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SOME PROPERTIES OF THE ALPINE VERTICAL KARSTIFICATION

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Abstract: *The paper studies vertical karstic forms that develop in the alpine region below the snow line. Three forms are differentiated by their dimensions: karren micro-forms, meso-forms (vertical shafts) and major forms (characteristic alpine vertical shaft systems). The origin of karren micro- and meso-forms are explained by the solution of the limestone surface as a process akin to the making of the karrenfelds. The origin of the major vertical caves is understood as a different phenomenon. The paper considers these caves a phenomenon corresponding to with the potholes of the Alsó-hegy in Hungary/Slovakia. The paper studies the meso-forms in detail and specifies three types: potholes (vertical caves), channel-end shafts and caved-in shafts. The process of the origin of these phenomena is explained by individual models. The paper suspects a strong relation between the origin of the potholes and the snow accumulated in them. The channel-end shafts are explained by the decapitation of the karren-channels and classifies them as karren-swallets. The origin of the caved-in shafts is explained by more than one ways: the collapse of cavities, the merging of fissures and the weathering of channel-end shafts by freezing.*

Introduction

During the karst-research program three sites in the Austrian Totes Mountains and two sites in the Italian Asiago Plateau were studied for vertical karst forms, their morphology, their origin and the frequency of their occurrence. The studies were extended to the relation of other karstic (mostly karren) and non-karstic phenomena. For a comparison studies were carried out on the Hungarian Alsó-hegy plateau.

Description of the Study Areas

I. The studies of 1996 were carried out in the Totes Mountains in Austria on two neighboring sites below the Hint. Bruder and Widerkar peaks on the bottoms and side slopes of glacial valleys at elevations about 1800 m above the sea level on terraced bedding plane surfaces devoid of vegetation or soil. On a 60.000 m^2 area 59 vertical shafts were surveyed.

II. Studies were carried out again in 1997 in the Totes Mountains in the upper part of a one time firn basin in the vicinity of the Scheibling Peak at an elevation of about 1900 m. on stepping big extension bedding plane surfaces devoid of vegetation or soil. On a 12,000 m^2 area 23 vertical shafts were surveyed.

III. The glacier valleys below the Rinner Peak (2012) in the Totes Mountains were studied as well in 1997. The plateau is broken by U shaped glacier valleys that are devoid of vegetation, only dwarf pines and some rock-grasses survive on the steep slopes on exposing narrow terraces of limestone. The glacier progressing down was probably cut in two by the ridge of the Rinner Peak towering as a nunatak. These two branches of the glacier probably joined the major glacier moving in a NNW direction as hanging glaciers. The bottom of this valley is located at about 1600 m of elevation already under the timber-line.

IV. Studies were carried out in the Italian Asiago Plateau in 1998 on two bedding plane sites that were dissected by rises and steps. One of them was elevated at 1900 m, the other at 2060 m. Both study sites were built of Jurassic dolomitic limestone.

V. Studies were carried out in 1999 on the Hungarian part of the Alsó-hegy Plateau visiting the Vecsembükki and Almási Potholes that are located at about 500 m elevation in middle elevation mountain environment.

During these studies sites of different elevation, vegetation and of various geological and geomorphological nature were compared. In spite of the differences in the conditions of origin and in the morphology many similarities can be recognized. The most outstanding in the conditions of origin is the vertical definition that is resulted by the very close fracturing in the alpine sites and by the close to vertical position of the bedding planes in the Alsó-hegy. The morphology of all study areas is characterized by vertically elongated karstic forms. This phenomenon was described in the study of the karstic micro-forms and karrenfelds of the Asiago plateau as well *(VERESS, M. - ZENTAI, Z. - KOVÁCS, GY. 1999).*

The methods of study

During the collection of data a number of varied methods were applied to achieve a many faceted approach to the subject.

The shafts situated in *Site I.* were surveyed and scale 1:100 maps and profiles were drawn. The shafts were classified to types according to their morphology and topography. During classification the following regards were observed:

- the position of the shaft-entrance related to the pre-forming fissures,
- the symmetry conditions of the shaft entrance (regular or elongated),
- the hydrographic situation of the shafts (have individual catchment areas or not),
- the neighborhood of the shafts (presence of soil covering or situated on bare rock),
- the roughness of the shaft-walls,
- the quantity and position of debris,

- the depth of the shafts,
- the number of individual shafts of potholes (complexity)

To describe the topographic distribution and relation to the fractures a scale 1:500 survey map was completed.

The survey of the shafts on *Site II.* was extended only to characteristic types. The classification was made observing identical regards as the ones used in *Site I.* A scale 1:200 survey map was completed about the site.

The catena principle was applied on *Site III.* The survey started at 1950 m of elevation and it was continued to the bottom of a former glacier valley 400 m below recording the parameters of phenomena met along the line (strip). (Length of the openings and the dimension at right angle to it, depth, measure of debris and vegetation covering.) As the alpine slopes are not easily traversed, karstic forms met along the often zigzagging tourist trail were surveyed. On a distance of roughly 2.5 km 253 occurrences were recorded.

A survey was made on *Site IV.* observing the described regards.

On *Site V* surface reconnaissance was carried out and morphological observations were made in two potholes that can be considered representative examples for the area. (Almási- and Vecsembükki-zsomboly).

Vertical karstification and the main types of karst-forms

Observations were made from the moderate climate, medium elevation karst-morphological territory to alpine (below the snow line) sites. Detailed survey was carried out on some contiguous bedding plane surfaces (some as large as 1000 m^2) of glacial/karstic origin. The common nature of these sites was the lack or minor role of vegetation and soil covering, the separation by scarps from the neighboring areas and the great degree karrenfeld development of the land surface. These are individual (autogenic) units of karstification crossed by very numerous fractures.

Three vertical types of karstification were classified on the study area in regards of extension and nature.

1. Micro-size surface and near surface karstification resulting karstic micro-forms, the karren. *VERESS, M.(1995)* classifies surface, linear, subsoil, vertical and subsurface solution. The various types of solution shall be classified to three types of karstification *(VERESS, M. - ZENTAI, Z. - KOVÁCS, GY. 1999)*, that are the following:

- Surface karren development that shall include surface, linear, local and subsoil solution.

- Vertical karren development that is the result of solution along fractures penetrating the rock, where unidirectional (fracture karren), two-direction (network karren) and local solution (pit karren) can be classified.
- The third type of karren development is represented by subsurface solution within the rock mass.

The present study concerns only vertical small forms made by local solution or connecting by solution.

2. Medium scale karstification and the generated karstic meso-forms. The development of these is tightly tied to the processes of surface solution, the karren development. They develop in part during the merging of smaller karren small-forms and in part as an "overgrowing" in size. It is the essence of the process that the simple growth in size changes the nature of the whole process (e.g. accumulation of snow commences) that activate further processes, in cases some hitherto secondary processes are activated. These meso-forms that are related to local solution and merging will be referred to as "shafts".

3. Grand scale karstification that result the typical alpine vertical forms, the major vertical caves. Processes occurring in this group do not resemble the micro- and meso- scale solution processes, the developing forms can not be derived from the processes of karren development.

This paper considers those forms vertical where the depth of the form is bigger than the biggest dimension of the entrance. Considering this the following vertical karst forms were classified:

1.1 Pit karren: An embryonic type of the vertical solution karst forms. A narrow (1-2 m) diameter cylindrical form (*VERESS, M.-PÉNTEK, K.* 1995). Their making is determined by fractures and their depth can be more than 100 m in extreme cases according to *ZÁMBÓ, L.* (1993). In these cases they can make a link between karren-forms and karstic meso-forms (shafts). Their occurrence is linked to the interior of major karstic forms and karrenfelds where they occur in great numbers. Pits developing near to one another can become connected and make a link towards shafts. *Pits becoming shafts:* can not be considered as full identity forms, they are transition between micro- and minor forms. It develops with the solution connection of pit karren.

Karstic mezo-forms can be classified into three categories: potholes (vertical caves), channel-end shafts and caved-in shafts. *COLLIGNON, B.* (1992) classifies these three types as debris type, snowy-bottomed type and potholes (vertical caves). This classification corresponds to the concepts used in this paper but some differences also occur.

2.1 Potholes: Can be identified with *COLLIGNON, B.* (1992)'s pothole concept. The name indicates vertical karst forms that do not have catchment areas, their entrances are round or clover leaf formed, their profile is narrowing (ice-cream cone shaped). Their walls are smooth, there is poor or no debris accumulation. The making of these pits is understood to be the effect of the karst-corrosion by the snow accumulation in them. Potholes in which snow accumulation commences (see later) can be identified with the snowy-bottomed type of potholes described by *COLLIGNON, B.* (1992). *FORD, D.C. -WILLIAMS, P.* (1989) calls the downwards tightening pits solution shafts that also identifies with the "pothole" (Hung. "zsomboly") word used by *VERESS, M. - HORVÁTH, T. - ZENTAI, Z. 1996, HORVÁTH, E. T.-ZENTAI, Z.* (1998).

2.2 Channel-end shafts are those vertical forms that are situated on bare bedding plane surfaces, have catchment areas and are joined by karren channels. These are nothing else than channel-end pits *(VERESS, M. 1995)* turned to "karren swallets" by growing. Their entrances are tight, irregular or plum-stone shaped, the surface of their walls very rugged. Their development is due to the water running down in the karren channels.

2.3 Caved-in shafts: This form can be identified as *COLLIGNON. B.* (1992)'s caved-in pit. These depressions are mostly situated at the edges of blocks and can be characterized by containing big accumulations of breakdown. Their origin can be explained by the way *KESSLER, H.* (1932) did - by the cave-in of cavities or by the secondary transformation of potholes or channel-end shafts by the effects of freezing that produced a big accumulation of debris.

A survey was completed in *Site III.* in a geomorphological environment and altitude different from those hitherto described (glacial valley). Partly as a consequence of the different morphological conditions and party due to the different method of data processing other vertical meso-forms were specified, part of which can be considered as a transition between vertical and horizontal forms or middle elevation forms (like dolines, *SZABÓ, L. 1998*).

2.4. Dolines transforming to pits: Such major well developed dolines (not the typical dolines of the middle elevation karst plateaus as they are different regarding their shapes and genetics) that contain pits and groups of pits merged by solution at their bottoms. Thus instead of surface solution deepening in the zone of pits is dominant.

2.5. Initial shafts: can be considered as a further developed version of 2.4.: The zone of pits is practically digested and a several meter diameter shaft replaces the merged pits with an accumulation of debris at the bottom, the remains of previous pillars.

3.1. Major potholes (vertical caves): Characteristic major alpine karst-forms. They are generally a complicated system of vertical shafts developing beside and below each other frequently reaching down to many hundreds of meters.

(*BÖRCSÖK, P. - GYOVAI, L.* 1984, *KARDOS, L.* 1988, *RYSZARD, K.* 1980, *SEBESZTHA, Z.* 1984). Their morphology and genetics is different of those described before as they are deeper by magnitude and more complex. *JAKUCS, L.* (1971) considers these caves pre-glacial forms that survived the Pleistocene as well as a result of chemical reactions of slowly and deeply percolating sub-nival cold waters. Hinting at their age the opinion of *BALÁZS, D.* (1990) was that the "giant" potholes of the Caucasian Mts. were made by the melt of retreating glaciers and that they were still being shaped by the accumulated snow and ice that they contain. The inner, deeper situated shafts of the major vertical caves frequently peter out as blind shafts at their tops (*BÖRCSÖK, P.-GYOVAI, L* 1985, *LUKÁCS, L.* 1980), the same way as shafts do in the medium elevation potholes in Hungary (*KÓSA, A.* 1963, 1965, 1989, 1992/a,b, *SZENTHE, I.* 1971). Among many, these facts verify our assumption that the development of major alpine caves does not begin starting from the surface but in the depths of the rock independently from surface karren processes. Thus they do not share any genetic relation to the surface micro and meso-forms. According to the observations of the authors the processes of development of potholes of the medium elevation plateau in Hungary show relations with the major alpine vertical caves.

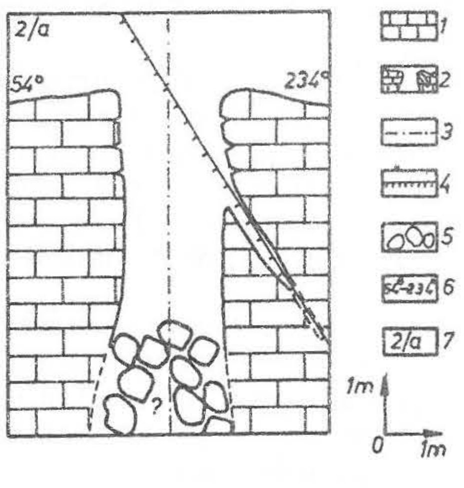

Fig. 1: Vertical section of the type 2/a pothole in the study site of the year 1996.
Legend: 1. limestone, 2. the profile of the pothole, 3. the long axis of the pothole, 4. the plane of the fracture that determines the location of the development. 5. debris (breakdown), 6. direction of the section, 7. identification code of the pothole.

The nature of the vertical meso-forms

Detailed studies were carried out about the vertical meso-forms.

Potholes: are situated at the bottom of glacial valleys and if on the sides of the valley, always on small slope terraces. On the sides of residual peaks and crests potholes were not found. More than one explanations seem to fit the phenomenon:

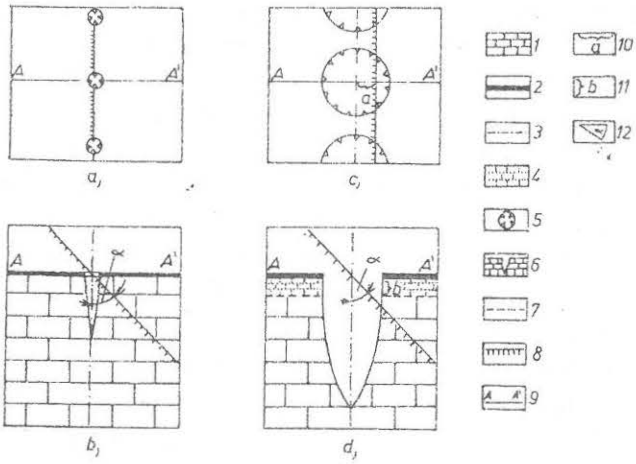

Fig. 2: A result of surface denudation by solution the long axis and the fissure line are shifted from each other (from the angle of the fracture plane to the vertical and the distance of the two lines the measure of denudation of the surface can be calculated since the time of origin of the shaft).
Legend: a, plan view of the site in the initial stage of development; b, A-Á direction section in the initial stage of development; c, plan view of the site in the advanced stage of development; d, A-Á direction section in the advanced stage of development.
1. limestone, 2. original ground surface, 3. long axis of the shaft, 4. rock mass removed by dissolution, 5. plan view of the shafts, 6. side view of the shafts, 7. new ground surface created by the removal of the original rock mass, 8. plane of fissure, 9. direction of the section, 10. distance of the long axis of the shaft and the intersection of the original fracture with the surface after denudation. 11. the measure of surface denudation, 12. the angle of the fracture plane to the vertical.

— Valleys were existing before the periods of glaciation and karstification was most intensive at the valley bottoms. This process prepared and promoted the terrain for present karstification.

— At the time of the retreating of the ice melt-waters infiltrated in the valley bottoms assigning the present locations of solution.

— The process of karstification is present everywhere but its traces are masked by intensive generation of debris on steep valley slopes.

— On terrain of small gradient vegetation is able to proliferate and soils develop generating concentrated solution.

— The axes of valleys are identical with the main tectonic directions as it is known from references *(KÓSA, A. 1967, 1992/b, ELEKES, B.-NYERGES, M.-ROSE, GY. 1992)*, and as it was verified by site studies. This is the cause of the most effective vertical solution.

According to the present knowledge of the authors probably more than one of the listed processes were effective simultaneously or in sequence. The shafts are situated along the fracture lines like beads on a necklace. Their entrances are always traversed by the fracture. The axis of the shafts is almost vertical (the "axis" is understood as the line drawn between the crossing point of the smallest and biggest dimension of the entrance to the deepest point of the shaft) but the angle of the fracture to the vertical varies. It can be seen that the vertical development of the shafts does not definitively follow the plane of the fissure (*Fig. 1*). This conclusion proves that the development of these shafts starts on the surface (at the intersection of the ground surface and the fissure) towards the inside of the rock body. In any other case the intersecting of the entrance and the fissure were not so regular. In cases when the long axis and the fissure line are not identical, possibly the two lines shifted from each other as a result of surface denudation by solution. Regarding this in the knowledge of the angle of the fracture plane to the vertical (α) and the distance of the two lines the measure of denudation (**a**) of the surface can be calculated (denudation by solution = ***a x ctg*** α) since the time of origin of the shaft (*Fig. 2*).

The depth of the studied karst-forms does not exceed 50 m, they consist of a single shaft. As they develop as the enlargement of primary fracture lines (*VERESS, M. - PÉNTEK, K. 1995*) starting at the surface (*VERESS, M.-HORVÁTH, E.T.-ZENTAI, Z. 1996*) they show a close genetic relation to karren development. That's why these forms shall be differentiated from the many hundreds of meters deep complex alpine vertical caves.

The snow accumulated in the pothole-type meso-forms is thought to have a significant role in their development. Based on this opinion four phases in the development of the potholes can be classified *(HORVÁTH, E.T.-ZENTAI, Z. 1998):*

I. The processes in the first phase are the same as described by *VERESS, M - PÉNTEK, K. (1995)*, that is: unsaturated water percolating on the walls of the fracture dissolves the material of the wall and the fissure is enlarged. A karstic micro-form, the crack karren *(PLUHAR A.-FORD D.1970, ZÁMBÓ L. 1993*) or fracture karren *(ZÁMBÓ, L. 1993)* is resulted by the process. The development of the majority of the fractures terminates at this phase (*Fig. 3/a*).

II. Only those forms get into the second stage that deepen quickly enough to keep pace with the widening of the fracture. The condition of this is the occurrence of solution in single points. This can happen in the crossing points of joints or some other lithological, hydrological or other reasons, at the "zones of weaknesses".

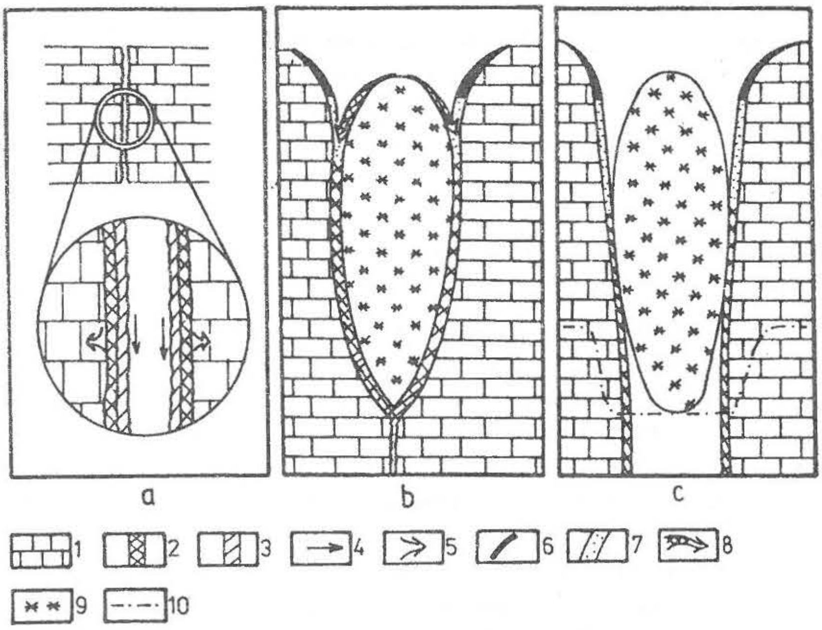

Fig. 3: Stages of development of a pothole.
Legend: a, first stage (after VERESS, M - PÉMTEK, K. 1995) widening of the primary fractures, development of fracture karren; b, second stage, snow accumulation; c, third stage, stabilized deepening after the reaching of the 0°C isotherm. 1. limestone, 2. saturated solvent, 3. unsaturated solvent, 4. direction of the flow of the solvent, 5. direction of the solution enlargement, 6. inactive zone, 7. zone of condensed water solution, 8. direction of the flow of snow melt, 9. snow, 10. maximal depth of frost penetration.

The accumulation of snow begins in the young initial shafts in this phase of development. The accumulating and compacting snow melt dissolves and deepens the shaft. During the annual period this season is the most intensive period of shaft development. After the melting of the snow the shafts (that have no catchment areas) get into a state of inactivity. The deeper, the more developed is the shaft, the longer the melting of the snow takes and the active period of shaft development elongates. For the volume of the shaft increases, not only the active period elongates but the absolute volume of the solvent increases as well. Thus a self-generating process commences in this period (*Fig 3/b*).

III. Phase No. three is not sharply different from phase II. It's the only difference that the accumulated snow would stay all around the year in the shaft. The snow accumulating in the shaft can completely fill it and spring thaw will produce water that makes a water film on the walls. The rock warms more easily than the filling snow and a gap originates between the walls and the mass of snow. The melt-water can dissolve only those parts of the wall where the snow and the rock touch. This section will be positioned ever deeper during the summer thaw. Consequently the bottom of the shaft will remain active all the time in the summer season while the upper levels are inactivated. Where gaps develop between the walls and the snow mass the melt-water corrosion stops. Condensed-water corrosion may commence as the humid air saturates because of the cooling effect of the snow and water condenses on the rock walls. The condensed water dissolves the rock surface, the wall becomes smooth. When the radius of the shaft exceeds a certain measure, the water film disintegrates (*VERESS, M. - PÉNTEK, K.* 1995) and clover leaf cross section shafts may develop.

IV. In the fourth phase of the development the deepening of the shafts stabilizes. This is caused by the equalization of the temperature below a certain depth where the temperature does not drop below 0°C, consequently no snow can be accumulated below the 0°C isotherm. Thus the accumulation of the snow is restricted to a zone close to the entrance. The shaft that reaches this depth can store the same volume of snow from year to year. It can not be excluded in the case of these shafts that the "snow plug" is melted in the winter season caused by upsurging warmer air. Thus these shafts can remain active in the wintertime and deepen (*Fig. 3/c*).

Surface runoff can temporarily enter the potholes, melt-water running on the snow surface can get into the shafts thus the potholes may have seasonal catchment areas. According to this two types of forms, the potholes and the channel-end pits may not be sharply differentiated, transitional forms may develop.

Channel-end pits develop on rocky slopes devoid of soil covering where the karren channels are crossed by fracture lines. At these locations water piracy occurs. During this process the linear surface solution turns to be vertical at the points of the piracy. On these locations vertical karren forms, pit-karren, channel-end pits (*VERESS, M.* 1995) develop. The cavities gradually widen and neighboring pits merge. At the points of the merging the thin terrain between the runnels remain as thin crests and can even make 0.5-1,0 m wide blades in the retreating pit walls making the walls extremely rugged. The channels emptying to the pits make the catchment area of the pits. These catchment areas are not more extensive than several times 10 m^2. The size of the catchment areas influences the depth of the pits. Their entrances are generally narrow quickly narrowing with depth. Their development is due to the effect of percolating melt-waters. They can be regarded as karren-swallets (*Fig. 4*).

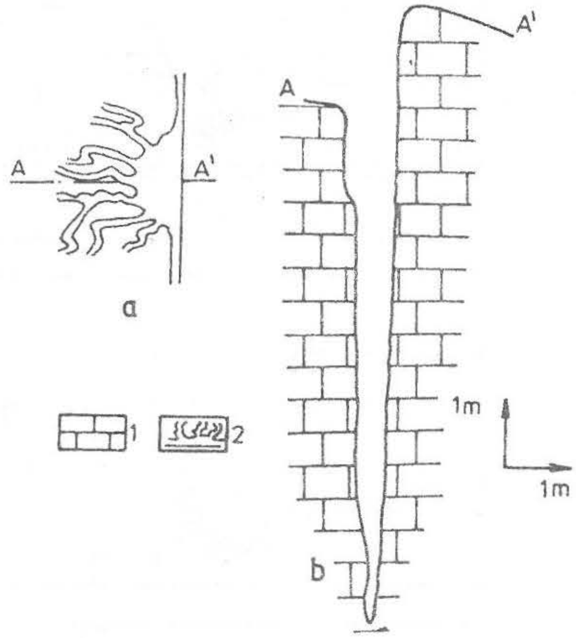

Fig. 4: Channel-end pit in the study site of the year 1996.
Legend: a: plan view, b: section,1. limestone, 2. karren channel system.

Caved-in shafts: can be of varied genetic origin.

— Caved-in shafts can develop as described by *KESSLER, H. (1932)* by the gradual cave-in of subsurface cavities or passages. According the observations of the authors if shafts of such origin are connected to extensive subsurface systems the accumulation of debris can be excessive. Explanation can be found in the great discharge of mild, humid air masses from the major cave system. The moisture in the mild air condenses to ice near the surface in the creases of the rock with much cracking force.

— Caved-in shafts can develop with the merging of fissures *(GRUBER, P.-KOVÁCS, GY.-SOMLAI, SZ. 1998)*. Fissures can develop at fractures, cracks or the planes of changing rock quality. A central role is played in the process by dissolution. Two zones of dissolution can be differentiated: the intensive and the slow zones. The intensive zones are situated at fracture- and bedding planes. Dissolution is quick here because the recharge of the solvent is quick and the process is directional. The zone of slow dissolution is the fresh rock itself that makes the shaft walls. Fractures can merge at the bedding planes if they occur frequently enough. The remnants of partition walls may collapse. The debris can break up even more by dissolution or freezing. This way large quantities of debris can be deposited in the bottoms of the merged fissure shafts.

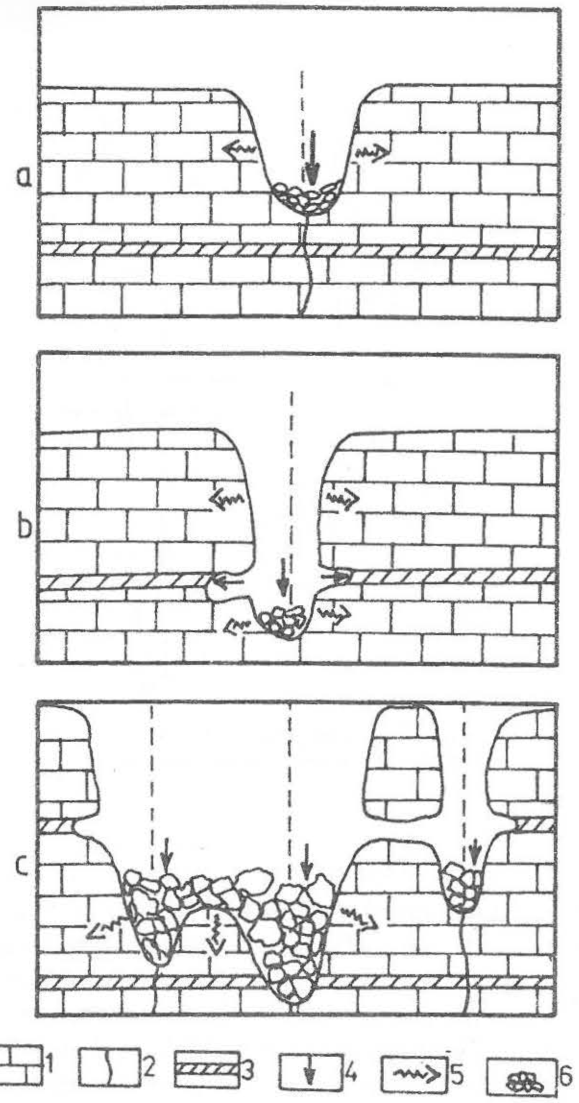

Fig. 5: The development of a caved-in shaft caused by the merging of fractures.
Legend: a. deepening along fractures, b. dissolution along bedding planes, c. merging.1. limestone, 2. fracture, 3. bedding plane, 4. zone of intensive dissolution, 5. zone of slow dissolution, 6. breakdown.

— Caved-in shafts can develop a secondary way too when channel-end pits or potholes are transformed by frost breaking up. During the process the original forms are destroyed. The studies show that such ruining occur more frequently in the potholes than in channel-end pits. This can be explained by the continual retreating of the walls in the channel-end pits caused by the water running in the channels and always new wall surfaces are exposed by dissolution. This way the ruining of the channel-end pits occurs only when the pit looses its catchment area due to some external reason (e.g. the

transformation of the karren environment). This phenomenon can occur partially, on one side the pit wall retreats continually while the other side of the pit looses its catchment area and braking up by frost can freely occur.
The debris in the pits can be originated by frost braking up and from solution. The merging of caved-in shafts can result in large depressions filled with debris. An important cause of the pit development can be their snow fill (*HORVÁTH E. T.-ZENTAI Z.* 1998).

Morphogenetic conclusions

During the survey of pits and shafts the horizontal width and length of the entrances were measured. The following conclusions can be made. The entrance of the caved-in shafts is generally larger than that of the channel-end pits.

Table I. Average dimensions of the entrances of different types of vertical forms

type of pits	width Site No. I.	length Site No. I.	width Site No. II.	length Site No. II.
caved-in type	6.5 m	14 m	6.2 m	9.8 m
channel-end type	2.1 m	4.3 m	2.1 m	5.5 m
pothole type	-	-	4 m	6 m

The two dimensions of the entrance of the pits measured at right angles characterizes the elongation of the entrance. If the ratio of the length and width is bigger than 2, the entrance of the shaft was considered elongated. The majority of the ratio of elongation of the entrances was more than 2.

Table II. The percentage of the occurrences of elongation of more than 2 on study sites I. and II.

type of pits	Site No I.	Site No. II.	average of Sites I. and II.
caved-in type	60 %	69 %	64.5 %
channel-end type	68 %	100 %	84 %

It is suggested that the depth of the pits is proportional with their age, that is: the shallow pits are younger, the deep ones are older. The length/width data hint at the way of development of the channel-end pits. The ratio of the cross section of pits of various depth varies around 2 indicating that the pace of the growth in length and width is approximately constant during the process of development.
The development of the less elongated pit shape can be caused by more than one causes that can be the following:

— The pit develops at the intersection of fractures crossing at right angle. In this case the development happens at the same pace in all directions.

— The surrounding terrain slopes toward the pit at all sides and the preparing fracture is not very well developed. In this case karren channels join the pit at all sides. The development of all karren channels at similar pace results that the catchment area of the pit develops at similar pace in all directions. This way the pit receives similar quantities of solvent from all sides and resulting the retreat of the pit walls at equal pace.

The relation of the depth and entrances of the pits were studied. Studies of this kind were carried out by *SÁRVÁRY, I.* (1970) in the potholes of the Alsó-hegy. The width of the caved-in shafts does not change much with the increasing of the depth while the length of the entrance grows considerably. The entrances of the small depth thus small entrance shafts don't show elongation. On the contrary, the shafts of big depth will be elongated as the width of the entrance remained almost the same but its length greatly increased.

In channel-end pits both entrance dimensions increase in the function of depth and elongation with greater depth is not detectable.

SUMMARY

The paper studies alpine vertical karstic forms. Three forms were differentiated by their dimensions and origin: micro or vertical karren development, meso-forms or the development of vertical shafts and major karstification. The meso-forms were studied in detail. Vertical caves lacking catchment areas but developed by snow accumulations in their interior were classified as "potholes". Karren swallets that are resulted by overgrowing pit karren were classified as "channel-end pits". "Cave-in shafts" were understood as the final product of more than one independent processes.

It was deducted that the studied karstic meso-forms were closely related to surface karren development, they are the products of karren development wholly or in part. As the development of these forms is related to surface karren development, their age can be equal or less than that of the karren. This conclusion puts their age to the time period to the retreating of glacial ice at the end of the Pleistocene.

As a consequence close relation was found between the studied meso-forms and the vertical karren forms. The development of the vertical macro-forms, the major vertical caves can not be explained by the described processes. Their origin and development is different from the above described processes. Their development is independent of surface karren development probably their age is considerably more. The development of the potholes

(vertical caves) of the Alsó-hegy Plateau in Hungary was related to the vertical alpine caves.

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