ROLE OF SOIL TEMPERATURE IN CONTROL OF DENUDATIVE PROCESSES OF DIFFERENT EXPOSURES IN KARSTIC REGIONS

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The differences in intensity of the denudative processes in the micro-areas of karstic surfaces are influenced not only by the thickness of the soil layer and by the composition of the vegetation covering the surface, but also by the control of exposure in interaction with these. In this respect the author has already dealt with the temperature and humidity conditions of the 10 cm air layer immediately above the surface on the example of sink-holes in the Bükk Mountains (BÁRÁNY I. 1974). In the present study the temperature conditions of the uppermost 30 cm soil layer are examined on 4 exposures (N, E, S, W) with regard to karst denudation effected via the soil.

In investigations of the CO_2 household of the soils of karstic micro-areas, JAKUCS L. (1970, 1971, 1973a, b) found that the CO_2 concentration determining the dissolution processes in the soil depends on the exposure. Via the aggressivity of the permeating precipitation water, the different CO_2 levels lead to differences in the intensity of the dissolution processes of weathering-away.

This presumably plays a large role in the development of the morphological shape of the large number of asymmetrical sink-holes in the Bükk Mountains, and in other karstic mountainous regions, too. The CO_2 level is closely connected with the temperature and moisture conditions of the soil.

According to the measurements of JAKUCS L., on a bright day in 1968 (17 August) the maximum of the CO_2 content of the soil was highest on the eastern exposure: 3.5% (Fig. 1); this is closely related with the fact that, on an average for 6 bright days, the morning temperature of the 5 cm soil layer here is higher than on the other exposures. The temperature maximum is around 21—22 °C, and it appears that this is the optimum soil temperature for CO_2 production. Similarly to the eastern exposure, the CO_2 level maximum on the southern exposure occurs at midday; however, the soil temperature maximum is somewhat later, and has a higher value.

It can be concluded from this that increase or decrease of the temperature from 21—22 °C has an impairing effect on CO_2 production.

Temperatures of the western exposure are close to the optimum, and favour bioactive CO_2 production, but temperatures below 20 °C on the northern exposure keep the CO_2 level low compared to the other exposures.

The above conclusive facts justify a study of the soil temperature in the various exposures. The course of the soil temperature in the eastern and western exposures was investigated by BOROS J. (1971), who found that the daily course of the tempera-

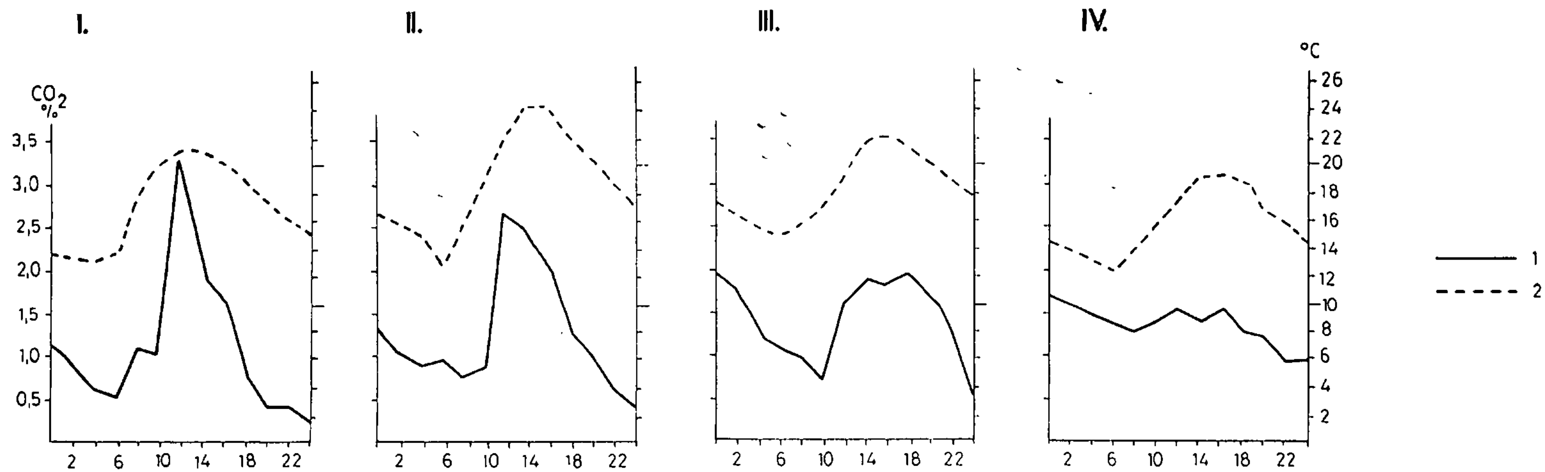

Fig. 1. Soil temperature and soil CO_2 concentration at a depth of 5 cm (CO_2 experimental data after JAKUCS L.)
I=eastern exposure; II=southern exposure; III=western exposure; IV=northern exposure.
1=CO_2 concentration (17 Aug. 1968);
2=average soil for 6 bright August days.

ture in the two exposures is regulated by the possible sunlight duration, the maxima conforming to the slope culmination.

Based on the microclimatic measurements made in the summers of 1969 and 1971 under the leadership of WAGNER R., the author studied the soil temperatures of the 4 different exposures as averages for bright days in an open sink-hole at Kurtabérc, and has attempted to distinguish the slope types from the soil temperature characteristics observed on these exposures.

The knowledge of the macroclimatic conditions for the given period was necessary for a correct evaluation of the microclimatic data recorded in August. In both 1969 and 1971, 6 bright days appeared suitable for investigations: in 1969, August 2, 3, 4, 5, 6, and 7; and in 1971, July 31, August 2, 7, 14, 15, and 18 (see Fig. 2.)

During the same period, the first 20 days of the month, there were 10 rainy days in 1969, and 5 in 1971. The 6 days selected in 1969 were the continuation of a

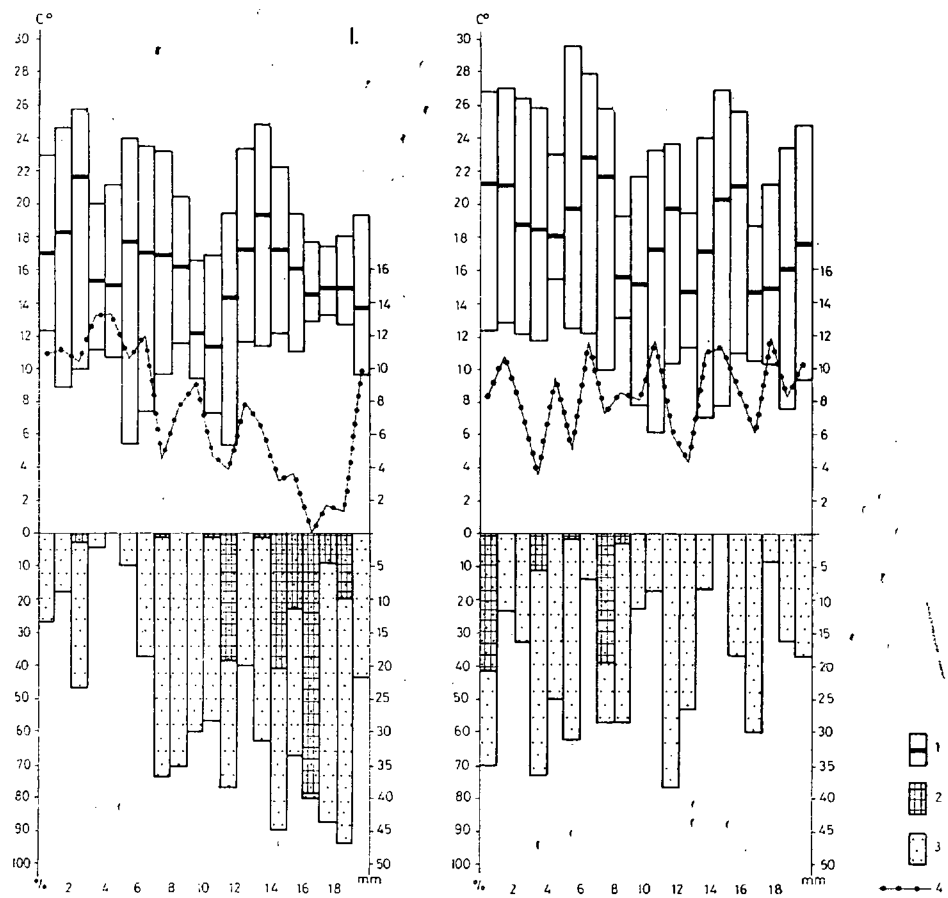

Fig. 2. Development of macroclimate at Kurtabérc at the time of the microclimatic measurements (1—20 Aug. 1969 and 1971)
I=1969; II=1971; 1=maximum, minimum and mean temperature; 2=precipitation; 3=cloud; 4=duration of sunlight.

nationwide bright, dry period at the end of July. The first wave of an air mass of polar origin, which arrived in the Carpathian Basin on August 4—5, resulted in a drop of temperature throughout the entire country. This also showed up in the values of the temperature maxima and average temperatures at Kurtabérc, and demonstrably moderated the heating-up of the soil, too. A similar temperature decrease due to cool advection occurred in 1971 only on August 18. Comparison of the August temperatures for the two years reveals that the daily maxima and minima on the selected bright days were lower in 1969 than in 1971. Since this also resulted in significant differences in the sizes of the temperature amplitudes, comparison of the various exposures will be free of distortion only if the given years are taken individually. (Microclimatic measurements were made on the northern and southern exposures in 1968, and on the western and eastern exposures in 1971.)

At depths of 2, 5, 10, 20 and 30 cm, in every exposure there is a regular phase delay with depth in the daily course of the soil temperature, and the temperature progressively decreases.

The soil temperature courses at the various depths on the 4 exposures were plotted as averages for the bright days with the aid of trigonometric polynomials (see Figs. 3—6).

At depths of 2 and 5 cm from the surface there is a larger difference in the phase shifts of the temperature courses on the eastern and western exposures, and in the size of the amplitudes on the northern and southern exposures. The heating-up begins earlier on the eastern exposure than on the western exposure, and the intensity of heating-up at the base of the sink-hole is also greater on the eastern exposure. At depths of 10 and 20 cm, however, the temperature is protractedly lower on the eastern exposure in the afternoon, and this state is also characteristic for the deeper levels. The shift in time of the occurrence of the maxima and minima is striking; this will be returned to in the discussion of the typical parameters.

At depths of 2 and 5 cm the temperature courses of the southern and northern exposures are nearly parallel, the temperature on the southern exposure naturally being the higher. At 10, 20 and 30 cm the amplitudes decrease in accordance with expectations.

Factual information on the differences in exposure is provided by the parameters of the trigonometric function of JORDÁN K. (1949):

$$f(x) = K + a_1 \sin(U_1 + 15x) + a_2 \sin(U_2 + 30x)$$

where K = mean temperature (°C),

a_1 = amplitude of the 12 hour wave (°C),

a_2 = amplitude of the 6 hour wave (°C),

U_1 = phase angle of the 12 hour wave (at zero degree position), and

U_2 = phase angle of the 6 hour wave (at zero degree position).

(The calculations were performed on the computer of the Cybernetics Laboratory of József Attila University.)

The characteristic parameters (see Table 1) give the possibility to examine a problem frequently raised by climatologists: the phase shifts with depth; a more important question here, however, is the analysis of the phase shifts relating to the different exposures.

At depths of 2 and 5 cm the mean temperature and the amplitudes are highest on the southern exposure. At depths greater than 10 cm the mean temperature con-

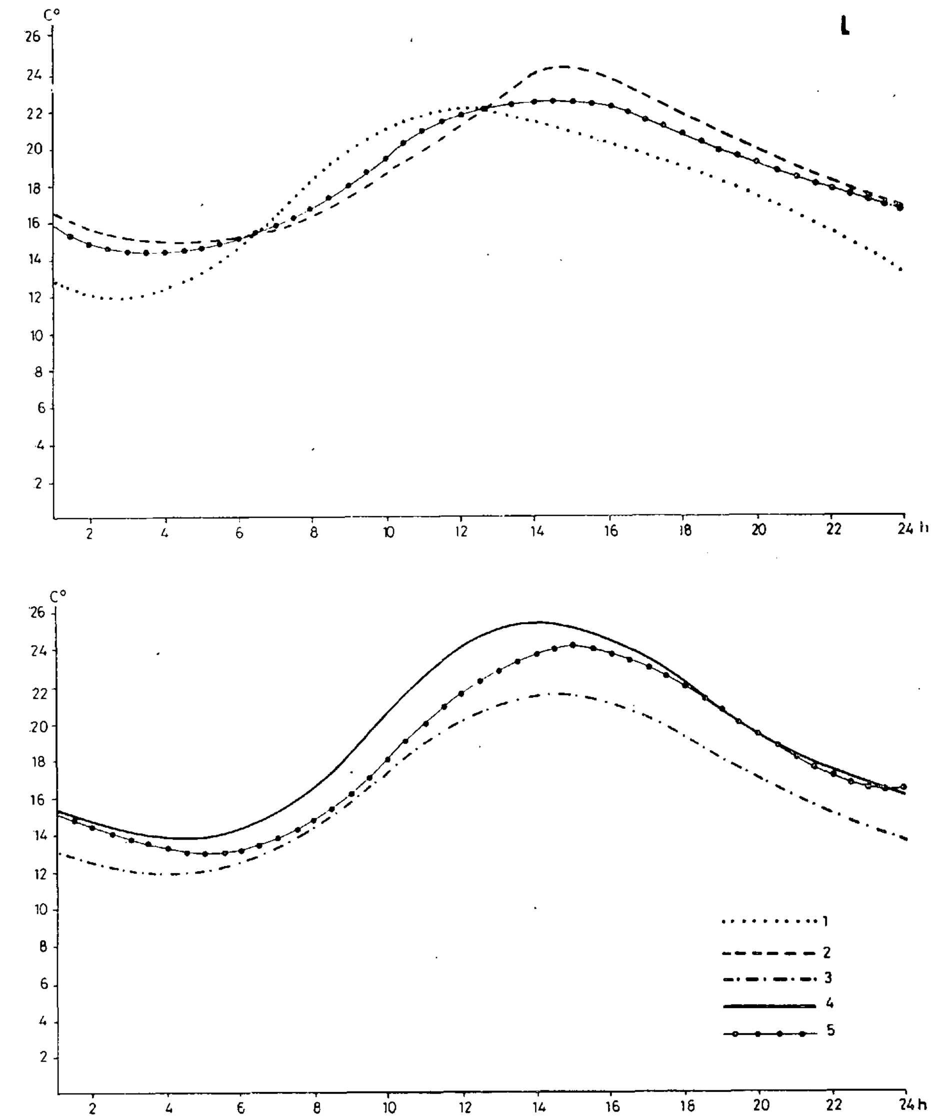

Fig. 3. Trigonometric polinomials at a depth of 2 cm I.
1=eastern exposure; 2=western exposure; 3=northern exposure; 4=southern exposure; 5=sink-hole base.

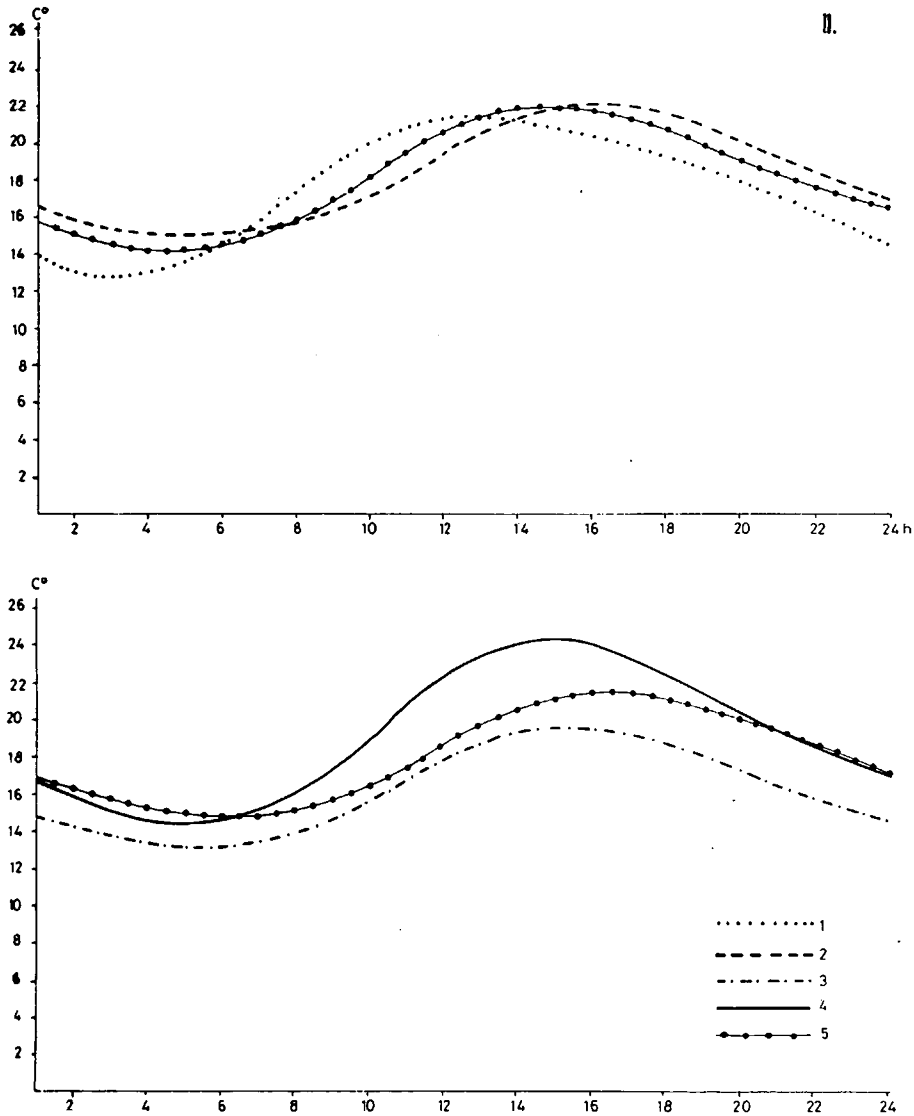

Fig. 4. Trigonometric polinomials at a depth of 5 cm II.
1 = eastern exposure; 2 = western exposure; 3 = northern exposure; 4 = southern exposure; 5 = sink-hole base.

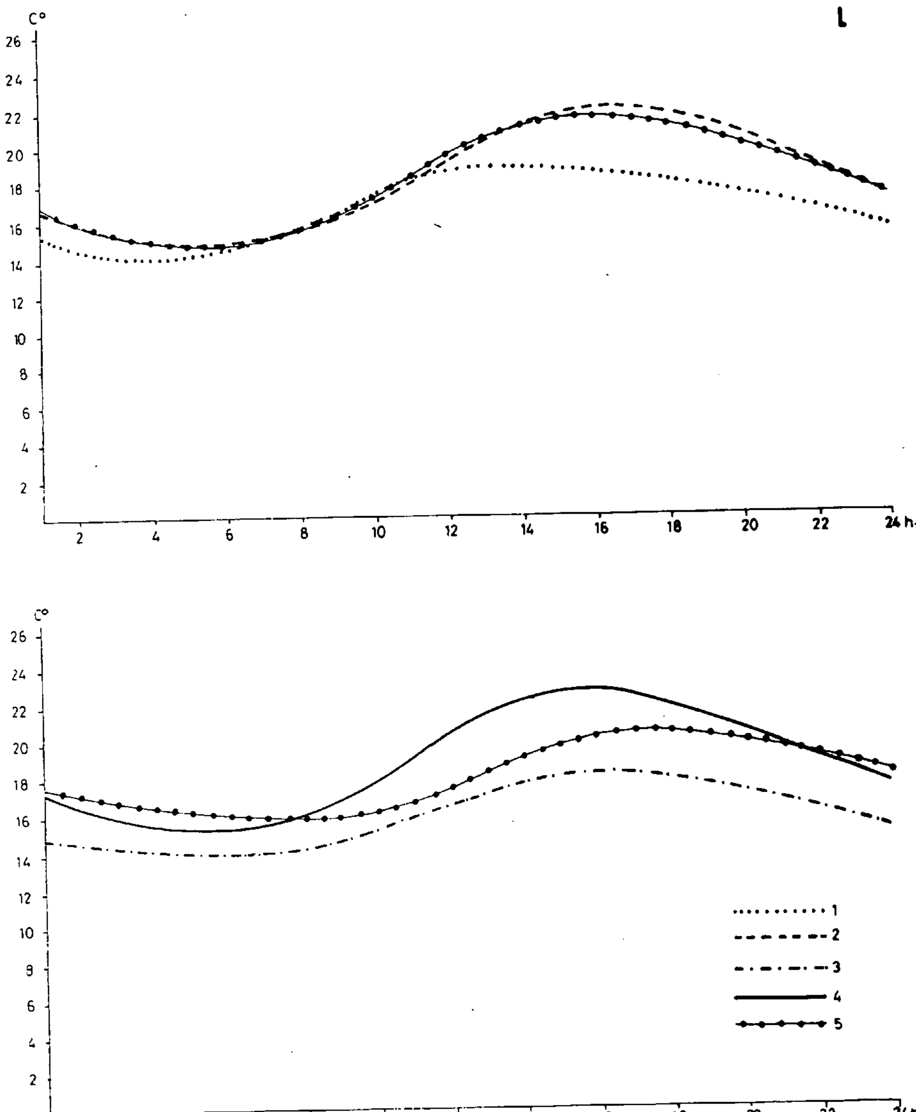

Fig. 5. Trigonometric polynomials at a depth of 10 cm I.
1=eastern exposure; 2=western exposure; 3=northern exposure; 4=southern exposure; 5=sink-hole base.

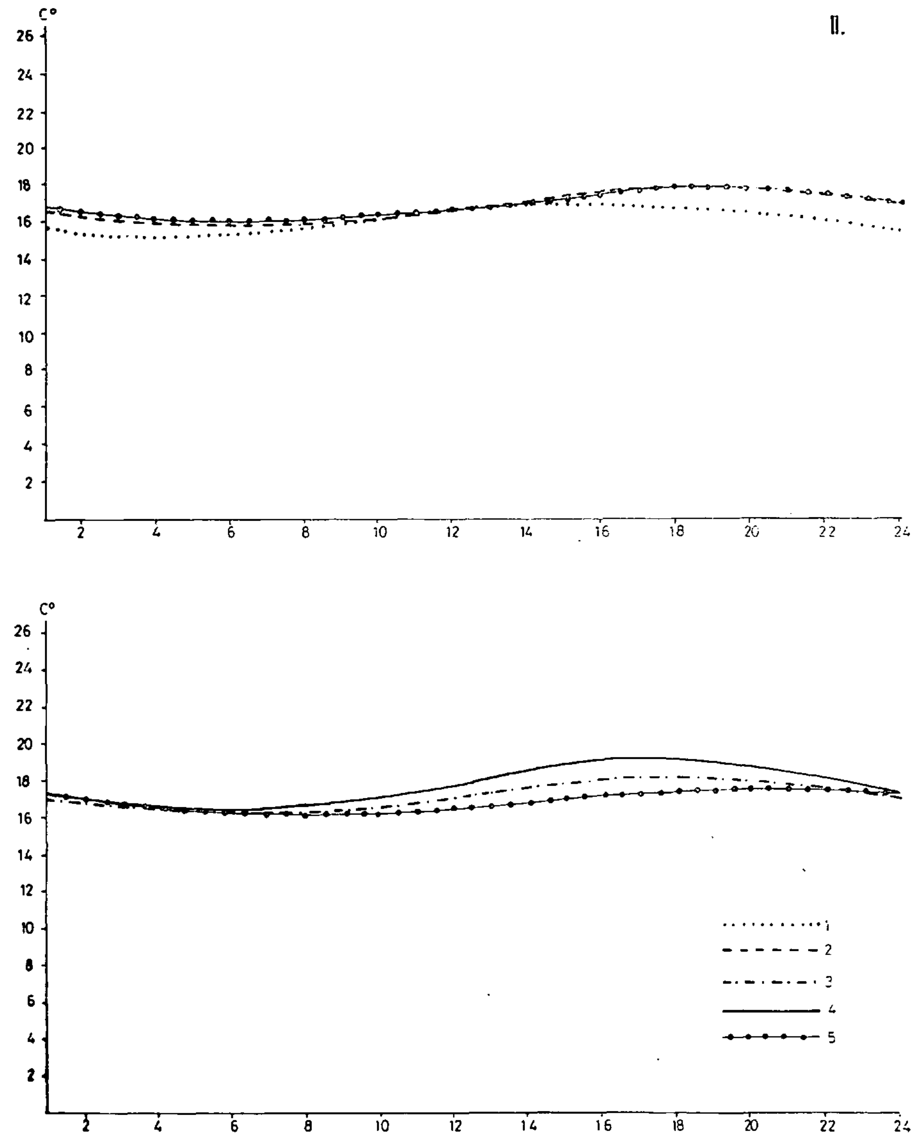

Fig. 6. Trigonometric polynomials at a depth of 20 cm II.
1=eastern exposure; 2=western exposure; 3=northern exposure; 4=southern exposure; 5=sink-hole base.

tinues to be higher on the southern exposure, but the amplitude is higher on the western exposure. At all depths the lowest temperature is found on the northern exposure. At a depth of 2 cm the other three exposures exhibit a significant phase delay compared to the eastern exposure. On the western exposure this delay is 2 hours 6 minutes (1 hour = 15°); at depths of 5 and 10 cm the difference is 2 hours 24 minutes and 1 hour 42 minutes, respectively. At depths of 20 and 30 cm the northern exposure shows a greater delay compared to the eastern exposure.

The transfer of heat towards greater depths requires the longest time on the northern exposure, the shift being 7 hours 24 minutes between 2 and 30 cm. The corresponding values on the eastern, western and southern exposures are 6 hours 6 minutes, 5 hours 42 minutes, and 5 hours 30 minutes, respectively.

The positions of the extreme soil temperature values, and the times of occurrence of these (see Table 2) conform to the above characteristics. The maximum arises first on the eastern exposure, and then on the southern, northern and western exposures. At depths greater than 10 cm the maximum for the western exposure precedes that for the northern exposure. A change of a similar sense as regards the minimum positions occurs between 10 and 20 cm. It may be concluded from the foregoing that between 10 and 20 cm there is a level where the rates of thermal transfer and thermal conduction change on the various exposures. Some data are already available in this respect, but the proof requires further analysis.

To sum up, therefore, it may be stated that the plots of the trigonometric polynomials and the maximum and minimum positions (averaged for the bright days investigated) indicate the soil temperature to develop in the most interesting way on the eastern exposure. It is here that the heating-up begins the soonest and with the greatest intensity, and here that the maxima and minima follow each other most rapidly on proceeding towards greater depths. The southern exposure comes next, with a more intense heating-up and a delay of at least 1 hour. After the southern exposure comes the northern exposure, with smaller maxima but a more uniform temperature course; this is hotter than the eastern exposure, because of the more protracted, higher temperatures in the afternoon.

The northern exposure is the coldest; it is here that the maxima succeed each other with the greatest phase difference between depths of 2 and 30 cm. On the basis of the courses smoothed out with the aid of harmonic analysis too, the exposure features characterizing the soil temperature are in synchronism with the initially discussed exposure differences of biogenous carbon dioxide production and plant evaporation. In this way the earlier research results are interpreted in a new light.

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Table 1.

Characteristic data of the trigonometric polynomials

Exp. / Depth.	2 cm					5 cm					10 cm					20 cm					30 cm				
	K	a_1	a_2	U_1	U_2	K	a_1	a_2	U_1	U_2	K	a_1	a_2	U_1	U_2	K	a_1	a_2	U_1	U_2	K	a_1	a_2	U_1	U_2
E	17,3	4,8	1,1	117	208	17,3	4,0	0,9	124	223	16,7	2,2	0,5	139	251	16,1	0,7	0,1	149	196	15,8	0,3	0,0	209	162
S	19,0	5,5	1,1	136	126	19,0	4,7	1,0	148	136	18,7	3,4	0,6	158	165	17,6	1,2	0,2	179	203	17,3	0,2	0,1	219	182
N	16,3	4,7	0,6	137	144	16,0	3,1	0,5	153	162	15,8	2,1	0,3	166	182	15,1	0,9	0,1	188	196	15,0	0,2	0,0	249	105
W	18,7	4,1	0,6	149	170	18,2	3,6	0,5	161	192	18,3	3,5	0,4	165	204	16,8	1,0	0,1	193	143	16,3	0,4	0,1	235	205

Table 2.

Maximum and minimum positions, and times of their occurrence

Exp.	Depth.	2 cm		5 cm		10 cm		20 cm		30 cm	
		Position	Time	Position	Time	Position	Time	Position	Time	Position	Time
E	max.	207	13^h48^m	214	14^h18^m	229	15^h18^m	239	15^h54^m	241	16^h06^m
	min.	27	1^h48^m	34	2^h18^m	49	3^h18^m	59	3^h54^m	61	4^h06^m
S	max.	224	14^h54^m	238	15^h48^m	249	16^h36^m	259	14^h12^m	309	20^h36^m
	min.	44	2^h54^m	58	3^h48^m	68	4^h30^m	79	5^h12^m	129	8^h36^m
N	max.	227	15^h06^m	243	16^h12^m	256	17^h00^m	278	18^h30^m	339	22^h36^m
	min.	47	4^h06^m	63	4^h12^m	76	5^h00^m	98	6^h30^m	159	10^h36^m
W	max.	239	15^h54^m	251	16^h42^m	255	17^h00^m	257	17^h06^m	325	21^h42^m
	min.	59	3^h54^m	71	4^h42^m	75	5^h00^m	77	5^h06^m	145	9^h42^m