Carpathian Journal of Earth and Environmental Sciences, September 2011, Vol. 6, No. 2, p. 183 - 194

DEVELOPMENT OF KARREN FORMATION ON THE SALTIC HILL OF PRAID (TRANSYLVANIAN BASIN, ROMANIA)

Márton VERESS, János PUSKÁS, Zoltán ZENTAI & Zsolt BENKÓ
Department of Physical Geography, University of West Hungary, H-9700 Szombathely, Károlyi G. tér 4. HUNGARY
vmarton@ttk.nyme.hu, szlgy@ttk.nyme.hu

Abstract: The karren formation of salt dome of Praid (Transylvania, Romania) was investigated. Different parameters of the karren features of the halite were measured along profiles. The rillenkarren and rinnenkarren were classified by using the measured data. The development of rillenkarren and rinnenkarren further more that of the Spitzkarren was presented. We explained the karren formation of the salt. It depends on the quantity of the water. The relationship between the quantity of the water and karren features was analysed. Using the development of karren formation we sketched the development of a salt slope.

Key words: salt dome, rillenkarren, rinnenkarren, spitzkarren, pinnacle, specific width, shape of the karren feature, karren formation, Praid, Romania.

1. INTRODUCTION

In this study we investigate the karren formation on the halite outcrops appearing in Praid (Transylvania, Romania, Fig. 1). The solution of the halite is a fast process. During solution halite is separated into ions. This process happens in one phase at the lower pH, values while it happens in two phases if the pH value is high.

Figure 1: Research area: Legend: 1. settlement, 2. road, 3. contour line, 4. waterwash, 5. salt dome, 6. research area

Karren features are produced by water flowing on slopes or infiltrating into the rock and by raindrops. The karren created by flowing water may be classified into two groups. A group of forms which were created by sheet water: such as rillenkarren, trittkarren, and scallops and solution bevels. Those created by rivulets: are rinnenkarren (rinns), wallkarren and meanderkarren (Fig. 2, Veress et al. 2009, Veress 2010). The following features can be created on halite too:

- Rillenkarren are flutes with the same direction as the dip of the slope. The depth and width of the flutes are a few centimetres. Their length is of a few decimetres. They widen at their ends.
- Rinnenkarren create troughs. The direction of the trough concedes with the line of the dip of the slope. Their width and depth may be a few decimetres, while their length is a few metres. They are areics and do not taper out at the ends.
- Wallkarren lie on steep slopes. They form channels or troughs.
- Pits (pipekarren) are vertical tubes in the rock.
- Spitzkarren are created from conical-shaped forms. These are solution remain forms. Their height is from a few centimetres to a few decimetres. But forms which are several metres high occur on the tsingy. These forms are termed as pinnacles already.
- The solution bevels (solution levels, Ausgleichfläche) are planar surfaces, which occur under the rillenkarren.

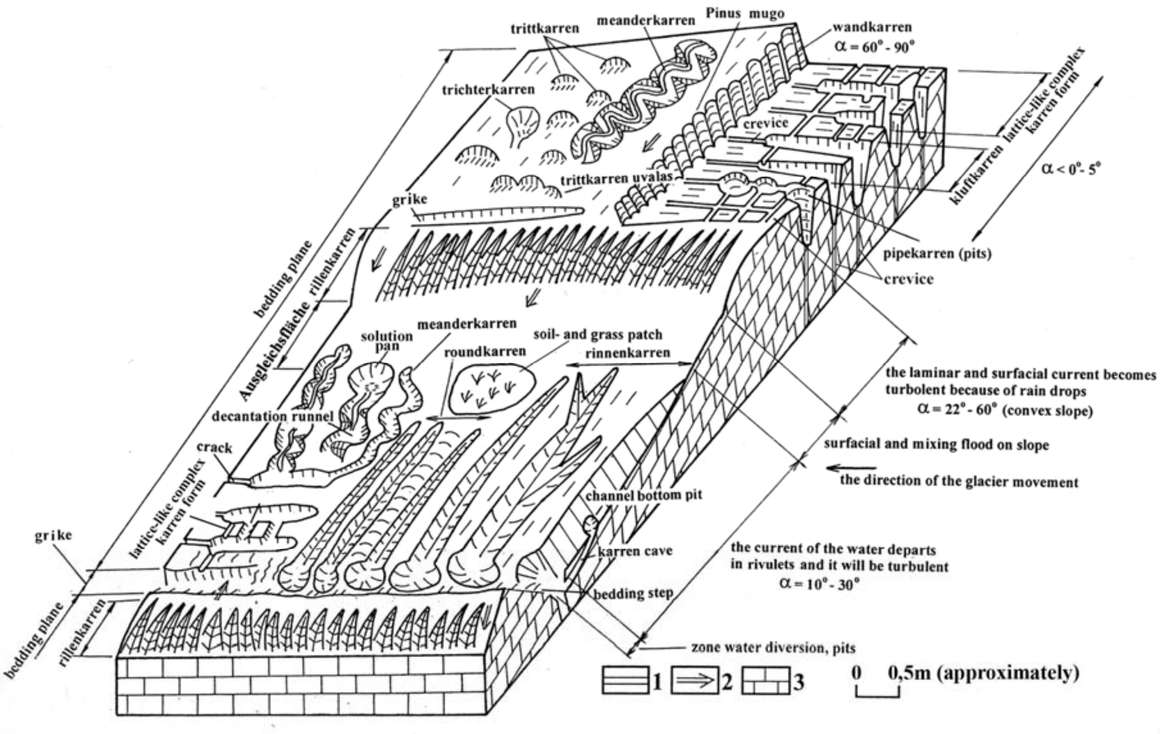

Figure 2: Main karren forms on bedding planes truncated by glacier in high mountains (Veress 2010)
Legend: 1. crack, 2. line of the dip of the surface, 3. limestone

The karren features of evaporates were described by Macaluso-Sauro (1996), Calaforra (1996), Andreichuk-Eraso (1996), Jennings (1985), Ford-Williams (1989, 2007). Where extrusion of the halite surface is slow, the karrenforms are rillenkarren, wallkarren, the pinnaclekarst (Ford-Williams 1989, 2007, Madonia-Sauro 2009). Where the extrusion is rapid, salt-glacier develops (Jennings 1985). See later Macaluso-Sauro (1996) distinguished micro, small and mesoforms in the Sicilian coastal environment. According to them the microforms of the halite are micro-meanders. The microforms of the salt are the minute craters, the minute spitz, the rills (rillenkarren), the solution levels and pans in boxes and runnels. The runnels create a transition to mesoforms. The mesoforms are roundkarren. Tubular karren on halite karst near Berezniki town (Urals) were described by Andreichuk-Eraso (1996). The depth of the tubular karren may be several metres. Their density is great. These features develop under the permeable covering sedimentary rock. This sediment is redeposited from the surroundings of the tubular forms to their bottoms.

The halite of Paraid is one of the outcrops of the Transylvanian Basin. Har et al. (2010) investigated the mineral characteristics of the outcrops near Sovata from the above mentioned halite outcrops. The expansion of halite appearance is 72 hectares at Praid .Its relative altitude is 60-80 metres. It is termed Salt Hill in earlier articles (Benedek 1905), concerning Saltic Hill in the newer studies (Ozoray 1963). The age of its outcropping is estimated to 6000 years (Ajtay 1989).

Various models were created to demonstrate the development of halite. The so-called deep basin – shallow water model explains the development of Transylvanian halite well (Kendall-Skipwith 1969).

The salt appears on the surface at several places on the margin of the basin. Therefore the margin is termed diaper belt (Ajtay 1989). The cause of the process is the following: the salt can become plastic (state) due to pressure, sometimes it moves towards places with less pressure. The belt with the less pressure will be the margin of the basin.

The salt creates diapers and salt stocks during its pushing because it goes through the covering sedimentary rock. Where the extrusion is slow capture happens on the diaper due to solution. If the extrusion is faster, the diaper is not captured (Talbot-Jackson 1987). In the former the case the salt diaper is covered by clay. Pipes, which are passed from salt to the clay, can occur on the clay (Quinlen 1978) in the later case the salt appears on the surface if the climate is dry. A salt-dome develops. Then salt-glaciers develop. But the salt dome may be truncated. Solution dolines, epigenetic pipes, crevasses and salt swamps can develop (Jennings 1985). If the elevation of the diaper is very fast, the salt may appear on the surface even at humid climate too. Therefore the salt of the diaper of Praid may appear at the surface and it creates a salt-dome. The velocity of the elevation of the salt-dome is 30 mm/year here.

The covering sediment rock on the area of the salt dome is created from fluvial sediment partially. Gravels occurring in the sediment prove this. The original covering sediment rock (clay) was partly destroyed from the salt-dome.

The gorge of the Corund Brook cuts the Saltic Hill. According to Ozorary (1963) the brook cuts into the lobe (side) of onticline during slipping. Antecedent gorge part was created during the process (Ozoray 1903). Its direction is E-W. As far as from the study of Orbán (1868) the Corund Brook bypassed the Saltic Hill from West in 1700 is. Later it created a through cave in the salt-dome. Probably the opening process contributed to the development of the antecedent gorge too.

2. THE METHODS

We carried out our investigation in a depression system at the side of the brook's valley.

The depression system is elonged in the dip direction of the slope. The depression system has a northern system part and a southern system part which are separated from each other by a ridge. The depressions are asymmetrical. Their northern slopes are long and gentle, their northern slopes are short and steep. The southern depressions are in a covering sedimentary rock. The salt appears to the surface only at a few places in them. The salt creates mounds ('salt rocks' or salt pinnacles) in the northern depressions of the system. The salt appears at the bottoms of the depressions in the northern depression system. The salt appears on the ridge which is between the two depression systems.

The karren features were measured along profiles. The profiles were created at the bottom of the northern depression system between an inner depression with pit and an inner doline.

Measuring happened along 5 profiles: 3 of them were on the surfaces with rillenkarren, 2 of them were on surfaces of the rinnenkarren (Table 1).

The following characteristics were measured along the profiles (the direction of the profiles were identical with the strike of the slope). The detailed presentation of the method may be seen, in studies of Veress et al. (2008) and Veress (2010):

- the places, the direction, depth and the width of the karren features,
- the inclination and dip angle of the bearing slope.

We calculated the density of the karren features (ρ), specific width (c), specific shape (l) of the karren features. These values may be calculated as follows:

$$c = \frac{\Sigma a}{m}$$

where: a: the width of the karren features

m: profil length

$$l = \frac{\Sigma f_0}{m}$$

$$f_0 = \frac{a}{b}$$

where: f_0: the shape of a the karren feature

b: the depth of the karren feature

We constructed the frequency dispersion of the width and the shapes of the different type rills (Fig. 3), further more the frequency dispersion of the direction of the various type-rills and rinns (channel) and the inclination of the bearing slope (Fig. 4, 5).

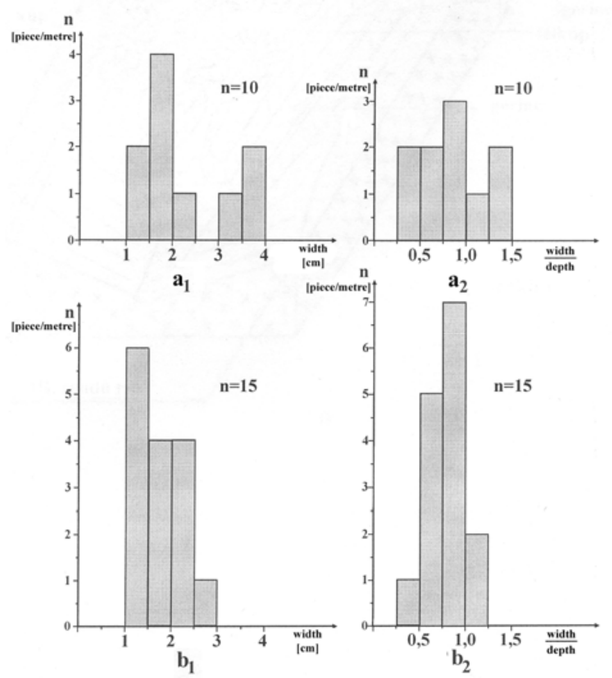

Figure 3. The parameters of the rills of the salt (data of profile marked P-5/2002)

Legend: a_1 the distribution of width of the first rills, a_2 the distribution of shape of the first rills, b_1 the distribution of width of the secondary rills, b_2 the distribution of the shape of secondary rills

3. THE FORMS OF THE PRAID HALITE

3.1. The karst features of the Saltic Hill

Dolinas developed due to solution and break-down are the most common features in this area (Ajtay 1989). The collapse dolines may have developed by opening up of solution caves or by opening up of such caves which were created during mining.

Table 1. The specific width and density of karren features

Profile mark	The altitude of the profile (m)	Length of the profile (m)	Dip angle of the slope	Wide rinn		Bottom rinn		Narrow rinn between spitzs		Ridge between rinns		rill		Number of the karren formation (pieces)	average		ridge	
				s.w. (cm/m)	d (p/m)	s.w. (cm/m)	d (p/m)	s.w. (cm/m)	d (p/m)	s.w. (cm/m)	d (p/m)	s.w. (cm/m)	d (p/m)		s.w. (cm/m)	d (p/m)	s.w. (cm/m)	d (p/m)
P-1/2002	499	6.6	50	57.58	0.45	17.73	0.76	33.03	1.97	30.61	1.21	0.00	0.00	29	138.94*	1.1	0.00	0.00
P-2/2002	499	9	40	63.33	0.33	23.00	0.89	19.33	1.56	37.78	0.78	0.00	0.00	32	143.44*	0.89	0.00	0.00
P-3/2002	499	0.7		0.00	0.00	0.00	0.00	0.17	2.86	0.00	0.00	54.29	20.00	31	54.46	11.43	11.31	21.43
P-4/2002	499	1.2	30	0.00	0.00	0.00	0.00	19.17	0.83	0.00	0.00	43.75	19.17	45	62.92	10	19.67	17.50
P-5/2002	499	0.7	55	0.00	0.00	0.00	0.00	11.43	1.43	0.00	0.00	78.57	35.71	49	90.00	18.57	10.86	32.86
average				24.18 60.45	0.16 0.39	8.05 20.36	0.33 0.82	16.63 16.63	1.73 1.73	13.69 34.19	0.4 0.99	35.32 58.87	14.98 24.96	37.2	97.95	8.4	13.94	23.93

Notice:
s.w.: specific width (centimetres/metres)
d: density (piece/metres)
the quantity of the average rainfall: 700-750 mm/year
rill: rills and tributary rill
*the cause of value greater than 1 metre: in case of specific width, the bottom rills were also taken into account.
Area average concerning specific width: which was calculated as the quotient of the overall specific width and the number of the profiles. [When counting the values in the upper line, the number of all profiles (5 pieces) was taken into account; in case of the lower line as many numbers of profiles were taken into account along which the calculated feature occurred.]
Area average concerning density: which was calculated as the overall quotient at the density and the number of the profiles. [When counting the values in the upper line, the number of all profiles (5 pieces) was taken into account; in case of the lower line as many numbers of profiles were taken into account along which the calculated feature occurred.]
** cannot be measured

The fossil dolines (buried doline) may occur too, because of the accumulation of the dolines, in which lakes may occur too.

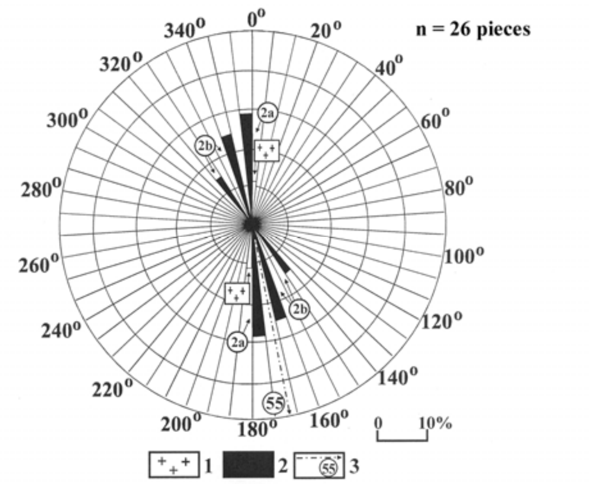

Figure 4. The rill distribution according to their direction (which occur along profile the P-5/2002)
Legend: 1. ridges between rills, 2. rill, 2a. first rill, 2b. secondary rill, 3. dip direction and dip angle

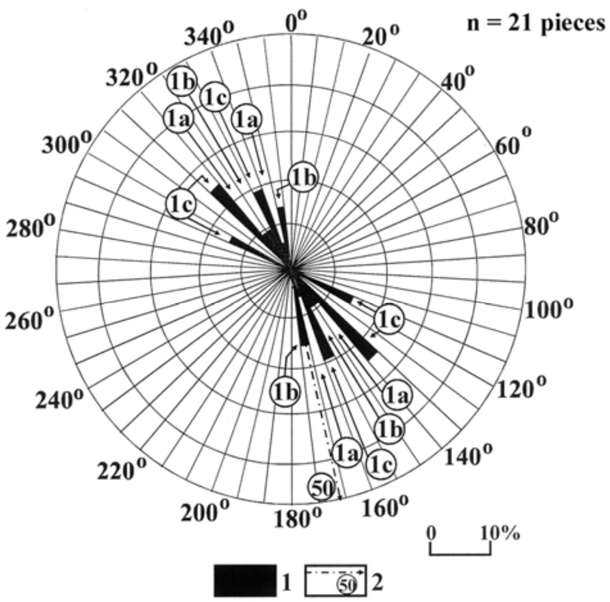

Figure 5. The rinn distribution according to their direction (which occur along profiles P-1/2002)
Legend: 1. rinn, 1a. wide rinn, 1b. bottom rinn, 1c. narrow rinns between spitzs, 2. dip direction and dip angle

The covered karstic (Figure 6) dolines may occur on the salt too. These features developed where covering sedimentary rock covered the salt. The water which seepages through the covering sedimentary rock ,dissolved the salt. Due to the matter absence the covering sedimentary rock collapsed or sank into the salt. It is difficult to distinguish the dolinas according to their genetic. A doline with covering sedimentary rock on its bottom may have developed due to covered karstification. But it may have also happened that covering sedimentary rock from their soroundings were transported to their bottom during their development. Thus the dolina is of solution origin.

Complex dolines and rows of dolines may develop. The complex dolines can be of anthropogenous origin. The doline rows may have developed during subsurface capture (Zentai 1994).

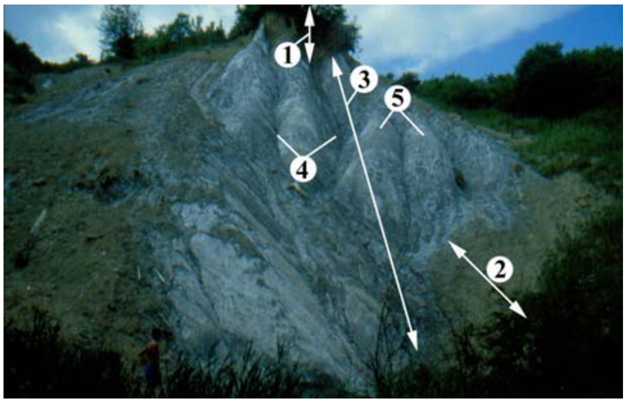

Figure 6 The features of the valley slope of the Corund brook
Legend: 1. covering sedimentary rock, 2. slided covering sedimentary rock, 3. karren formation surface of the salt, 4. wide rinn, 5. pinnacle

There are sinkholes which may continue in caves (Zentai 1994). The sinkholes occur in the solution dolines. The catchment areas of the sinkholes were created by those surfaces parts which were covered by mass movements.

'Salt gorge' which developed along cutting of the road (Ozoray 1963). It takes 5 years for the salt gorge to develop.

There are salt pinnacles, which were termed by Benedek 1905 (salt rocks), furthermore, there are salt columns. The salt columns are isolated from their environment by solution which took place along fractures (Ozoray 1963).

The salt manifests certain concretion features in the shape of cauliflower-like surfaces. Their structure is not lamellar. Therefore they developed due to the evaporation of the sheet water. But they may have developed due to the concretion which leaves hidden moisture (Ozoray 1963).

The covering sediment rock was transported, during mass movements to the lower sides and bottoms of the depressions. According to Ozoray (1963) the mass movements may be mud flows and solifluctions. Furrows and water cuts are characteristics of surfaces with covering sedimentary rock.

The following karren features have been described from this area so far:

Toothed ridges and spitzs were described by

Kalecsinszky (1901). It is true from Sovata. According to Ozoray (1963) there are kanneluras on the perpendicular surfaces, while rock crests can be found on the gentle surfaces. The forms of the rock (salt) crests are sharp (profile) undulate and diverge (on top view). Between the rock crests there are kanneluras which show meandering-like characteristics. The rock crests are separated into spitzs. Spitz develops where the salt is more contaminated and more compact. Undulate features can be found, on the upper slopes while channels can be found on the lower slopes parts (Zentai 1994). Karren tables were mentioned on salt surfaces by Ozoray (1963), Zentai (1994).

Figure7 Secondary rills (at the P-5/2002 profile)
Notice: the rills developed partly on the salt concentration surface

3.2. Karen features

The most repeated karren features of salt in Praid are rillenkarren (Figures 7, 9, 10, 11), and rinnenkarren or channels (Figure 12). There are half pits, pits, wallkarren, as well as karren remnant forms such as spitzkarren (Figures 9,14) and ridges (Figures 9-10). But there are not grikekarren, trittkarren, kamenitzas, meanderkarren, and solution levels.

3.2.1. Rillenkarren (rills)

The sizes of the rills of the salt are greater than those developed on limestone. The rills of the salt develop in slopes with smaller dip angle (30^{o}) compared to those on limestone (Table 1). The density of rills is 24.96 pieces/metre using the average of three profiles. The specific width of rills is 58.87 centimetres/metre (Table 1).

The rills create a complicated network. The rills may occur anywhere. They create smaller – greater groups. They are wide-spread on salt pinnacles, in great-sized channels (at the bottom of the channel, on the ridges of the channel bottoms, on the sides of the channels), on the side of the rills, on sides of various-sized depressions, concerning where the surface of the salt is covered by concentration (Figure 7). If they are on concentration surfaces, their size is small. Their width and their depth are smaller than 1 centimetre. The characteristics of the occurrence of the rillenkarren are: the rills are not created in a row, but they occur continuously under each other in rows on the slope. Their occurrence is not continuous, at the bottom of the rinnenkarren, but they occur only in wide-spread patches.

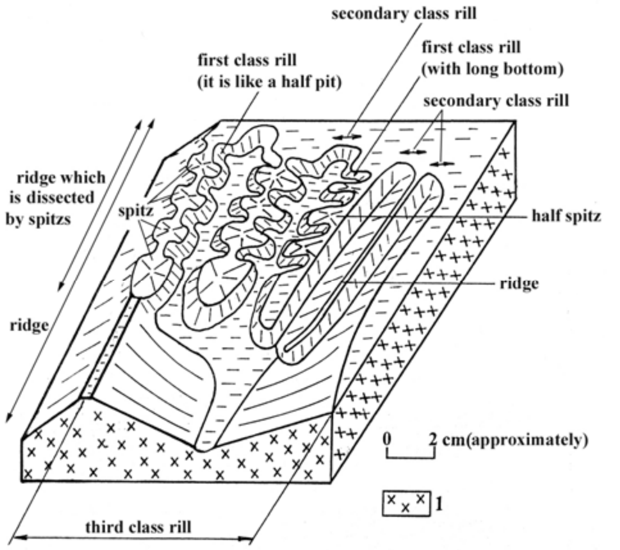

Figure 8. Type or rills, Legend: 1. salt

Rills create rill systems (Figures 8, 9, 11). The main form of the rill systems is secondary rill (Figures 7, 9, 10). The direction of the secondary rills is identical with the dip direction of the slope. The width of these flutes is between 1-3 centimetres, while their depth is between 2-7 centimetres. Ridges with various features separated these features from each other. The width of the ridges is fairly narrow; it is smaller than 0.5 centimetre. But their width sometimes may be greater than 1 centimetre. The secondary rills may branch or connect into each other (Figures 10). The profile of the ridges from the top may be planar, but they may be dissected by spitz partly (ridge with spitz, Fig. 9), or totally (spitz rows). In the case of the spitz rows spitzs are attached to each other level of the bottoms of the rills. The first rills (Class I) occur on the side slopes of secondary rills (Fig. 9). These forms may be distinguished into two various types a rill with a longer bottom, and rills which are like half pits (Figures 8-9). The rills which are like halt pits, do not have bottoms and they occur on the steep slopes (Fig. 9). Their direction is similar to the dip direction of the slope. If they have great density then they form undulate surfaces (a surface with spitzs develop) on the margins of secondary rills and between ridges of the secondary rills (Fig. 9).

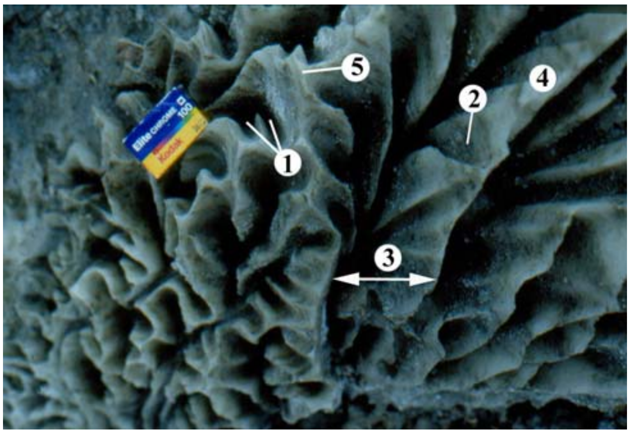

Figure 9: Spitzkarren and rill system: first rills dissected the ridges between the secondary rills into spitzs
Legend: 1. rill with a longer bottom (first rill), 2. half-pit like rill (first rill), 3. secondary rill, 4. ridge, 5. spitz


Figure 10: Branched and uniting rills (secondary rills)

Secondary rills are greater if first class rills are connected to them (Fig. 9). In this case the width of the secondary rills may be 4 centimetres, their depth may be 10 centimetres too. The third class rills are the greatest. These rills develop if secondary rills are attached to each other and those do not wedge out. The width of rills is small compared to their depth. The value of the shape of the secondary rills which occur profile marked P-4/2002 is 1.09. The value of the shape of the first rills is similar or it is even smaller. The shape of the first rills of the marked area is 0.77.

The rill system may be created from the following rill classes:

- secondary and third class rills,
- first and secondary class rills (Fig. 9),
- first, secondary, and third class rills (Figs. 8 and 11).

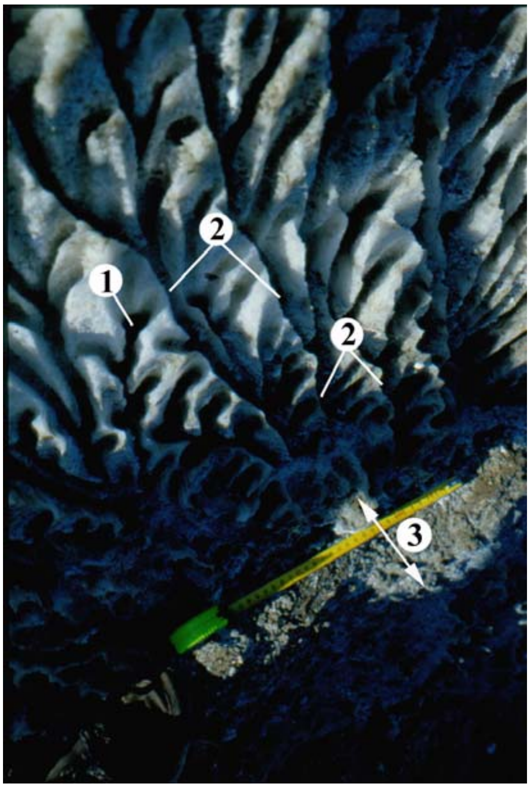

Figure 11: Rill network
Legend: 1. first rill, 2. secondary rill, 3. third class rill

3.2.2. Rinnenkarren

Rinns are the great-sized features of the opened-up salt slope. Their length may be several dozen metres long. Their width may be more than 1 metre. (The width of the greatest rinn is about 4 metres.) Their depth is rarely greater than 0.5 metre.

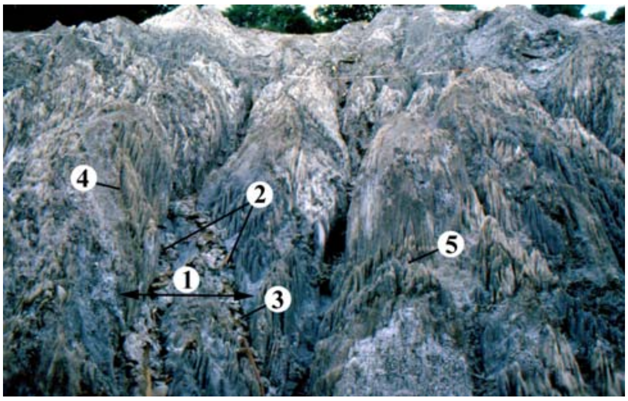

Figure 12. Karen features in the surroundings of profile marked P-1/2002 Legend: 1. wide rinn, 2. bottom rinn, 3. debris, 4. narrow rinn between spitzs, 5. rills

The various rinns are the following:
The width of the wide rinn (Fig. 12) is greater than 1 metre. Its width is small compared to its depth. For example the average slope of the wide rinn along the

profile marked P-2/2002 is 3.54. They develop along the total length of the exposured salt slope. They start exclusively from the margin of the covering sedimentary rock which borders. They lead to different-sized pits or shaft-like features. The direction of the rinns is not always parallel, but they are converging into each other's direction. Therefore a greater depression develops on the slope where the rill system appears. The direction of the converge rinns which are at the margins of the depression may differ from the direction of the bearing slope. Steps, bottom basins, and kamenitzas are absent from the bottom of the wide rinns.

Bottom channels (rinns) develop at the bottoms of the wide rinns. Their width is greater compared to their depth than in case of wide rinns. For example the average shape of the bottoms rinns which occur along the profile marked P-2/2002 is 2.83. The bottom of the bottoms rinn is not dissected either. Salt debris and wrecks of the covering sedimentary rock (a mixture of the salt and the covering sedimentary rock) may often occur on their bottoms. Those may be slightly rounded. The roundness proves the flowing water at the bottoms of the bottoms rinns. The wide rinns may be distinguished into three various groups according to the bottom rinns:

- The bottom rinns do not occur on the bottoms of the wide and simple rinns. Rills develop on the bottom of the rinns (Fig. 13a) and the side of the rinn is steep.

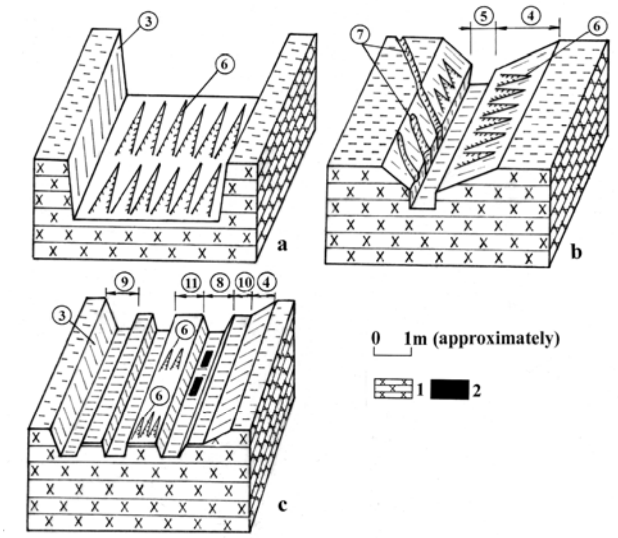

Figure 13. Rinns of the salt (halite)
Legend: a. simple wide rinn, b. complex wide rinn, c. manifold complex rinn (several bottom rinns on its bottom), 1. salt, 2. covering sedimentary rock, 3. steep rinn side, 4. gentle rinn side, 5. internal rinn, 6. rill, 7. narrow rinn, 8. bottom rinn, 9. margin positioned rinn, 10. bottom residual, 11. ridges between bottom rinns

- The side slopes of the complex wide rinn are gentle, its bottom is narrow. Only one bottom rinn develops on the bottom of the rinn. Its width is identical with the bottom of the complex wide rinn. Rills and narrow rinns can be found on the gentle side slopes the rinns. The direction of these latter ones differs from the dip direction. They close a sharp angle with the direction of the bearing rill (Fig. 12, 13b).
- Several internal rinns occur on the bottom of manifold complex wide rinn (Figs 12, 13c). In this case there are ridges on the bottom of the wide rinns. Rills develop on the ridges. The side slopes of the rinn are steep.

The narrow rinns between pinnacles belong to a further type of rinns. These narrow features develop on the surfaces with rills between pinnacles of the salt.

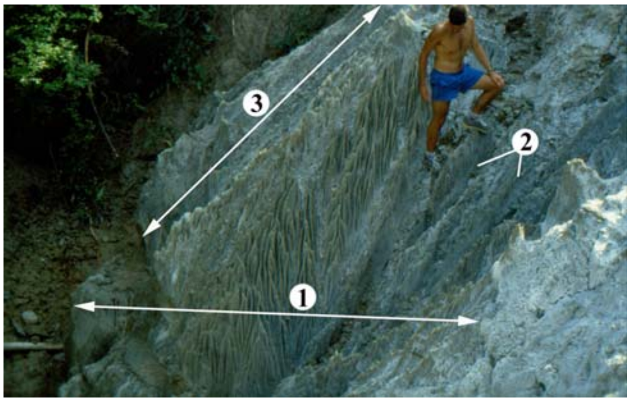

Figure 14. Narrow rinn. Legend: 1. covered karst form, 2. narrow rinn, 3. pinnacle and its rills and spitzs

During their development they cut through the rillenkarren surface (Fig. 14). Their catchment area is the surface of a salt pinnacle. Covering sedimentary rock may occur on the surface of the pinnacles. Rinns of this rinn type often change their direction. Pinnacles border their margins. Their depth is considerable big compared to their width and the average shape of one narrow rinns which occur along the profile marked P-2/2002 is 2.16. Their width is smaller than the width of the bottom rinn. Their length may be considerable. They are connected to wide rinns. Wrecks of sediment may occur on the bottoms of the narrow rinns.

The density and the specific width of the rinns were calculated using the averages of two profiles data. The wide rinns belongs to the greatest specific width (60.46 centimetres/metres). The specific width of the bottom rinns has the smallest value (20.37 centimetres/metres). The density of the narrow rinns is the greatest (2.86 pieces/metres), while it is the smallest at wide rinns (average density is 0.39 pieces/metres).

4. THE DEVELOPMENT OF RILLS AND RINNS ON THE SALT

The pattern of the karren features is belting on limestone slopes. They occur in various belts. The most common patterns may be the following from the upper to the lower parts of the slope (Veress 2010):

- Rillenkarren – solution level,
- Rillenkarren – solution level – rinnenkarren – pitkarren (or grike karren, Fig. 2),
- Rinnenkarren – pitkarren (or grike karren).

Rillenkarren develop on the upper section of the slopes (Bögli 1961). They are produced by sheet water and its flow is periodically turbulent (Glew-Ford 1980). Solution levels develop where the flow of the sheet water is not turbulent any more. It is where the sheet water becomes thicker. It is under the rillenkarren. Rinnenkarren develop in the middle and the lower parts of the slope. Sheet water here is separated into rivulets these. Rinnenkarren are created due to the turbulent water of the rivulets (Trudgill 1985, Veress 2010). They may increase even if the rivulets and turbulent flow are absent. Then meltwater dissolves the bottoms and sides of the rinns during seepage, which originates from the snow fill of the rinn (Veress 2010).

The rillenkarren belt is built by only one rill row on the limestone (Fig. 15). The karren features develop on each other on salt. Rills may occur in the total length of the slope in several rows under each other (see later), or on the sides and bottoms of the rinns. The rinns may develop on the area of the rills too.

We can sketch the following development process using the morphology and position of the rills:

- The development age of the different classes rill is various. It may be seen in Fig. 4, that the directions of one group of secondary rills show less deviation from the dip direction than in case of first class rills. The cause of this: secondary rills developed earlier in the direction of the slope. Later first rills developed on the side slopes of secondary rills. Their direction differs from the dip direction of the bearing slope. Because the dip direction of the secondary rills' slopes is different from that of the bearing slope. There is an other group of secondary rill, whose direction is different in a greater value from the dip direction of the bearing slope. Probably the rills of this group developed later too. In this case first rills changed into secondary rills.
- The deepening and the regression of the first rills are intense. Rills like half pits develop during the deepening. The rill with longer bottoms can be created during regression. The ridges which are between the secondary rills are dissected into spitzs due to regression. Namely the upper ends of the first rills coalesce into each other during their regression. The coalescing rills occur opposite each other on the opposite sides of the ridges.
- The sizes of the first rills are greater than those of the secondary rills, if first rills feed the secondary rills.

Figure 15. Rills on limestone
Legend: 1. destroying pit, 2. rillenkarren, 3. grike

- The pattern of rillenkarren may be two kinds of halite. Rills belonging to different classes may occur under each other on the slope. This pattern is termed by us as heterogeneous belting. Hence, secondary rills may occur in several rows too. Then the rills can branch or be connected. This pattern is termed by us as continuous development. The cause of this pattern on the halite is the following.The rain water which flows on the surface of the halit (sheet water) becomes saturated. Under the line of the saturation ,solution can take place again, because unsaturated rain-water falls on this slope part . Hence newer sheet water develops from the rainfall which can dissolve. Therefore new solution can occur newer and newer of rills will develop. This process is proved by the length of the rills which is smaller than the width of the rill belt. Namely if the flowing sheet water of the slope is not saturated, then the length of the rills would be similar to the width of the rillenkarren belt. Further more contretations would not occur on the slope. The development of the rills may change from sheet water to rivulets. When the sheet water is separated into rivulets, third class rills develop when secondary rills are connected to each other. The sheet water is divided when the depth of the secondary rills can achieve a certain value too. (Therefore first rills develop on the side slopes of the secondary rills.) Rills may develop under the rivulets too. This process may be proved by their depth which is greater compared to their width.

- The cause of the development of the wide rinns and bottom rinns is that they are fed from the bordering covering sedimentary rock surface. The rinns develop under rivulets. Therefore the direction of the wide rinns and the bottom rinns also differs (Fig. 5). Namely the directions of the wide rinns differ in greater value from the dip direction than that of bottom rinns. The cause of the phenomenon is that: the rivulets of the wide rinns are forced to deflect due to mounds (for example pinnacles and spitz karren). The direction of the wide rinns may differ from the dip direction, because they lead to the pits of the salt. The direction of the rinns positioned at the margin differs from the dip direction. The direction of the bottom rinns differ less from the dip direction of the slope, because their direction is controlled by the wide rinns.
- Wide rinns widen rather than deepen during their increasing. Their widening may happen due to surface solution or due to the re-development of the rills. Their widening may happen as their side slopes change and become gentle or they become steeper and steeper, then the side slopes retreat parallel to themselves.
- Secondary karren formation may happen on the bottoms of the wide rinns. Bottom rinns develop during the process. Rills develop on the ridges of the bottoms. The level of the ridges decreases. The secondary karren formation is not conriderable, because the width of the rinns is bigger than their depth. The erosion denudation is not considerable either because the wrecks of the covering sedimentary rock only occur on the bottoms of the bottom rinns only. But the depth of the bottom rinns is not considerable either.
- Rivulets are only significant at the initial development phase of the wide rinns. This is proved by the rills which occur in great density at their bottoms and inner rinns and also features due to turbulent flow are also absent. However they get much water from the bordering covering sedimentary rock. Their rivulets do not cover their bottoms because of their width. Therefore several narrower rivulets develop on their bottoms. Later the development of the bottom rinns starts. The several inner bottom rinns develop on the bottoms of the wide rinns. Or even a rivulet would not develop at their bottom (rills on the bottom of a wide rinn).
- Narrow rinn is created from a rill or rills whose development happened under a rivulet.

The intensity of the solution on the limestone depends on the quantity of the CO_2, the velocity of the flow, the type of the flow (it can be turbulent or laminar), the quantity of the water (Trudgill 1985). The velocity of the flow depends on the dip angle, the quantity of the water the value of the rainfall and, the length of the slope. The turbulent flow depends on the velocity of the flow, the shape of the slope, and concerning the roughness of the surface (Emmett 1970).

The value of the solution does not depend on the quantity of the CO_2 on halite. It even does not depend on turbulent flow. Namely the rills and rinns of the salt develop during non-turbulent flow. The solution of the salt happens during laminar flow, if the quantity of water is great enough. The following proves this:

- The rillenkarren belt is created by rill rows. Thus rills may develop if the sheet water is thicker, but not turbulent. It does not happen on limestone. Because turbulent flow does not develop if the sheet water is thicker. Namely one of the pre-conditions of turbulent flow is that rain drops should hit the sheet water (Glew-Ford 1980). If it is too thick, rain drops are unable to cause turbulent flow.
- Rills and rinns develop where the quantity of the water increases. The development of rinns stops, or changes where the quantity of the water decreases (for example where the rinn can become too wide).
- Rills develop on slopes with smaller dip angle too. The chance of the turbulent flow is smaller if the dip angle of (the) slope is smaller.
- The features of turbulent flow are absence from the bottoms of the rinns (for example bottom basins).

The relationship between the quantity of the water and solution (and thus the development karren) are proved as follows:

- The secondary rills are greater in size if first rills are connected to them. In this case their catchment areas are greater too.
- Those rinns which get water from the covering sedimentary rock are greater (wider).

A slope must develop to create water cover (sheet water or rivulet) on halite. If the slope is longer it can receive more and more water. Therefore greater forms develop on longer slopes. The solution can be greater also, if the salt slope is bordered by a covering sedimentary rock surface. Because more water can flow onto the halite surface from the covering sedimentary rock surface. The increasing of the dip angle does not increase solution, because the increasing of the velocity of the flow does not increase the solution on the salt.

5. SURFACE DEVELOPMENT ON HALITE

A salt diaper rises. Because of the fast elevation of the diaper, it partly loses its covering sedimentary rock and therefore karren formation happens on its surface.

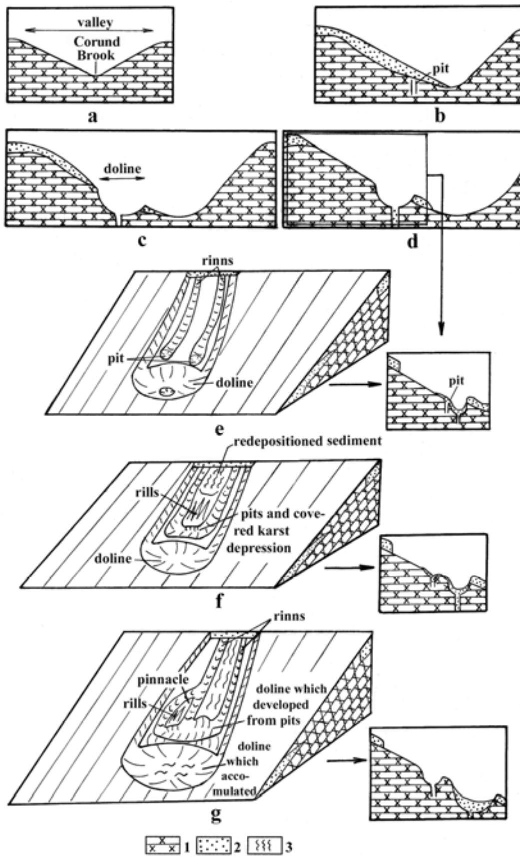

Figure 16. Theoritical example of surface development and covered karst in Saltic Hill
Legend: profile: a Corund Brook creates a valley, b. the side of the valley is covered by sediments, pit development begins, c. covered karst form develops over the pit, d. the covering sedimentary rock of the valley slope fills the dolina, the halite of the valley side slope outcrops from the front view/and profile: e. rinns develop on the side slopes of the outcropped halite, pits develop at their ends f. newer covered karst feature develops when the pits are united, g. the older covered karst form is filled, newer rinn is created, salt pinnacles are created between the rinns, 1. salt/halite, 2. covering sedimentary rock, 3. repositioned sedimentary rock.

The karren features are covered, because of the redeposition of the covering sedimentary rock. The altitude of salt dome decreased due to solution. Therefore, the Corund Brook developed on its area (Fig. 16 a). Fluvial sediment covered the covering sedimentary rock partly.

Antecedent gorge developed. At the side slopes of the antecedent gorge was covered by sediment flows, solifluctions and slumps (Fig. 16 b).

Collapse dolines developed (Fig. 16 c). Some of them may have developed by breakdown of the mine cave. The sediments of mass movement were transported into the dolines and their pits (Fig. 16 d). Rinns developed, which led into dolines or pits (Fig. 16 e).

The pits at the ends of the rinns joined together. Newer dolines developed on the upper part of the slope above the dolines which were on the lower parts of the slopes (Fig. 16 f). The older dolines which are on the lower slope are accrued. Newer rinns developed between the older rinns. Salt pinnacles were created between the rinns (Fig. 16g).

The lower part of the slope is connected with the bottom of the valley (gorge). The upper of the slope became steeper because of the karren solution. Newer mass movement developed, whose matter can partly cover the karren slope .Newer pits develop under of the covering sedimentary rock which are far from the brook. The above detailed surface development occurs again and again.

6. CONCLUSIONS

The karren features of the salt do not create belting. However the pattern of the rillenkarren may be belting. Rillenkarren may develop in belts or continuously.

The size of the karren features depends on the quantity of the water. The type of the karren features is controlled by the quantity of the water too. First class rills develop if the quantity of the water is less. The reason for the development of rill rows which are under each other is that solution is a repeated process on the slope. The water which flows on the slope becomes saturated gradually. The solutability of the sheet water on the slope under the saturation line renews due to the rainfall which fell on the slope under the saturation line.

Secondary sometimes third class rills develop if the quantity of the water is more. The solution of the surface happens in a line if the quantity of water is even bigger. Rinns develop.

The slope is divided into slope parts during the karren formation. More and more features (which are smaller and smaller) develop on the smaller and smaller slope. First rills develop on the slopes of the secondary rills. Bottom rinns and rills develop on the bottoms of the widening rinns. The smaller and smaller features are younger and younger.

Karren features which occur in the surroundings of a karren feature are destroyed. The catchment area of the karren features increases. The development of the karren feature can be faster. A relatively great-sized karren feature (class III rill) develops.

The great-sized solution features of the salt (dolines) help the karren formation. The great-sized features increase and their shape changes due to karren formation.

The karren formation causes superficial denudation of the salt. The different karst forms (dolines) cause the dissection of the salt surface, but the dissected surfaces became even during karren formation.

REFERENCES

Ajtay F. 1989. *Az Erdélyi-medence nagy kincse: a kősó* – Természet Világa, 5. 203-206. (The Treasure Of The Transylvanian Basin: The Halite).

Andreichuk, V. & Eraso A. 1996. *Karren landforms on the artificial salt massives in the Ural area*. - In: Fornos, I. J.-Gines, A. (szerk.): Karren Landforms, 243-252. Universitat de les Illes Balears, Palma de Mallorca.

Benedek K. 1905. *Emlékirat a parajdi sóbányászat érdekében* – Bányászati és Kohászati Lapok, 41, 240-242. (Memoirs in the Interest of the Halite Mining of Praid).

Bögli, A. 1961: *Karrentische, ein Beitrag zur Karstmorphologie* – Zeit. f. Geomorph. 5, 185-193.

Calaforra, J. M. 1996. Some examples of gypsum karren - In: FORNÓS, I. J.-GINÉS, A. (Editors): Karren Landforms, p. 253-260. Universitat de les Illes Balears, Palma de Mallorca.

Emmett, W.W. 1970. *The hydrauliks of overland flow on hillslopes,* U. S. Geolog. Survey Profess. Paper p. 662-667.

Ford, D.C. & Williams, P.W. 1989. *Karst Geomorphology and Hydrology* - Unwin Hyman, London, 601 p.

Ford, D.C. & Williams, P.W. 2007. *Karst Hydrogeologyand Geomorphology* – John Wiley & Sons, Ltd, 562 p.

Glew, J. R. & Ford, D. C. 1980. *Simulation study of the development of rillenkarren* – Earth Surface Processes, 5, 25-36.

Har, N., Rusz, O., Codrea, V. & Barbu, O. 2010. *New data on the mineralogy of the salt deposit from Sovata (Mures County – Romania)* Carpathian Journal of Earth and Environmental Sciences, Vol. 5, No. 2, p. 127 – 135.

Jennings, J.N. 1985. *Karst Geomorphology* – Basil Blackwell, 293 p. New York.

Kalecsinszky S. 1901. *A szovátai meleg és forró konyhasós tavakról, mint természetes hőaccumulátorok* – Földt. Közl. 34, 329-353 (Study on the Warm and Hot Water Lakes of Sovata as Natural Heat-Batteries).

Kendall, CH. G. S. & Skipwith, P.A. D'E 1969: *Holocene shallow-water carbonate and evaporite sediments of Khor al Bazam*, Abu Dhabi, Shoutwest Persian Gulf – AAPG Bull 53, 841-869.

Macaluso, T. & Sauro, U. 1996. *The Karren in evaporitic rocks: a proposal of classification* - In: Fornos, I. J.-Gines, A. (szerk.): Karren Landforms, 277-293. Universitat de les Illes Balears, Palma de Mallorca

Madonia, G. & Sauro, U. 2009. The Karren Landscapes int he Evaporitic Rocks of Sicily – in Ginés, A., Knez, M.-Slabe, T.-Dreybrodt W. (edit): Karst Rock Features Karren Sculpturing p. 525-533, Karst Research Institute, Postajna-Ljubljana 561 p.

Orbán B. 1868: *Székelyföld leírása* – Pest I. köt., Róth Mór Bizománya (Reprint: 1982, Helikon Kiadó és a Magyar Könyvkiadó és Könyvterjesztő Egyesület) (Description of Transylvania).

Ozoray Gy. 1963: *Az Erdélyi-medence nagy kincse: a kősó* – Természet Világa, 5, 203-206. (The great theasure of Transylvanian Basin: the salt).

Talbot, C.J. & Jackson, M.P.A. 1987: *Sótektonika* – Természet Világa X, 56-65. (Salt/Halite Techtonics)

Trudgill, S. T. 1985. *Limestone geomorphology* - Longman, New York 196 p.

Veress M. 2010. *Karst Environments – Karren Formation in High Mountains* – Springer Dordrecht Heidelberg London New York, 230 p.

Veress M., Péntek K., Zentai Z. & Mitre Z. 2008: *Development of rinnenkarren on bare slopes and on slopes with dwarfpine* - Geographical studies of the University of West Hungary, University of West Hungary, Faculty of Sciences, Szombathely, p. 52-68.

Veress M.,Tóth G. , Zentai Z. & Schläffer R. 2009. *The Ankarana tsingy and its development* – Carpathian Journal of Earth and Environmental Sciences, 4(1), 95-108.

Zentai Z. 1994: *A Parajdi sókarszt geomorfológiája* – A BDTF Tud. Közl. IX. Természettud. 4, 233-248, Szombathely. (Geomorphology of the halite karst of Praid).

Received at: 24. 04. 2010
Revised at: 23. 03. 2011
Accepted for publication at: 27. 04. 2011
Published online 05. 05. 2011