SOME METHODS TO OBSERVE KARST CORROSION AND PERCOLATION

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Received: 31. 12. 1979.

In the past decade plenty of data available helped the scientists to draw more accurate conclusions, referring to karst morphology. Yet, in nine cases out of ten morphological processes are explained by deduction drawn from the observation of the developed forms. The description of measurements in recent formations of karst is only occasional and long term monitoring is scarce in literature.

Methods of chemistry, physics, geology and other branches of sciences greatly contribute to the revelation of new aspects, dealing with the genetics of karst. But in most cases morphological observation needs special methods to be developed which provide us with the possibility of monitoring in the site of the investigation. The application of laboratory analysis is difficult to carry out in the field and data thus gained are not objective.

While I was observing the development of karst formations I worked out some methods on theoretical and experimental basis. None of these methods take a lot of money and the results achieved are accurate enough.

My observations in which I applied new field-work methods concern the revelation of the formation of dolines, the process of solution in rock and all processes related to them.

The investigated area was chosen by bearing in mind that the results should be accurate enough and that the area should represent a temperate zone karst area. In this way all data gained can be applied to any similar phenomenon and generalization can be made. In the following I give a detailed description of three methods to be applied in field-work.

I. Registration of downflow and percolation on the slopes of dolines

The investigated area, just like any other of the same kind in temperate zone or semi-tropical areas, is mostly covered by a thin layer of clay which belongs to the terra rossa soil group. In some places the layer of red clay is replaced by open rock outcrops or other soils (black forest soil of karst areas), but in general it is a covered or half covered karst area. The slopes of the several number of dolines are covered by a thin, while the bottom by a thick layer of clay (2 – 20 metres). The survey of the recent development of dolines can not be carried out without observing the flow of water in the catchment area of the dolines, which are the slopes themselves. We can neither neglect the erosional and corrosional effect of water. To study all these I have chosen an area clearly representing the features of half covered karst areas.

The most important respects of choosing the area were as follows:

1. The structure of rock on the slopes should correlate with the general petrological state of karst rocks.
2. The thickness and composition of deposits and soil on the karst should be the average.
3. The inclination of slopes should be an average but segments of different slope angles must alterate.
4. The area to be surveyed should be one, well demarcated hydrological unit.
5. The ecology of the area and the surroundings should not be disturbed and no anthropogene impact can be tolerated.
6. The equipment used during the observation should be set up without any basic interference in the water system of the area. The area should be accessible by the observer under any weather condition.

The selection of the right doline needed an earlier survey of more than a hundred dolines. The following parameters had to be examined:

a) Amount, distribution and intensity of precipitation.
b) Surface water runoff and deposits taken hold of.
c) The quantity of infiltrating water towards the deepest point of the doline and the average carbonate solution capacity of the infiltrating water, which was determined by taking samples from the water.

The structure, registrating runoff and infiltrating water, was built mostly from natural materials and I tried not to disturb the natural surroundings.

The investigated area was a 646 sq. metre western slope of a doline (Fig. 1). The upper border of the slope was a sharp ridge between two dolines while the boundaries on both sides were clearly marked by karr rocks rising high above the surface, preventing the inflow of water from the neighbouring areas. The boundary at the bottom was artificially determined right along a line where the thin layer of clay on the slope mingles with the thick layer of clay on the bottom of the doline.

In this line a ditch was dug as deep as the limestone bedrock (Fig.2). The 28.3 metre long ditch revealed the layers of the soil and clay deposits. I took samples of the soil and the structure was never disturbed. The examination of the soil samples took place in laboratory.

The site of the ditch was determined by the examination of several preliminary hole drillings (Fig. 3). The soil dug out of the ditch was tempo-

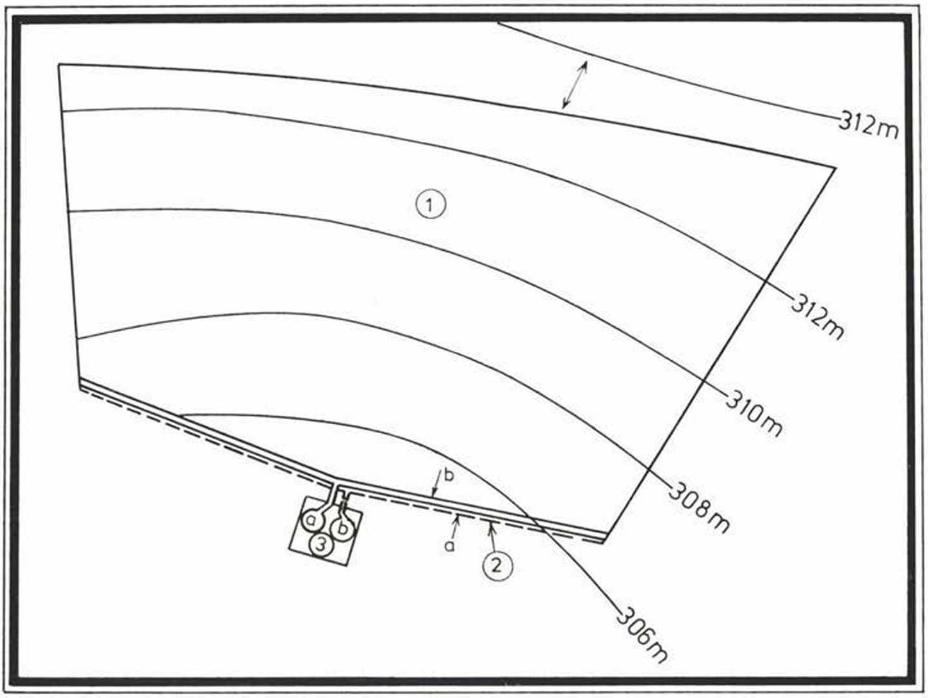

Fig. 1. The investigated area

1. Slope of doline 2. Ditch with pipe duct (*a*) and with drain pipe (*b*) 3. Shelter

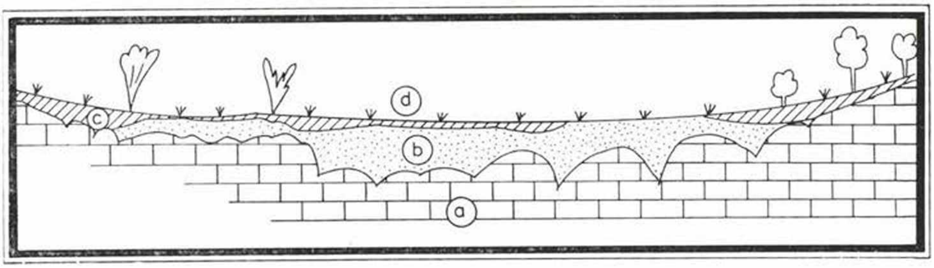

Fig. 2. Longitudinal profile of the ditch

a) Bottom of doline *b)* Terra rossa sediment *c)* Soil *d)* Surface with vegetation

rarily piled up far from the investigated area. The ditch was dug to catch and conduct downward filtering water in the soil of the slopes into a tank. The outer wall of the ditch was covered by PVC, the edge of which was turned in order to lead infiltrating water back on the bedrock. At the bend of the PVC sheet a closely perforated drain pipe was put in a ballast (flint-gravel-sand) bedding to catch and drain the infiltrating water. This bedding prevents the choking of perforations in the drain pipe. At the deepest point of the ditch a forking of PVC drain pipe conducts water into the tank. Above the ballast the ditch was filled in with the original soil, taking care of the right order and compactness of layers.

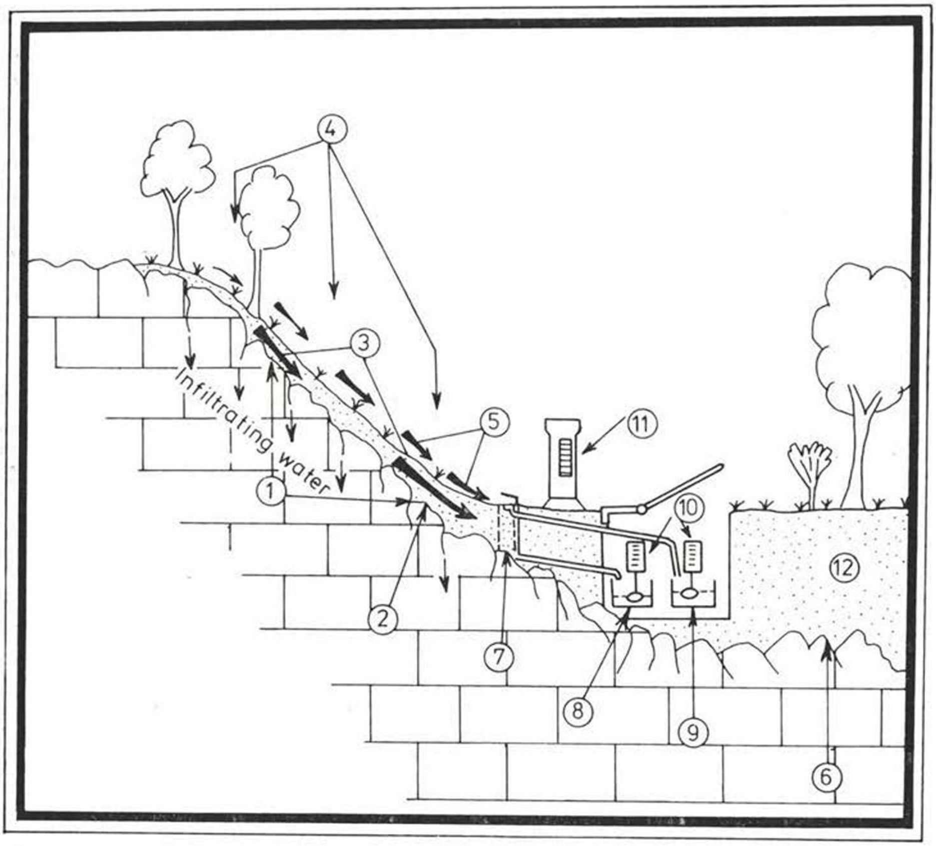

Fig. 3.

1. Slope of the rock 2. Thin layer of deposits and soil 3. Downflow of infiltrating water 4. Precipitation 5. Surface runoff and erosion of deposits 6. Bottom of doline 7. Ditch 8. Tank No 1. 9. Tank No 2. 10. Registration equipment 11. Registration equipment (ombrograph) 12. Thick layer of clay

On the top of the ditch a pipe duct collected the surface runoff. The pipe duct was covered from above, so that the direct rainfall should not add up to the amount of water of the surface runoff. On the side of the slope the pipe duct was connected with the soil in the level of the original surface and thus gave way to the drainage of water into the second tank. (Fig. 4).

The tanks were put in a 2 by 3 metres covered shelter, which is in the thick layer of clay in the bottom of the doline. The shelter is timbered.

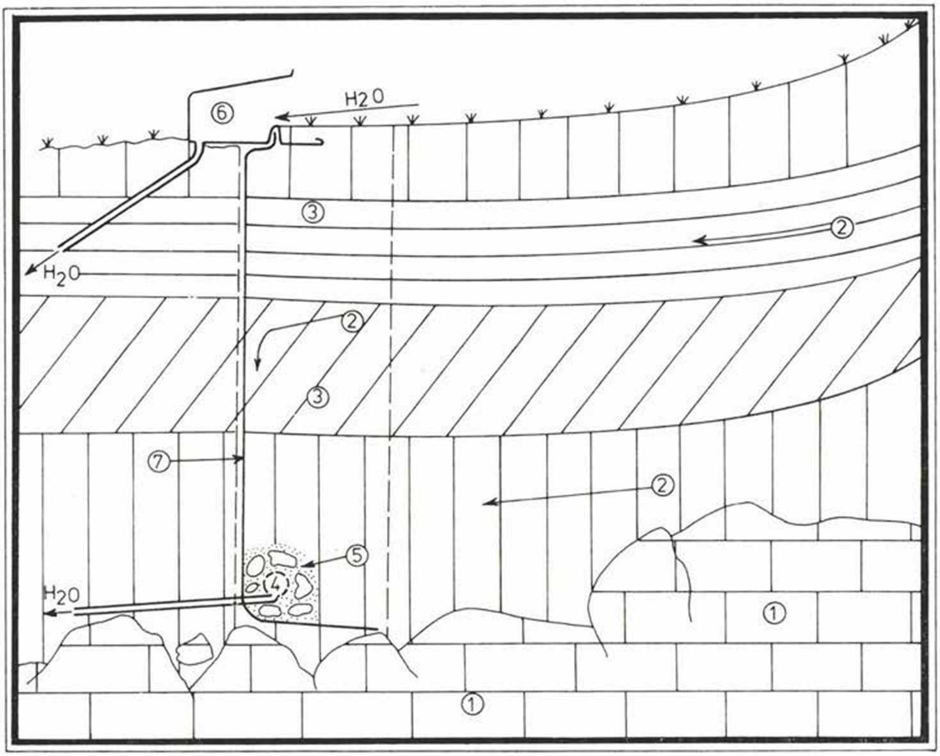

Fig. 4. Cross section of the ditch

1. Limestone 2. Infiltrating water 3. Deposit filled back 4. Drain pipe 5. Ballast 6. Pipe duct 7. PVC-cover

In each tank there is a sensitive equipment registering the level of water in the tank. The colledted water can be let out by a tap but in case the tank fills up too quickly, it is emptied automatically though a self-discharging siphon. The registration is continuous. The drain pipes leading into the tanks are also supplied with a water sampling unit.

The tanks are big enough to receive the water of a heavy rainfall without being emptied.

Erosional deposits collect partly in the pipe duct and partly in the tank. Soil and terra rossa layers (black forest soil and humuous terra rossa) vary to a large extent. Their structural characteristics (Table 1), water absorption capacity and permeability (Table 2) indicate that the speed of water percolation differs from site to site on the slope.

The figures of permeability by layers show that there is hardly any infiltration in areas where there is no humuous soil, thus runoff is heavy. In other places rainfall of high intensity is also absorbed by the rock and downward seepage is heavy. It is particularly true where the thick humuous layer is on a thick layer of red clay. In the first case the rock of the

Table 1.

Structural characteristics of the deposits in the investigated area

Number	Specific gravity	Volume of soil without pores per cent	Total pore volume	Volume weight	Speed of absorption capacity 20 mm/hour	Permeability mm/hour
1 a	1,93	43,0	57,0	0,832	2″	>1500
2 a	1,3	58,0	42,0	0,76	3″	>1500
3 a	2,25	57,8	42,2	1,29	18′37″	71
4 a	1,66	62,0	38,0	1,03	–	805
5 a	2,05	56,8	43,1	1,16	3h 36′57″	impermeability
5 b	2,77	47,11	52,89	1,30	54′12″	impermeability
6 a	1,89	70,40	29,60	1,33	–	400
6 b	2,10	62,7	37,25	1,33	23′	37
7 a	2,05	66,9	33,01	1,37	–	86
7 b	2,39	59,3	40,7	1,41	10′24″	93
8 a	2,00	61,9	38,1	1,24	2′43″	363
8 b	2,34	60,1	39,9	1,41	21′9″	85
9 a	2,76	50,1	49,9	1,38	36′40″	45
9 b	2,49	52,2	47,8	1,30	27′8″	68
10 a	2,13	60,0	40,0	1,27	–	620
11 a	2,4	55,7	44,3	1,32	5′51″	169
12 a	1,37	81,9	18,1	1,12	8″	1063
12 b	1,90	53,0	47,0	1,01	–	540
13 a	2,47	59,2	40,8	1,16	5″	1324
14 a	1,68	59,0	41,0	0,99	3″	>1500
15 a	1,69	52,5	47,8	0,89	2″	>1500

Table 2.

Permeability of layers of humuous soils and red clay according to the position
mm/hour

Black forest soil and humuous terra rossa	>1500	>1500	–	805	impermea-bility	400	–	363	620	169	1063	1324	>1500	>1500
Terra rossa ...	–	–	71	–	–	37	86	68	–	–	–	–	–	–

slope is not at all solved, in the second it is strongly solved, while in the third we can expect a modest corrosion of the rock. After a while these changes can contribute to the morphological changes of the slope. The data obtained also helps to plan the dimensions of the measuring system.

II. Quantitative analysis of karr-development

An increasing number of typical karr formations is known from the various climatic zones. The pertaining studies reveal much about the factors of karr development, there are, however, but few measurement data characterizing the growth process of karr grooves. The analyses to be presented in the following have served two objectives:

1. To obtain data about the speed of contemporary karr development by means of systematic measurement for several years of the solution of the sides of the karr furrow.

2. To study the role of humic soil at the bottom of the karr groove in karr development.

In order to achieve these objectives the measuring spot was selected on a well soluble Triassic limestone rock surface with karrs, evolved on the steep (60%) slope of northward exposition of a deep doline. From the edge of the doline, in the direction of the slope there extended a pair of parallel karr furrows, each more than three meters long and well developed within the temperate climatic conditions. This site has proved adequate for carrying out the analyses. The measuring device was prepared so as to collect the whole amount of precipitation dripping on the sides of the karr furrows, and to detect its dissolved carbonate content and lime-agressivity by means of quantitative analysis. It was essential to ensure that no amount of water would get into the karr furrow from other surfaces, and thus the dissolved lime-content would origin from the solution of the sides of the karr furrow only. This condition was provided owing to the fact that the pair of karrs selected for measurement strated from the top of the slope, at the edge of the dolina. The furrows had V shape in cross-section, i.e. grew narrow towards the bottom, they ran in parallel, and their length was about the same, which yielded possibilities for comparison.

For collecting the water flowing on the sides, the bottom of the furrows (where their width was less than 3 cm) was filled with concrete in accordance with the slope, their lower end was closed down by means of a concrete barrier. Thus a channel was achieved in both furrows, which led the water flowing on the sides of the karr to the barrier, from where it flew through a filter and an undergroud PVC conduit into plastic samplers and a PVC tank of appropriate capacity to receive the total water quantity, all placed in the collecting space sunk in the slope. In order to avoid that the water flowing on the sides of the karr solve, by means of its remaining agressivity, from the material of the concrete surface, this latter was covered with synthetic resin. The applied synthetic resin of two components and of mesh structure had been selected after several years' experiments. Before its application the bottom of the karr furrow and the concrete channel had been cleaned with wire brush and treated with HCl solution. On the surface thus prepared the synthetic resin held fast, and no repairing was needed for about three years. As the preliminary experiments had proved in advance, the water maintained its natural chemical features while flowing on the synthetic resin cover into the closed collecting

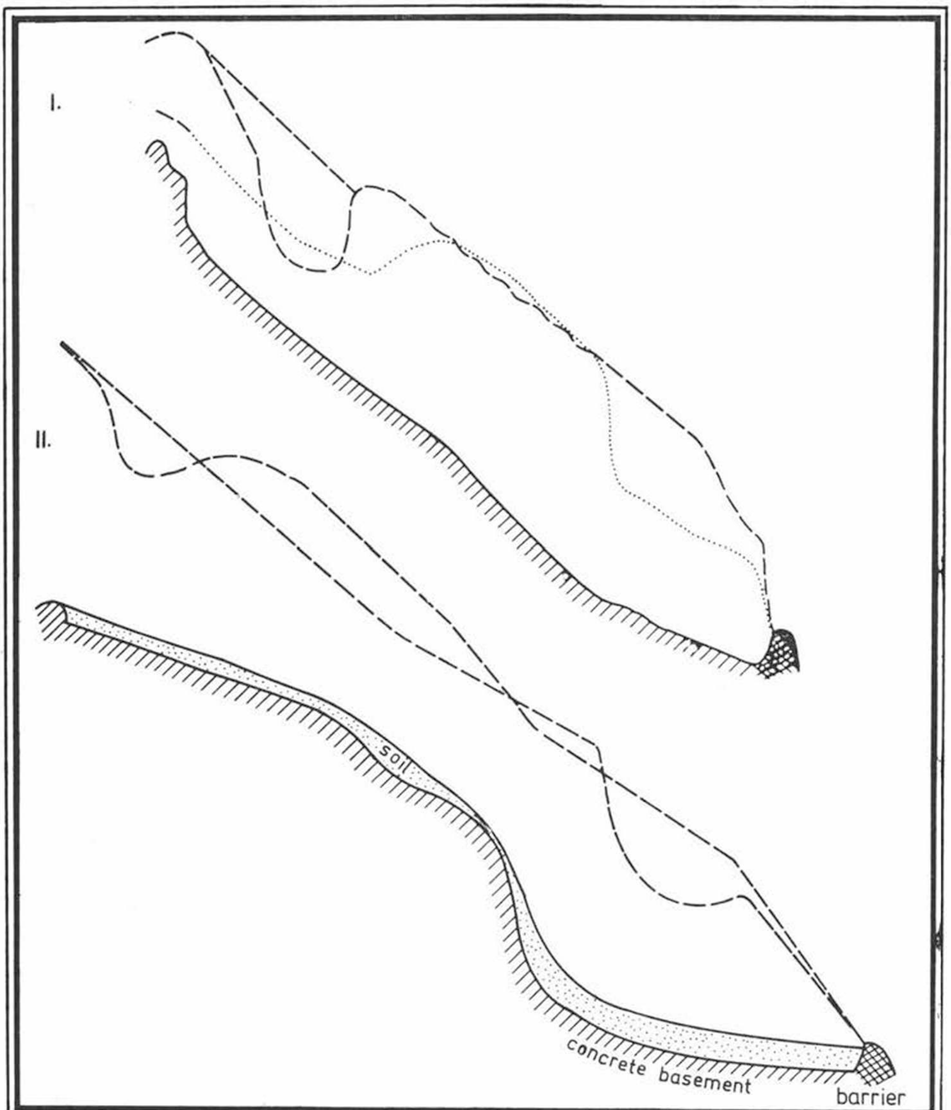

Fig. 5. The surface extent of the walls of the two inverstigated karr channels. Scale 1:10
I. Karr filled in with deposits in the original order of layers of soil
II. Karr without soil

system. By means of underground channeling, collecting and storing it was possible to collect precipitation and melting snow in winter too, without trouble.

In the course of these preparations the original condition of the rock surfaces with karrs, moss and lichen cover remained intact.

For defining the rate of solution per surface unit it was necessary to measure the extension of the side surfaces of the furrows. In view of the roughness of surfaces this measurement was made by means of detailed mapping (Fig. 5.), and by the application of a smooth layer of material disposable without trace.

In one of the parallel furrows the humic soil taken out before filling the bottom with concrete was reposited. Thus in this furrow the flowing water underwent chemical change while filtering through the soil at the bottom. In the other furrow the solution power of water was identical with its overground, natural solution power. The difference in the lime aggressivity of waters flowing from both furrows indicates the role of soil in lime solution (Fig. 6.).

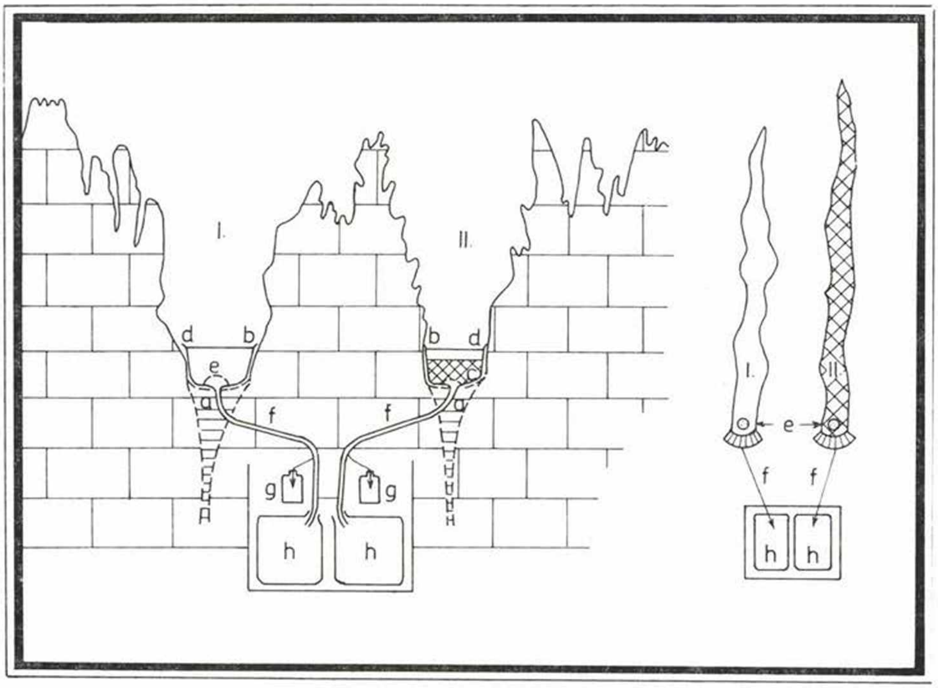

Fig. 6. The two karr channels and the gauging equipment

a) concrete basement *b)* synthetic resin cover *c)* soil filled back *d)* concrete bar to catch the water *e)* filter *f)* PVC-pipe *g)* water sampling unit *h)* tank

III. Analysis of the solution of rock surfaces

Water flowing from well delimited rock surfaces of definite size can be collected and examined. For this purpose it is essential to build a water collecting device so as to ensure that the original solution process and the quantity and composition of flowing water are not changed.

1. Measuring method of the solution of cliffs

Two cliffs of measurable size, standing side by side were selected according to the above mentioned aspects. At their lower end the cliffs were engirdled by concrete collecting ditches with synthetic resin cover. The total amount of water solving the surface of cliffs flew into the ditch, and from there, through a filter and underground conduit into a sampler and tank placed in an underground closet with door on the top. The first cliff (no. I.) yielded data about lime solution, whereas the other (no. II.), where the original soil surrounding the cliff was reposited in the concrete ditch about the chemical changes of water filtering through the soil.

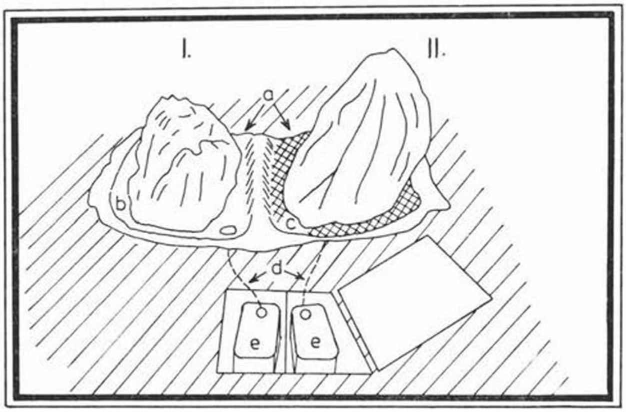

Fig. 7. Two limestone columns with ditches
I–II. Rock columns *a)* ditch *b)* synthetic resin cover *c)* soil filled back *d)* PVC-pipe *e)* tank

2. Measuring method of the solution of flat rock surfaces

Water flowing from the delimited flat surface of a solitary rock was collected in a concrete trough with synthetic resin cover, sunk in the soil at the foot of the rock. From there it flew into a tank. The whole collecting device was covered thus ensuring that the collecting system received the water flowing from and corroding the rock surface only. (Fig. 8.)

In case of all the three methods elaborated for the analysis of carst corrosion and carst infiltration processes the following aspects of observation were applied:

a) Observation is a continuous process within regular periods for several years.

b) The regular series of measurements are carried out weekly, but in the periods of maximum precipitation and snow melting extra measurements may be carried out.

c) Water samples are analyzed partly on the spot (pH value, temperature, dissolved carbonate content, CO_2 content), and partly in laboratory (pCO_2, organic material content, Fe, Mg, Mn, Cl, S content, microelements).

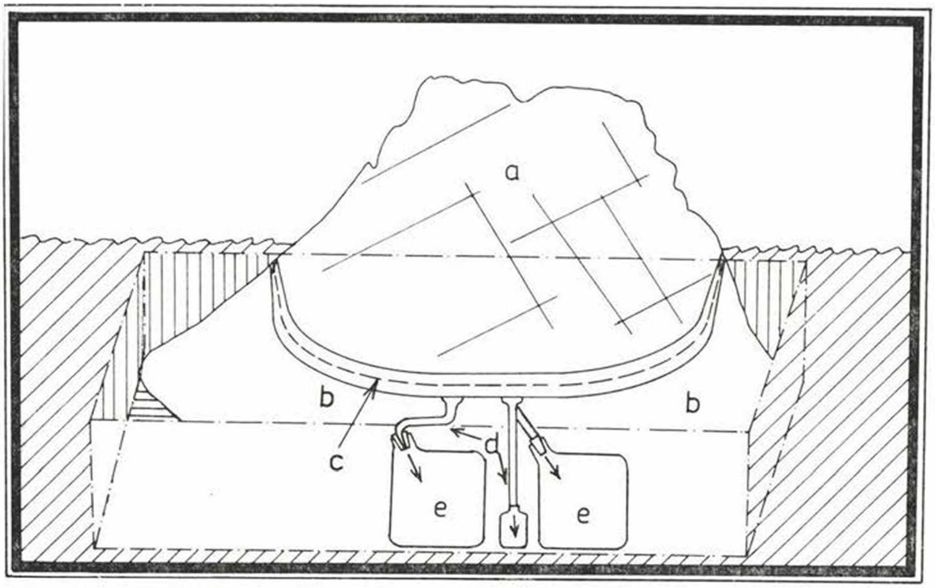

Fig. 8. Concrete canal

a) solved rock surface *b)* concrete canal *c)* synthetic resin *d)* PVC-pipe *e)* tank

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РЕЗЮМЕ

НЕКОТОРЫЕ МЕТОДЫ НАБЛЮДЕНИЙ КАРСТОВОЙ КОРРОЗИИ КАРСТОВОГО ПРОСАЧИВАНИЯ

В интересах того, чтобы теоретические выводы карстоморфогенетического характера в большей степени основывались на применении количественных методов исследований, срочной задачей является осуществление систематических наблюдений и регистрация современных процессов развития карста. Постоянное изучение развития некоторых форм карста требует разработки специальных методов наблюдений. По отношению к применяемым методам наблюдений выдвигается требование, чтобы посредством их стало возможным дифференцированное измерение влияния важных факторов в развитии форм карста и чтобы используемая методика не искажала параметры отдельных процессов. На основании результатов многолетнего экспериментального применения ряда методов наблюдений способ измерений, разработанный для трёх различных форм карста (долины, каррового канала и оголённой скальной поверхности), можно считать приемлемым для проведения систематических измерений.

I. Измерение просачиваемости, поверхностного стока и эрозии склона долины. Измеряемая территория может быть таким склоном долины, свойства которой отражают общие характерные черты территории. Важным условием является то, чтобы почвы и склоновые отложения, покрывающие измеряемую территорию, не имели гидрологической связи с соседними участками склона. На границе склона и дна долины сооружена траншея, выложенная поливинилхлоридной плёнкой, которая накапливает воду, просачиваемую через склоновые отложения и эта вода затем через дренажную трубу отводится в приёмный бак, где прибор регистрирует уровень просачиваемости. Поверхностный сток по склону долины и увлекаемые при этом отложения накапливаются в специальном приёмнике, сооружённом над траншеей, откуда затем отводятся в другой подземный регистрационный бак. Система оборудована также прибором для взятия проб воды и омбрографом.

II. Измерение степени растворимости боковых стен каррового канала: Внизу отобранных для измерений карровых борозд крупного размера с помёщью бетона сооружается специальный канал, стенки которого покрываются полиэфирной синтетической смолой. Вода, растворяющая боковые стенки карровой борозды, через этот канал попадает в подземный приёмный бак, где производится отбор проб воды. В канал второй карровой борозды, которая параллельна первой и сооружена подобным образом, есть возможность поместить прежнюю погву и таким образом стекающая вниз вода, просачиваясь через почву, после соответствующих анализов отражает те гидрохимические изменения, которые произошли в почве.

III. Измерение растворимости оголённых скальных поверхностей: Внизу склона точно измеренной скальной поверхности на уровне почвы сооружается покрытый синтетической смолой бетонный жолоб, который накапливает стекающую воду. В дальнейшем вода попадает в закрытый приёмник и не подвергается дальнейшим химическим изменениям.

В изложенных методах измерений общим является то, что они требуют еженедельных наблюдений, являются простыми и дёшёво осуществимыми и не означают отрицательное вмешательство в те процессы, которые мы хотим измерить.