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Processes and Features of Subsidence Dolines (Sinkholes)

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ABSTRACT

This study deals with the processes of subsidence dolines. These processes contribute to the understanding of the characteristics of karst areas and the relation between dolines and their environment. For this, several hundred dolines of various karst areas were studied. Investigations included measurements of doline size and processes (for example mass movements), the mapping of their morphology and processes, observation and tracking of some processes (for instance water inflow). Laboratory experiments were carried out, and we had VES measurements performed to obtain data on their sediments. The processes of dolines with various development phase were distinguished. The processes of developed dolines were classified according the site of their effect which may be present in the environment, on the side slope, on the floor, on the cover below the floor and in the bedrock. The processes were also put into groups based on their direction. It was established that the degree of supplier and transporting away processes and their value compared to each other controls doline size, while the denudation of the doline slope and the accumulation on its floor influences doline shape.

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1. Introduction

The aim of this study is to overview and categorise processes taking place in the environment of subsidence dolines, inside them, in the cover below the floor and in the bedrock and to investigate their effect on the morphology, size, shape and development of dolines. With the knowledge of doline processes, data can be obtained on a more proper understanding of the characteristics of karst areas and the relation between dolines and their environment.

Specific features of the karst are dolines among which solution dolines, collapse dolines, caprock dolines and subsidence dolines are distinguished [1-6]. Subsidence dolines develop on karsts where there is permeable cover on the karstic rock [2, 3, 7] thus, moraine, weathering residue, loess and alluvium [7-10]. Subsidence dolines are widespread on the Earth’s karst areas such as on tundra karst, taiga karst, temperate karst, mediterranean karst, tropical karst, coastal karst, glaciokarst, limestone karst, dolomite karst and evaporate karst [4, 6, 10-12]. They are widespread in valleys, in larger karst depressions (in solution dolines, in poljes), on abrasion platforms and on fluvial terraces as well as on intermountain plains [7, 12-15]. Varieties of subsidence dolines are suffosion dolines, dropout dolines (cover collapse sinkholes), compaction dolines and sagging dolines [2, 3, 5-7, 15, 16]. Subsidence dolines develop during the local material loss of the cover. Suffosion dolines develop by suffosion, dropout dolines are formed by collapse and grain fall, compaction dolines develop by cover compaction and sagging dolines (sinkholes) are formed by warping of the cover [3, 6, 7], but in addition to suffosion, the above processes may take part more or less in the development of suffosion dolines.

The evolution and development of subsidence dolines is also influenced by other impacts such as water flows, earthquakes, meteoric water, the fluctuation of karstwater level and groundwater level, the burden due to vehicle traffic, vibration and anthropogenic activity and pore water pressure [7, 15, 17-25].

The depressions of subsidence dolines are separated into side slope and floor. The side slope of dropout dolines is steep (nearly vertical), while other varieties have a gentle side slope. They are frequently connected by gullies and creeks, but these features also occur on their floor. Smaller suffosion and floor dropout dolines (with a diameter of some tens of centimetres) may be present on their floor [7].

Their size (diameter and depth) ranges from some meters to several tens of meters. Their density may be great. On the Mecsek Karst, a surface section with a doline density of 380 doline /km^2 occurs [26]. Their development rate (especially that of dropout dolines) is high thus, it can be 0.2 $km^{-2}year^{-1}$ on Kentucky Karst [24], while in Eastern Tennessee a rate of 0.64 $km^{-2}year^{-1}$ [27] is also characteristic. They are mostly young features, their life expectancy is also short, maybe some thousand years.

The processes of dolines are primarily material flows, but there are no material flows as well or processes which are only partly of this character (lakes, dissolution).

2. Methods

More than a hundred subsidence dolines were studied (Carpathian Basin, the Alps, the Dinarides, from the environs of Yakutsk Lena and from the Croatian Adriatic coast) on the covered karst of karsts of various types (temperate karst, mediterranean karst, coastal karst, taiga karst, glaciokarst). The size and processes of dolines were measured (for example the speed of mass movements), their morphologies and processes were mapped and these processes were observed in several dolines. Certain process (for example water flow and the related phenomena) were tracked at various dates and their characteristics were interpreted. The processes were determined by analysing doline features. The processes were identified, taken into consideration and then classified according to their sort and site in the studied dolines. Process varieties were distinguished based on feature varieties (for example mass movements).

Doline covers were investigated to look at doline cover composition by vertical electrical sounding (VES). With the help of laboratory measurements, the relation between the grain size of the cover and the water motion of its water content was studied.

VES measurements and the geoelectric-geological profiles prepared with their help were made in the following way. With the multi-electrode geoelectric technique, two of the electrodes among the many (in our case) stuck into the cover deposit are for current input, while two others function as potential electrode. The current input and the potential-measuring electrodes are continuously exchanged. Eventually, measurements along profile (showing the horizontal variability of specific resistance) and soundings (depicting vertical variability of specific resistance) can be performed without moving the electrodes during measurement. The outcome of the measurement is the so-called pseudo-profile under the measurement line. Applying a suitable inverting programme, a profile of the distribution of specific resistance can be constructed from this profile. Down to some metres depth, the detailed and continuous resistance 'structure' of the cover deposits can be determined. Regarding deviations in resistance, the moisture content of cover deposits and, indirectly, the changes in their pore volume values are measured. The changes in pore volume are represented along a profile.

Laboratory examinations were carried out. Fluvial alluvium was dried at 105 Celsius degree and with the Hungarian standards sieve series of 8 mesh the following grain size fractions were distinguished: < 0.063 mm; 0.063-0.125 mm; 0.125-0.250 mm; 0.250-0.500 mm; 0.500-1.000 mm; 1.000-2.000 mm; 2.000-2.500 mm; 2.500 – 5.000 mm. Density (with pycnometer) and total pore volume were determined. Water lifting ability was studied on materials with grain size of < 0.063 mm; 0.063-0.125 mm; 0.125-0.250 mm; 0.250-0.500 mm; 0.500-1.000 mm; 1.000-2.000 mm, (there was no water lifting on the sediments with the two largest grain size diameter) which were placed into pipes of 100 cm height and 1 cm^2 diameter.

3. Results

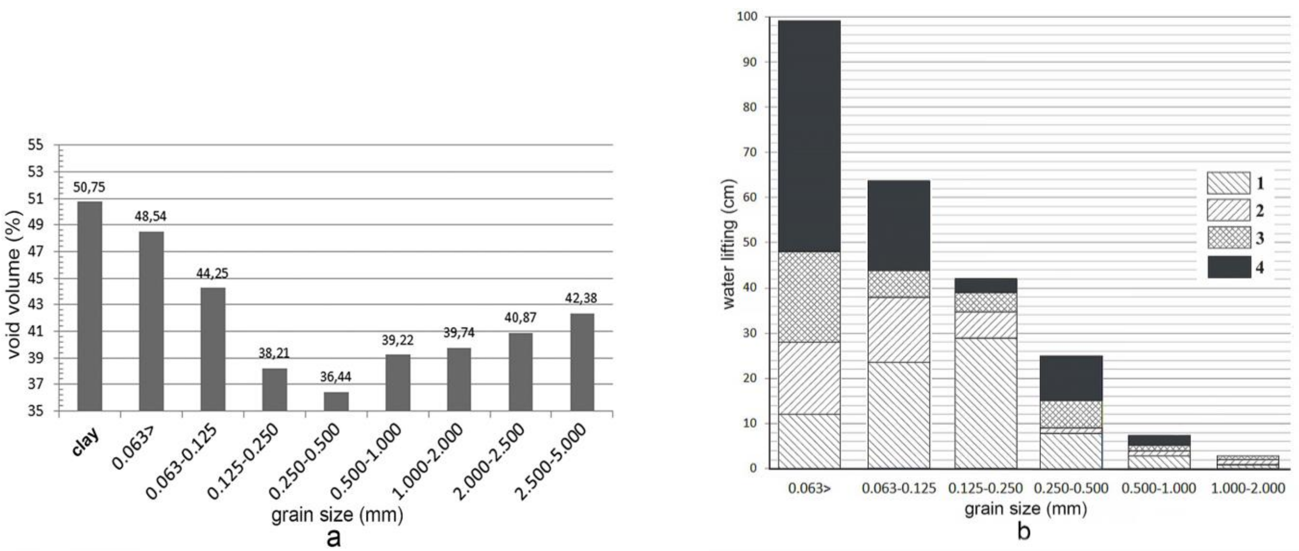
According to VES measurements, the cover can be clay (<0,002 mm), loess, sand, limestone debris (>0.02 mm), or debris of other material (for example sandstone debris) and their mixed varieties (Table **1**). Thus, the doline fill or the sediments of the doline floor are of extremely diverse grain size. Sediments within the same doline may be homogeneous or heterogeneous. In the latter case, the cover is constituted by sediments of various grain size.

Table 1: Sediment types below the floor of some subsidence dolines.

Number of Doline	Sediment (their Order from the Bedrock to the Surface)	Karst Area
1	clay (with loess and limestone debris); limestone debris (clayey); limestone debris	Kőris Mountain, Bakony Region (Hungary)
2	loess (sandy limestone debris)	Tés Plateau, Bakony Region (Hungary)
3	limestone debris (clayey); clay with limestone debris[1];	Tés Plateau, Bakony Region (Hungary)
4	sand-loess (with limestone debris); clay (with limestone debris, sandy); loess, soil, sand, aleurit;	Western Mecsek (Hungary)
5	loess (clayey, muddy), or clay with limestone debris, limestone debris (clayey);	Nagy-mező, Bükk Mountains (Hungary)
6	clayey silt; loose ground (sandstone and limestone debris); loose ground (sand, sandstone and limestone debris)	Pádis Plateau (Romania)
7	limestone debris (clayey); clay with limestone debris;	Totes Gebirge (Austria)
8	clay with limestone debris; limestone debris; clay with limestone debris;	Dachstein, Austria

Notice: [1]it is only present at one of the doline slopes.

As the results of laboratory experiments show, the direction of water motion in the cover depends on grain size (Fig. **1b**). In sediment with a grain size smaller than 0,063 mm, the rise of water level is 99 cm at a 100 cm high column during an hour until it reaches the maximum (it is of various duration in materials of different grain size), while in sediment with smaller grain size, water lifting is smaller and smaller. In the cover with a grain size 0.063-0.125 mm, water lifting is 64 cm, in the cover with a grain size of 0.125-0.250 mm, it is 42 cm, in the cover with a grain size of 0.250-0.500 mm it is 24 cm, in the cover with a grain size of 0.500-1.000 mm, it is 8 mm and in the cover with a grain size of 1.000-2.000 mm, it is smaller than 4 cm (Fig **1b**). In case of larger and larger time, the degree of lifting shows decrease with the increase of grain size. Although the total pore volume increases both by the increase and decrease of the grain size (Fig.**1a**), the capillary pore volume and aggregate pore volume changes differently depending on grain size in the sediment. If the grain size decreases, capillary pore volume increases, while the increase of grain size results in the growth of aggregate pore volume. In fine-grained sediment with a large capillary pore volume [28] water motion is rather horizontal due to great water lifting, in sediments with a larger and larger grain size with large aggregate pore volume, it is gravitational thus, vertical. Thus, the coarser grain size the cover, the more effective the suffosional material transport from the cover into the karst. However, beyond a certain limit, estimated to be some millimetres, suffosion acts as a hindrance thus, the transport of large grains by percolating water is less possible and the drainage passage if it is of small diameter also brakes material transport [29]. In case of a cover with larger grain size, if transportation happens grain by grain, grains can be trapped in narrow passages. This results in the filling of the passage and thus, the material transport stops.



Legend: 1. one-hour-water lifting, 2. five-hour water lifting, 3. 24-hour water lifting, 4. maximum water lifting over 24 hours.

Figure 1: a. All pore volumes at sediments with various grain sizes **b**. Water lifting capacity in the function of time and grain diameter.

Taking their morphologies into consideration, dolines can be developing, developed and denudation dolines according to their development phase. Processes of developing and denudation dolines take place in the cover, while the processes of developed dolines take place not only in the cover, but also in the depression and in its environment due to depression character. Processes and material transport taking place in the doline of different development phase, in its environment and in its cover are described in Table **2**. In the developed doline, the source of the processes and material transport may be outside the doline (its types are mass movements, meteoric water, water flow and wind). Processes inside the doline may occur on slopes (mass movement, meteoric water, water flow) and on the doline floor (water flow, percolation). These processes create denudation and accumulation features in the developed dolines. Material transport from the doline floor may take place into the cover below the floor or into the karst.

4. Discussion

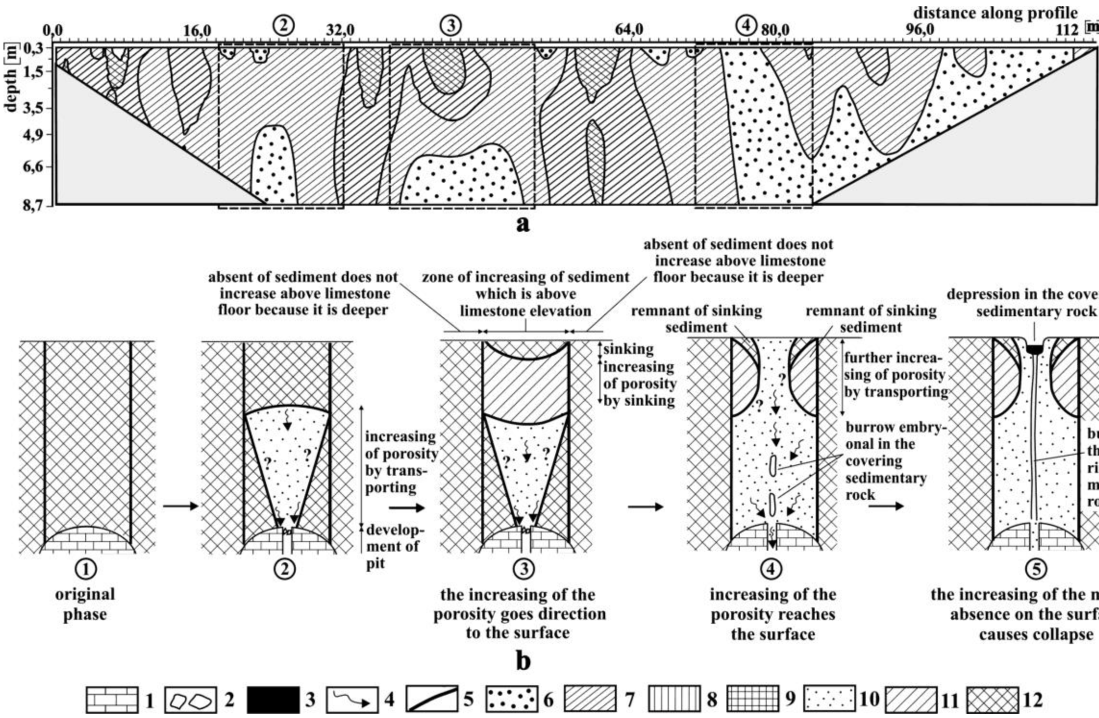
Processes of Developing Dolines

There is no depression yet, or if it exists, it is very small. In the latter case, the feature is mostly not closed, its depth is of some centimetres, and its diameter is some decimetres. Processes directed into the doline are absent. Material transport takes place from the cover from the area of the later doline by collapse [15, 25], by suffosion [3, 7], or by warping [6]. According to laboratory investigations, suffosion happens if the cover is coarse-grained and non-cohesive.

Table 2: Processes and phenomena of dolines.

Process, Phenomenon	Transported Material	Its Site	Doline Development Phase
collapse	solid, liquid (water)	at the site of the later doline	developing
liquefaction	plastic		
material jetting	plastic		
infiltration	water		
suffosion	water, solid		
mass movement	solid, water, air	environment	developed
infiltration of precipitation	water		
avalanche	snow, debris, air		
water flow	air, solid		
wind	air, solid		
zoogenic passages	water, solid		
mass movement	solid, water, air	doline slope	
infiltration of precipitation	water, solid		
water flow	water, solid		
zoogenic passage	water		
infiltration of precipitation	water	doline floor	
suffosion	water, solid		
water flow	water, solid		
collapse	solid		
zoogenic passages	water, solid		
tree deformation	-	doline slope and floor	
root system deformation	-		
material uptake at tree	water		
material loss at tree	solid		
deposition	vegetation waste, solid	inside the lake	
overflow	vegetation waste	at lake margin	
colloid ring	solid	on trees of lake	
water flow	water, solid	in the cover	
dissolution	solution	doline slope and floor	
material jetting	solid	from cover passage into doline	
collapse	solid	bedrock passage	
overflow of permanent lake	water, solid	at doline margin	denudation
activated charcoal	-	cover	
limonite	-	cover	
limestone concretion	-	cover	

Suffosion is accompanied by material loss and then it is followed by pore volume increase which results in passage development and the warping of beds (Figs. **2**, **3**). Developing dropout dolines are characterised by collapse (Figs. **4A**, **4B**, **4C**), in case of suffosion dolines, collapse is only specific of developed dolines. Collapse takes place in case of fine-grained and cohesive cover [3,15] since fine grains favour horizontal water movement and cavity formation in the cover. The cohesiveness of the cover increases the chance of the stability of the cover



1, limestone, 2, breakdown which consists of limestone, 3, breakdown which consists of superficial deposit, 4, water infiltration and suffusion in the superficial deposit, 5, boundary of sedimentary rock with various porosity; a. measured specific resistance: 6. 1-5 Ωm, 7. 5-50 Ωm, 8. 50-120 Ωm, 9, 120-400 Ωm, b. theoretical porosity by using specific conduction: 10, porosity of the superficial deposit is high, 11, porosity of superficial deposit is medium, 12, porosity of superficial deposit is low; The sub figures 2, 3, 4 of the figure were constructed with the parts of the measured figures (a) marked with broken lines.

Figure 2: Development phases of non-karstic pipe in the sedimentary cover [30].

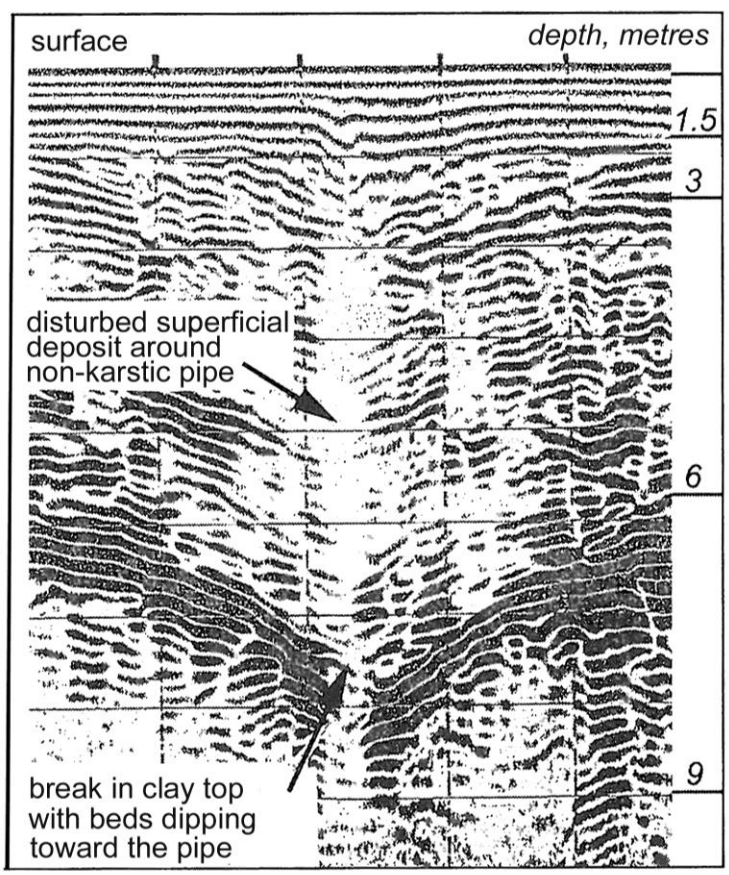
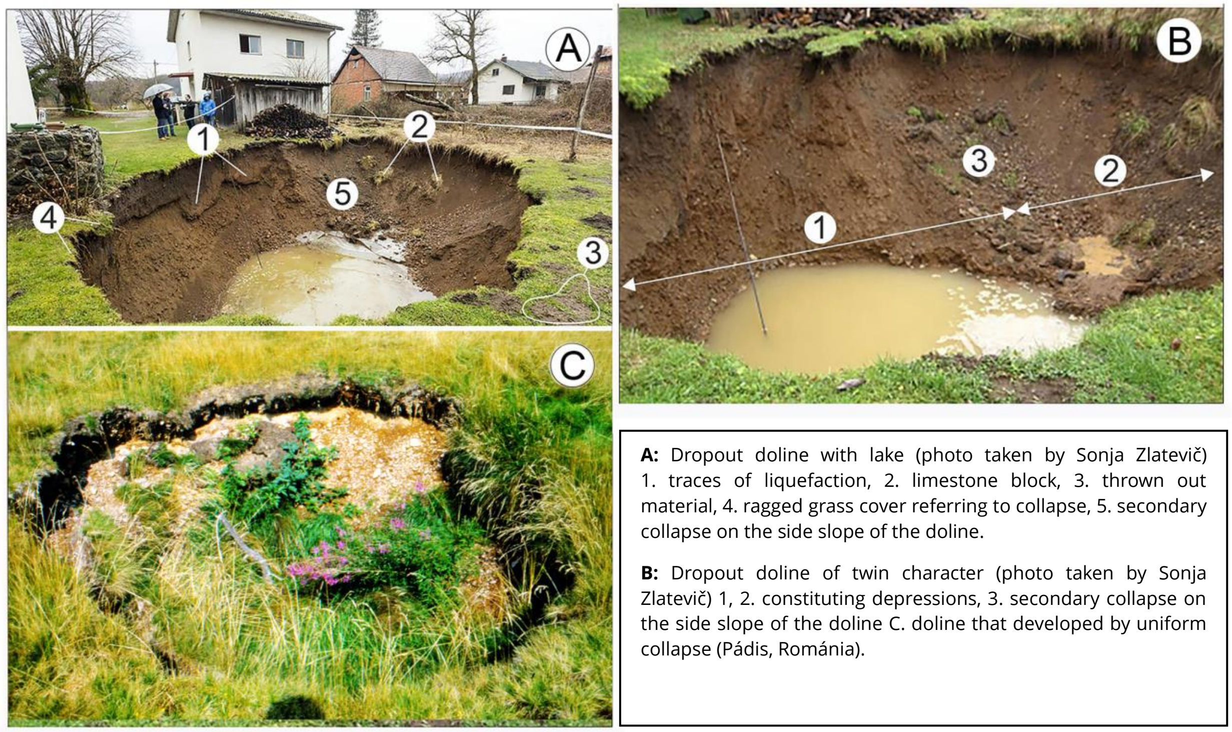


Figure 3: An image from ground probing radar that could not reach below the clay [31].



A: Dropout doline with lake (photo taken by Sonja Zlatevič) 1. traces of liquefaction, 2. limestone block, 3. thrown out material, 4. ragged grass cover referring to collapse, 5. secondary collapse on the side slope of the doline.

B: Dropout doline of twin character (photo taken by Sonja Zlatevič) 1, 2. constituting depressions, 3. secondary collapse on the side slope of the doline C. doline that developed by uniform collapse (Pádis, Románia).

Figure 4: Dropout dolines.

cavity. The chance of the collapse of the cover cavity is increased by water level decrease [25], earthquakes [32], vibration and vehicle traffic [15]. Water level decrease and drainage may be accidental [19, 33, 34], or active, conscious water level reduction [20, 35, 36]. Collapse may happen by the collapse of the cover cavity [15,25,32], which is enabled and triggered by the large bedrock cavity [37-39]. The process may take place in a way that the collapse of bedrock cavities is inherited onto the surface through the cover resulting in the development of dropout dolines [40].

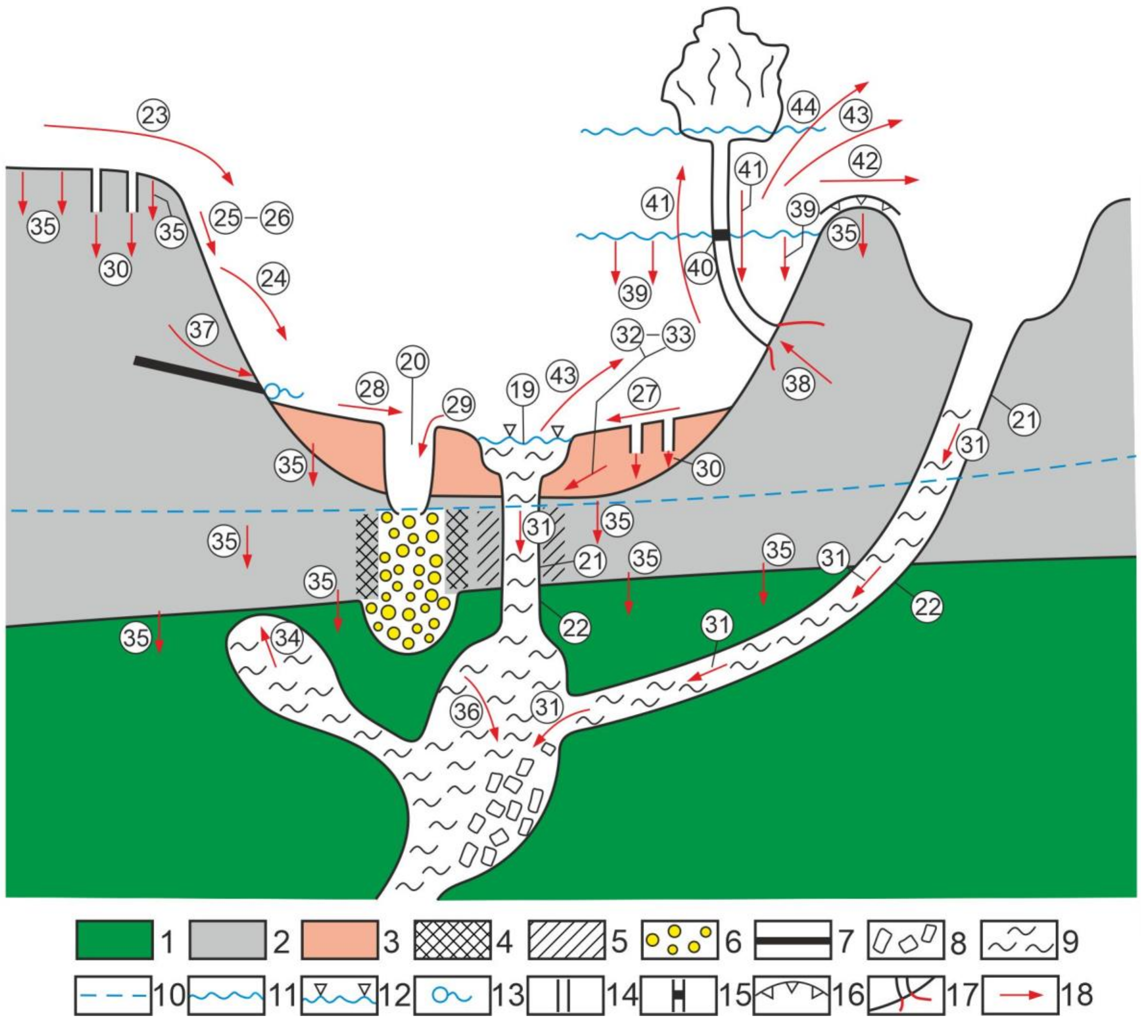
Processes of Developed Dolines

A developed doline has a depression which may take place by the warping (subsidence) of cover beds if there is material shortage below the beds, by surface subsidence (the beds thin out) which can be the result of suffosional material transport and the erosional denudation of the surface. A precondition of the latter is the existence of a drainage passage. Warping happens when material is transported away from the lower cover layer and the upper layer bends into the thinned-out lower beds which developed in this way [41], or at the evaporate bedrock [6], where intensive dissolution results in material deficit. Their processes are described in Table **2** and in Figs. (**5** and **6**). The processes are material flows of various state. The processes of developed dolines are mass movements (solid material, water, air), water flow (water and dissolved material, suspended and traction solid material), avalanche (solid material, water), wind (air and suspended, solid material). Since dolines of this maturity have a depression, material transports take place from their environment, but processes are also induced inside them. The processes may be active (it is triggered by the relation between the depression and its environment) and passive (material transport into the doline is accidental).

Meteoric water and water flows are active processes. The quality, quantity, and composition of the inward transported material depends on surface inclination and cover quality. Meteoric water destroys the environment of the doline evenly, while water flows create channels, gullies, creeks, and valleys (Fig. **7A**). Passive processes are mass movements, on coasts, transgression, in river valleys, floods and material transport by organisms. The occurrence of mass movements is controlled by the dissectedness of the environment, and the quality of the constituting rock therefore, they mainly exert their effect in high mountains and on glaciokarsts. The inward transported material may be accumulated in one part of the doline (Figs. **7B**, **8A**) or in its entire area. In the latter case, the doline may become filled completely. In case of transgression, dolines are not only filled up, but also buried. Upfilling may be uneven in case of the wind and avalanches. Here, the sedimented material may be accumulated in one part of the doline increasing its asymmetry.

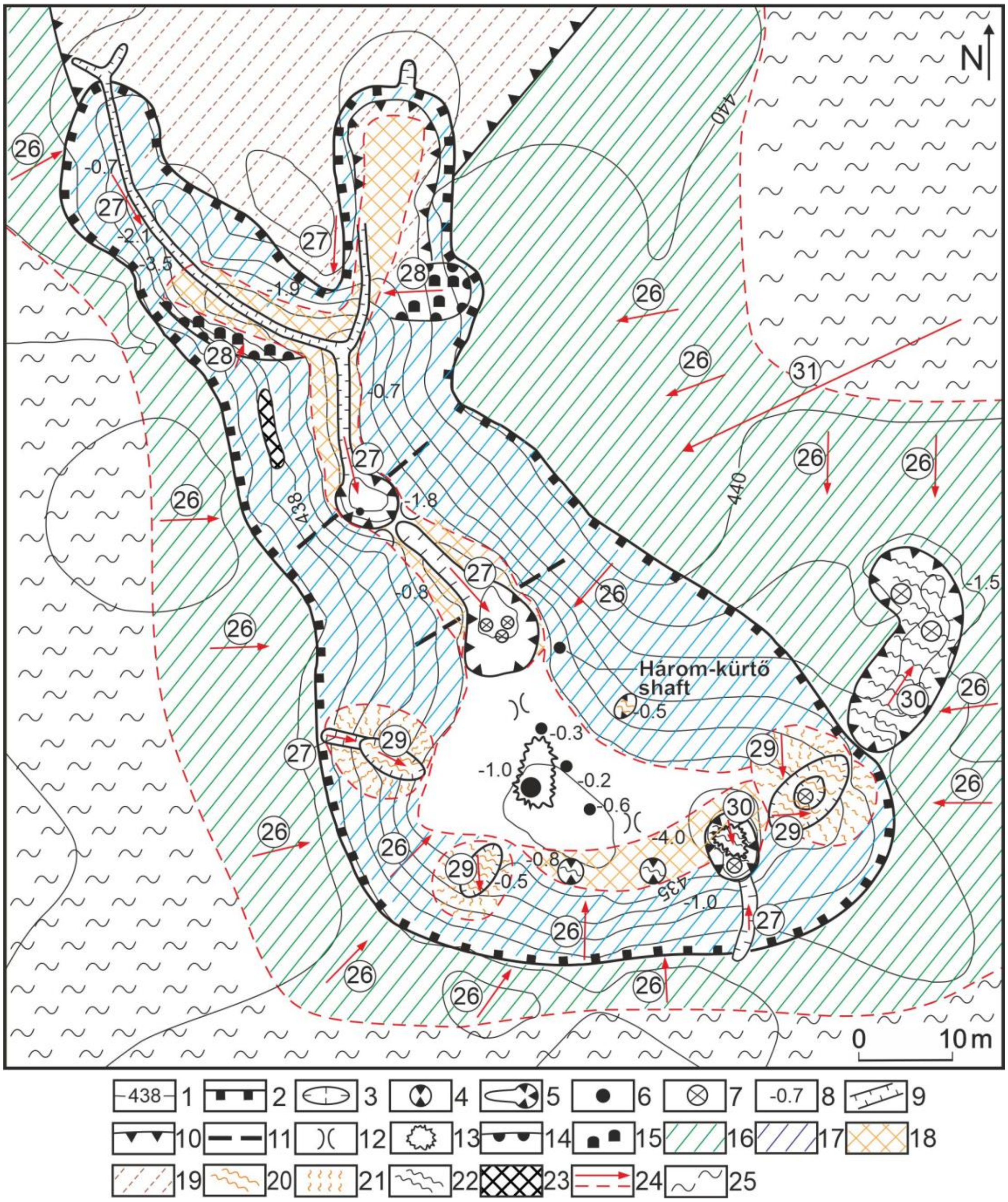
The material transported into the doline may be accumulated for longer or shorter time on the floor and may be transported partially or completely into the karst. The proportion of this two depends on to what extent the doline is filled (if it is filled to a great degree, the transportation away is of lower degree) and on the maturity of the passage that developed on the floor.

Material cycle within the doline is directed from the doline slope to the floor. The processes of doline slopes are mass movements, meteoric water and water flows. The latter may be fed by meteoric waters of external origin (mainly snow melt) or the intermittent springs of the doline slope whose waters originate from the superficial deposit.



1. limestone, 2. autotochthonous cover, 3. allochthonous deposit, 4. fine-grained, cohesive cover, 5. coarse-grained cover, 6. collapse sediment, 7. impermeable intercalation, 8. collapsed bedrock, 9. water fill, 10. high groundwater level, 11. water level of intermittent lake, 12. water level of the intermittent lake of suffosion doline of floor position, 13. spring, 14. zoogenic passage, 15. colloidal coating on tree, 16. accumulation of vegetation waste, 17. tensile roots and supporting roots, 18. process, 19. floor suffosion doline, 20. floor dropout doline, 21. suffosion passage, 22. passage in the bedrock, 23. external effects: precipitation, water flow, mass movement, wind, organisms, flood of fluvial origin, transgression, processes on the slope: 24. mass movements: collapse, slide, landslide, soil creep, 25. precipitation, 26. water flow, processes on the floor: 27. precipitation, 28. water flow, 29. collapse causing dropout doline development, cover and bedrock processes: 30. water motion in zoogenic passages, 31. water motion through karstic passages, 32. CO_2 absorption, 33. dissolution on the limestone debris of the cover, 34. paragenetic dissolution, 35. infiltration and suffosion, 36. collapse of cover, 37. water motion above aquifuge, processes related to lakes and vegetation: 38. tensile effect of root system, 39. deposition from lake, 40. colloidal coating development, 41. material transport related to vegetation, 42. overflow, 43. material transport related to rising water level, 44. material thrown out to the effect of earthquake (only at dropout dolines)

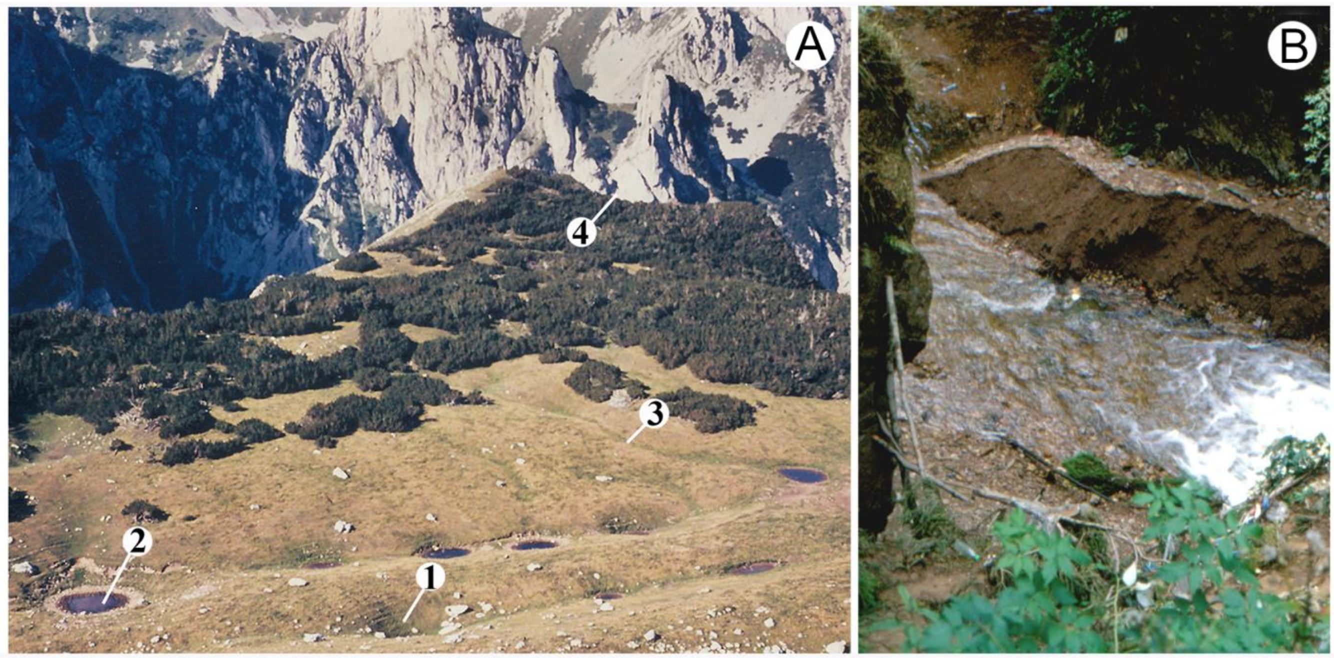
Figure 5: Processes of developed suffosion dolines.



1. contour line, 2. depression margin, 3. suffosion doline, 4. dropout doline, 5. ponor, 6. shaft, 7. drainage passage, 8. doline depth, 9. channel, 10. creek, 11. rock boundary, 12. saddle, 13. rock outcrop, 14. scar of landslide, 15. pile of landslide, 16. external denudation due to meteoric water, 17. internal (slope) denudation due to meteoric water, 18. accumulation due to water flow and meteoric water, 19. creek transformed by pluvial erosion, 20. area of large suffosion, 21. area of small suffosion (estimated expansion) 22. area of collapse, 23. area of slope part transformed by zoogenic effect (badger), 24. process, expansion area of process, 25. surrounding terrain, 26. material transport by meteoric water, material transport by water flow, 28. material transport by landslide, 29. infiltration, suffosion, 30. collapse, 31. former material transport by wind (material of loess).

Figure 6: Processes of a depression (Tés Plateau, Bakony Region, Hungary).

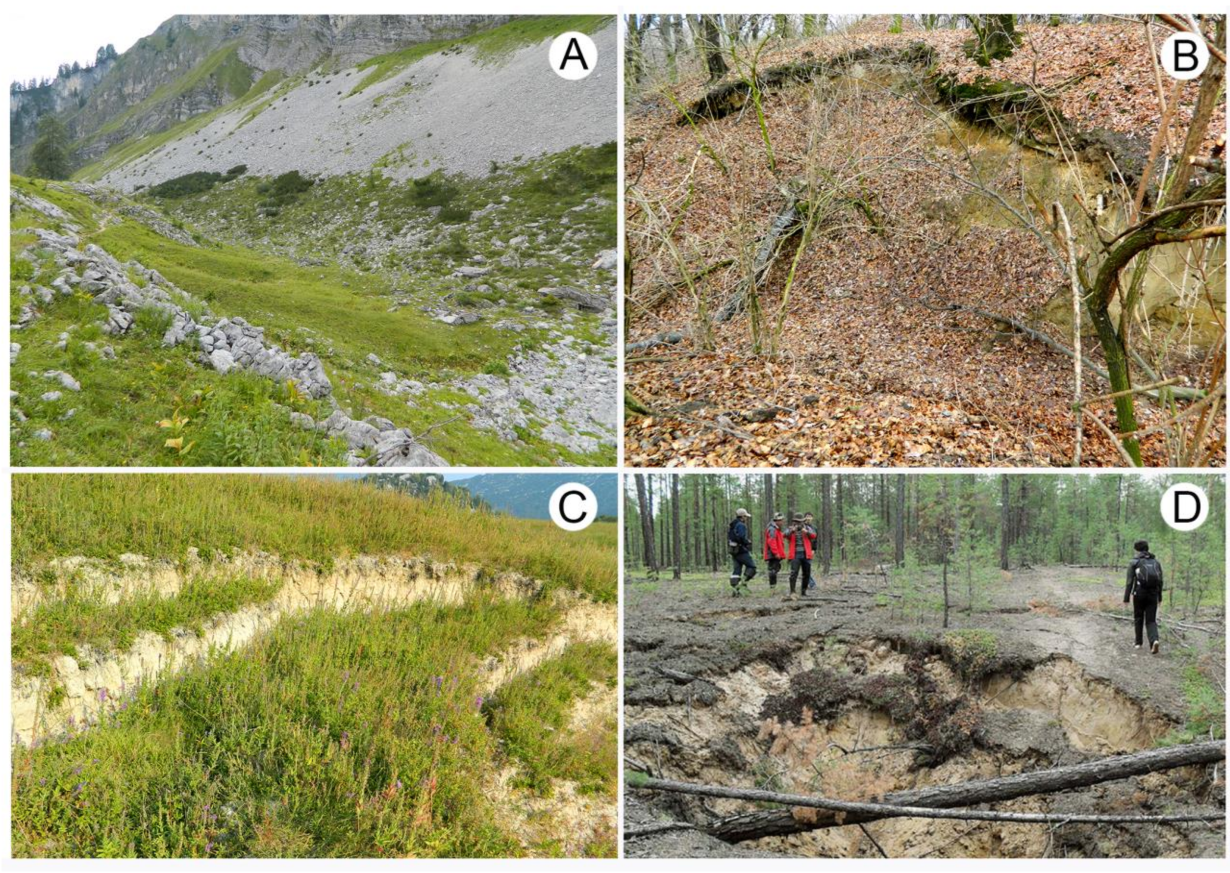
Mass movements occur in dolines where the slope is steep, the cover is waterlogged, the sediment is thick and there is an aquifuge in it and there is no or only a little vegetation. The mass movements of dolines are of small expansion, their groundplan coincides with the shape of the doline side, and they are arcuate. Among them there may occur collapses (Figs. **4A**, **4B**), various slides (Figs. **8B**, **8C**, **8D**), landslides and soil creeps. The latter results in the modification of the trunk and root system of trees. Mass movements cause local accumulations on doline floors which may also increase doline asymmetry. These processes are reflected by the trees of dolines among which there are partly buried trees (Fig. **9A**), inclined trees, trees whose trunk is curved because of slow mass movements and trees whose root system adjusted to the process (Fig. **9B**).



A: gullies related to dolines (Durmitor, Hungary) 1. active doline, 2. inactive doline, 3. erosional channel, 4. Susica canyon.

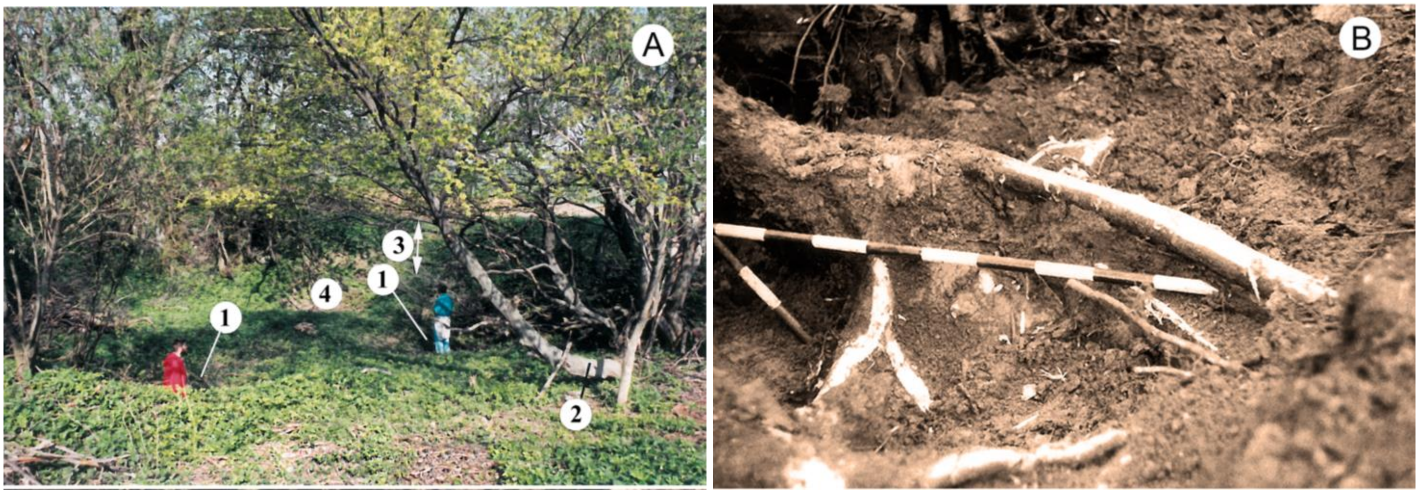
B: denudation of the accumulating sediment by creek on a depression floor (Pádis Plateau, Romania).

Figure 7: Water flows.



The debris cone of mountain fall and stone fall at the slope of a glacier valley, the dolines partly developed on this and its material was partly transported into them (Totes Gebirge, Austria), B: arcuate slide on a slide slope of a depression (Tés Plateau), C: slice-like landslide on the side slope of a doline of a Croatian polje, D: soil collapse and liquefaction on a side slope of a doline as a result of melting permafrost (Léna Valley, Italy).

Figure 8: Mass movements in dolines.

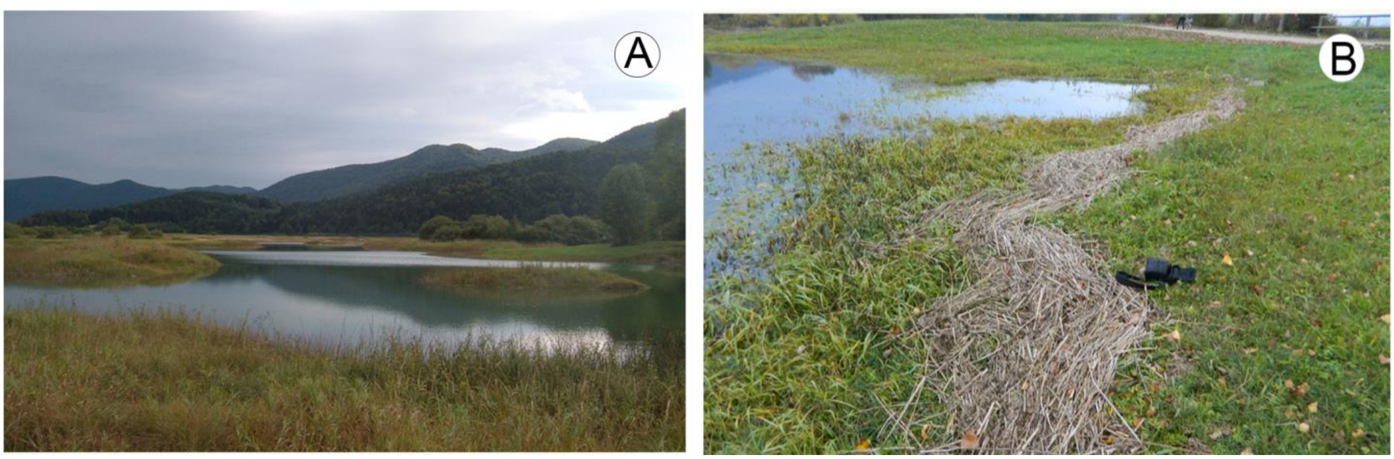


A: Tree with buried trunk at the margin of a doline (Hárskút Basin, Bakony Region, Hungary), 1. internal depressions, 2. buried trunk, 3. western side of the filled depression, 4. depression floor almost plane due to infilling, **B:** modification of the root system of a tree (at the top, modified root system due top due to tensile effect, at the bottom, supporting root) as a result of soil creep (Hárskút Basin, Bakony Region, Hungary).

Figure 9: Trees in dolines.

The processes of the doline floor can be related to denudation and accumulation too. Water flows, percolation, and thus, suffosion (suffosion can only take place above the current groundwater level) have an effect here too. Denudation features can be connected to water flows such as gullies and creeks, at the termination of water flows alluvial cones (Fig. **7B**), in case of mass movements, debris cones may develop.

In subsidence dolines lakes may develop [7] during floods (when the quantity of inflowing water exceeds the degree of drainage) or during the rise of groundwater level (Figs. **4A**, **4B**), and karstwater level (Fig. **10A**). Lakes may overflow dolines and the lakes of adjacent dolines may coalesce (Fig. **10A**). The water level of intermittent lakes fluctuates. In case of standing water level, rings of vegetation waste are formed at the margin of lakes (Fig. **10B**), while on trees colloidal rings develop. In the doline, material with that grain size settles down from the suspended sediment whose deposition rate exceeds the subsidence rate of the lake water level [7, 42].



A: Common lake filling the floor depressions of several poljes which developed as a result of the rise of karstwater level due to rainfalls (Cirknitz-polje, Slovenia) **B:** Vegetation waste ring at the lake margin of a subsidence doline of Cirknitz polje

Figure 10: Lakes in subsidence dolines.

The transportation of floor sediments which can be autochthonous or transported, is directed into the cover below the floor or into the bedrock. Transportation away may happen by percolation and thus, by suffosion or through passages due to water flows (which may also be of zoogenic origin) and by collapse.

Material motion below the doline floor is of two direction: either it is transported deeper or oppositely into the doline or into its environment.

Doline development is repeated on the dolina floor to a lower degree. During this process, both floor suffosion dolines and dropout dolines may also develop in the same depression. In case of coarse-grained cover, floor suffosion doline is formed, while in case of fine-grained and cohesive cover, dropout dolines develop.

The sediment below the doline floor may also move towards the surface. Sediments are transported on the doline floor when the rising groundwater level or karstwater level reaches the doline floor. This process is common on polje floors (Fig. **11**).

Liquefaction may also take place to the effect of earthquakes [43-45], mainly on sandy sediments in case of earthquakes with a magnitude larger than 5.5 M [43, 46]. Quakes cause pore volume decrease which results in material jettings [47]. This phenomenon characterises the first phase of doline development when doline formation is triggered by earthquakes (Fig. **4A**). However, material is also transported out of the doline when the lake with fluctuating water level reaches the doline margin and the water overflows it.

Denudation Dolines

If the passages of the doline floor are plugged, the depression becomes filled (Fig. **12**). The first sign of the stop of water transmission from the doline into the karst is indicated by the vegetation waste that settled down on the floor (at most decreased water drainage occurs with percolation) then sediments with laminate develop when percolation stops [7]. Plate pairs of some millimetre thickness are formed. Plate of coarser material develops from permanent lakes by deposition, while plate of finer material is the result of the evaporation of lake water. (Every lake development is followed by the formation of a plate pair).

Figure 11: A: Sediment that deposited from karstwater flowing out of passages on the subsidence doline floor of Cirknitz polje.

Figure 12: Upfilled subsidence doline (Durmitor, Montenegro).

Groundwater develops below the doline floor when the whole water drainage stops. The water of the lake (which may originate from groundwater too) may flow out of the doline and contribute to the development of other dolines. Subsequently the stop of water transmission mainly various materials of lenticular and concretionary structure develop in the fill. Veress [7] distinguished limonite, limestone concretions and activated charcoal in the sediments that became exposed in the test pits. According to Fekete [48], limonite is formed in reductive environment at groundwater. The formation of limestone concretions is due to the decrease of acidity since activated charcoal fixes acids. The development of activated charcoal can be traced back to oxygen deficient environment (thus, it develops below groundwater level).

Conclusions

Several processes can be distinguished in subsidence dolines and in their environment. Processes indicate the state of environment and of dolines and the maturity of dolines. The character and intensity of the processes represents the presence or lack of the balance between the dolines and the karst. The disruption of the balance results in the rearrangement of the processes, the new balance causes the alternation of the system of processes.

The doline is in balance when the quantity of the inward and outward transported material is equal. The balance relations of the doline change if the quantity of the material arriving from the environment or that of the material transported away from the doline changes.

In developing dolines, transportation away processes are specific, while in denudation dolines, accumulation processes are dominant. In case of developed dolines, inward transportation processes decrease the size of the doline by filling, while transportation away processes increase doline size and thus, the diversity of doline morphology. (Doline morphology is also shaped by processes inside the doline.) The most important inward transportation and reworking process is water transport, while among transportation away processes, suffosion is dominant.

If the quantity of the material transported out of the doline is larger than the quantity of the material transported into the doline, the size (mainly the depth) of the doline increases, if it is smaller, then its size decreases. If the quantity of the material that was denuded from the doline slope is larger than the away transported material quantity, the shape of the doline changes because of its filling up, but its expansion may increase too. Its shape also changes if the material that became denuded from the slope is not transported away, but it is accumulated on the floor. If the intensity of transportation away lags behind the intensity of accumulation, the doline is filled up. Finally, the change of the shape may be the result of the fact if material of different quantity is transported from various parts of the environment of the doline or from its opposite slopes onto the floor or on it slopes.

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