy cave (Photo: Szabolcs Leél-Őssy)

ground *Sáros* ("Muddy") *Spa* of the Gellért Hill, Budapest. When the moving or dripping water breaks the thin crusts (which looks like a thin crust of ice), the broken "raft" sink to the bottom of the lake, forming a gradually and concentrically thicker layer (Fig. 14). There are a lot of cave rafts in the *Józsefhegy*, *Szemlőhegy* and *Pálvölgy Cave*. The cave rafts give the best data for the cave genesis, (Leél-Őssy & Surányi 2004).

Unusually large calcite crystals. Twinned scalenohedral crystals with up to 3–6 cm length (Fig. 15) They are generally white or yellow, and can be observed in the *Józsefhegy*, *Mátyáshegy* and in *Pálvölgy Cave*.

Dogtooth spar (called as wolftooth spar in Hungary). Lot of scalenohedral calcite crystals, rarely several cm big occur in the *Ferenchegy* and *Mátyáshegy Caves* at the joints. These crystals precipitated from relatively high temperature (160 °C) fluids (Gatter, 1984).

Scour groove of subsidence. It marks the discontinuous sinking of the water level: scour grooves were formed when the water level was permanent for a longer period of time. It is a 0,5–1,0 cm large curved form jutting out from the wall. These forms can be seen in the *Józsefhegy* and in *Pálvölgy Caves*.

Flowstones. In the Eastern part of the *Józsefhegy Cave*, very thick flowstones cover the wall, the floor and the broken fragments of the rock. Generally, 3-5 generations can be distinguished, with 1-5 cm cumulative thickness. The diameter of the thickest flowstone is about 20 cm!

Calcite crust covering mud cracks. The settled insoluble residual clay dried up on the floor of the largest room of the *Józsefhegy Cave*, therefore many mud cracks were formed in it. Later, when the water level has raised again, thin calcite crust precipitated in the cracks of clay, forming beautiful pseudomorphs.

"Moonmilk". This microcrystalline form of calcite occurs in the *Ferenchegy Cave,* close to the surface. It can be observed also on the surface in building pits.

Basin fingers. It is characteristic to the greater halls of the *Józsefhegy Cave* only. Typically, they developed on the vertical sidewall. The sizes of precipitations are up to 1-2 cm in diameter and 3-8 cm in length. Rounded terminations with an empty pipe with max. 0.5 cm in diameter are characteristic to these forms of calcite.

Tetaratas. Cold water accumulating or slowly flowing at the bottom of certain passages of the *Pálvölgy Cave* and the *Józsefhegy Cave* built tiny (barely 1-2 cm high) rimstone dams.

Calcite rombohedra precipitated from cold water. These are very fine crystals with dissected surface. They precipitate from the water of the small ponds accumulating behind the tetaratas described above.

Calcite veins, older than the caves, regularly crosscut the rocks in which the caves were formed. They can be observed in several places in every cave, on the sidewalls of the passages. The most beautiful and largest (10-20 cm thick) ones can be seen in the *Ferenchegy Cave*.

Collaric precipitation. In the *Pálvölgy* and *Józsefhegy Caves* larger or smaller ponds (with a surface of several m^2 at most) occur at several places. The collar-like, max. 2-3 cm thick precipitation appears on the walls of the ponds, and on the surface of other precipitations covered by water, respectively.

The genesis (formation) of many types of the calcite precipitations is easily explained but some of the most frequent ones are of debated origin. The way of formation of the dripstone is well known. The formation of the *cave raft* can be studied at several other places in the Buda Hills (*e.g.* at the thermal springs of the Gellért Hill). Its recent precipitation from cold karst water of 8–10 °C temperature could also be observed at many localities. Cave raft precipitates as an ice-like film on the surface of the still waters rich in calcium carbonate, then breaks into pieces, sinks down and continuously getting thicker in the water of the lake. Its final thickness depends on the rate of burial due to the accumulating newer cave raft pieces, as well as the calcium carbonate content of the water. A special accumulation of *cave raft* is the *cave cone*, the cave "Christmas tree", reminding of snow-bound pine. In this case, the lime film breaks always at the same spot and may form surprisingly sharp, column-like cones after sinking, once even considered as geyser cones.

Origin of the *cave botryoid* is unclear in many instances. Before World War II, all speleologists believed that the common botryoid is a precipitation from warm water. Nowadays, the aerosol origin is generally accepted. Certain types of cave botryoid (*e.g.* the draught botryoid that appears frequently even on dripstones) must have precipitated from aerosol, but their formation differs undoubtedly from that of the common botryoid, which has been more widespread in the caves of

Rózsadomb. The aerosol origin of the rare angular botryoids is not duly proved. However, the glass ball botryoid, precipitating from cold water flowing slowly on the sloping surface, certainly does not precipitate from aerosol. The dripstone botryoid develops under similar conditions, in cold water. Even the morphology of these basic types is totally different, suggesting a different origin.

The *multigeneration calcite crust* (flowstone) precipitated from warm water filling up the passages on the bottoms and sides of the lakes.

Coarse crystalline calcite, the *dogtooth* and the *calcite veins* might have precipitated from warm water circulating in the cracks, prior to the formation of the cave in many cases. If the precipitation totally filled up the available space, massive calcite veins formed. If there was empty space left in the crack, the grown-up crystals (large crystals of calcite as well as dogtooth) might also have precipitated.

We have no data concerning the formation of *calcite sponge*. On the basis of its position, precipitation from warm water is probable, similarly to that of the multigeneration calcite crust.

Formation of tetaratas by precipitation due to CO_2 escapement from cold water flowing slowly downwards is a well-known process. *Cold water calcite rhombohedra* precipitate from cold water lakes, accumulating behind the tetaratas.

The *cave pearls* precipitates around a detrital grain, from dripping waters, rich in calcium carbonate, accumulated in ponds.

According to our investigations, the *moonmilk* is a typical form of carbonate at explicitly ventilated places and occurs generally near the exit of caves. It can be interpreted as a microcrystalline calcite variety (Dódony, pers commun.).

Dolomite

The XRPD pattern made from of some aragonite crystal groups, which were collected in the *Józsefhegy Cave* a few years ago, revealed the presence of a considerable amount of dolomite in the study material. Dolomite probably formed from the aerosol.

Ankerite

This mineralogical peculiarity was found in special botryoids in the *Erdőhát úti* Cave (Nádor, 1992).

Fig. 16. Aragonite bushes in the Józsefhegy Cave (Photo: Szabolcs Leél-Őssy)

Aragonite

Aragonite is a very rare mineral in the caves of the Rózsadomb. It forms either hemispherical aggregates of 1-3 cm diameter, consisting of generally 1-2 mm thick crystal needles, or acicular aggregates of 4-8 cm length (Fig. 16). The most beautiful crystals can be found in the *Józsefhegy Cave*. These crystals are polysynthetic twins. The **aragonite** crystal needles precipitated on the sidewalls, ceiling or bottom of certain caves of Rózsadomb from the aerosol (Gádoros & Cser, 1988) after the regression of water. However, on the basis of their age data, their formation might also be connected to the periods of warm water fillings of the cave. This process is probably still active in the deeper (and, unfortunately, unknown) levels of the cave. On the other hand, observations verify that the infiltrating water dissolves these crystal needles.

Hydromagnesite

This mineral is white and soft and looks like flour or sour cream. It was first collected in *Józsefhegy Cave*, but it can also be observed in the *Szemlőhegy* Cave (Kraus, 2001). These are the first known hydromagnesite occurrences in Hungary. It is believed that this mineral forms from the aerosol.

Fluorite

Its several mm large crystals were described from core samples of the Vérhalom-1 borehole. On the surface (in a building pit) it was detected at the entrance of the *Pusztaszeri Cave*, discovered by author. Fluorite crystallized from hydrothermal solutions prior to the formation of caves.

Other minerals, detected by microscopic or X-ray powder diffraction investigations studies only, are as follows:

Quartz, garnet, zircon, pyroxene

Fragments of these minerals were separated from the clayey infillings of higher passages of the *Józsefhegy Cave* and were determined by microscopic studies. These minerals are solution residues of the country rocks of the caves.

Huntite

According to XRPD investigations, the powdery material found in the higher passages of the *Józsefhegy Cave* contains huntite.

4. Field stops

4.1 Field stop 1. Mátyáshegy Cave (Mátyás-hegyi-barlang)

The *Mátyáshegy Cave* (Fig. 17) entrance is located just opposite to the *Pálvölgy Cave*, in an abandoned limestone quarry on the N side of the Szépvölgyi road (Fig. 3). With its 4800 m known length, it is the fourth longest cave of Hungary due to

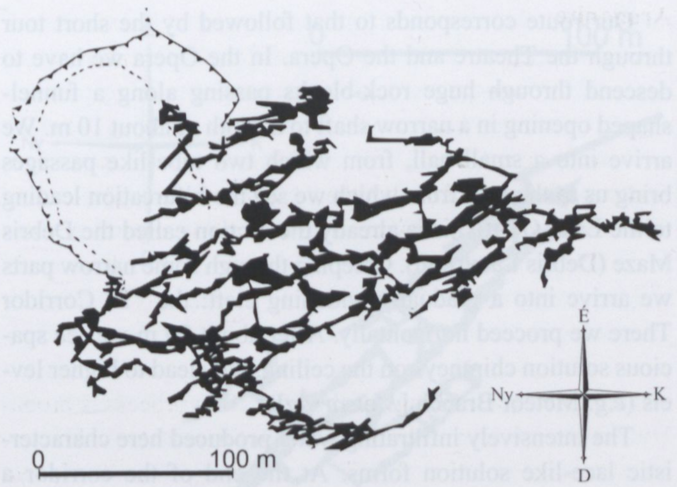

Fig. 17. Outline map of the passages of the Mátyáshegy Cave (based on the map of Sándor Jaskó, 1949, amended by József Kárpát, 1982, processed by Gyöngyvér Szanyi and Ádám Papp)

the most recent discoveries. This is a multilevel thermal-water cave with a maze-like ground-plan; it is rather poor in the sense of formations, but, on the other hand, rich in solution forms. The cave is site of multidisciplinary investigations (cave exploration, climatic investigations, karsthydrological measurements andobservations, etc.) and also an excellent terrain for training speleologists.

The cave was discovered by the BETE caving group in 1948, from an artificial tunnel-system constructed during World War II partly from small earlier known small caves. The ~2 km long cavity-system discovered at that time, got the name "Centenary Cave" (*Centenáris-barlang*, now "Centenary Section") for the anniversary of the foundation of the Hungarian Geological society. Further exploration was carried out by the "Vörös Meteor" and the "Acheron" Cavers Club in the 1960s and after 1981, respectively.

The Centenary Section consists of four corridors, which follow the strike of the bedding-planes of the host rock, namely 1) Mohos squeeze *(Mohos-szorító)* – Dining room (*Ebédlő*); Great Hall (*Nagy-terem*, Fig. 18); 2) Anonymous Corridor (*Névtelen-folyosó*); 3) Theatre (*Színház-terem*) – Giants' Road (*Óriások útja*) and 4) Globe (*Földgömb-terem*) – Mousetrap (*Egérfogó*) and they are interconnected with shorter passages. These almost parallel four corridors follow each other in the direction of the dip of the limestone toward SE in increasing depth (altogether by 10 to 15 m). The Centenary Section is characterised by broad corridors and large dissolved caverns (Theatre, Geographer's Hall [*Geográfus-terem*], Great Hall, Geological Institute's Hall [*Földtani Intézet-terem*]). Also the Debris Maze (*Törmelék-labirintus*) is part of it, which nevertheless is different from the other main corridors because of its highly tectonised character.

Short Tour

Tour time: about 2 hours.

Entering through the steel-gate of the cave we are in the man-made tunnel – in the inner (closed) parts a geophysical observatory is functioning. Climbing down on a 10 m long steel ladder in a shaft we get down to the level of the natural cave. Passing a rather narrow and flat hall we will see the tube-like bottleneck part of the Mohos Squeeze, through which creeping on all fours and crossing the top of a small heap of boulders we reach a branching-off. Here we proceed straight until the sloping muddy corridor leading us into the Dining Room, a large hall with decorative solution forms. At the end of the slope, we turn in an acute angle to the Razorblade Cleft (*Zsilett*), where nice limonite concretions are seen in a siliceous vein on the ceiling. After some metres being passed and creeping through a squeeze we enter the Great Hall, which is one of the most spacious cavities of the whole cave. The walls are decorated by very nice potholes and hemispherical solution forms. At the SW end of the hall, in the continuation of a thick siliceous vein, begins the Toldy Branch (*Toldy-ág*), which leads the Theatre in one direction and to the Meteorite branch (Meteor-ág) in the other, through the Cop Chimney (Hekuskürtő) and the "T" Corridor („T"-folyosó).

In the Great Hall we descend along a slope and turn to left. Here the ceiling is formed by an oblique plane surface, representing the dip of the bedding. After about 25 m we arrive to collapsed stone blocks, through which one has to creep for reaching the Anonymous Corridor, but we pro-

Fig. 18. Group of cavers in the Great Hall of the Mátyáshegy Cave (Photo: Ákos Kocsis)

ceed to right instead. Here, having climbed up in a low ceiling and hard-to-find ascending, we reach the top of the 2 m abrupt Laci Steps (*Laci-lépcső*) and descending it, after some metres, we arrive into the main corridor of the Centenary Section. Creeping under a large rock-block the Library (*Könyvtár*) and the Giants' Road begins. Right after about 30 m of rather comfortable passing we arrive into one of the largest and most famous halls of the cave: the Theatre. From the really spacious but rather barren, clay-bottomed, slippery hall a crawl leads into the Toldy Branch.

Returning to the entrance of the hall, we proceed along the Wild Waters' Path (*Vadvizek útja*), which will lead into one of the most characteristic parts of the cave with its passages richly decorated by solution forms. The winding corridor runs into the Opera Hall – which is one of the central junctions. In the spacious hall interrupted by large boulders, begins the road toward the Debris Maze through the Backstairs (*Cselédlépcső*). This is a multi-level, very complex part with sharp cleft-like passages and 50 m height difference.

We will proceed from the Opera toward the BETE Traverse (*BETE-traverz*): a monumental cleft. Up to the end of the cleft the ceiling is formed by a thick siliceous vein, which leads through the Elephant (*Elefánt*) up to the Imre Hall (*Imre-terem*). After a simple climb and a 20 m long and low passage we enter the Globe Hall (*Földgömb-terem*).

From the Globe Hall we climb up to the Elephant through a narrow cleft, from which we see a sloping exploratory shaft along a broad siliceous vein to the left. A short corridor, partly covered by debris, leads to the Imre Hall. The ground is a fallen-down rock plate. Having passed the rock plates, slightly to the left, we get through upward a small vertical hole at the end of the hall. Climbing up through a cleft-like 6 m high chimney above our head, we return to the Main Corridor.

Entering the Dripstone Hall (*Cseppköves terem*) we can discover that despite its name there are hardly any dripstones there. At the far end of the hall we descend into the Library, named after the surprisingly regular form of the stone slabs.

Further ahead the Giant's Road begins, with its 5 to 7 m width and 10 to 12 m height, it is one of the mightiest corridors of the cave. Its walls are variously decorated by huge, solution-formed vein-like forms. On its clayey ramp we climb up to the Stone Bridge *(Kő-híd),* where one passes under a boulder detached from the roof and got wedged between the walls, until we reach the end of the passage.

From the Giant's Road through the Main Corridor we pass along the already described route and by passing the Laci Stairs and the Great Hall we leave the cave.

Long Tour

Tour time about 3 to 3.5 hours; technical equipment is not necessary.

During the programme we will go further than with the short one – we will descend to the lake in a depth of 90 m and visit the Debris Maze and the joint-system of the T-Corridor.

Our route corresponds to that followed by the short tour through the Theatre and the Opera. In the Opera we have to descend through huge rock-blocks passing along a funnel-shaped opening in a narrow shaft to a depth of about 10 m. We arrive into a small hall, from which two tube-like passages bring us to the spot from which we see the bifurcation leading to the Lake (*Tó*). This is already the section called the Debris Maze (Debris Labyrinth). Creeping through some narrow parts we arrive into a gradually widening cleft: the "T" Corridor There we proceed horizontally. After about 20 m we see spacious solution chimneys on the ceiling, they lead to higher levels (*e.g.* Meteor Branch [*Meteor-ág*]).

The intensively infiltrating water produced here characteristic lace-like solution forms. At the end of the corridor a short, wet creeping section leads to a broad joint. According to the quantity of precipitation (rainfall or snow) even several m deep ponds may develop here. The connection between the *Pálvölgy Cave* and *Mátyáshegy Cave* was discovered in 2001 in this part of the cave.

Through the T Corridor we return to the Maze through a tilted cleft and then we climb down a 5 m deep shaft until we reach a horizontal corridor. At the end of this corridor a 5 m and a 8 m descent follows (Large descent [*Nagy lemászás*]), and then we reach the bed of the cave-brook. This part of the cave has developed already within limestone and its morphology is characterized by solution forms of cold water.

Through a comfortably downward sloping corridor we reach a lake after about 40 m. The 3–4 m deep lake has a surface area of 5–6 m^2. This is the end of the passable section of the cave in a relative depth of 90 m. (Here we are already almost on the level of the Danube River.)

Returning to the Large descent – but proceeding under it – we climb up through smaller ascents and after these through a maze of broad clefts. Still some narrower parts and we enter the Globe Hall. on a level of –40 m. Here we join the route of the short tour and through the Elephant – Giants' Road – Great Hall we reach the surface.

4.2 Field stop 2. Szemlőhegy Cave (Szemlőhegyi-barlang)

The entrance part of the Szemlőhegy cave (Fig. 19) was discovered in 1930 during the foundation works of a the house of a pharmacist, Géza Miklóssy. The actual length of the cave is 2.2 km, out of which, since 1986, a 300 m long part is also furnished for visits of tourists.

The passages of the cave were produced by the corrosion of upsurging thermal waters. The corridors of the cave are in Eocene limestone and follow the SW–NE striking joints of the rock. The main parallel corridors are connected perpendicularly by short passages. The morphology and the formations of the cave are similar to those of the *Ferenchegy* and *Józsefhegy Caves*. The walls of the cleft-like corridors are decorated by

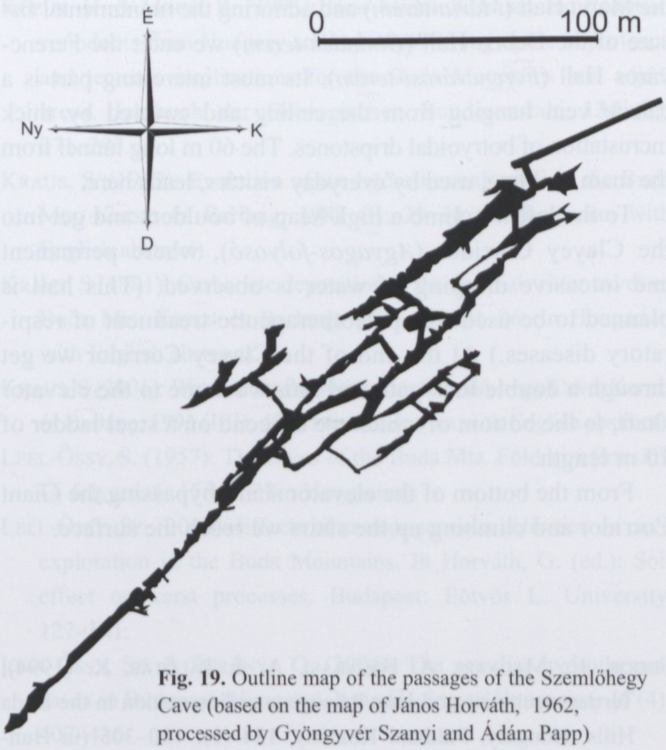

Fig. 19. Outline map of the passages of the Szemlőhegy Cave (based on the map of János Horváth, 1962, processed by Gyöngyvér Szanyi and Ádám Papp)

kettle-like spherical solution forms and by calcite pisoliths and gypsum crystals. Characteristic plate-like calcite crystals can also be found in several places. Dripstones are present only sparsely in the cave.

During the development of the show cave two artificial entrances were constructed: a 60 m long gallery from the Pusztaszeri road and a 45 m deep vertical shaft from the Barlang street side, site of the planned elevator.

Fig. 20. The Giant Corridor in the Szemlőhegy Cave covered by botryoids (Photo: Ákos Kocsis)

Short Tour

Tour time is about 2 hours; technical equipment is not necessary.

Our tour begins on the hilltop at the Discovery-corridor entrance (*Felfedező-ági bejárat*), or the so-called Vortex Corridor (*Örvény-folyosó*). After a few m walk on concrete floor we arrive into a tube-like, steeply descending passage. The walls of this ancient thermal water chimney are interesting, because of solution forms. In a distance of about 15 m beyond the entrance a vertical shaft leads into the University Section (*Egyetemi-szakasz*). We proceed downwards along the stairs. After 50 m we reach the broadest part of the cave: the Giant Corridor (Óriás-folyosó, Fig. 20) and here we enter the parts open for tourist

In the light of lamps peculiar pisolites and huge solution sills occur, product of the inhomogeneous solubility of the limestone. To the right, we can cast glances through window-like openings towards the other, neighbouring passage, being separated from us by a calcite vein. The height of the 45 m long corridor, formed along a joint, is 15 to 20 m. Descending along some stairs, a great mass of plate-like calcite crystals appears. Overhead high-reaching chimneys lead toward higher levels of the cave.

At the end of the Giant Corridor a 7 m long steel ladder offers ascend into the intact Radio Corridor (Rádió-folyosó), discovered in 1958. Through a high-reaching cleavage, divided in certain spots by spherical cavities, one can reach the Death Corridor *(Halál-folyosó)*. The name comes from the rather dangerous caving-ins. The loose blocks are now supported by steel scaffoldings.

We still climb upwards and then, in a steep clay-bottomed cleft, we descend into the Kadić Hall (for Ottokár Kadić, 1876–1957, geologist, paleontologist, speleologist, who made the first scientific exploration of the cave). From here we either go down into the Snow Palace *(Hópalota),* covered by white calcite incrustation, unfortunately showing traces of damage. After a short ascent we arrive at the 3 April Corridor *(Április 3. folyosó),* a broad, hall-like cavity with nice flowstones. Along the left wall descending down to 7 m a small dripstone pool is found. The corridor proceeds between botryoidal and flowstone formations toward the Heart of the Earth (A Föld szíve), a red coloured hall. Crawling through above it, we enter the Bell Hall (*Harang-terem*), full of plate-like calcite crystals, after which the name was given. From its bottom through a tube-like hole we arrive to the SW end of the cave, the Assembly Hall *(Közgyűlés-terem),* but only very slim cavers can wriggle into it.

From this spot we return (along the already described route) to the Giant Corridor and proceeding through it we turn to right in the branching-off Long Corridor (*Hosszú-folyosó*). After about 40 m walk between rich calcite formations and ascending we reach the entrance into the Crawling Passage *(Kuszoda).*

This part of the cave developed along two parallel joints. The double-level corridor-system is very narrow upstairs, while the lower part is a series of small halls, rich in formations. The two main corridors are interconnected by three narrow, cross-cutting passages.

From the Crawling Passage we return to the Long Corridor and proceed in a pisolite-covered cleft getting higher and higher. After a larger hall we get between two concrete walls and from here the 45 m deep vertical shaft leads to the surface. Crossing the Maria Hall (*Mária-terem*) and admiring the monumental fissure of the Debris Hall (*Omladék-terem*) we enter the Ferencváros Hall (*Ferencvárosi-terem*). Its most interesting part is a calcite vein hanging from the ceiling and covered by thick incrustation of botryoidal dripstones. The 60 m long tunnel from the main building, used by everyday visitors, leads here.

To the left we climb a high heap of boulders and get into the Clayey Corridor (*Agyagos-folyosó*), where permanent and intensive dripping of water is observed. (This hall is planned to be used for speleotherapeutic treatment of respiratory diseases.) At the end of the Clayey Corridor we get through a double lock gate and thus we come to the elevator shaft, to the bottom of which we descend on a steel ladder of 10 m length.

From the bottom of the elevator shaft, bypassing the Giant Corridor and climbing up the stairs we reach the surface.

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