CO_2 Evolution from Soils Formed on Various Parent Materials in the Eastern Cserhát Mountains (Hungary) During Laboratory Incubation

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Introduction

The parent material is one of the most important factors determining soil formation and vegetation succession. The primary aim of regional geological surveys used to be the mapping of mineral resources, but nowadays more attention is paid to environmental quality. The aim of environmental geochemistry (ANDÓ, 1992) is to detect and predict anthropogenic effects which may change the equilibrium of material migration and the mobility and local accumulation of certain elements. An environmental geochemical information system based on the landscape geochemical approach is a suitable and necessary tool for characterizing biochemical processes at regional and local levels.

The present study aimed to investigate the soil biological activity which could be linked to the database of this information system. Soil biological activity is related to the mobilization and immobilization of plant micro- and macroelements and the formation of soil structure. It was characterized by basal respiration (CO_2 evolution) in a laboratory experiment (SZEGI & SZILI KOVÁCS, 1991).

Materials and Methods

Characteristics of the model area

The model area (about 18 km²) is located in the Eastern Cserhát mountains (Northern part of Hungary, Fig. 1) bounded by the village of Ecseg, Kozárd and Cserhátszentiván (KUBOVICS et al., 1971; MAROSI & SOMOGYI, 1990). From the morphological, geological and pedological points of view this area is vari-

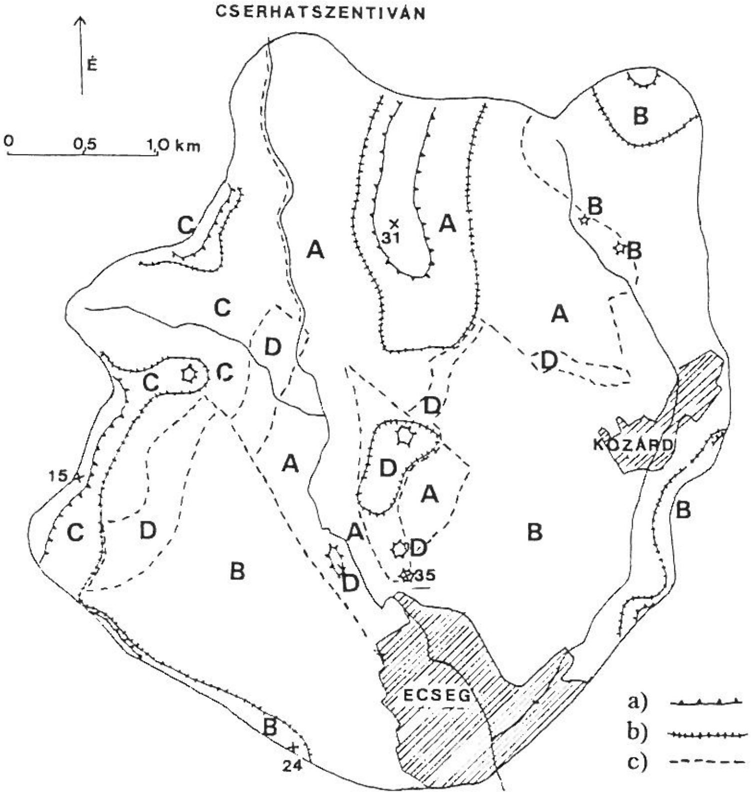

Fig. 1
Schematic map of the model area in the Eastern Cserhát mountains (after ANDÓ, 1992) Legend: Border of the: a) eluvial (autonomous area); b) transeluvial area; c) occurrence of different rocks. Sampling sites for soil incubation experiments: 15, 24, 31 and 35. A: andesite-tuff; B: marl; C: andesite; D: limestone

able but not too complex. The geological formations containing different rocks are well separated. The larger part of the area is covered by forest, with a smaller proportion of arable land. The average temperature is 9-9.5 °C, the number of sunny hours 1900 and the annual precipitation 600 mm. The relief is dissected into well developed, clearly visible subunits by catchment and valley systems. In some places intensive soil erosion can be seen. A continuous underground water table has been formed, principally in the valleys, and is generally polluted by nitrate. The geological structure of the area was reviewed by HÁMOR (1985). Two main soil types could be distinguished: brown earth and brown forest soil with clay illuviations. There is a smaller extent of meadow soil in the valleys. Soil samples were taken at four different points (Fig. 1) according to the occurrence of the main rock types on top of the hills. Samples were divided into a top humus-rich layer (approx. 0-20 cm) and a humus-poor layer (approx. 20-50 cm), which corresponds to the AB, B or C level.

Soil incubation

The original dry soils and mixtures with a 1:1 ratio were used for the incubation experiment (Table 1). Soil organic-C, carbohydrate-C and pH (KCl) were determined from air-dried soil samples. The top and subsoil layers were mixed according to the matrix plan (Table 2). The matrix plan was created using the SITOBI programme, which is based on the DISITOBI model (SZILI KOVÁCS et al., 1991). This quadratic orthogonal experimental plan is very effective. Samples were moistened to five different levels with distilled water and incubated in the dark. Two repetitions were used, but there were 12 so-called central repetitions (15th - 20th treatments). On the 9th day of incubation the vessels were stoppered and the CO_2 was measured after 24 hours of incubation. The incubation vessels were purged with air before incubation to remove the

Table 1

Organic-C, carbohydrate-C content and pH of the soil samples

Code/ Parent material	Organic-C, %	Carbo-hydrate-C, mg/g	pH (KCl)
Top soil layers			
151 Andesite (C)	1.94	1.148	4.4
241 Marl (B)	0.90	0.588	4.5
311 Andesite Tuff (A)	2.80	1.120	4.9
351 Limestone (D)	3.56	1.232	7.0
Subsoil layers			
152 Andesite	1.12	0.728	4.6
242 Marl	0.39	0.280	5.0
312 Andesite Tuff	1.08	0.560	5.0
352 Limestone	2.64	0.952	6.7
Mixture (1:1) of top layers			
151-311 CA	2.39	1.138	4.5
151-241 CB	1.40	0.860	4.7
151-351 CD	2.73	1.196	6.7
311-241 AB	1.82	0.846	4.5
311-351 AD	3.12	1.166	6.7
241-351 BD	2.26	0.920	-

previously accumulated CO_2. The CO_2 evolved in the headspace was measured by gas chromatography, and the dissolved carbonic acid and hydrogen carbonate in the soil liquid phase was calculated.

Table 2

Experimental design based on quadratic orthogonal matrix plan (SITOBI programme)

Treatment Code	Temperature °C	Water holding capacity, w%	Topsoil content in the mixture, h %
1.	35.00	80.00	75.00
2.	15.00	80.00	75.00
3.	35.00	40.00	75.00
4.	15.00	40.00	75.00
5.	35.00	80.00	25.00
6.	15.00	80.00	25.00
7.	35.00	40.00	25.00
8.	15.00	40.00	25.00
9.	40.25	60.00	50.00
10.	9.78	60.00	50.00
11.	25.00	90.50	50.00
12.	25.00	29.50	50.00
13.	25.00	60.00	88.13
14.	25.00	60.00	11.88
15.	25.00	60.00	50.00
16.	25.00	60.00	50.00
17.	25.00	60.00	50.00
18.	25.00	60.00	50.00
19.	25.00	60.00	50.00
20.	25.00	60.00	50.00

Quadratic Design Matrix of Experiment:

Number of factors = 3
Number of treatments = 20
Alfa rounded = 1.525
Design-file name: Cser3. Des

Results

The CO_2 production data were evaluated using the SITOBI programme, which involved the parameters and the significance level of the parameters, the determination coefficients (Table 3), the difference between the measured and calculated values and the performance of analysis of variance.

The model used was:

$$Y = BO + B1 \cdot T + B2 \cdot W + B3 \cdot H + B4 \cdot T \cdot W + B5 \cdot T \cdot H +$$
$$+ B6 \cdot W \cdot H + B7 \cdot T^2 + B8 \cdot W^2 + B9 \cdot H^2$$

where:
Y = mg CO_2-C/100 g soil/day;
T = temperature (°C);
W = water holding capacity (%);
B(0) - B(9) = parameters of the model.

The interception (B0) and the linear elements (B1-B3) of the models were generally highly significant in all cases, while the interaction (B4-B6) and quadratic elements (B7-B9) were not (Table 3).

CO_2 production was affected to the greatest extent by temperature, then by organic carbon and finally by soil moisture. The organic carbon content was the highest in soil formed on limestone and the lowest in marl-based soil. The rate of CO_2 production differed according to the organic carbon content of the soil. In mixtures containing 50% limestone-based soil the amount of organic C and CO_2 production corresponded to the mixture ratio, but the pH was much closer to the pH of the limestone-based soil. The B3 parameter, which is related to humus content, was less significant in the case of limestone and limestone-containing mixtures because the difference in the organic carbon contents of the top and subsoil layers was lower than in other soils.

In this experiment, in 22 out of 180 cases the difference between the measured and calculated values exceeded 20%. Most of these cases occurred in limestone-containing soils, due probably to sample heterogeneity. There was a relatively high significance in measured and calculated values in the 10th treatments, indicating that the model, which forced the curves through the measured points by a polynomial fit, was not very convenient over a wide range of temperature. The measurement of CO_2 evolution was a simple, rapid and sensitive method for the characterization of soil biological activity, but it was chiefly affected by the organic carbon content of the soil. the direct effect of the type of rocks on the CO_2 production is not clear, but it undoubtedly has an indirect effect by determining pH, porosity, etc.

Table 3

Parameters and determination coefficients of the model

	A9	AB9	AD9	B9	C9	CA9	CB9	CD9	D9
B0	-0.6769****	0.1555****	-5.3822****	0.2645****	0.6843****	0.3575****	-0.2776****	4.4064****	7.3121****
B1	-0.0431****	-0.0564****	0.0991***	-0.0241****	-0.0049****	-0.0141****	0.0059****	-0.1995****	-0.6081****
B2	-0.0536	0.0242*	0.0994*	0.0095****	0.0146*	0.0188*	0.181*	-0.0569**	-0.0714**
B3	0.0023****	-0.0023***	0.0583*	-0.0061***	-0.0344***	-0.0101****	0.0001***	-0.0430**	-0.0055
B4	-0.0003	-0.0001	0.0016	0.0001	0.0000	0.0004	-0.0000	0.0017*	0.0037*
B5	0.0008*	0.0003	0.0008	0.0003	0.0003	0.0005	0.0004	0.0012	0.0008
B6	-0.0000	0.0000*	-0.0001	0.0001	0.0001	0.0001	0.0001	0.0003	-0.0005
B7	0.0013	0.0017	-0.0025	0.0004	0.0011	0.0004	0.0007	0.0027	0.0110**
B8	-0.0002	-0.0001	-0.0008	-0.0001	-0.0001*	-0.0001	-0.0001	0.0002	0.0004
B9	0.0000	0.0000	-0.0004	0.0000	0.0003	0.0001	-0.0000	0.0001	0.0003
R^2	0.960	0.957	0.823	0.970	0.979	0.970	0.982	0.974	0.947

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$; **** $P < 0.0001$

Summary

In the area of the Eastern Cserhát mountains (North Hungary) various geological parent materials (rocks) can be found in a mosaic-like situation, while in some places, in valleys and basins, the rock fragments occur miscellaneously. Due to erosion the topsoil mixes with the deeper mineral layer, too. Within the framework of an environmental geochemical survey, the soil biological activity was studied. Traditional sampling was not sufficient or economical for characterizing the whole area.

The approach followed was to make soil mixtures according to the natural existence of various rocks (andesite, andesite-tuff, marl and limestone). The topsoil and humus-poor subsoil layer were also mixed. The experiment was based on a 3-factorial orthogonal quadratic matrix plan.

Soil moisture, temperature and top/subsoil ratio were varied. The 24-hour CO_2 evolution was measured on the 9th day of incubation as a measure of soil biological activity. The daily CO_2 production values were influenced to the greatest extent by temperature and soil organic carbon content. The effect of soil moisture was less pronounced but significant. The differences in CO_2 production between soils having various parent materials can be attributed primarily to the different organic carbon contents.

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