KARSZTFEJLŐDÉS IV.
Szombathely, 2000. pp. 77-108.

THE STUDY OF THE HISTORY OF DISSOLUTION OF KARREN GROUND SURFACES DEVELOPING TO KARREN MONADNOCKS AND INSELBERGS - WITH SOME EXAMPLES

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Abstract: Scale 1:10 morphological surveys were prepared about six selected parts of the karren landforms in the Austrian Totes Gebirge. The concepts of karren inselberg and monadnock are introduced and these residual ground surfaces are specified. Karren inselbergs and monadnocks developed by karren troughs are studied in detaile. These can develop by the merging of tributary ends or tributary and main troughs, as well as by the false and true beheading of bends. By the examination of the merging of troughs (that is possible with the observation of the locations of appearance of trough bottom divides and steps in the course of merging by solution) the way of the development of inselbergs and monadnocks and the sequence of the various karren forms can be determined. In the knowledge of the relative ages of development the history of dissolution of a single part of the ground surface can be determined. Considering the relative ages of development of the various karren forms such series of maps were prepared that illustrate the history of dissolution of the surrounding of the monadnocks.

1. Introduction

An inselberg is a hill spared by erosion in its proximity. It is called a monadnock if the top of the hill retains the original land surface (*BULLA, B.* 1954, *BALÁZS, D.* 1987). (Table mountain, mesa, butte etc. are locally used in the English language without geomorphological distinction.)

The karren parts of the ground surface of the karst are denuded by solution of intensity and duration varying with the location. Parts of the surface that are denuded at relatively lesser degree as their proximity or not at all are called karren inselbergs and karren monadnocks respectively.

Karren inselbergs and karren monadnocks show differences in more than one aspects to erosion made inselbergs and monadnocks. These differences are the following:

- Inselbergs and monadnocks made by erosion can be of several kilometers wide and long and they can be many hundreds of meters high. The karren inselbergs and monadnocks are only several meters of lateral size and several decimeters high.
- Erosion made inselbergs and monadnocks are sculpted from their vicinity by erosion, karren inselbergs and monadnocks by solution. The sides of the letter are much steeper than those of the former. The bordering slopes are

often overhanging. Their surface is rougher too. Several centimeters tall small size cones occur frequently on their tops as well as shallow, wide initial karren troughs and some centimeter deep and wide type III troughs.

Karren inselbergs and monadnocks can be developed by various karren processes. Thus they can be developed by the partial merging of neighboring solution pots, heel marks or karren troughs. (*VERESS, M.* 1995). They can develop at karren tables (*BÖGLI, A.* 1976, *BALÁZS, D.* 1990). While the surface is denuded by solution in the vicinity of the karren table, this does not happen under the rock of the table (*Fig. 1a*). This paper reports about studies aimed at karren inselbergs and monadnocks developing during the development of karren troughs.

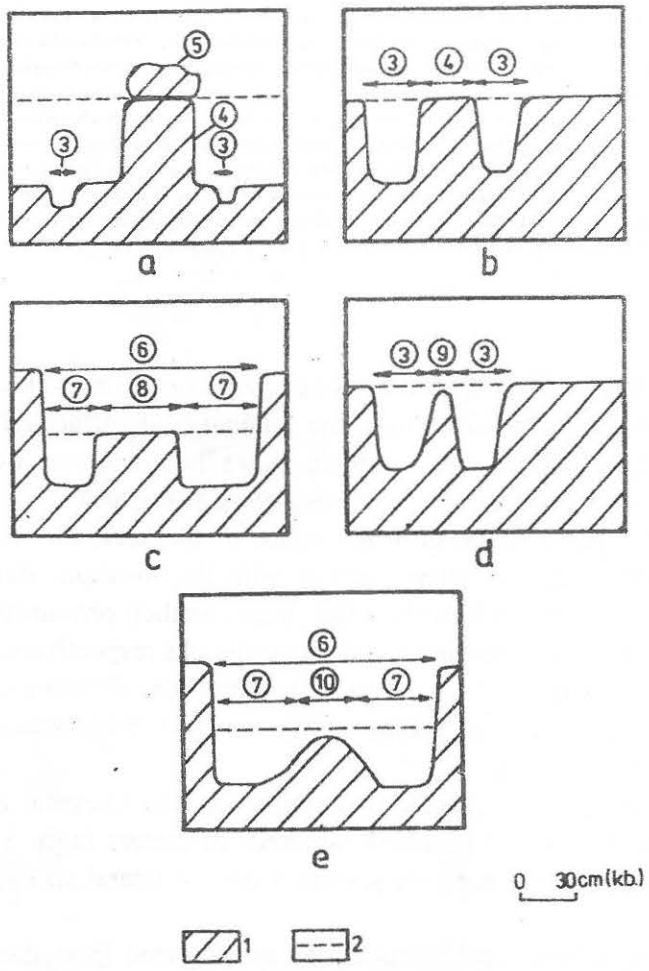

Figure 1: Cap-rock protected karren monadnock (a), monadnock developed by troughs (b), monadnock on the bottom (c), karren inselberg (d) and karren inselberg on the bottom (e)

Legend: 1. karren developing on rock, 2. elevation of karren ground surface before the separation of the residual ground surface, 3. type I karren trough, 4. karren inselberg, 5. boulder, 6. older type I karren trough, 7. I. or II type younger karren trough, 8. monadnock on the bottom, 9. karren inselberg, 10. karren inselberg on the bottom

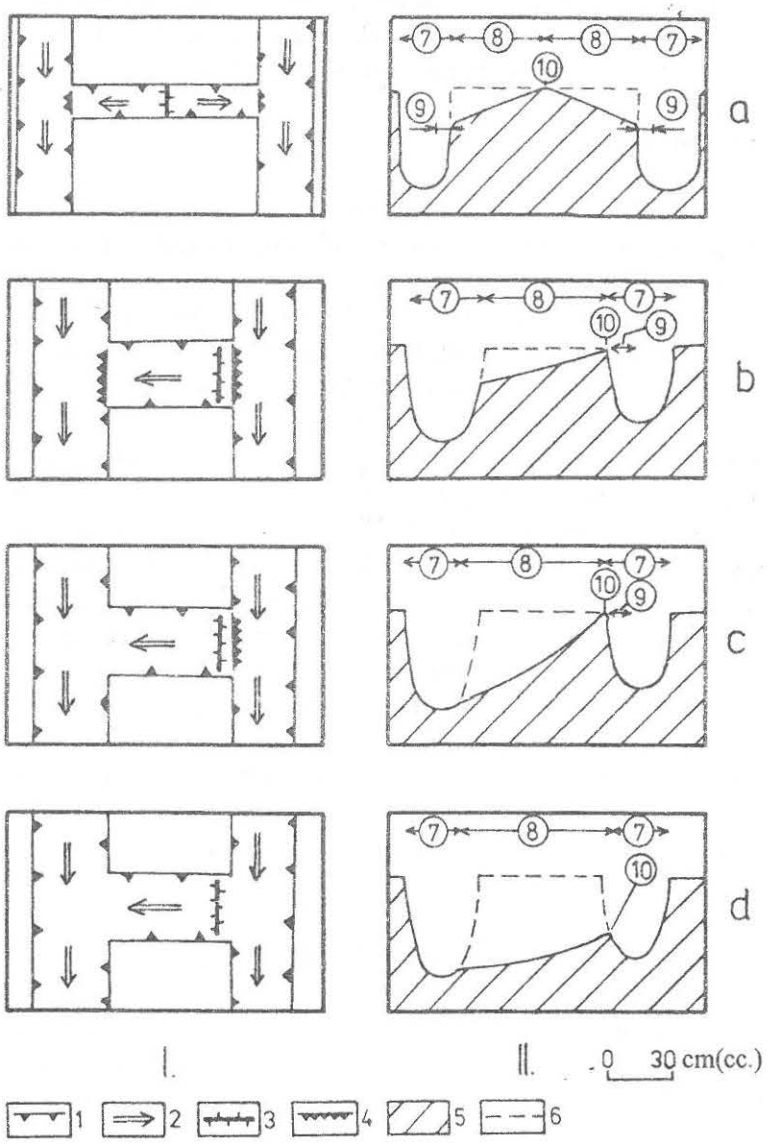

Figure 2: Meeting of trough ends (a) and false beheading (b, c, d)
Legend: 1. type I karren trough, 2. direction of slope of type I karren trough bottom, 3. trough bottom watershed, 4.step, 5. karren developing the rock surface, 6. ground surface before trough entrenchment , 7. master trough, 8. regressive tributary trough, 9. step, 10. trough bottom watershed, I. view from above II. side view (sections along the side of troughs connected by beheading), the regressive trough ends join (a), the beheading trough deepens constantly (b), the beheading trough retreats (c), the beheading trough entrenches to the bottom of the main trough (d)

For the presentation and the interpretation of the history of processes (history of denudation by solution) occurring on the terrain of inselbergs and monadnocks geomorphological surveys were completed. The data needed for

the field maps that is the basis of the geomorphological surveys were obtained with the surveying method developed and applied by *SZUNYOGH, G.* (1995, 1998). For a more detailed survey instead of the 50x50 cm rectangular network a 10x10 cm network was applied.

2. Site of the Study

The site of the study was an area under the Widerkar Peak in the Totes Gebirge on the slope of a valley of glacial origin at an elevation of 1800 m. The study area is a closed-drainage karstification unit (*VERESS, M.-ZENTAI, Z.-HORVÁTH, E. T.* 1996) isolated from its surroundings. The rocks of the karstification unit are tilted, the closed-drainage conditions have been only magnified by surface solution. For this reason the site has been divided to smaller sub-units during its development. The fractures and faults bordering the sub-units at 55-235° strikes have developed to fissures by solution. The upper fringe of a particular sub-unit joins the upper unit with a threshold of karstic origin while its lower fringe ends at the edge of the fissure bordering the unit at its lower end. The karstic thresholds that border the units are bed-edges, the surface of the sub-units are bedding planes. Karren troughs occupy the bedding plane surfaces. In the major (type I) troughs sporadically type II and more often type III troughs develop (*VERESS, M.* 1995). As long the type I troughs are in the range of decimeter width, type III troughs are only several centimeter wide or deep. The karren troughs conduct to the fissures bordering the sub-unit or to trough-end pits. The karren troughs often form bends or are composed of sections of various direction. It occurs frequently that side troughs branch off from the main troughs this making karren trough systems.

3. Types of Karren Monadnocks and Inselbergs

Karren monadnocks and inselbergs are remnants of the original ground surface. These remnants can be classified by the processes responsible for their development or by the way they were isolated from their surroundings.

3.1. The Specification of Monadnocks and Inselbergs by the Development of Their Surfaces

Karren monadnocks are those remnants of ground surface whose elevation was identical with the elevation of the ground surface that they had been separated from (*Fig. 1*). A monadnock one with dissected surface (the

surface dissected by karren indentations and rises) is a karren surfaced monadnock. Karren development could occur before the isolation from the original surface (monadnock with primary karren) or after (monadnock with secondary karren).

It shall be noted that some of the surveyed ground surfaces can be expected to be the remnants of trough bottoms. These are older than the presently existing trough bottoms so the trough bottom monadnocks can be taken as monadnocks with primary karren. It may occur that karren development characterized the top of the monadnock before as well as after the isolation. Bottom monadnocks develop at the bottoms of older karren forms. Most frequent are the trough bottom monadnocks (*Picture 1*). In these cases the remnants of the ground surface develop on the trough bottoms. The bottom monadnocks make a transition between the monadnocks and terraces. Terraces are older trough bottom remnants that developed because the younger, widening troughs digest in part the bottom of the older troughs (on which it is developing; *VERESS, M.* 1995).

Inselbergs are those remnants of the ground surface of which the top elevation decreased during the isolation (*Fig. 1*). Such remnants that had been lower than their surroundings before isolation are considered inselbergs too. Bottom inselbergs can develop on trough bottoms.

Resulted by the lateral growth of karren troughs the ground surface remaining between them may become inselbergs (crest inselberg). Peninsular inselbergs develop when the remnants between the karren troughs are not separated from the surrounding ground surface.

3.2. Categories of Inselbergs and Monadnocks by Their Way of Isolation

Karren inselbergs and monadnocks can develop on ground surface isolated between main and tributary troughs as well as in the recesses (concave sides) of bends.

3. 2. 1. The Turning of Ground Surface into Inselbergs and Monadnocks Between Main and Tributary Troughs

The troughs on rocky ground surfaces retreat by solution at the effect of the solvent flowing in them (*VERESS, M.* 1995).

The possibilities of the connection of karren troughs have been studied (*VERESS, M.* 1995) applying the statements of *CHOLNOKY, J.* (1926) on the development of regressive river valleys. Studies having performed ever since need some modifications or further development.

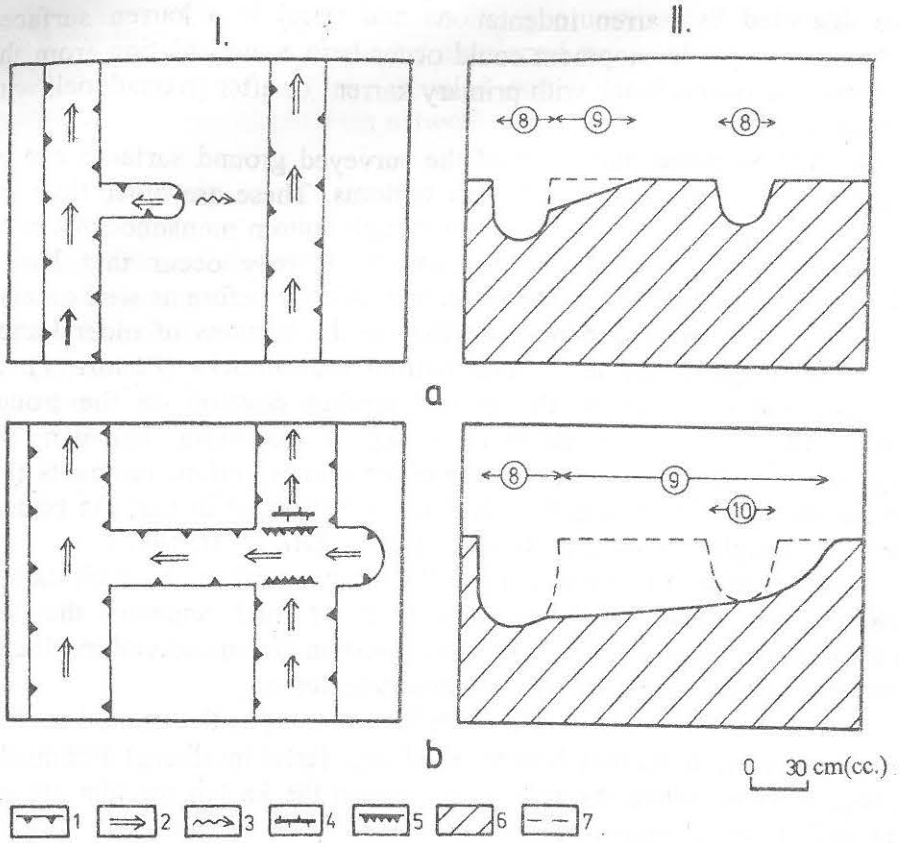

Figure 3: True beheading
Legend: 1. type I karren trough, 2. slope direction of type I karren trough bottom, 3. direction of retreating of trough end, 4. trough bottom watershed, 5. step, 6. karren development on the rock, 7. ground surface before trough entrenchment, 8. main trough, 9. regressive tributary trough, 10. ruined main trough, I. vertical view, II. side view (section along beheading trough), a. before beheading, b. after beheading

A regressive trough can reach the end of another regressive trough (*Fig. 2a*) or the side of another one (*Picture 2*).

In the first case a trough-end meeting, trough-end merging, in the second case a beheading occurs. At the merging of the troughs bottom divides develop (*VERESS, M.* 1995). The troughs bottom divides are a couple of centimeters tall and wide thresholds.

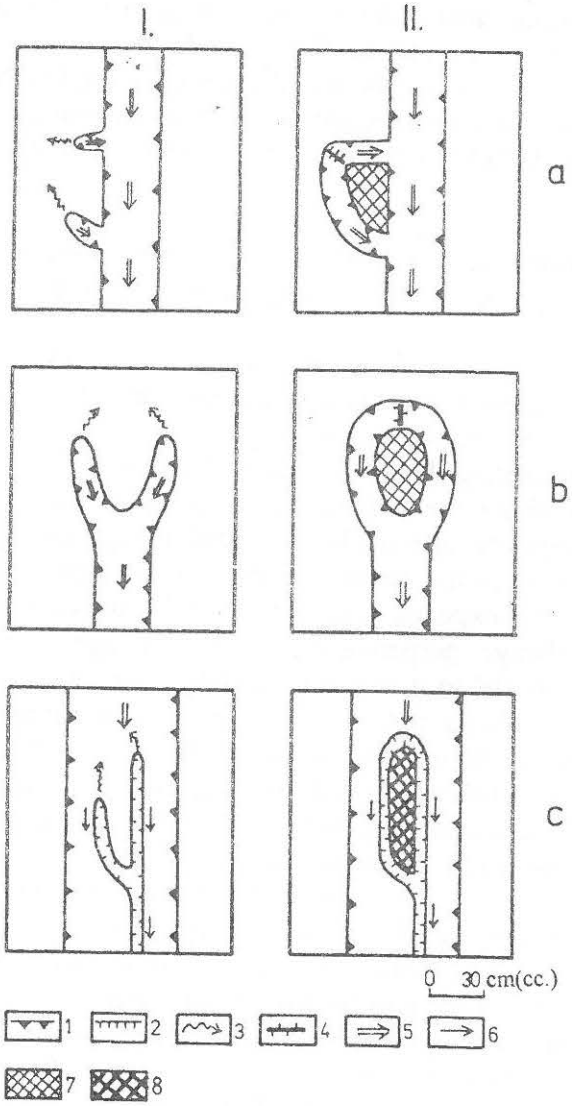

Figure 4: Development of karren inselberg and monadnock by the merging of trough ends
Legend: 1. type I karren trough, 2. type III karren trough, 3. direction of the regression of trough end, 4. trough bottom watershed, 5. slope direction of type I karren trough bottom, 6. slope direction of type III karren trough bottom, 7. monadnock, 8. bottom monadnock, I. initial condition, II. fully developed condition

In the course of trough beheading false beheading (*Fig. 2b, c, d*) and true beheading can be specified (*Fig. 3*). At false beheading the original flow conditions of the trough bottom do not change while at true beheading they do. The kinds of false beheading are as listed below.

- The retreating trough that makes the beheading entrenches at a slower pace (*Fig. 2b*). At the upper end of the beheading trough (where the false beheading is occurring) trough bottom divides develop. On the side of this at the beheaded trough a step develops that is the remnant of the trough side. The bottom of the beheading tributary trough hangs above the bottom of the main trough.
- The lower end of retreating trough entrenches at a quick pace. At the site of the beheading trough bottom divide develops with a step. The bottom of the beheading tributary trough bottom merges with that of the main trough (*Fig. 2c*).
- The retreating tributary trough entrenches at a quick pace at its whole length. The side exposed to the false beheading can be totally digested. Only a trough bottom divide develops here (*Fig. 2d*).

At true beheading the trough exposed to beheading is always digested by the trough making the beheading. At trough crossing beheading this occurs on the opposite side of the beheaded trough as well (*Fig. 3*). The developing divide does not develop in the trough responsible for beheading but in the one that is exposed to it. While at false beheading the direction of the divide is always perpendicular to the trough responsible for the beheading, it is parallel to it at true beheading (*Fig. 3*). The extension of the trough bottom divide is not the same in the described cases. At false beheading the trough bottom divide reaches from one rim to the other in the trough making the beheading. At true beheading, because it developed earlier the divide develops in the bottom of the exposed trough and its length does not exceed the width of the bottom.

At true beheading the waters of the upper part of the beheaded trough flow into the trough the beheading. If the entrenchment of the trough responsible for the beheading is intensive, one or two steps develop with directions identical with that of the trough bottom divide.

At the merging of the trough ends monadnocks may develop if the two tributary troughs of the main trough that retreat towards one another. The monadnock develops at the side of the main trough (*Fig. 4a*) but it can develop at the end as well (*Fig. 4b, c, Picture 3*). In the letter case the main trough forks to two tributary troughs.

At false beheading monadnocks develop when the retreating end of the tributary trough reaches up to the rim of the main trough. This may occur if an arced tributary develops from a straight main trough (*Fig. 5a*), but it may occur if at an arced section of the main trough one or two straight tributaries (*Fig. 5b*) develop.

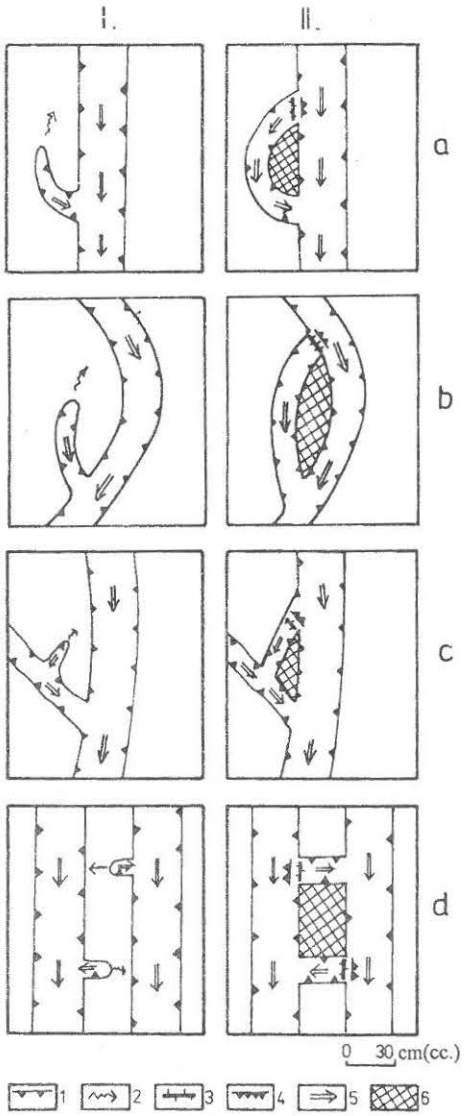

Figure 5: Developing of karren monadnocks with false beheading
Legend: 1. type I karren trough, 2. direction of regression of trough end, 3. trough bottom watershed, 4. step, 5. slope direction of type I karren trough bottom, 6. monadnock, I. initial condition, II. fully developed condition

Karren monadnocks can develop between major troughs too. In this case two tributary troughs take part in the development of the monadnock (*Fig. 5d*).

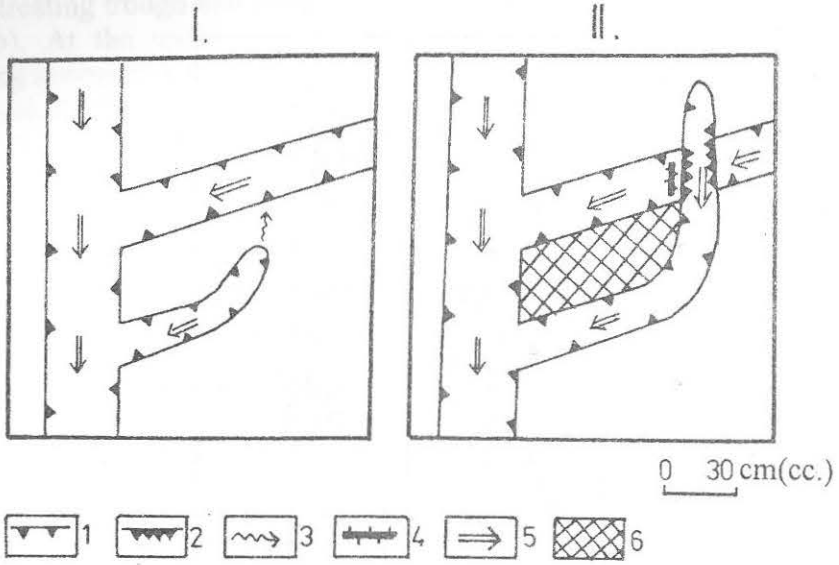

Figure 6: Developing of karren monadnocks with true beheading
Legend: 1. type I karren trough, 2. step, 3. direction of regression of trough end, 4. trough bottom watershed, 5. slope direction of type I karren trough bottom, 6. monadnock, I. initial condition, II. fully developed condition

Monadnocks can develop at true beheadings as well. In this case some major trough and its two tributaries surround the monadnock. The isolation of the monadnock is completed when the tributary trough developing quicker reaches the side of the trough that has developed at an earlier time (*Fig. 6*).

Monadnocks can develop other ways than the described ones, two of them is mentioned here.

Seldom, but it may occur that karren cavities play a role in the development of monadnocks. In this occurrence the tributary trough reaches the main trough above its section that contains a karren cavity (or a second tributary trough belonging to it). The development of the monadnock is complete when the roof of the cavity vanishes (*Fig. 7a*).

If the main trough is shallow and it bends too, the solvent flow in it hits the trough rim and spills over. The spilling water dissolves a trough downwards on the sloping ground surface (progressive trough). The lower end of the tributary trough may reach the main trough again. As a result, a monadnock develops independently from any bend (*Fig. 7b*). The progressive tributary trough quickly becomes hanging (at both ends joining the main trough with steps) because the main trough flows with more solvent and consequently its entrenchment is quicker. Such tributaries don't receive water from the main trough any more. Trough bottom divide does not develop in the progressive trough.

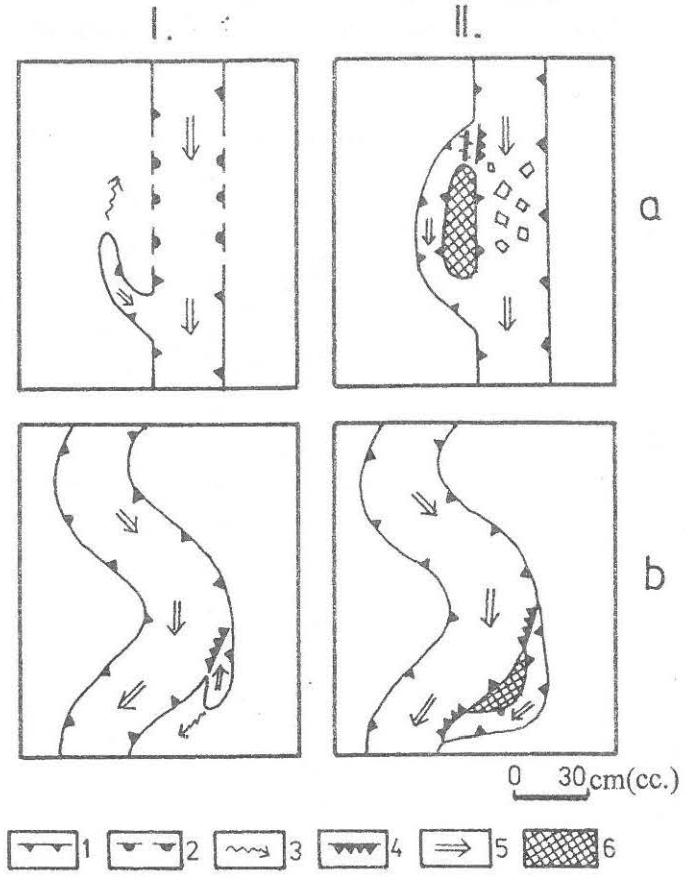

Figure 7: Developing of karren monadnocks after opening up the karren cavity (a) and development of progressive trough (b)
Legend: 1. type I karren trough, 2. karren cavity, 3. direction of regression of trough end, 4. step, 5. slope direction of type I karren trough bottom, 6. monadnock, I. initial condition, II. fully developed condition

3.2.2. Development of karren inselbergs and monadnocks in the recesses (concave sides) of bends.

The recesses of karren troughs can develop at true- or false meandering. The cutoff of the recesses may happen with false- or true beheading. At false beheading it is not the solvent flowing in the trough that executes the cutoff. In this case rainfall on the recess and its neck develop karren troughs. These are the tributaries of the trough making the bend and they are hanging in position. False beheading can happen at the neck or at any other part of the recess. It may happen by the retreating of a single karren trough (*Fig. 8a*) or by the connecting of two retreating troughs (*Fig. 8b and Picture 4*). In the first case the trough bottom divide develops at the

end of the tributary trough (the step develops at both ends of it) while in the letter case at the joint of the two troughs. Steps develop at both trough mouths.

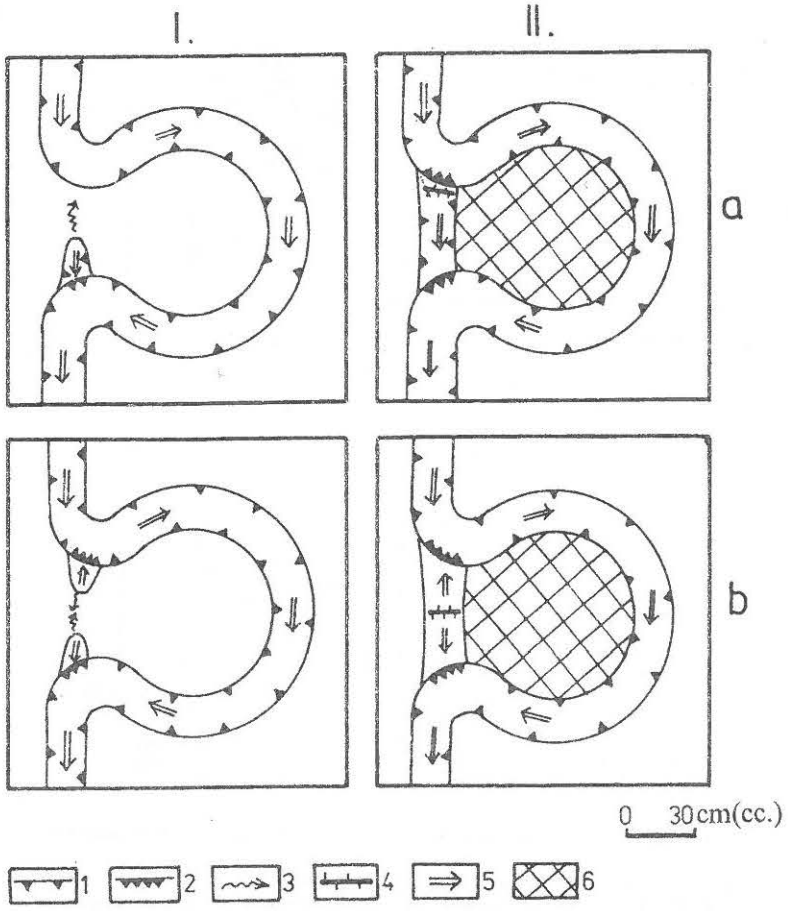

Figure 8: Developing of karren monadnocks with false beheading of bends in the case of regression of 1 (a) or 2 (b) tributary troughs
Legend: 1. type I karren trough, 2. step, 3. direction of regression of trough end, 4. trough bottom watershed, 5. slope direction of type I karren trough bottom, 6. monadnock, I. initial condition, II. fully developed condition

Troughs developing at various parts of the bend can cut up the recesses to monadnocks of various sizes. In the case of the retreating of two tributaries the divide develops within the neck zone. In the case of one retreating tributary the divide develops where its upper end reaches the main trough. The ends of the neck troughs hang above the bottom of the main trough.

At true beheading the recess is separated by the solvent flow in the trough.

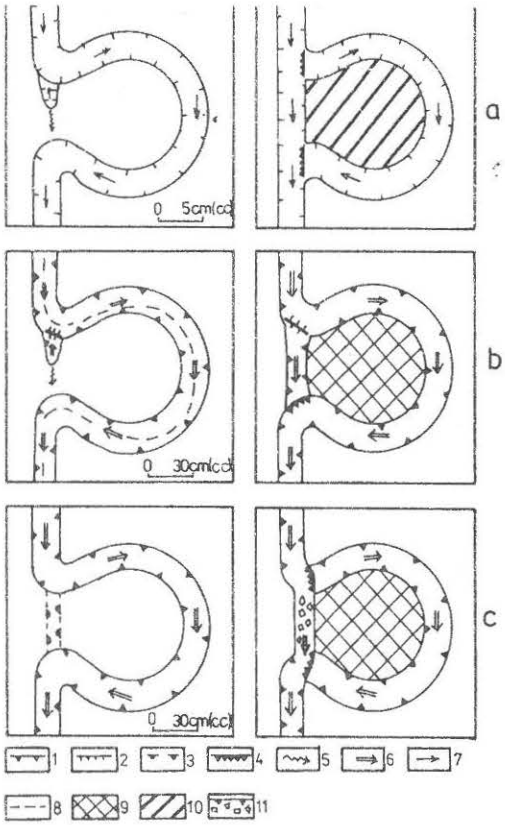

Figure 9: Developing of karren monadnocks with true beheading of bends
Legend: 1. type I karren trough, 2. type III karren trough, 3. karren cavity, 4. step, 5. direction of regression of trough end, 6. slope direction of type I karren trough bottom, 7. slope direction of type III karren trough bottom, 8. channel line, 9. monadnock, 10. karren inselberg on the bottom, 11. opened-up karren trough, I. initial condition, II. fully developed condition a. b. developing progressive trough, c. cave-in of karren cavity

True beheading occurs most simply in type III troughs, because they are only a few centimeters deep. When the gradient of the master trough (type I trough) is moderate and the meander zone of the type III trough is wide, the meander arc is long, the solvent flow in the trough does not follow the arc of the loop but spills over. Thus an intensively developing progressive trough is made on the neck.

Beheading occurs if the depth of the progressive trough exceeds the depth of the trough in the bend. The separated trough section becomes hanging with both ends connecting to the new trough section in the neck with steps. As bend slippage may happen on the surface of the recess, lateral small extension pointed inselbergs may develop (*Fig. 9a and Picture 5*). The phenomenon can be observed in type II troughs too. In these cases the cutoff of the recess occurs during the development of type III troughs.

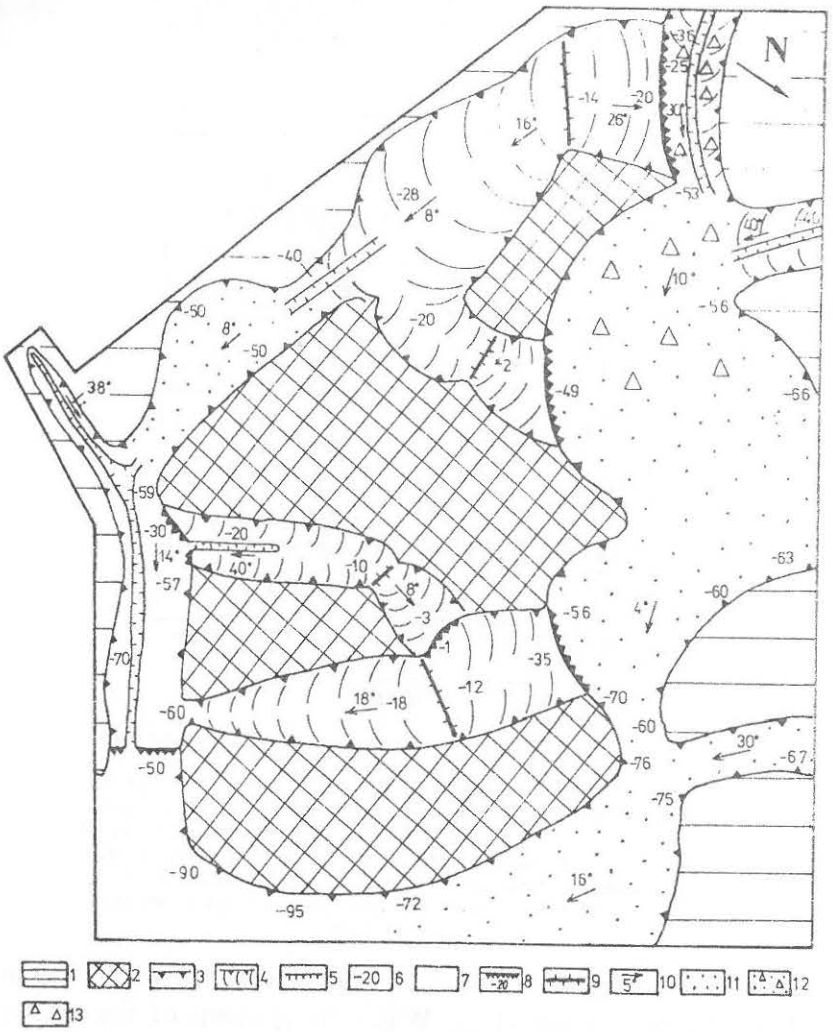

Figure 10: Morphological map of the "A" karren ground surface detail
Legend: 1. karren development on the rock near the mapped ground surface part, 2. monadnock, 3. type I karren trough (vertical-sided), 4. type I karren trough (gently sloping-sided), 5. type III karren trough, 6. trough with depth in centimeters (it is indicated at the point where it was measured between the bottom and rim), 7. trough bottom without sediment, 8. step with depth in centimeters, 9. trough bottom watershed, 10. direction of slope of karren trough bottom, 11. soil and weathering products, 12. soil with rock debris, 13. rock debris

True beheading can develop in type I troughs too mostly when the trough consists of a single meander (loop meander in an overdeveloped trough). The channel line hits the trough rims at the necks. If the depth of the trough is moderate at these places part of the flow in the trough spills over that results the partial cutoff of the loop (*Fig. 9b*). The developing

progressive trough at the neck and the bottom of the meander can entrench together. Both trough sections remain active because water can flow in both the progressive trough and in the cutoff part of the main trough. The lower end of the progressive trough hangs above the bottom of the master trough, at its upper end a trough bottom divide develops. The monadnock developed by the progressive trough can be cut up to monadnock remnants by further troughs by false beheading.

Karren cavity may develop in the necks. The development of the monadnock is complete with the destruction of the roof of the karren cavity (*Fig. 9c*). The beheaded bend is hanging, it joins the existing trough sections with steps at the necks.

4. The History of Dissolution of the Mapped Karren Ground Surfaces

The history of dissolution of ground surfaces mapped at the Widerkar Peak will be presented in the followings. At the sketching of the history of dissolution not only results obtained in the analysis of the karren inselbergs and monadnocks were applied but the results of the study of meander development as well (*VERESS, M.* 1998).

4.1. The "A" Karren Ground Surface Detail (Fig. 10, Picture 6)

The arcing type I and II karren troughs develop by retreating. The letter is the tributary trough of the former (*Fig. 11a*). These two karren troughs develop parallel to each other in part.

The ends of the type I and II karren troughs reaching up to one another create a series of monadnocks (*Fig. 11b, c, d*). First the No. V, then the No. VI, VII and finally the No. VIII monadnocks develop. The trend of the described series of development can be especially caught in the case of the monadnocks Nos. V and VI. That is, the No. III tributary trough can develop only (a premise of the development of monadnock No. VI) when the Nos. II and III troughs connect. (The development of these two letter troughs results the development of monadnock No. V.)

Of the tributary troughs retreating towards each other those retreating from the No. II trough are the older. This is proved by the trough bottom divides being closer to the No. I trough. Another proof is that the difference of elevation of the bottoms of the No. II trough and its tributaries are smaller than that of the No. I trough and its tributaries.

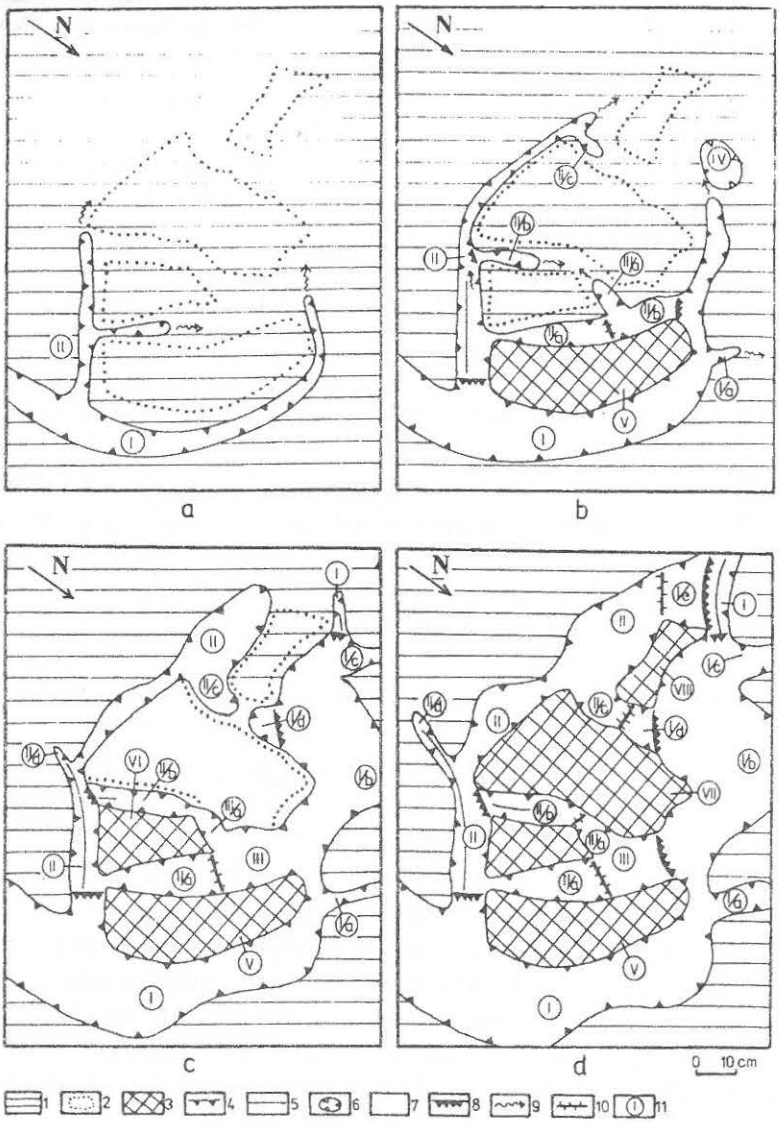

Figure 11: Solution history of "A" ground surface detail
Legend: 1. surface without karren, or showing no reconstructable karren forms, 2. monadnock developed at a later time, 3. monadnock, 4. type I karren trough, 5. type III karren trough, 6. initial solution pan, 7. trough bottom and solution pan bottom without covering sediment, 8. step, 9. direction of regression of trough end, 10. trough bottom watershed, 11. identifying sign of trough, solution pan and monadnock (a, b, c former condition, d present condition)

4.2. The "B" Karren Ground Surface Detail (Fig. 12, Picture 7)

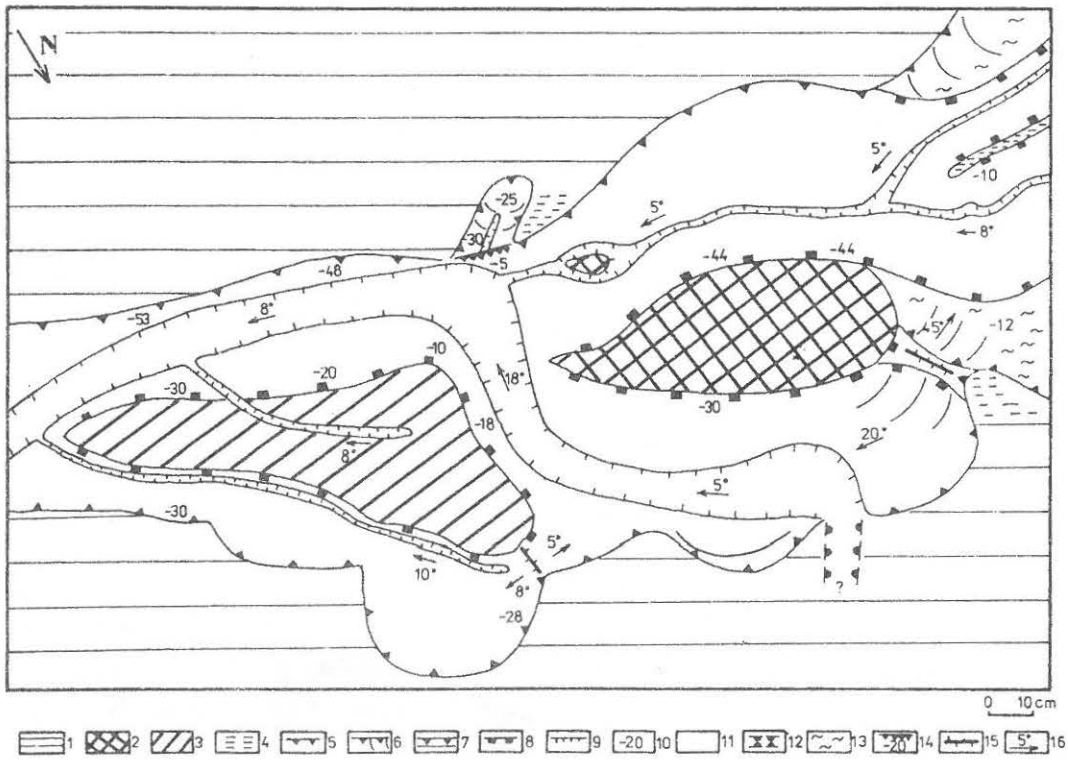

Figure 12: Morphological map of the "B" ground surface detail
Legend: 1. karren development on the rock near the mapped ground surface detail, 2. bottom monadnock, 3. karren inselberg on the bottom, 4. karren half-inselberg, 5. type I karren trough (vertical-sided), 6. type I karren trough (gently sloping-sided) , 7. type I karren trough (overhanging-sided), 8. type II karren trough (vertical-sided), 9. type III karren trough, 10. trough with depth in centimeters (it is shown where it was measured), 11. trough bottom without covering sediment, 12. karren cavity, 13. terrace, 14. step with depth in centimeters, 15. trough bottom watershed, 16. direction of slope of grade of karren trough bottom

The type I, No. I karren trough develops. The development of a type II trough, No. II begins in the bottom of this trough (*Fig. 13a*). The intensive widening of trough No. II then that of trough No. V digests the bottom of trough No. I in the direction of its rim. In these locations the remnants of the

No. I. trough do not remain even in the form of terraces. (Such remain only in its interior as bottom inselbergs and monadnocks.) The No. IIa and IIb troughs develop forking from trough No. II as well as its No. III tributary trough (*Fig. 13b, c*). Because of the less intensive widening of the No IIa and IIb troughs terraces develop in this section of trough No I.

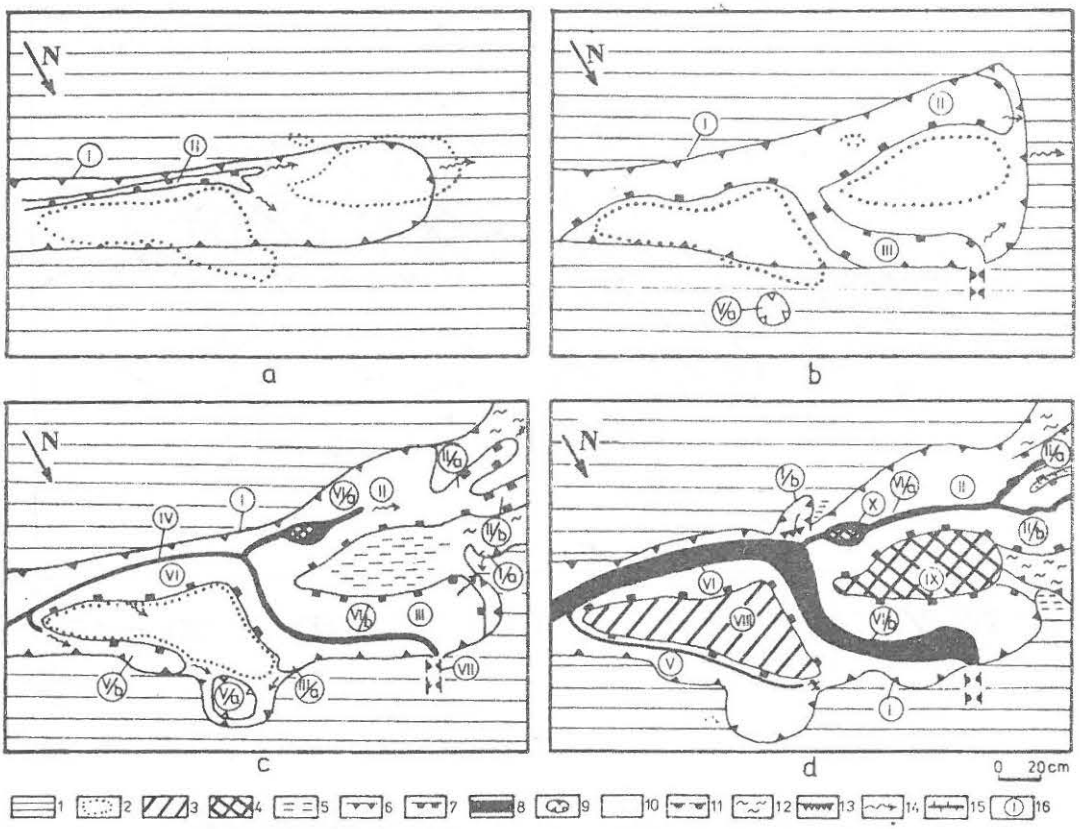

Figure 13: Solution history of "B" ground surface detail
Legend: 1. surface without karren, or showing no reconstructable karren forms, 2. karren inselberg and monadnock developed at a later time, 3. karren inselberg on the bottom, 4. bottom monadnock, 5. karren half-inselberg, 6. type I karren trough, 7. type II karren trough, 8. type III karren trough, 9. little solution pan , 10. trough bottom and solution pan bottom without covering sediment, 11. karren cavity, 12. terrace, 13. step, 14. direction of regression of trough end, 15. trough bottom watershed, 16. identity sign of trough, solution pan , karren cavity, monadnock and karren inselberg (a, b, c former condition, d present condition)

With the connecting of the troughs Nos. V and III the No. VIII bottom monadnock and with the connecting of the troughs Nos. III and I the No. IX bottom monadnock develops. (The No. VIII monadnock rises only a few centimeters above the trough No. V that hints at the intensive destruction of its surface.) As a result of the forking of trough VI. such a bottom monadnock develops that is a residue of the bottom of the No. II trough (*Fig. 13c, d*).

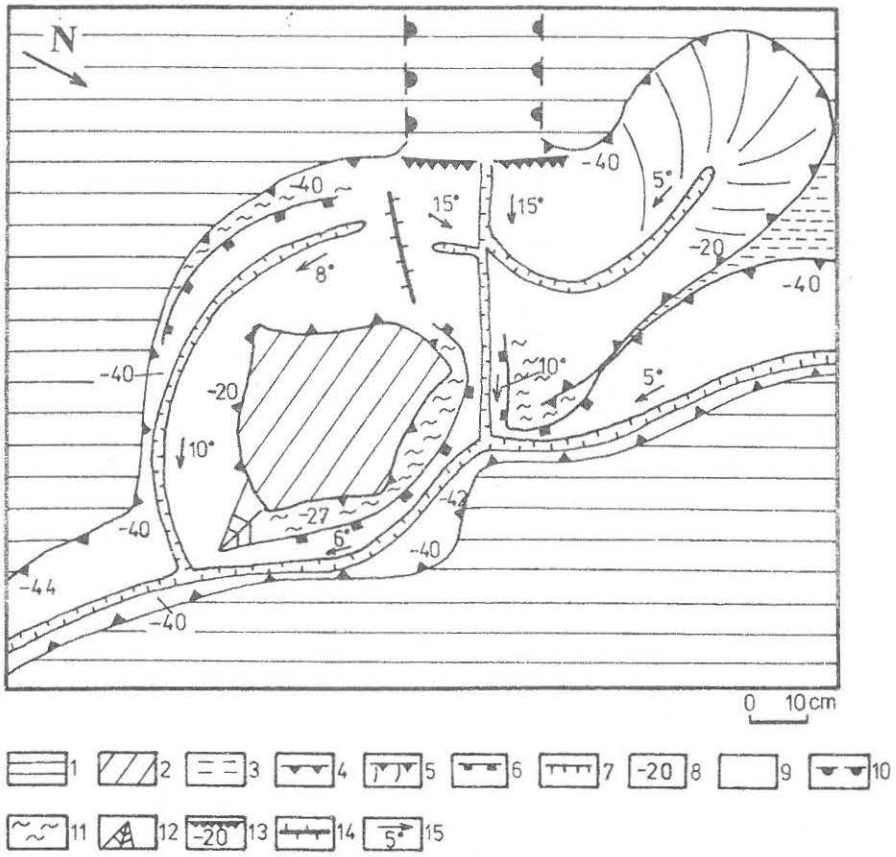

Figure 14: Morphological map of the "C" ground surface detail
Legend: 1. karren development on the rock near the mapped ground surface detail, 2. karren inselberg, 3. karren half-inselberg, 4. type I karren trough (vertical-sided), 5. type I karren trough (gently sloping-sided), 6. type II karren trough (vertical-sided), 7. type III karren trough, 8. trough with depth in centimeters (it is shown where it was measured), 9. trough bottom without covering sediment, 10. karren cavity, 11. terrace, terrace remnant, 12. skirt, 13. step with depth in centimeters, 14. trough bottom watershed, 15. direction of slope of grade of karren trough bottom

4.3. The "C" Karren Ground Surface Detail (Fig. 14, Picture 8)

From the No. I karren trough retreating to the northwest the Nos. II and III karren troughs develop (*Fig. 15a*). The age of the No. II karren

trough is more or its development is quicker than that of trough No. III. For this reason the No. IIIa tributary trough reaches the rim of trough No. II during its westward retreating (*Fig. 15b*). Because the development of the former is quicker, it beheads the letter (*Fig. 15c, d*).

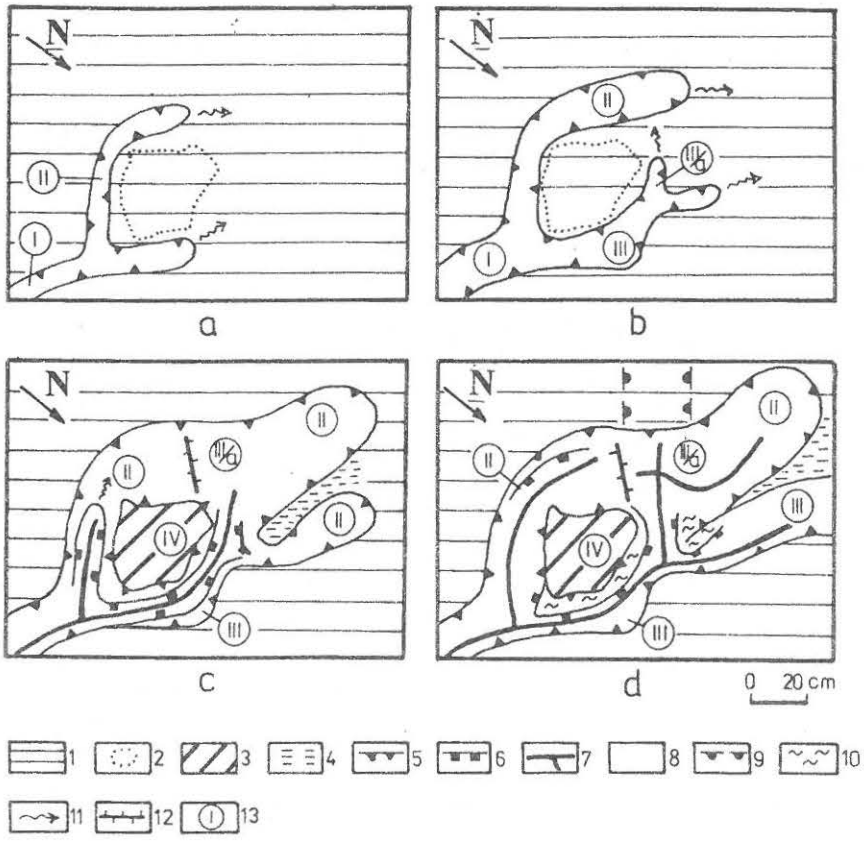

Figure 15: Solution history of the "C" ground surface detail
Legend: 1. surface without karren, or showing no reconstructable karren forms, 2. karren inselberg developed at a later time, 3. karren inselberg, 4. karren half-inselberg, 5. type I karren trough, 6. type II karren trough, 7. type III karren trough, 8. trough bottom without covering sediment, 9. karren cavity, 10. terrace, 11. direction of regression of trough end, 12. trough bottom watershed, 13. identity sign of trough and karren inselberg (a, b, c former condition, d present condition)

Type II troughs develop on the bottoms of type I troughs (Nos. II and III). The widening of these cause the development of terraces in troughs Nos. II and III. The development of the type II troughs is completed to the time of beheading. This is hinted by the fact that the type II troughs and terraces do not develop in the beheaded trough sections.

The No. IV inselberg develops as a result of the beheading. Its top is lower than the elevation of the surrounding surface. There is no trace of any such effect during the development of troughs Nos. II and III that would

have caused the denudation of the surface of the top of the monadnock. That's why it is possible that the karren development of the top of the monadnock has been the result of karren processes independent of the above described processes.

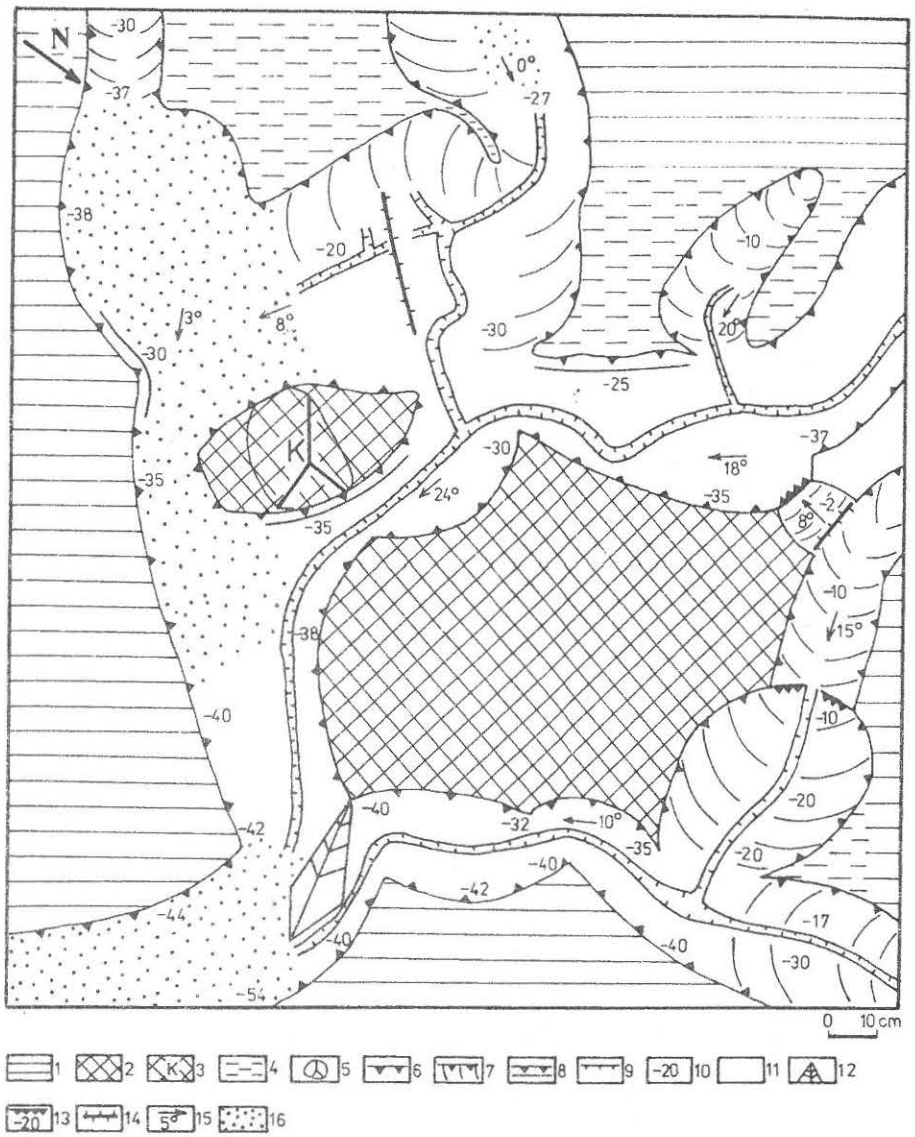

Figure 16: Morphological map of the "D" ground surface detail
Legend: 1. karren development on the rock near the mapped ground surface detail, 2. monadnock, 3. karren monadnock, 4. karren half-inselberg, 5. karren rise, 6. type I karren trough (vertical-sided), 7. type I karren trough (gently sloping-sided), 8. type I karren trough (overhanging-sided), 9. type III karren trough, 10. trough with depth in centimeters (it is shown where it was measured), 11. trough bottom without covering sediment, 12. skirt (at slippage), 13. step with depth in centimeters, 14. trough bottom watershed, 15. direction of slope of karren trough bottom, 16. soil and weathering products

4.4. The "D" Karren Ground Surface Detail (Fig. 16)

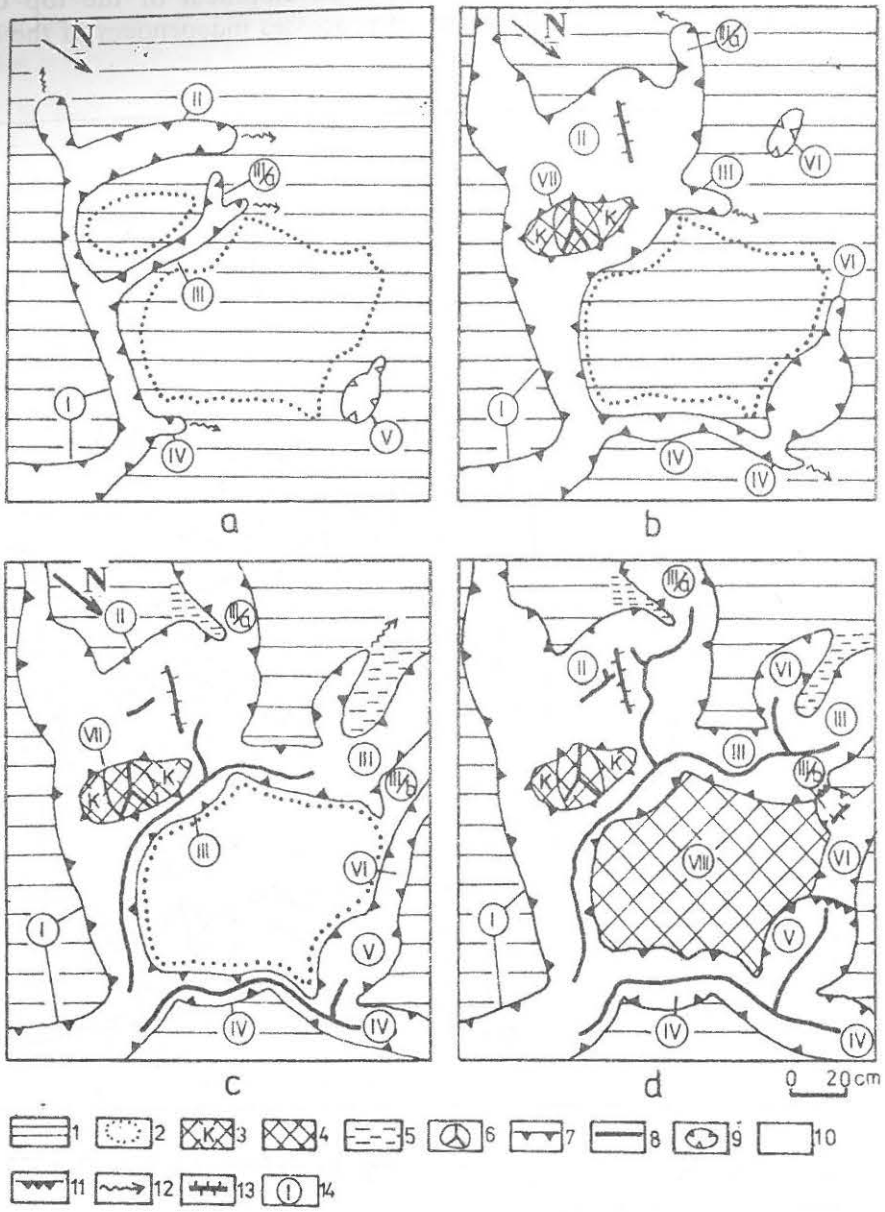

Figure 17: Solution history of the "D" ground surface detail

***Legend:** 1. surface without karren, or showing no reconstrutable karren forms, 2. karren inselberg and monadnock developed at a later time, 3. karren monadnock, 4. monadnock, 5. karren half-inselberg, 6. karren rise, 7. type I karren trough, 8. type III karren trough, 9. small solution pan , 10. trough bottom without sediment, 11. step, 12. direction of regression of trough end, 13. trough bottom watershed, 14. identity sign of trough and monadnock (a, b, c former condition, d present condition)*

The No. I trough develops from the east to the west and making a bend to southwest it develops further ever retreating. Retreating westwards from the karren trough tributary karren troughs develop (Nos. II, III, IV, *Fig. 17a*). The older No. II is beheaded by the younger, more intensively developing No. III that is proved by the trough bottom divide in the former. The No. VII rough surfaced karren monadnock develops (*Fig. 17b*). Its surface probably carries the traces of older trough bottoms that hints at previous karren development. Following this (*Fig. 17c*) the No. IIIb karren trough reaches the No. VI. karren trough (false beheading) that proves the higher age of development of the No. III trough being higher than that of No. VI, or its higher rate of development. The monadnock No. VIII develops (*Fig. 17d*).

4.5. The "E" Karren Ground Surface Detail (Fig. 18, Picture 9)

The No. I karren trough develops with its tributary trough (I.a). The No. I karren trough makes a system (with a karren trough swallet) with the No. V karren cavity. A solution pan (No. III) develops above this karren cavity that is joined by the No. II karren trough. (*Fig. 19a*).

The roof of the karren cavity had possibly thinned so much at the bottom of the No. II karren trough and solution pan that part of it may have developed to an opening up karren trough (*Fig. 19b*). This way the connection between the No. II karren trough and the solution pan has been severed. The merging by solution of the No. Ia karren trough and the solution pan can be expected as well as the collapse of the roof of the karren cavity in its whole length (*Fig. 19d*). Resulted by these processes the remnant of the original ground surface becomes a monadnock between the remnant of the solution pan (V) and the bottom of the No. II karren trough becomes an inselberg (VI).

4.6. The "F" Karren Ground Surface Detail (Fig. 20, Picture 10)

The karren trough No. I develops as a rainwater runnel with three meanders (*Fig. 21a*). The two smaller meanders (m_1 and m_2) are true meanders this proven by the skirts on the trough sides. In the big meander (m_3) that is a loop meander, a skirt can not be recognized. In spite of this the development of this bend has probably happened by true meandering proven by the overhanging wall in the concave side of the band.

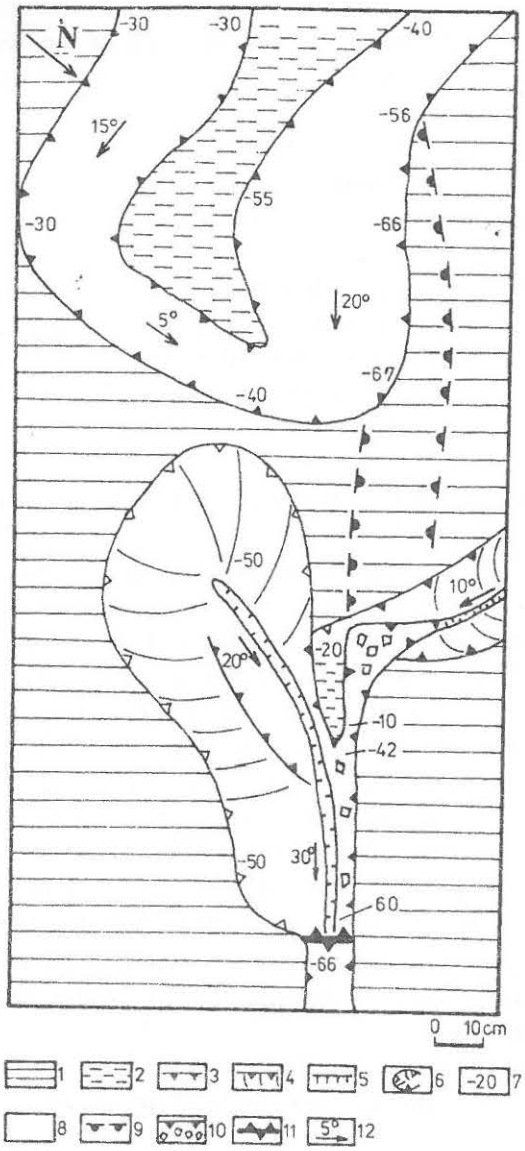

Figure 18: Morphological map of the "E" ground surface detail

Legend: 1. karren development on the rock near the mapped ground surface detail, 2. karren half-inselberg, 3. type I karren trough (vertical-sided), 4. type I karren trough (gently sloping-sided), 5. type III karren trough, 6. vertical-sided and gently sloping-sided solution pan remnant, 7. trough and solution pan with depth in centimeters (it is shown where it was measured), 8. trough bottom without covering sediment, 9. karren cavity, 10. trough developed by opening up, 11. trough arch, 12. direction of slope of karren trough bottom

Early begins the development of the No. II trough in the m_3 meander, that separates the No. XV monadnock by false beheading (*Fig. 21b*). The early beheading is proven by the smallest step height than can be associated with the big entrenchment of the trough.

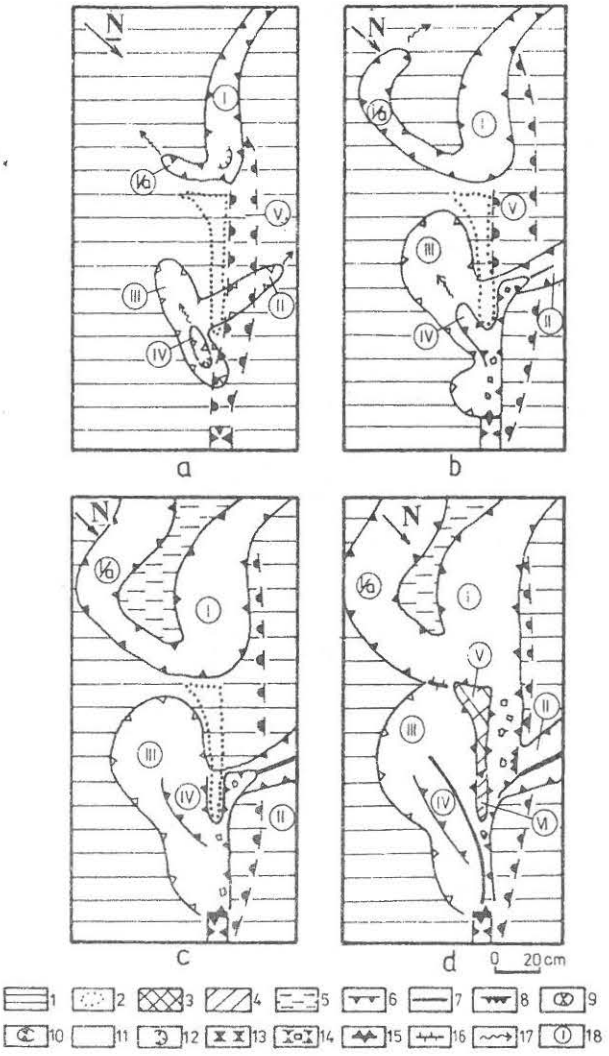

Figure 19: Solution history of the "E" ground surface detail
Legend: 1. surface without karren, or showing no reconstructable karren forms, 2. karren inselberg and monadnock developed at a later time, 3. monadnock, 4. karren inselberg, 5. karren half-inselberg, 6. type I karren trough, 7. type III karren trough, 8. step, 9. solution pan , 10. destructed solution pan , 11. trough and solution pan bottom, 12. trough sink, 13. karren cavity, 14. trough developed by opening up, 15. trough arch, 16. trough bottom watershed, 17. direction of regression of trough end, 18. identity sign of trough, solution pan and monadnock (a, b, former condition, c present condition, d condition in the future)

The channel line swing intensifies in the quickly widening trough No. I resulting the progressive development of troughs Nos. III and IV (*Fig. 21b, c*). The loop type development of trough No. III develops the No. XIV monadnock. (The surface of both the Nos XIV and XV monadnocks are karren. The time of the karren development can not be specified.) Many

more tributary troughs develop in the No. I trough (Nos. VII, VIII, X, XI). The No. XII karren cavity develops and trough end connecting occurs between the troughs Nos. V and VI.

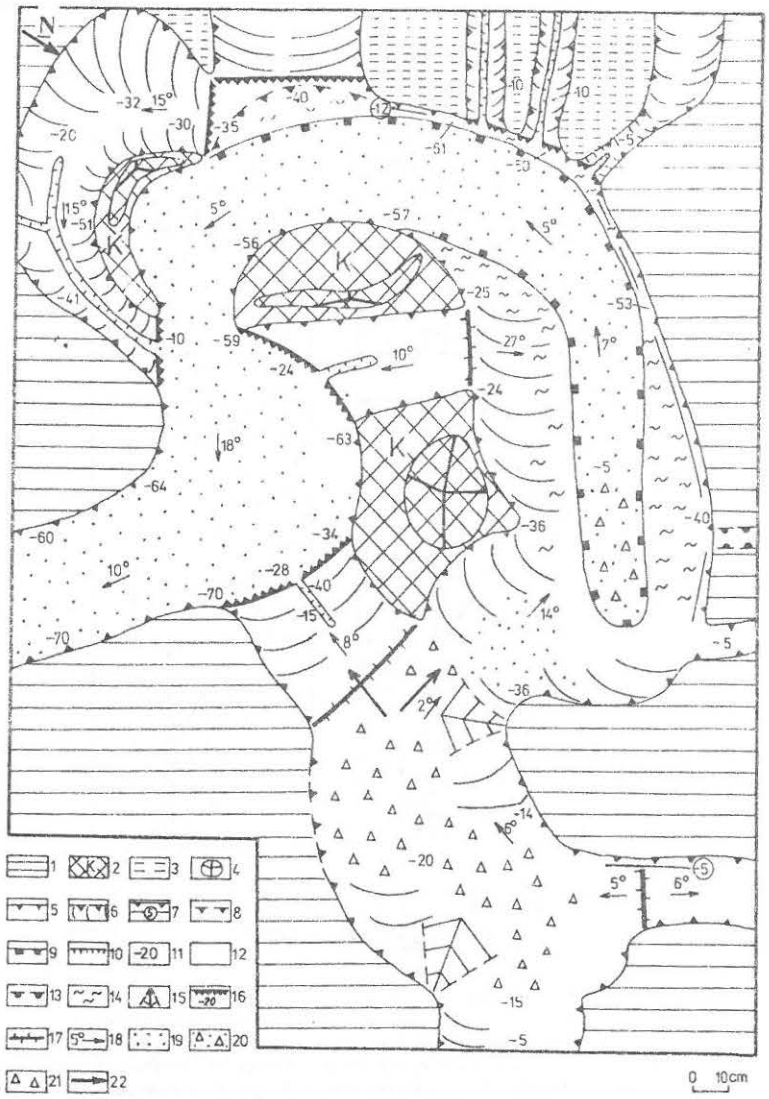

Figure 20: Morphological map of the "F" ground surface detail
Legend: 1. karren development on the rock near the mapped ground surface detail, 2. karren monadnock, 3. karren half inselberg and monadnock, 4. karren rise, 5. type I karren trough (vertical-sided), 6. type I karren trough (gently sloping-sided), 7. type I karren trough (overhanging-sided, the number shows the biggest horizontal distance in centimeters between overhanging side and edge of trough), 8. ruined edge of trough, 9. type II karren trough (vertical-sided), 10. type III karren trough, 11. trough with depth in centimeters (it is shown where it was measured), 12. trough bottom without covering sediment, 13. karren cavity, 14. terrace, 15. skirt remnant (at slippage), 16. step with depth in centimeters , 17. trough bottom watershed, 18. direction of slope of grade of karren trough bottom, 19. soil and weathering products , 20. soil debris, 21. debris, 22. water flow directions at the time of mapping

The beheading of the recess is done by the No. IV progressive trough, the No. XVI monadnock develops (*Fig. 21d*).

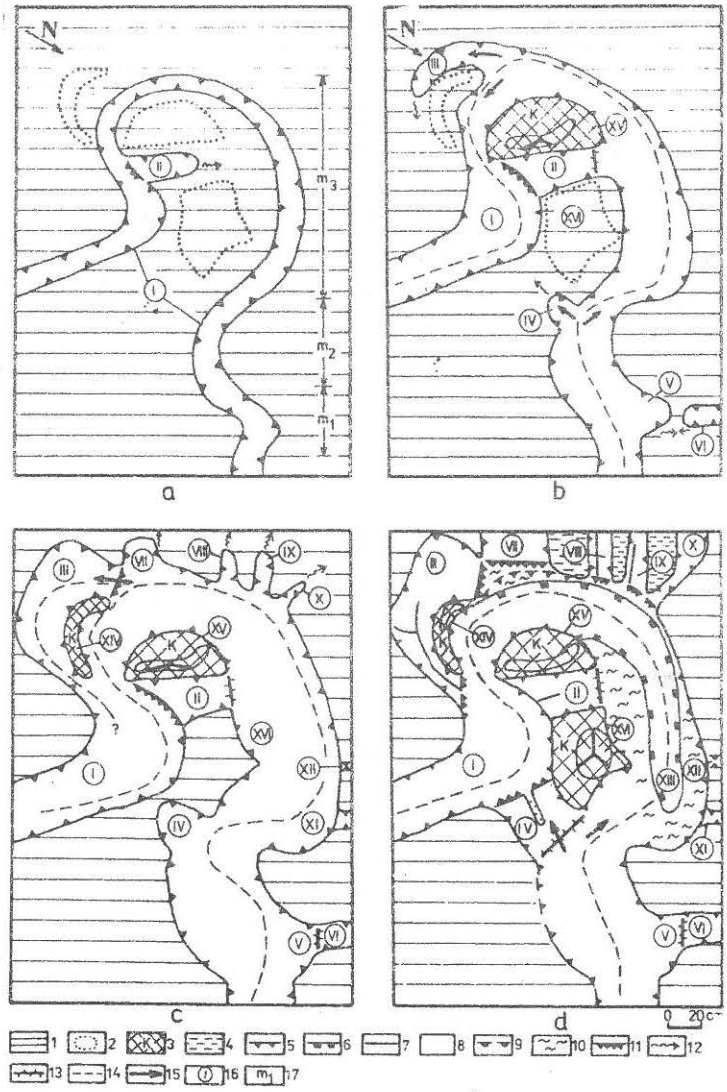

Figure 21: Solution history of the "F" ground surface detail
Legend: 1. surface without karren, or showing no reconstructable karren forms, 2. karren inselberg and monadnock developed at a later time, 3. karren monadnock, 4. karren half inselberg, 5. type I karren trough, 6. type II karren trough, 7. type III karren trough, 8. trough bottom without covering sediment, 9. karren cavity, 10. terrace, 11. step, 12. direction of regression of trough end, 13. trough bottom watershed, 14. channel line, 15. probable water flow directions, 16. identity sign of trough and monadnock, 17. identity sign of meander (a, b, c former condition, d present condition)

The solvent that flows from the karren cavity develops a type II trough (No. XIII) with the partial entrenchment of the No. I trough. This

results the development of terraces at parts of the trough No. I. The overhanging walls of trough No. I collapse.

5. Consequences

a. Those troughs that are separated by trough bottom divides and steps have developed regressively. The location and position of these features give ground to the determination of the type of connecting.
b. Considering the trough-end merges, the false and true beheading of troughs and bends the type of development of inselbergs and monadnocks and the sequence of the development of karren forms can be determined on some specific karren ground surface.
c. Using the detailed morphological survey of some specific karren ground surface and the relative sequence of the development of karren forms such a series of maps can be prepared that can describe the process of dissolution to a certain profundity.

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Picture 1: Developing trough bottom monadnock (Totes Gebirge)
Legend: 1. type I trough, 2. type III trough, 3. bottom monadnock, 4. terrace

Picture 2: Trough beheading (Asiago Plateau)
Legend: 1. beheaded trough, 2. beheading trough, 3. step, 4. slope direction of trough, 5. fissure karren

Picture 3: Karren inselberg developed by the connecting of tributary troughs (Totes Gebirge)
Legend: 1. tributary trough, 2. karren inselberg, 3. type I trough, 4. older type II trough, 5. younger type II trough, 6. remnant of trough bottom developed by inside trough shifting, 7. ridge between older and younger type II troughs

Picture 4: Karren inselberg developed by false beheading
Legend: 1. loop meander, 2. recess surrounded by meander, 3. karren monadnock, 4. regressive trough, 5. trough bottom divide , 6. step

Picture 5: Karren inselberg developed by true beheading (there are meander remnants in the trough section above the karren inselberg, Totes Gebirge)
Legend: 1. karren inselberg (beheaded skirt), 2. older, cut off trough bottom, 3. skirt, 4. developing meandering trough section, 5. trough section with meander remnants

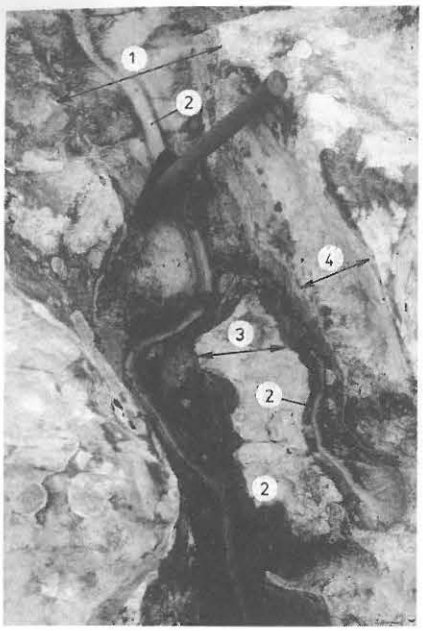
Picture 6: The „A" Karren Ground Surface Detail (Totes Gebirge)
Legend: 1. karren monadnock, 2. vertical-sided type I trough, 3. gently slooping-sided type I trough, 4. trough bottom divide

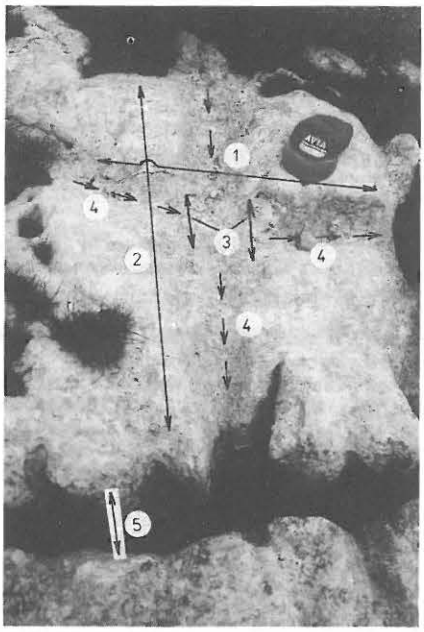
Picture 7: The „B" Karren Ground Surface Detail (Totes Gebirge)
Legend: 1. trough bottom monadnock, 2. trough bottom inselberg, 3. type I trough, 4. type II trough, 5. type III trough, 6. karren cavity, 7. trough bottom divide

Picture 8: The „C" Karren Ground Surface Detail (Totes Gebirge)
Legend: 1. karren inselberg, 2. karren halfinselberg, 3. vertical-sided type I trough, 4. gently slooping-sided type I trough, 5. type III trough, 6. type II trough, 7. karren cavity, 8. terrace, 9. trough bottom divide

Picture 9: The „E" Karren Ground Surface Detail (Totes Gebirge)
Legend: 1. karren kalfinselberg, 2. vertical-sided type I trough, 3. type III trough, 4. kamenitza remain, 5. karren cavity, 6. opening karren trough, 7. trough arch

Picture 10: The "F" Karren Ground Surface Detail (Totes Gebirge)
Legend: 1. loop meander, 2. recess surrounded by meander, 3. karren monadnocks, 4. progressive trough, 5. regressive trough





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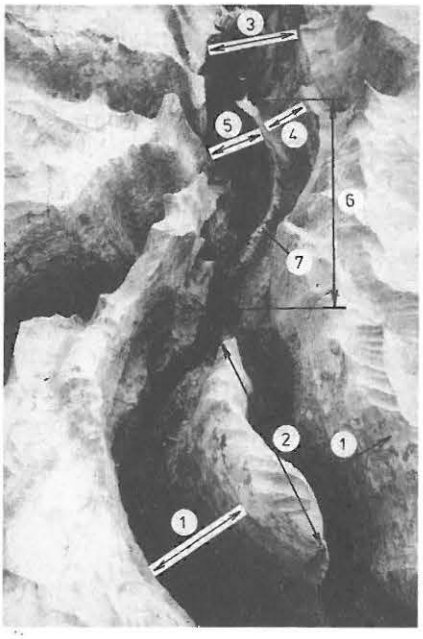

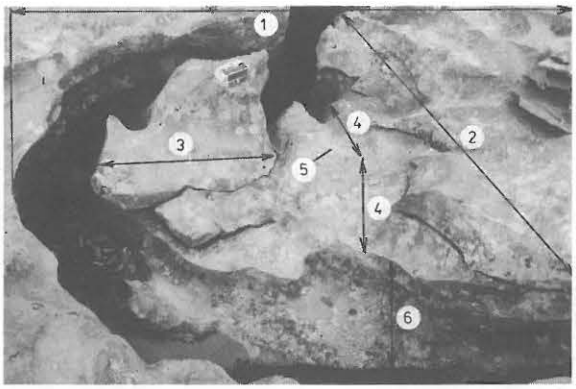

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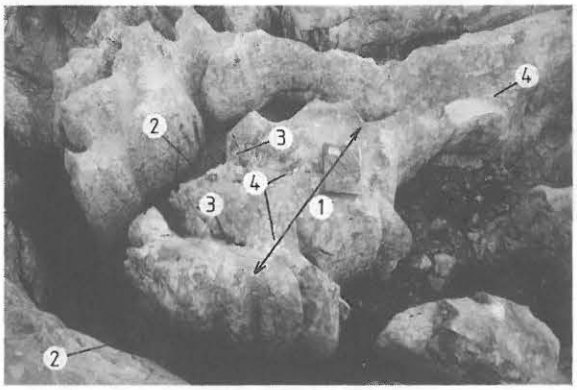

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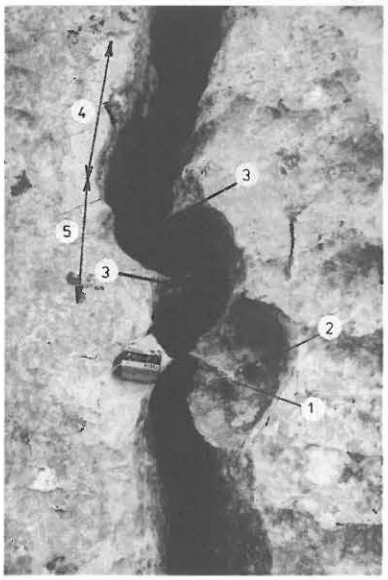

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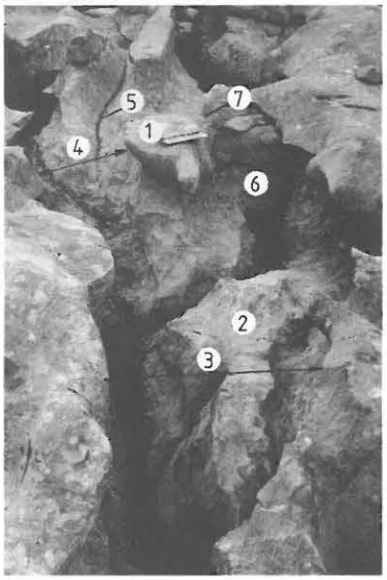

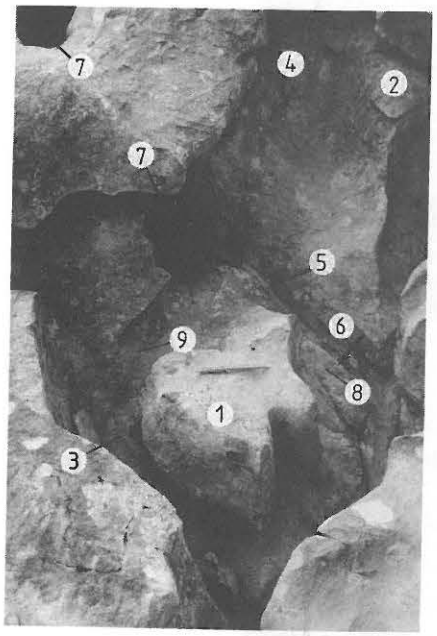

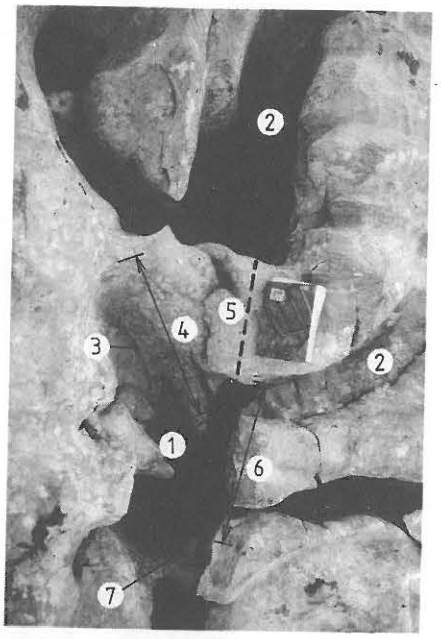

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