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RESEARCH ARTICLE

THE CAVE OPENING TYPES OF THE BAKONY REGION (TRANSDANUBIAN MOUNTAINS, HUNGARY)

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ABSTRACT

The genetic classification of the cave openings in the Bakony Region is described. The applied methods are the following: studying the relation between the distribution of phreatic caves and the quality of the host rock and in case of antecedent valley sections, making theoretical geological longitudinal profiles. The phreatic caves developed at the margins of the buried karst terrains of the mountains. The streams of these terrains created epigenetic valleys, while their seeping waters created karst water storeys over the local impermeable beds. Cavity formation took place in the karst water storeys. Phreatic cavities also developed in the main karst water of the mountains. The caves are primarily of valley side position, but they may occur on the roof or in the side of blocks. The cavities of valley side position were opened up by the streams downcutting the carboniferous rocks (these are the present caves of the gorges). While cavities of block roof position developed at the karst water storey at the mound of the block.

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INTRODUCTION

In this study, the cave openings of the Bakony Region and their genetic types are described. Cave openings are widespread in karst areas. Thus, caves with such genetics of the glacier valleys of glaciokarst can be mentioned (AUDRA *et al*. 2003; PLAN *et al*. 2009), which were opened up by fluvial erosion (horizontal passages) or by glacial erosion (vertical passages) according to KLIMCHOUK *et al*. (2006). However, caves opened up by abrasion can also be mentioned (GINES – FIOL 1981). In the area of the Bakony Region (mainly of the Northern Bakony) cave openings are characteristic and widespread. Their significance is due to the fact that several varieties of their development way can be distinguished which can be attributed to the geology and development of the mountains. This also makes it possible to study,describe and classify the process of opening and here.

A general description of the Bakony Region: The Bakony Region (its elevation is 150-700m, its expansion is 4300 km^2) is constituted by the Bakony Mountains (their area is 2200 km^2) and the surrounding environs with a lower elevation. The Bakony Region is a meso region, which is separated into five micro region groups (Keszthely Mountains, Balaton Uplands, Southern Bakony, Northern Bakony, Bakonyalja). Karst phenomena are present to some extent in all micro region groups (Northern Bakony is the richest in karst features). However, at micro region level, there are only pseudokarstic caves in the Tátika group (Keszthely Mountains, micro region group). However, the greatest exception is the Bakonyalja micro region group since a karst phenomenon only occurs in the Pápai-Bakonyalja region among the three micro regions (spring cave ofTapolcafő). As a part of the Transdanubian Mountains macro region (Alpaca Macrostructural Unit) the Bakony Region got into its present position from a southern alpine surroundings with a NE shift by the time of Miocene (Stegena *et al*. 1975; Csontos – Vörös 2004). As a consequence, but also as a result of the changing of the position of the Eurasian Plate, its climate gradually became temperate from a tropical one. The Alpaca Macrostructural Unit is regarded as the uppermost, non-metamorphic member of the Austro-Alpine Nappe (Budai– Konrád 2011). Its main constituting rock is Triassic Main Dolomite (Main Dolomite Formation). The main dolomite is without impermeable intercalations, its thickness may exceed 1500 m in the Transdanubian Mountains (Haas 1993), but it is reported to have a thickness of 1400 m in the Southern Bakony and 550-750 m in the Balaton Uplands (Budai *et al*. 1999). Its bedrock is composed of Sándorhegy limestone (Sándorhegy Limestone Formation) with marl intercalations (Gyalog 2005) then the bedrock of the latter is the Veszprém marl (Veszprém Marl Formation). The main dolomite is overlain by Triassic Dachstein limestone (Dachstein Limestone Formation), Jurassic, Cretaceous and Eocene limestones in patchy expansion mainly in small thickness (from some 10 m to some

100 m). The main characteristic feature of its structure is given by its disproportionate development: in the SE there are old Triassic, Palaeozoic, partially non-karstic rock, in NW there are also old (Triassic) Carboniferous rocks entirely on the surface, while in its middle part where the Triassic floor forms a depression (Láng 1962, Budai-Konrád 2011) limestones that developed in Jurassic, pelagic, Cretaceous and Eocene shallow sea environment occur. In the mountains, the permeable carboniferous rocks are interrupted by impermeable beds or beds with a bad permeability. Thus, silica, clay, marly limestone, marl, abrasional gravel and calcareous marl (Deák M. 1972). As a result of the vertical movements of the blocks, these beds are situated in various elevations even adjacently to each other. The tropical karstic peneplain of late Cretaceous age of the mountains (Szabó1966, 1968; Bulla 1968) became already tectonically dissected from the Eocene (Pécsi 1980) thus, the delta gravel of late Oligocene and Early Miocene (Csatka Gravel Formation, Korpás 1981) covered a dissected surface. Younger, Middle-Miocene limestones (Lajta Limestone Formation, Tinnye Limestone Formation) and Pliocene freshwater limestones developed mainly at the marginal parts of the mountains (Császár *et al*. 1981). However, Pannonian clay can also be found in small expansion (Jaskó 1961) then, loess was formed in a wide expansion too. On some horsts of the Southern Bakony, basalt covers (horsts with basalt cap) developed by the volcanic activity of Pliocene age (Lóczy L 1913).

Karstification took place in the mountains several times. Thus, in the Upper Triassic (Raincsák 1980), in the Jurassic (Konda 1970) and in the Cretaceous (Noszky 1964). The products of paleokarstification are infilled and buried dolines (Pataki 1983; Szabó 1968; Bárdossy *et al*. 1983). The karst water of the mountains (main karst water) mainly developed in the main dolomite. (It was named after the reservoir rock, it extends to the whole area of the Transdanubian Mountains and it is located at the base level of erosion of the mountains.) Based on the elevation data of mountain marginal springs, karst marshes and lakes, its elevation was about 117-220 m at the margin of the mountain preceding artificial karst water lowering in the 20th century. At the northern margin of Northern Bakony it was situated at an elevation of 140-180 m, while in the south-eastern part of the mountains it was located above 200 m (Papp 1942; Szádeczky-Kardoss 1941, 1948). In case of impermeable intercalation, a karst water storey developed and develops in carboniferous rocks. (The karst water storey is a locally developing system above the level of the main karst water level.) The karst water storey can be inactive (it does not have karst water any more at present) and active (it owns karst water now too). The Bakony Region is separated into blocks and block groups with different elevations which create mountains. Leél-Őssy (1960) claims the Northern Bakony and Southern Bakony to be a tectonically dissected, karstic peneplain section group. As a result of their oscillation movements, the blocks may be of various evolution. Taking this fact into consideration, classifying the horsts (the horst groups) of the mountains, Pécsi (1980, 1991) distinguished horst in summit position (its present elevation is above 600 m, on its surface with Triassic and Jurassic carboniferous rocks, possibly in patches with loess and reworked cover), horst elevated to summit position (its present altitude is 400-550 m, with Cretaceous and Eocene limestones on its surface with widespread loess cover and reworked deposit, possibly with gravel cover in patches). The above-mentioned author distinguishes an exhumed and semi-exhumed variety of this type. He also differentiated cryptopeneplain (its elevation is below 300-400 m and its surface is covered by Tertiary sediment) and threshold surface (its elevation is below 300-400 m and its surface is mainly constituted by Triassic carboniferous rocks), which lost its gravel cover by pedimentation, if it has a cover, it is reworked.

Considering the coveredness of karst, various karst types can be distinguished (Gvozdetskiy 1965; Hevesi 1986; Jakucs 1977; Veress 2016): thus, bare karst, soil-covered karst, covered karst, buried karst and mixed autogenic allogenic karst. Covered karst can be cryptokarst (the cover is impermeable), concealed karst (the cover is permeable) and buried karst (the cover is thick and impermeable). On bare karst or on soil-covered karst, solution dolines and collapse dolines are characteristic, on cryptokarst caprock dolines are specific, while subsidence dolines are typical karst features of concealed karst. (Sweeting 1973; Waltham *et al*. 2005). The features of allogenic karst are ponors (Jakucs 1977; Ford – Williams 2007). Dropout dolines and suffusion dolines are varieties of subsidence dolines (Williams, 2004). In the Bakony mountains soil-covered karst, mixed autogenic allogenic karst, cryptokarst, concealed karst and buried karst alternate. The caves of the mountains are of karstic and non-karstic (pseudokarstic) origin. Their number including non-karstic caves is over 700 (ESZTERHÁS 2013). Caves of karstic origin can be of cold water and hydrothermal development. According to their development environment, those of cold water origin can be put into two types: those that developed in the vadose zone and the phreatic zone (VERESS 2000). The caves of the vadose zone are the pits and shafts with an almost vertical position between the surface and the karst water table. They developed under point-like superficial water recharge sites. The Kessler Hubert cave (Keszthelyi Mountains) with a depth of 200 m and with a length of 1900 m that developed in main dolomite is a transition between the caves of vadose and those of phreatic origin. Its lower part indicates a phreatic origin which was connected by a shaft to the effect of superficial water inflow (Szilaj 2014).

Fissure caves of tectonic origin are also characteristic of Keszthelyi Mountains. The caves of the phreatic zone are almost of horizontal position, and they may occur at the margin of the mountains (effluent cave) or in the sides of blocks and/or valleys inside the mountains. There are only some presently active effluent caves (thus, caves close to the outlet of karst water) or former effluent caves in the mountains. Thus, the effluent cave of Hévíz (active cave), at Hévíz, its elevation is 109.5 m (PLÓZER 1977), the pits of the spring cave of Tapolcafő (became inactive because of karst water sinking) with an altitude of 174-182 m (VERESS *et al*. 1993) and the caves of Tapolca. Among them, the most important is the active (karst water) cave system under the town of Tapolca, in a depth of 12-15 m under the surface. The total length of the caves of the cave system is (Tavas-cave and the Kórház Cave and the Berger Károly Cave which are connected to each other) 12 km (MÓGA *et al*. 2011). (The artificial entrances of these latter are at an altitude of 132 m and 137 m.) The reason for the subordinate appearance of effluent caves can probably be ascribed to the fact that the main karst water emerged gallery-like at the surface at several places at the margin of the mountains (SZÁDECZKY-KARDOSS 1948), and that some of the karst water flowed and flows into the rocks of the surrounding basin (Kisalföld) (CSEPREGI *et al*. 2014). Cave formation of hydrothermal origin took place in the Keszthely Mountains (Leél-Őssy 1953) where the surface of main dolomite was dissolved below the Pannonian sandstone (Kárpát 1982, 1983). In the well cave of Cserszegtomaj the sandstone survived in form of pillars since it filled the depressions of dolomite, while there are no pillars in the well cave of Acheron. The Lóczy cave in Balatonfüred is also of hydrothermal origin (Láng, 1958, Leél-Őssy 1958) and the spring Cave of Hévíz Lake is partially of hydrothermal origin (Plózer 1977). Pseudokarstic caves (Eszterhás 2013) commonly occur in the basalt of buttes with basalt. They can be found on Agár Mountain, on Csobác Mountain and on Szigliget Mountain. Among them, the longest one is the Pulai basalt cave (151m) on Kab Mountain. These caves mainly developed during the mass movements (collapse) of the margins of the basalt cover, but caves of gas bubbles also occur (Eszterhás 2013). Cavities of hydrothermal origin also occur on the Tihany Peninsula. Here, there are caves in the spring cones which were formed from the hydrothermal water (where the water moved upwards) or spring chimneys of solution origin.

MATERIALS AND METHODS

- Various karst types were distinguished by the classification of the non-karstic cover and with the consideration of different karst features in the mountains. Concealed karstic terrains are those where the cover is permeable (mainly loess) and there are subsidence dolines. Cryptokarst is where the cover is consolidated, impermeable rock and on which there are caprockdolines, or where the cover is impermeable, non-karstic, unconsolidated rock, and there are gorges at its margin.
- The morphology, the distribution of the altitude of their entrances, the occurrence environment, and genetics of short, horizontal caves was studied in the mountains by the analysis of cave maps.
- The morphological and geological environment of the sections of valleys with caves (gorges) was studied.
- The host rock of the caves in the valley sides of Ördög Valley and one of the tributary streams of Dudar Stream (Magos Mountain) as well as at the caves of Likas-kő of Hódos stream and Nagy-Törkő-lik and Kis-Törkő-lik (Középső-Hajag) were sampled and determined.
- Theoretical geological longitudinal profiles were made at epigenetic-antecedent valley sections. Taking them into consideration, phreatic cavity formation types were distinguished.

RESULTS

It can be stated that on blocks of various types, different karst types developed. However, several karst types can also be present on some blocks. On horsts elevated to summit position, from which the loess denuded to a small degree because of their relatively low position, concealed karst occurs. On horsts in summit position (from which the loess denuded as a result of their greater elevation)and on threshold surfaces, mainly the soil-covered karst type occurs, but this type can also be found on the surface of horsts elevated to summit position. In the area of cryptopeneplains, mainly buried karst is present. The areas with gravel cover of Dudar basin, the northern part of Lókút basin and Porvai basin belong to this karst type.

The horizontal caves of valley sides (gorges) developed in marly limestone (rarely in marl) or in rocks above them, the age of which is Jurassic, Cretaceous and Eocene (Table I). Thus, 50 caves out of 53 caves in the area between the Cuha stream and the Dudar basin occur in impermeable (of impermeable nature) intercalation or above it (Fig. 1). (The three other caves developed in Dachstein limestone and in main dolomite.) This indicates that the water movement being responsible for their development was horizontal. The horizontal water movement can be explained by the existence of former karst water storey. The karst water storey and the spherical cavities of the caves refer to the phreatic origin of the caves of the gorges. The water of karst water storey developed above impermeable intercalations, but if the impermeability was only partial (marly limestone), dissolution also took place in them and thus, caves developed (for example the caves of Ördög Valley, Table I), or if several impermeable intercalations were present, cave development also took place between them (Nagy-Törkő-likandsKis-Törkő-lik, Table I).

- Caves of phreatic orig in primarily occur in the gorges of the mountains (epigenetic-antecedent valley sections) at different elevations (Table I), in valley sections following the termination of gravel cover (Fig. 1).
- The number of caves of phreatic origin is at least 225. 212 out of them is situated in valley sides (gorges or in valley sides with gorges), 10 is situated in the sides of blocks (at fault plane) and three can be found on the roof of blocks.
- The altitude of the entrance of horizontal caves differs in the same gorge, but it is also various in different gorges.

DISCUSSION

The streams leaving the area of basins (cryptopeneplain) create epigenetic valleys in limestone areas (Fig. 1). If the stream goes through a block that is elevated as compared to its environment, gorges are formed. Such a gorge is for example Kerteskő gorge (its stream is called Gerence, which collects the waters of Lókút and Hárskút basins), or the gorges of Ördög valley and the gorges of Gaja(the water of the latter originates from the area of Dudar basin). The water of streams percolated (and percolates) in the valleys, but mainly in their gorges and it gets into the main karst water directly or indirectly (through the karst water storey). Thus, in Kerteskő gorge, 75% of Gerence stream percolated at a discharge of 600l/s (BRATÁN *et al* 1967). The effect of the streams arriving at the gorges is dual. On the one hand, they create a karst water storey by their percolating water if there is an impermeable bed in the limestone below their valley floor (VERESS 2016). On the other hand, they downcut into the limestone with cavities by a significant erosion. During downcutting they partly destroy the phreatic caves and partly open them up. The morphology of the caves is an evidence for the opening up of cavities. Crossovers often occur thus, short cave remnants with two entrances (for example Csesznek crossover) and caves branching out at their entrance thus, having several entrances at one or both of their terminations (for example Likas-kő of Hódos stream). The cave openings of the mountains may have been created from the cavities of karstwater storeys (these are situated over impermeable intercalations in Jurassic, Cretaceous, Eocene limestones) or from the cavities of the main karst water (the latter mainly occur in Triassic Main Dolomite).

According to geological and morphological environment, the development types are the following (Fig. 2):

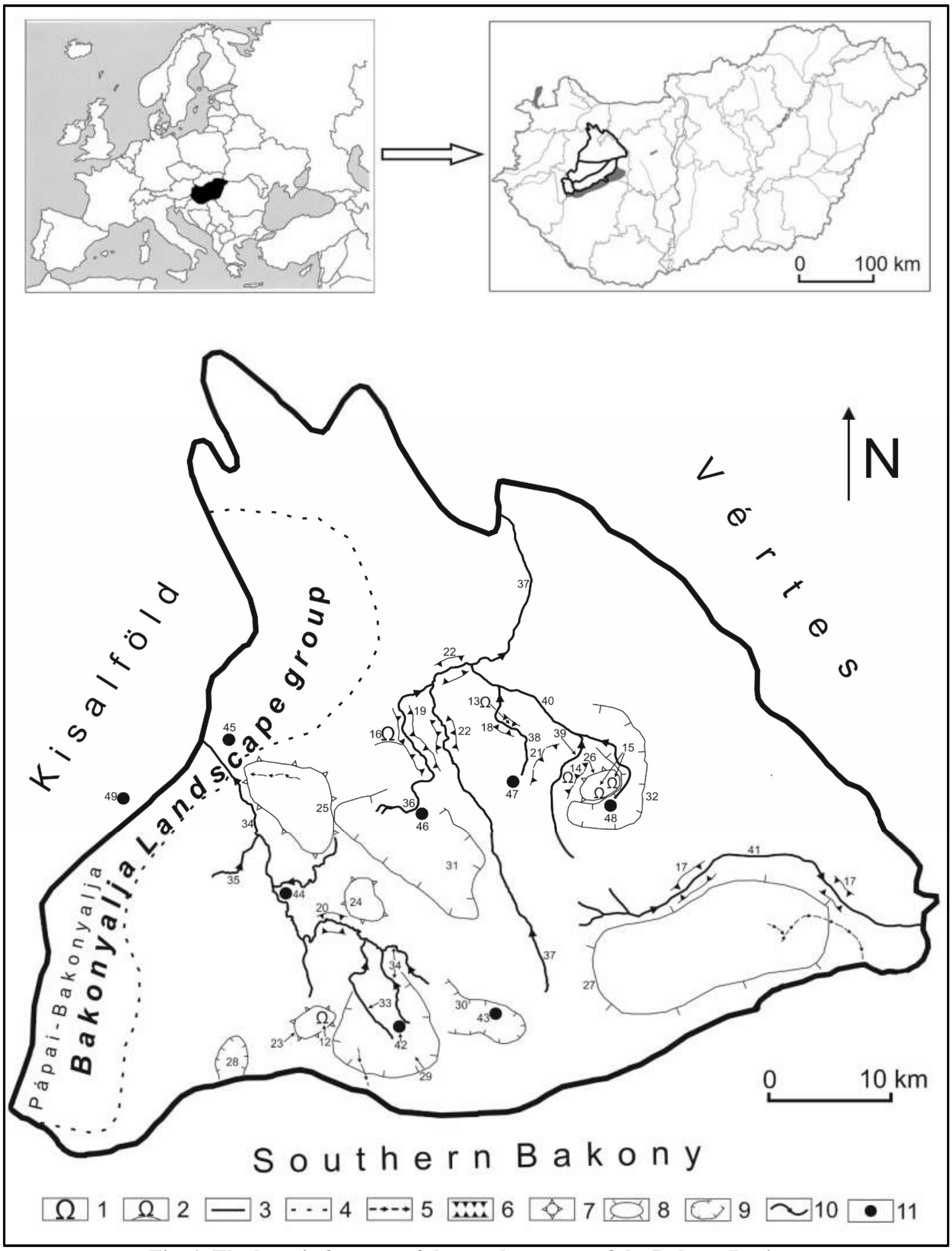

Fig. 1. The karstic features of the northern part of the Bakony Region

Legend: 1. cave opening in valley side, 2. cave opening (exposed) on the mound of a block, 3. boundary of the northern part of the Bakony Region, 4. boundary of micro region group, 5. dry valley, 6. gorge, 7. block roof, 8. plateau, 9. basin, 10. stream and its valley, 11. settlement, 12. Nagy- and Kis Törkő-lik (cave), 13. Cseszneki crossover (km-1), 14. Ördög-lik (cave) by Dudar, 15. caves of Magos mountain, 16. Hódos-éri Likas-kő cave, 17. Gaja gorge, 18. Kőmosó gorge, 19. gorge of Hódos stream, 20. Kerteskői gorge, 21. gorges of Ördög Valley, 22. gorges of Cuha stream, 23. Középső-Hajag block, 24. Som block, 25. Kőris block, 26. Magos block, 27. Tési Plateau, 28. Csehbánya Basin, 29. Hárskút Basin, 30. Lókút Basin, 31. Porvai Basin, 32. Dudari Basin, 33. Öreg Stream, 34. Gerence Stream, 35. Vörös János Stream, 36. Hódos Stream, 37. Cuha Stream, 38. the stream of Kő Valley, 39. the stream of Ördög Valley, 40. Dudar Stream, 41. Gaja Stream, 42. Hárskút, 43. Lókút, 44. Bakonybél, 45. Bakonykoppány, 46. Porva, 47. Gézaházapuszta 48. Dudar, 49. Pápa

Table 1. The host rocks of some cave openings (Determination of rocks was performed in the Geological Institute of Hungary)

Cave	Host rock		Sample site	Material of the sample
	Material	Age		
Ö-12	limestone	Upper Eocene	entrance	marly limestone
Ö-15 (Ördög-lik)	limestone	Upper Eocene	above entrance	marly limestone
Ö-15	limestone	Upper Eocene	entrance	marly limestone
Ö-15	limestone	Upper Eocene	above entrance	marly limestone, fossils
Ö-16	limestone	Upper Eocene	below entrance	sligthly marly limestone, foraminifera
Ö-20/b (Ördög-árki Róka lyuk)	limestone	Lutetian	at the northern part of the entrance	limonitic, marly limestone, with nummulites and sea urchin stings marl, marly limestone
M-2	limestone	Eocene	entrance	
caves marked M-5, M-6, M-7, M-8	limestone	Lutetian	beds below caves	slightly marly limestone with fossil
Törkő-likak	limestone	Jurassic	at and below the caves	silica intercalations with a thickness of 1-2 dm
Likas-kő of Hódos-ér	limestone	Middle Eocene	below entrance	abrasional brecca[1]

Notice: Cave names starting with 'Ö' are in Ördög Valley of Dudar, while those beginning with M are in the cliff wall of Magos Mountain situated in the valley side of one of the tributary streams of Dudar stream [1]Source: Veress, Futó 1987

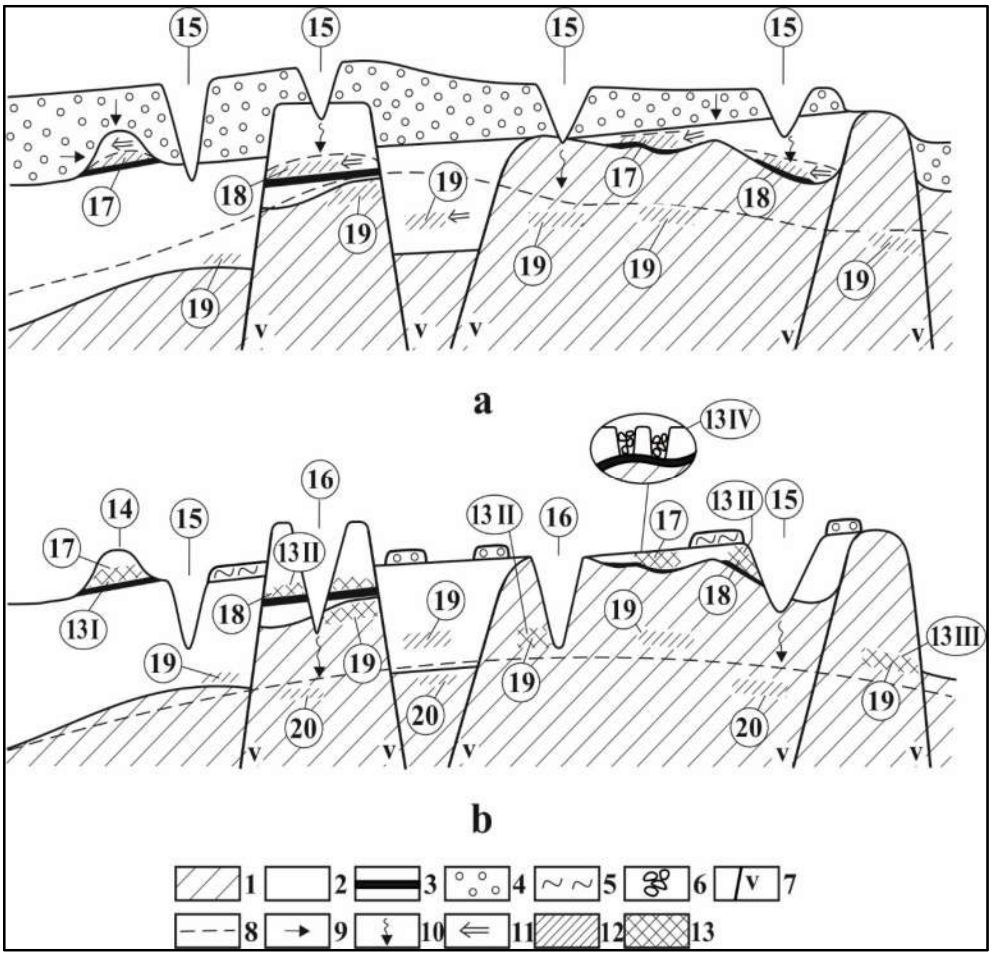

Fig. 2: The phreatic caves of the mountains according to development environment and the way of opening up

Legend: a. former state, b. present state, 1. main dolomite, 2. Eocene and/or Cretaceous limestone, 3. impermeable beds or partially impermeable intercalation, 4. Oligocene-Miocene gravel, 5. loess, 6. collapse blocks of the ceiling, 7. fault, 8. karst water table, 9. water flow in the cover, 10. seeping water of a stream, 11. horizontal flow of karst water, 12. closed, non-opened-up cavities, 13. opened-up cavities: 13.I. cavity exposure during the denudation of the cover, 13.II. opening up during valley development, 13.III. opening up during the denudation of the side slope of the block, 13. IV. opening up by the collapse of the ceiling, 14. limestone mound (hill), 15. epigenetic valley, 16. epigenetic-antecedent gorge, 17. karst water storey that developed from the water of the cover and its cavity formation, 18. karst water storey that developed from the seeping water of a stream and its cavity formation, 19. former cavity formation that can be associated with main karst water, 20. present cavity formation primarily in the main dolomite (supposed)

The cavity on the roof of the block is in the paleokarstic mound of the uneven bedrock. Aspecific occurrence of this variety is known: Likas-kő of Hódos stream. Here, the limestone mound was once covered by gravel (its remnants can be found in the environs of the cave), the waters of which created a small karst water storey in the mound. The cavities became transformed and exposed during the denudation of the cover (VERESS – FUTÓ 1987).

The cavities are in the side of epigenetic valleys or in the side of their gorges. The most frequent case is when the valley being inherited from the gravel, reaching the limestone created a karst water storey by the seeping water of its stream, where cavity formation occurred. Water flow and cavity formation above the impermeable intercalation is indicated by the fact that at these sites the passages are more developed laterally than vertically or where there is also a fracture, they have a circular cross-section. Subsequently, some cavities were completely destroyed by the erosion of streams and by the denudation of the valley sides, while other cavities were only partially destroyed by which they opened up. The opened-up caves become shorter during the denudation of the valley sides and they are dissected by the local denudation of the ceilings, but also newer cavities may open up during the process (VERESS 2000).

Such caves occur in the Ördög Valley of Dudar(Fig. 3f), in Kőmosó gorge (Fig. 3a), in the middle part of Cuha Valley (Fig. 3e) and in Kő Valley. However, in Kerteskő gorge, above the present channel floor, cavity formation was not horizontal in Cretaceous limestone, but vertical in lack of impermeable beds. The developed shafts were opened up by erosion (basically, these are features of the vadose zone that developed under the valley floor), from which only shaft remnants survived in the side of the gorge (Fig. 3b). The lower part of the limestone covering the main dolomite is often impermeable. Also in this case, a karst water storey developed, the cavities of which were also opened up by the valley inheriting and deepening into the main dolomite. This variety includes the caves of Magos Mountain of Dudar (Fig. 3c).

No karst water storey is formed under the valley deepening during inheritance in lack of impermeable intercalation. In this case, the deepening valley opens up the cavities situated below the former main karst water table. Such caves are the caves of the section with gorgesat the lower part of Cuha Valley (Fig. 3d), or the lower level of Ördög-likcave and a section of it, and some caves of the lower part of Ördög Valley (Fig. 3f). Caves developing without impermeable beds are characterized by vertical cross-section.

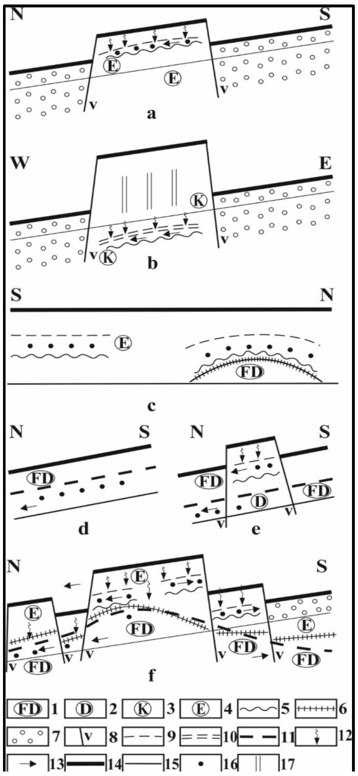

Fig. 3. Some occurrences of cave openings that developed in the karst water zone of the former karst water storey in the mountains (along valleys)

Legend: 1. main dolomite, 2. Dachstein limestone, 3. Cretaceous limestone, 4. Eocene limestone, 5. impermeable intercalation, 6. Eocene limestone and the boundary of main dolomite, 7. non-karstic cover (gravel, clay, alluvial sediment), 8. fault, 9. former karst water table of former karst water storey, 10. karst water table of present karst water storey, 11. former karst water table of main karst water, 12. seepage, 13. water movement in the zone of karst water, 14. margin of valley, 15. valley floor, 16. opened-up cavity, 17. shaft remnant; type occurrence in the mountains: a. in epigenetic-antecedent gorges opened-up cavities develop from the cavities of former karst water storey (Kőmosó gorge), b. In epigenetic-antecedent gorges, in the lack impermeable beds, shafts develop which turn into shaft remnants by opening-up (Kertes-kő gorge), c. in valley sides, opened-up cavities develop from the cavities of the former karst water storey above the main dolomite (Magos Mountain, valley of the tributary stream of Dudar stream), d-e. in epigenetic-antecedent gorges, opened-up cavities develop in the cavities of former main karst water Gerence (its part between Bakonybél and Bakonykoppány, middle part of the valley of Cuha and its section with gorges of Ördög-rét), f. in epigenetic-antecedent gorges opened-up cavities develop from the cavities of former karst water storey and from cavities of former main karst water (Ördög Valley)

This can be experienced in case of the above-mentioned Ördög-lik, where the average quotient of width and depth is 0.94 at the passages of the upper level that developed in the marly limestone and over it, while this value is 0.62 at the lower level which was formed in dolomite.

If the main dolomite is overlain by impermeable beds, but the limestone is thin over it, a karst water storey develops too. In lack of a valley, the water of the karst water storey originated from the former gravel cover. Cavities located close to the surface of limestone and thus, having a thin ceiling were formed, which collapsed during or subsequently the denudation of the gravel. As a result of the process, not cave openings but small depressions with collapse material developed. Such features occur in the area between Gézaháza-puszta and Ördög Valley as well as between Likas-kő of Hódos stream and Hódos-stream. The caves of blocks being exposed by fault planes are further denuded by frost weathering, which can also contribute to the exposure of the cavities (but also of the cavities of the karst water storey) of main karst water. Such caves occur in the sides of the blocks bordering Séd stream from the south (FUTÓ 2000).

Conclusion

The most common caves of karstic origin of the Bakony region (mainly the Northern Bakony) are the cave openings of phreatic origin. Spring caves rarely occur in the mountains. At sites, where epigenetic valleys reach the former karst water level, they explore the phreatic cavities. This is primarily specific of those blocks where karst water storeys develop, above the local impermeable (or partially impermeable) intercalations and where the catchment area of the stream is on the buried karst terrain surrounding the block since the stream has a relatively large amount of water in this case. In the developing gorge, the percolating water increases the extent of local cavity formation in the karst water storey, the larger discharge increases erosion and thus, the denudation and/or opening up of cavities below the valley floor. Cave openings also develop from the cavities of the main karst water, if the three developed cavities are exposed by epigenetic valleys. Cave openings are also formed in the block side explored by fault plane. At the exposing mounds of the block roof, the cavities of karst water storey crop out. Depressions of collapse origin develop from the cavities being close to the surface of the bedrock.

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