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THE EXPERIMENTAL EXAMINATION OF MICROBIAL ORIGIN CORROSION AGGRESSIVITY OF KARST SOILS

EKSPERIMENTALNA ŠTUDIJA KOROZIJSKE AGRESIVNOSTI MIKROBIOLOŠKEGA IZVORA V KRAŠKIH PRSTEH

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EKSPERIMENTALNA ŠTUDIJA KOROZIJSKE AGRESIVNOSTI MIKROBIOLOŠKEGA IZVORA V KRAŠKIH PRSTEH

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Izvleček UDK 631.417:551.44

László Zámbó: Eksperimentalna študija korozijske agresivnosti mikrobiološkega izvora v kraških prsteh

Ena izmed najpomembnejših komponent v procesu vpliva prsti na kraško korozijo je proizvodnja CO_2 v prsti. Med osnovnimi mehanizmi, ki veljajo za glavni vir CO_2 v prsti, je dihanje korenin. O vplivu mikrobiološke aktivnosti na stopnjo kraške korozije je na voljo samo nekaj ocen. Da bi te ocene izboljšali in določili te vplive bolj natančno, je bilo izvedenih nekaj poskusov. Prvi rezultati teh poskusov so podani v tem prispevku. Na podlagi zbranih podatkov je mogoče sklepati, da sposobnost korozije mikrobiološkega izvora pomembno variira glede na tip prsti.
Ključne besede: korozija v prsti, CO_2, Madžarska.

Abstract UDC 631.417:551.44

László Zámbó: The experimental examination of microbal origin corrosion aggressivity of karst soils

One of the major components of the corrosion aggressivity in karst soil is CO_2 production in soils. Among the principal mechanisms usually identified as major sources of CO_2 production in soils is root respiration. On the influence of microbial activity on the rate of karst corrosion only some estimates are available. To improve estimates and to determine this influence more precisely, experiments were performed. The first results are presented in this paper. From the data gathered it can be concluded that corrosion capacity of microbial origin significantly varies according to the soil type.
Key words: soil corrosion, CO_2, Hungary.

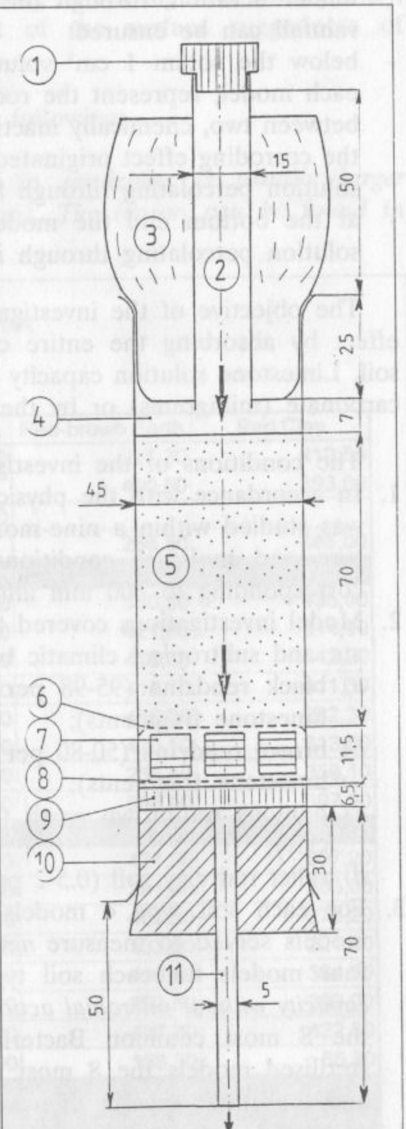
The investigations of recent decades have revealed and made it generally accepted that karst processes depend upon various acids acquired by the water circulating in the karst and these acids are seen 'as the primary chemical driving force' (White 1998). It is also widely accepted that one of the major sources of the acids is the soil cover of karst regions. I myself prefer to call the influence of soils on corrosion 'soil effect on karstification'.

According to the professional literature, among the acids produced in soils CO_2, fundamental in hydrocarbonatic solution, seems to be of decisive significance. There is a broad agreement among researchers that the acids accumulating in soils and controlling the solution of carbonates - including the predominant CO_2 - mostly derive from three groups of processes:

1. root respiration of higher plants;
2. decomposition of soil organic matter by microorganisms (microbiota) and
3. other decomposition processes not associated with microbial activities.

There are only sporadic estimates in literature on the share of the above processes (CO_2 sources) in karst corrosion, and an equal distribution (1:1:1) is generally suggested.

Investigating carbonatre solution in soils and attempting to obtain more precise data, I performed studies of corrosion on small samples. Altogether 96 corrosion models of identical composition, suitable for the measurement of corrosion below the soil layer have been constructed.



1,10 - ruber plugs; 2 - water recharge; 3 - bacteria filter; 4 - glass tube; 5 - soil sample; 6,8,9 - plastic filters; 7 - 1cm³ volume limestone cubes; 11 - percolating solution

Their structure is shown in *Figure 1.* It consists of the following parts:

- a glass tube of 40 mm diameter enclosing the sample, a 9 cm deep solum of undisturbed structure, characteristic of mid-latitude open karsts;

- at the upper end the model is plugged by a bacteria filter, which does not hinder aeration; through this filter bacteria-free water recharge modelling rainfall can be ensured;
- below the solum 1 cm^3 volume, easily soluble limestone cubes, seven for each model, represent the rock affected by corrosion; the cubes are placed between two, chemically inactive, plastic filters. The investigations show that the corroding effect originated in the soil is entirely manifested and the soil solution percolating through becomes saturated.
- at the bottom end the model is closed down by a rubber plug and the solution percolating through it is gathered by a sterile plastic bag.

The objective of the investigation was to allow the comparison of solution effect by absorbing the entire carbonate solution capacity originating in the soil. Limestone solution capacity is expressed by the concentration of dissolved carbonate (milligrams) or by the equivalent amount of CO_2.

The conditions of the investigations can be described as follows:

1. In accordance with the physical environment of Hungary, model operation was studied within a nine-month frost-free period, under the soil temperature and moisture conditions typical in karst soils and water recharge corresponding to 600 mm annual precipitation.
2. Model investigations covered the 4 most common karst soils in the temperate and subtropical climatic belts:
   a) black rendzina (95-98 per cent organic matter; 2-5 per cent clay and limestone fragments);
   b) brown rendzina (50-80 per cent organic matter; 20-50 per cent clay and limestone fragments);
   c) humous red-brown earth (2-5 per cent organic matter, 95-98 per cent clay);
   d) relict red clay soil (0.5-2 per cent organic matter; 99.5-98 per cent clay).
3. For each soil type 4 models involved the original microbiota and these models served to measure *natural solution capacity.* On the other hand, in four models for each soil type the soil was sterilised and here *solution capacity without microbial action* could be determined. In 8 sterilised models the 8 most common Bacteria tribes were injected and in a further 8 sterilised models the 8 most common Streptomycetes tribes were injected and thus their specific effects on carbonate solution were studied.

The most common Bacteria and Streptomycetes tribes, 8 for each group, were selected from the 160 Bacteria and Streptomycetes tribes found in earlier microbial investigations.

The corrosion effect was measured in three approaches in order to arrive at numerical results suitable for comparison:

1. total carbonate content of water percolating through models and accumulat-

ed in bags (calcium and magnesium carbonates, milligrams);
2. loss of weight of limestone cubes representing karstifying rock (milligrams);
3. computer-aided microscopic measurement of the surface ruggedness of limestone cubes derived from solution.

Major results of the investigation are the following:

Table 1: The amount of infiltrated water in rendzinas is usually larger (170-350 mm) than in clay soils (250-430 mm). The reason can be found in different rates of evaporation.

Table 1 **Infiltrated water of the soil**

Infiltration (ml)	Black Rendzina	Brown Rendzina	Red-brown Earth	Red Clay
Original 1	322,50	283,50	327,30	410,50
Original 2	306,00		400,50	393,00
Original 3	240,50	162,50		
Original 4			266,50	468,00
Average Orig.	289,67	223,00	331,43	423,83
B1	434,00	419,50	330,50	435,90
B2	387,50	364,30	421,00	314,90
B3	422,50	162,50	425,00	442,20
B4	353,50	217,10	416,70	411,50
B5	405,50	432,10	415,00	282,30
B7	291,00	266,20	410,50	313,80
B8	418,50	377,00	256,50	359,10
B10	221,50	410,50	388,00	397,30
Average ser.B	366,75	331,15	382,90	369,63
S1	378,50	327,70	421,50	307,20
S2	220,50	417,60	391,80	203,00
S3	423,20	426,80	405,50	275,20
S4	387,90	411,00	133,00	221,00
S5	401,90	410,50	416,30	384,50
S7	369,80	390,70	292,50	399,00
S8	408,70	319,70	407,70	422,50
S10	429,50	333,00	158,30	85,30
Average ser.S	377,50	379,63	328,33	287,21
Aver. B & S	372,13	355,39	355,61	328,42
Steril 1				
Steril 2	234,00	182,00	266,50	221,00
Steril 3	91,00	182,00	266,50	390,00
Steril 4	195,00	162,50	234,00	266,50
Average steril	173,33	175,50	255,67	292,50

Table 2: In samples with original conditions the carbonate concentration of infiltrated water was much higher under rendzinas than under clay soils.

Table 2 Carbonate concentration of the infiltrated solution

Conc.(mg/l)	Black Rendzina	Brown Rendzina	Red-brown Earth	Red Clay
Original 1	637,98	470,02	185,98	80,00
Original 2	655,00		210,01	121,98
Original 3	1.096,59	1.218,46		
Original 4			156,37	41,62
Average Orig.	796,52	844,24	184,12	81,20
B1	610,00	368,46	140,00	74,99
B2	566,09	240,02	129,29	224,99
B3	455,01	281,72	170,00	69,00
B4	549,00	329,99	271,99	76,99
B5	569,99	374,98	104,99	151,97
B7	518,01	0,00	211,99	81,99
B8	492,04	57,11	205,96	308,99
B10	1.000,00	370,01	176,01	98,31
Average ser.B	595,02	252,79	176,28	135,90
S1	473,00	375,89	100,00	80,01
S2	689,98	287,45	128,00	93,00
S3	400,00	335,00	148,98	52,00
S4	534,98	299,00	200,08	36,02
S5	454,99	320,00	171,99	89,99
S7	500,00	195,01	100,55	236,04
S8	291,00	224,99	178,00	81,99
S10	439,00	334,98	104,99	126,03
Average ser.S	472,87	296,54	141,57	99,38
Aver. B & S	533,94	274,66	158,93	117,64
Steril 1				
Steril 2	142,14	114,78	30,99	47,74
Steril 3			38,61	30,97
Steril 4	101,54	73,17	39,10	21,31
Average steril	121,84	93,97	36,24	33,34

The solution capacity derived from microbial action was almost an order of magnitude higher under rendzinas (in original samples) than the solution capacity not due to microbial sources (sterile samples). Under clay soils this effect is only half as intensive.

Table 3: In the original samples total carbonate contents under the various soil types adjusts to organic matter content.

Table 3 Sum of solved Carbonates

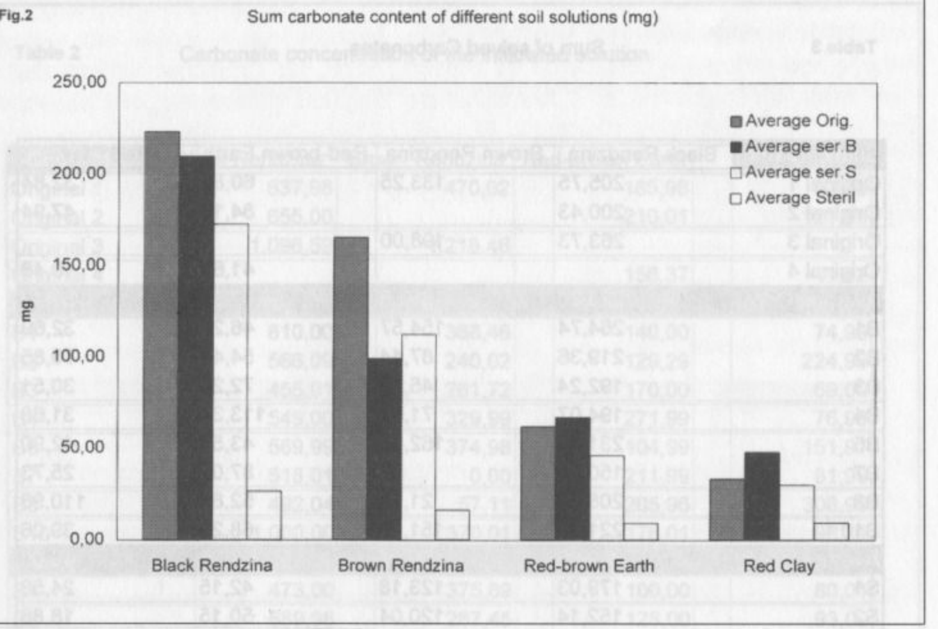
Sum.carb.(mg)	Black Rendzina	Brown Rendzina	Red-brown Earth	Red Clay
Original 1	205,75	133,25	60,87	32,84
Original 2	200,43		84,11	47,94
Original 3	263,73	198,00		
Original 4			41,67	19,48
Average Orig.	223,30	165,63	62,22	33,42
B1	264,74	154,57	46,27	32,69
B2	219,36	87,44	54,43	70,85
B3	192,24	45,78	72,25	30,51
B4	194,07	71,64	113,34	31,68
B5	231,13	162,03	43,57	42,90
B7	150,74		87,02	25,73
B8	205,92	21,53	52,83	110,96
B10	221,50	151,89	68,29	39,06
Average ser.B	209,96	99,27	67,25	48,05
S1	179,03	123,18	42,15	24,58
S2	152,14	120,04	50,15	18,88
S3	169,28	142,98	60,41	14,31
S4	207,52	122,89	26,61	7,96
S5	182,86	131,36	71,60	34,60
S7	184,90	76,19	29,41	94,18
S8	118,93	71,93	72,57	34,64
S10	188,55	111,55	16,62	10,75
Average ser.S	172,90	112,52	46,19	29,99
Aver. B & S	191,43	105,89	56,72	39,02
Steril 1				
Steril 2	33,26	20,89	8,26	10,55
Steril 3			10,29	12,08
Steril 4	19,80	11,89	9,15	5,68
Average Steril	26,53	16,39	9,23	9,44

Solution capacity expressed by total dissolved carbonate content shows distinct values, characteristic for the individual soil types.

In each of the soil types studied, the solution caused by microbial activities exceeds the rate of solution resulting from other factors but there is a manifest dropping trend from rendzinas to clays.

This trend is also clear in *Fig. 2:*

Fig.2



The solution effect of total microbial action is usually somewhat more intensive than that induced by a single Bacteria or Streptomycetes tribe; the difference, however, is not significant. This means that the species diversity of microbiota does not have particular significance in corrosion. Reversely, this also means that a deterioration in environmental conditions - for instance, as a result of environmental pollution - may be harmful to individual species but does not necessarily involve a major change in the rate of corrosion.

Figures 3 and 4: Within total carbonate content, the solubility of calcium carbonate and magnesium carbonate substantially differ with the individual soil types:

- The solution of magnesium carbonate takes place at a much slower rate by the influence of microbial activities than that of calcium carbonate. Further investigations are needed to draw conclusions for a presumable carbonate-specific solution effect under the soil.
- Under certain soils (eg. black rendzina) well-defined Bacteria species are the more active contributors to corrosion, while under other soil types (eg. brown rendzina) Streptomycetes species are.

Fig.3 Calcium carbonate content of different soil solutions (mg)

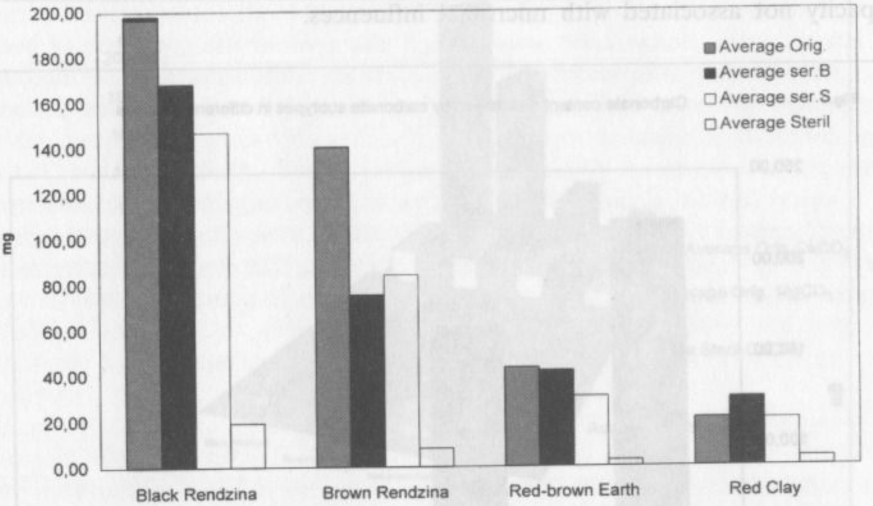


Fig.4 Magnesium carbonate content of different soil solutions (mg)

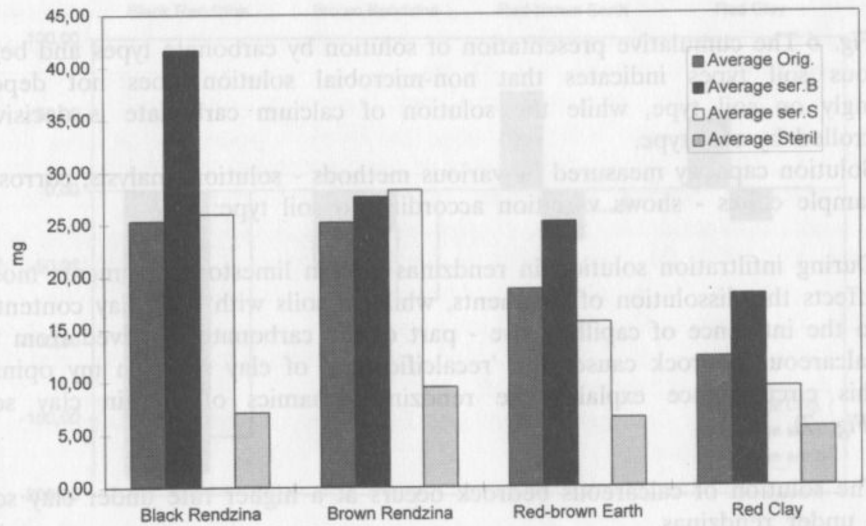


Fig. 5 It seems probable that calcium carbonate solution shows much greater diversity below various soils than magnesium carbonate solution. The latter, as indicated by the above observations, is more dependent on solution capacity not associated with microbial influences.

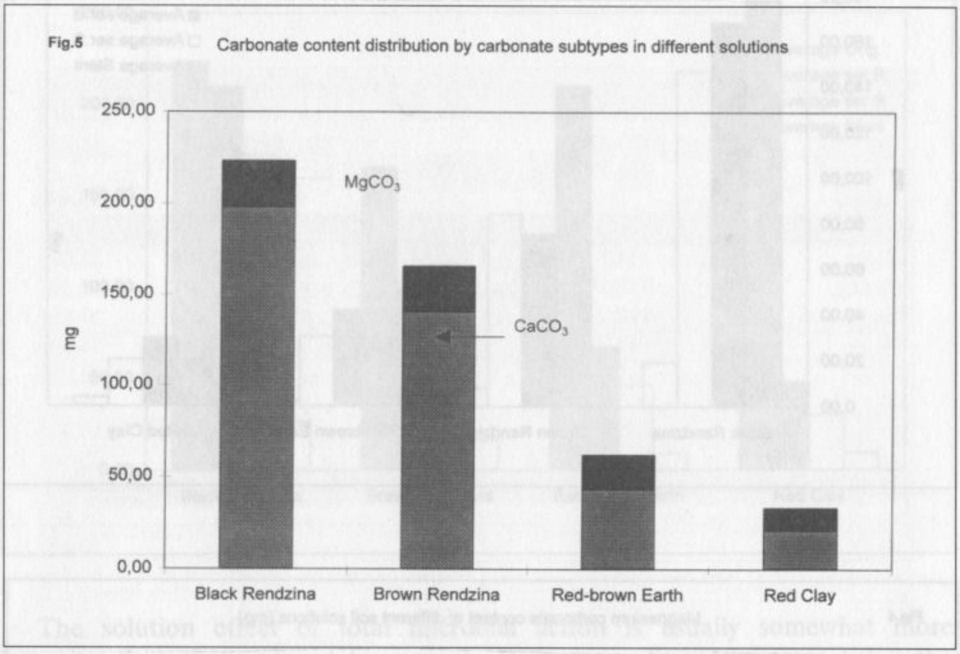


Fig. 6 The cumulative presentation of solution by carbonate types and below various soil types indicates that non-microbial solution does not depend strongly on soil type, while the solution of calcium carbonate is decisively controlled by soil type.

Solution capacity measured by various methods - solution analysis, corrosion of sample cubes - shows variation according to soil type:

- During infiltration solution in rendzinas rich in limestone fragments mostly affects the dissolution of fragments, while in soils with high clay contents - to the influence of capillary rise - part of the carbonate dissolved from the calcareous bedrock causes the 'recalcification' of clay soils. In my opinion this circumstance explains the rendzina dynamics of certain clay soils *(Fig. 7)*.

The solution of calcareous bedrock occurs at a higher rate under clay soils than under rendzinas.

Fig.6 Average solved carbonate content of solutions of different original and steril soils

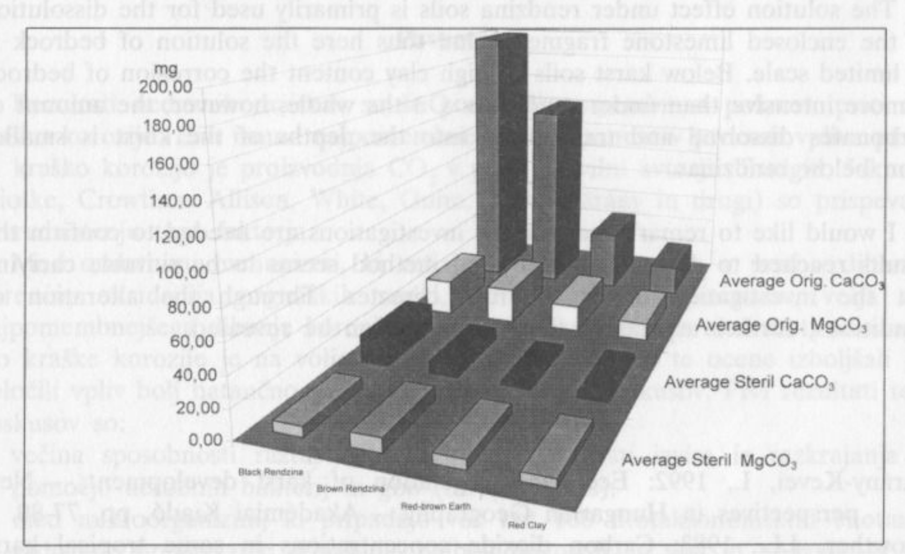
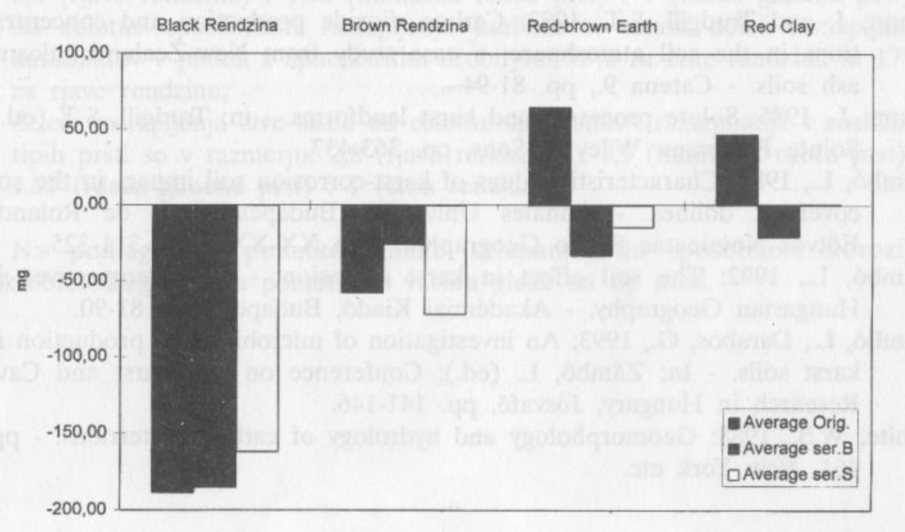


Fig.7 Carbonate precipitation during the investigation



Based on the above, the following assumptions seem to be well founded:

The solution effect under rendzina soils is primarily used for the dissolution of the enclosed limestone fragments and thus here the solution of bedrock is of limited scale. Below karst soils of high clay content the corrosion of bedrock is more intensive than under rendzinas. On the whole, however, the amount of carbonates dissolved and transported into the depths of the karst is smaller than below rendzinas.

I would like to remark that further investigations are needed to confirm the results reached to date. The elaborated method seems to be suitable carrying out the investigation under different climates. Through the alteration of conditions, further aspects of the soil effect can be revealed.

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EKSPERIMENTALNA ŠTUDIJA KOROZIJSKE AGRESIVNOSTI MIKROBIOLOŠKEGA IZVORA V KRAŠKIH PRSTEH

Povzetek

Rezultati nedavnih raziskav so še poudarili pomembnost pokrova prsti za kraško korozijo. Ena izmed najpomembnejših komponent v procesu vpliva prsti na kraško korozijo je proizvodnja CO_2 v prsti. Številni avtorji (Trudgill, Jakucs, Miotke, Crowther, Allison, White, Gunn, Kevei-Bárány in drugi) so prispevali k vrednotenju tega faktorja.

Med osnovnimi mehanizmi, ki veljajo za glavni vir CO_2 v prsti - dihanje korenin, oksidacija organskih snovi, dihanje mikroorganizmov, velja za najpomembnejšega dihanje korenin. O vplivu mikrobiološke aktivnosti na stopnjo kraške korozije je na voljo samo nekaj ocen. Da bi te ocene izboljšali in določili vpliv bolj natančno, je bilo izvedenih nekaj poskusov. Prvi rezultati teh poskusov so:

- večina sposobnosti raztapljanja karbonatov v prsti izvira iz razkrajanja s pomočjo aerobnih bakterij in gob (Streptomyces);
- med mikroorganizmi, ki pripadajo več kot 160 fitotaksonomskim enotam, zadostuje preučevanje obnašanja najbolj pogostih 16 vrst in podvrst, ki so prisotne v vseh prsteh;
- intenzivnost raztapljanja karbonatov, ki je posledica dejavnosti mikroorganizmov in poteka s pomočjo prenikajoče vode v najbolj razširjenih tipih kraških prsti (črna rendzina, rjava rendzina, humusna rdeča prst in rdeča glinena prst), lahko opišemo z naslednjimi razmerji: 4,9 (črna rendzina) : 2,9 (rjava rendzina) : 1,33 (humusna rdeča prst) : 1 (rdeča glinena prst);
- od celotne sposobnosti raztapljanja karbonatov znaša delež raztapljanja karbonatov v prsteh z apnenčastim drobirjem 55% za črne rendzine in 17% za rjave rendzine;
- deleži raztapljanja žive skale od celotne sposobnosti raztapljanja v različnih tipih prsti so v razmerju: 2,8 (rjava rendzina) : 1,7 (humusna rdeča prst) : 1,57 (rdeča glinena prst) : 1 (črna rendzina).

Na podlagi teh podatkov lahko sklepamo, da sposobnost korozije mikrobiološkega izvora pomembno variira glede na tip prsti.

Photo 1: Arrangement of the 96 models. (page 275)
upper row: black rendzina
second row: brown rendzina
third row: red-brown earth
fourth row: red clay

Photo 2: The model in a closer view. (page 275)

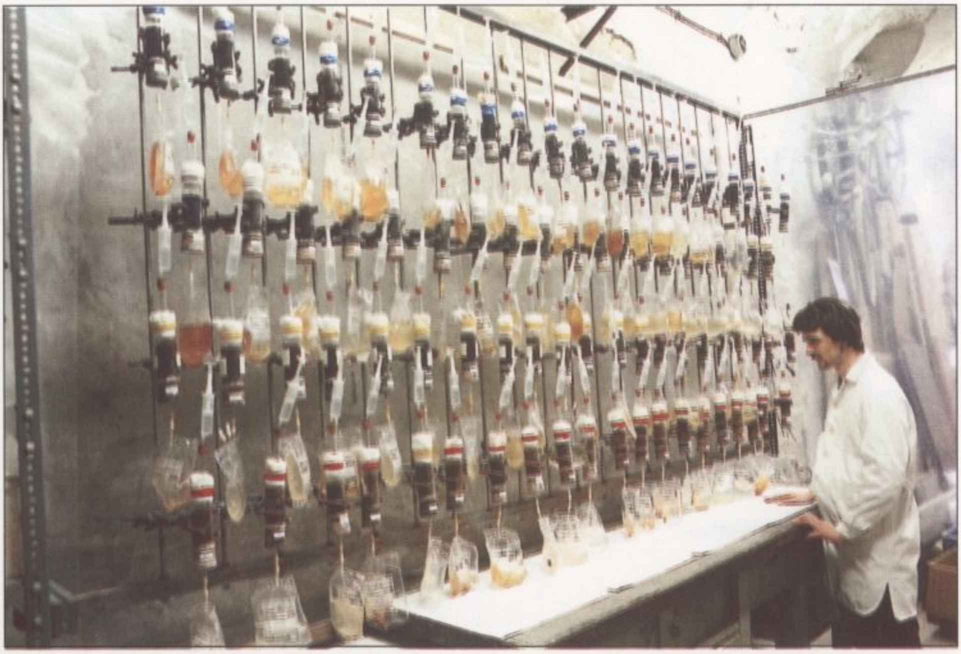

Photo 1.

Photo 2.