THEORETICAL AND METHODICAL PROBLEMS OF RELIEF ENERGY MAPPING

by

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Geomorphology gathers useful basic facts through the results of orometric, hypsometric, and relief energy investigations for the definition of the relief form combinations or relief types. Earlier SONKLAR (1873), PARTSCH (1911), KREBS (1922), BRÜNING (1927), BEHRENS (1953), and THAUER (1954) dealt with calculation and mapping of relief energy. In Hungary it was LÁNG who made a relief energy map of the medium high Mátra and Börzsöny (1955) and a relief energy map of Hungary (1962) using and perfecting the method of KREBS, while the author of the present paper dealt with mapping of the relief energy of flat and hilly country (FEHÉR 1971).

KREBS (1922) was amongst the first who tried to use, besides absolute altitude data of the relief, also the magnitude of the relief energy to differentiate the types of relief. According to him we can call a plain an area the relief energy of which is under 200 m. The relief energy of perfect plains does not exceed 30 m and the sloping of their surface is no more than 6‰. In our temperate humid climate the name medium high mountain can be applied only to an area the relief energy of which is less than 1000 m. If it is more than 1000 m, the mountain is termed ”high”.

KREBS remarks in connection with this that in the categorization of mountains on the basis of altitude the concept of ”high mountain” is often confused with the terms ”high mountain character” or ”alpine relief” which refer to the richness of forms of the mountains. In order to clear this he proposes that in the definition of the categories of medium high and high mountains only absolute altitudes should be considered, i.e. up to 1500 m altitude we should speak of ”medium high” mountains, while mountains higher than 1500 m should be termed ”high”. Again, the term ”alpine relief”, which characterizes the mountains morphologically, should be used only on the basis of relative differences of altitude, i.e. on the basis of relief energy. According to him the term ”alpine relief” should be applied only to mountains with higher than 1000 m relief energy.

It should be noted that KREBS worked on the basis of a 25 km^2 network wich means that the relief energy values mentioned by him always refer to relative altitude differences measured within 5 km distances; in other words the basic unit of the relief energy indexes is 25 m/km^2 in his system.

The relief energy values can no doubt be well used for a more precise, more exact definition of the concept of the different types of relief, but a difficulty arises from the fact that the methods of calculating relief energy are not uniform and they are not in general use. Even in the case of relief energy examinations made on the basis of relative altitude differences calculated within given distances in a squared network the starting point, the size of the network of squares or meshes is different with every author. PARTSCH for instance worked with a network of 32 km^2, meshes KREBS with a network of 25 km^2, LÁNG with a network of 88 km^2, one of 4 km^2 and one of 1 km^2 meshes; thus they calculated also the differences of altitude within 1 km distances. Consequently the relief energy maps published by the different authors cannot be compared, and the upper limit values (perfect plain 30 m, plain 200 m, medium high mountain relief 1000 m, high mountanin relief above 1000 m) proposed by KREBS for definition of the types of relief cannot be applied uniformly because *the use of networks of different mesh sizes gives quite different relief energy values.* This conclusion is illustrated by the following example.

On the map of the Mátra mountain of Hungary made by LÁNG with a network of 1 km^3 meshes the highest relief energy value is 360 m, while on the map with a network of 4 km^2 meshes the relief energy of the same area is 520 m, on the relief energy map of Hungary with an 88 km^2 network the whole area of the Mátra mountain is shown as having higher than 300 m relief energy and the highest parts have values of 800—850 m. It is obvious that on the basis of these relief energy maps with different network sizes no limit values of general validity can be used.

The relief energy examinations made by the author in plain and hilly country and the relief energy maps of medium high mountain areas made by LÁNG and the relief energy maps of the eastern Alps made by KREBS convince us that *the smaller areal units are used for a relief energy map, the more truly does it represent the real aspect of the relief.* A large-size mesh falsifies, especially in the case of the relief of plains, the picture of the vertical arrangement of the surface features. This is shown in Table 1 in which the relief energy values of the same region, the area of the Danube-Tisza interfluve, are compared on the basis of relief energy maps made with a 1 km^2 network by the author and maps made with an 88 km^2 network by LÁNG in relation to the area and in percentile distribution.

In this perfect plain in the alluvial flood basin of the rivers the value of the relief energy is generally 0—4 m/km^2. There is hardly a perceptible eminence here; rather it is the remains of filled-up one-time river channels that lie a little lower than the average level of the land. In spite of this the relief energy map with a large meshed network shows high values here too which are not characteristic of the real landscape. This error is due to the method. If for instance a solitary eroded inselberg rises 20 m above quite level land, then only those squares show such a value in whose area the eminence is. In the case of a large-

TABLE 1

Relief energy	1 km^2 network		88 km^2 network	
	Area in km^2 and %		Area in km^2 and %	
0—10 m	12297	97,4%	3344	26,4%
10,1—15 m	224	1,8%	2640	20,8%
15,1—20 m	74	0,6%	3168	25,0%
20 m	21	0,2 %	3520	27,8%
Total	12616	100,0%	12672	100,0%

meshed network, however, the whole square of 88 km^2 is given the value of a hill of only a few square kilometers even though all the rest of the area is perfectly flat and without differentiated surface features. This why the two columns of Table 1 present quite different pictures: on the basis of the goss-meshed netwok 73,6% of the whole area has a relief energy of 10—30 m and only one quarter of it has a value of 0—10 m. In contrast to this on the map with 1 km^2 mesh network 97,4% of the area has a relief energy of less than 10 m (of this 58% = 0—2 m/km^2, 23% = 2—4 m/km^2, 10% = 4—6 m/km^2, etc.) and only 2,6% has a relief energy above 10 m.

Relief energy maps constructed on the basis of relative altitude differences calculated in a network of 1 km^2 meshes and value categories corresponding to the relief properties (degree of vertical differentiation of the surface features, petrological structure etc.) show well the distinct features of the relief but also the structural and morphological properties which are the result of the interaction of endogenous and exogenous factors involved in the formation of genetically different areal units.

This is well illustrated by the parts of the relief energy maps presented which show the distinctive relief energy conditions of different types of relief: perfect plain (Figs. 1, 2, 3), imperfect plain (Fig. 4), hilly country (Fig. 5), and medium high mountains (Fig. 6).

Our method of construction the maps was as follows: On the 1:25 000, scale topographic maps a network with 1 km^2 meshes was laid, and with the help of the altitude data or contour lines the numeric value of the difference of altitude in meters between the lowest point and the highest point was determined and then, as a relief energy value, referred to the center of the square. Points of the same value obtained by interpolation were connected by so-called iso-relief energy lines on the basis of value limits chosen according to the character of the given area. After this the territorial distribution of relief energy was represented by hachures.

In areas of plain-like character where the relief energy is mostly under 10 meters a grading of 2 m from 0 to 10 m (0, 2, 4, 6, 8, 10 m) was used. Upward of 10 m, higher value limits, growing parallelly with

TABLE 2

Percentage distribution of relief energy indexes in different of relief

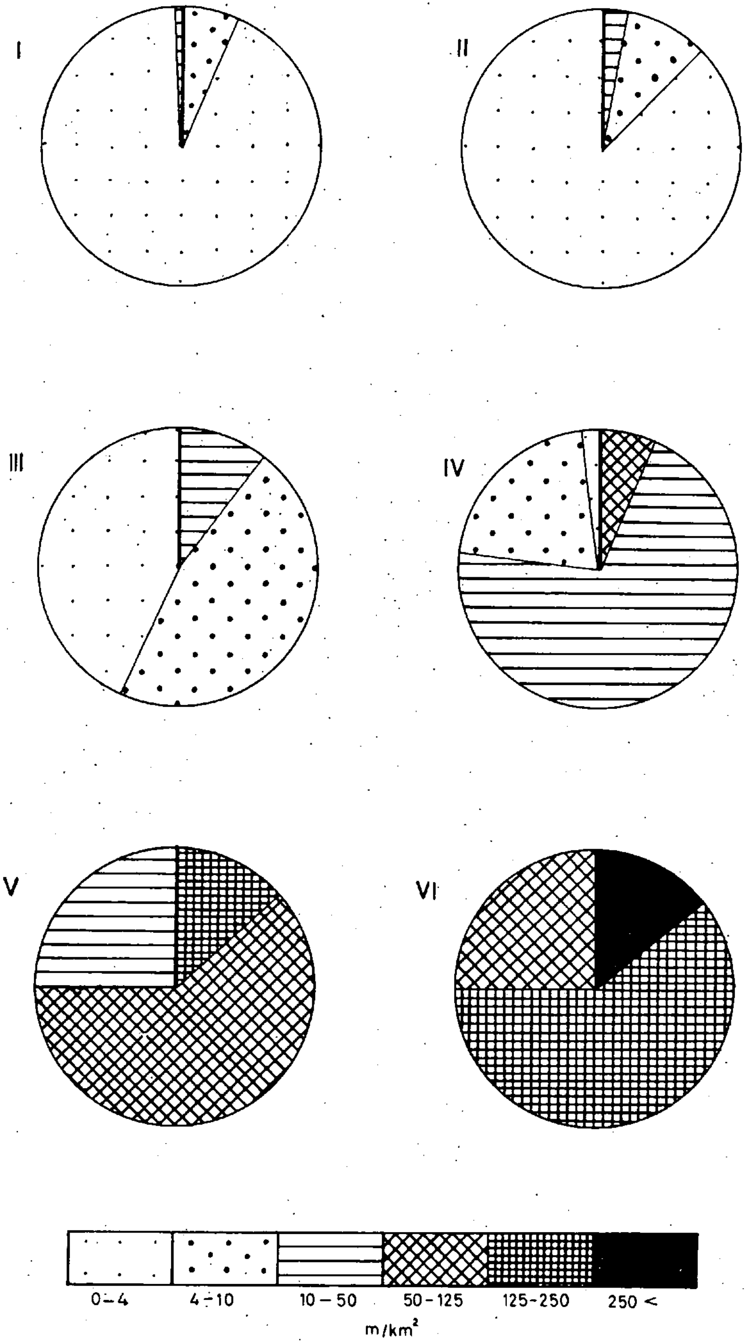
Relief energy m/km²	Perfect plains			Imperfect plain	Hilly country	Medium high mountain	
	fluviatile	eolic	fluviatile and eclic				
	Danube valley plain	Sandy area in Danube Tisza interfluve	Loess plain of Bácska	Loess area in Mezőföld	Hilly country of Szekszárd	Börzsöny	Mátra
0— 2	70	77	11	0,5	—	—	—
2— 4	23 } 98%	11	32	1,5	—	—	—
4— 6	5	4 } 97%	23 } 90%	6,0	—	—	—
6— 8	1	3	13	9,0	—	—	—
8— 10	0,3	2,4	11	8,0	—	—	—
10— 20	0,7	2,4	8	33	5	—	—
20— 30		0,2	1,5	22 } 69%	5	—	—
30— 50			0,5	14	15	—	—
50— 75					20 } 77%	—	—
75—100					27	10	4
100—125					15	15	20
125—150					11	14	16
150—200					2	26 } 76%	29 } 85%
200—250						21	20
250—300						8	8
300 m<						6	3
	100%	100%	100%	100%	100%	100%	100%

the meters, were chosen. Thus categories between 10, 15, 20, 30, 50 and 75 meters were represented.

For the hilly country and medium high mountain types of relief even wider value limits (50, 75, 100, 125, 150, 200, 250, 300, 350) had to be used on account of the much higher relief energy.

The characteristic relief energy conditions of the different types of relief are tabulated in Table 2 on the basis of statistical analyses of data of relief energy maps. The territorial distribution of the relief energy characteristic of the different types of relief can be seen from the table.

1. The type of areas having the lowest relief energy in the Great Hungarian Plain is represented by the wide alluvial flood plains formed


I
II
III
IV
V
VI
0-4
4÷10
10-50
50-125
125-250
250 <
m/km²

by fluviatile accumulation which lie at an altitude of 80—100 m. Their relief energy is extremely low. Two-thirds of their area has a relief energy of 0—2 m, while the relief energy of more than 90% of the whole territory is below 4 km. The relief indexes between 4 and 6 m are negative surface forms: they are imperfectly filled one-time branches and abandoned channels or artificially cut-off ox-bows of the Danube. Hardly can a value above 6 m be found in the whole area. Eminences with 15—20 m relief energy can be found at two spots; they are two small eroded inselbergs that rise like foreign bodies from the perfectly flat alluvial plain near the Danube. Such a low relief energy is a regular characteristic of young potamogenic plains formed by fluvial leveling.

The distribution of relief energy according to chategories is shown in Table 2 which is based on the evaluation of an area of 1200 km^2 of the plain on the left bank of the Danube. Fig. 1 shows a small part of this area.

2. *The land with drift-sand in the Danube-Tisza interfluve* presents a more varied picture. Here the surface was shaped by the wind. With the help of the relief energy map two types of areas with different morphological appearance can be distinguished: deflationary areas and accumulation areas.

Most of the *deflationary areas* (80—90%) have low relief energy with chiefly negative surface forms. The subsoil water table, which is generally near to the surface, determines the lower limit of the effect of deflation; therefore only shallow deflationary depressions could form, in some of which there are temporary or permanent lakes. In some places relatively 4—6—10 m high, isolated, very gently sloping sand ridges parallel with the prevailing NW wind direction rise above the low relief energy basal terrain. It is first of all these positive surface formations that distinguish these areas in respect of relief energy conditions from the otherwise very similar fluviatile accumulation conditions. (See the eastern part of Map 2.)

Among the deflationary surfaces there are so-called *eolic accumulation areas* with much more varied relief energy. In these eolic areas the relative height of the agglomerated sand dunes reaches even 10—15 m; thus the relief energy exceeds even 20 m/km^2 in some places. (See the western part of Map 2.) In these areas the ratio of the relief indexes between 4—15 m/km^2 is higher.

3. *The loessial area of Bácska* is situated in the SW part of the rolling plain of the Danube-Tisza interfluve, and is characterized by higher average relief energy due to the effect of the material of the superficial loessial rock. The relief energy is 2—6 m/km^2 in 55% and 6—15 m/km^2 in 32% of the 750 km^2 area. These are extensive patches made still more varied by small areas with 10—30 m/km^2 relief energy values which constitute 10% of the whole area. The relief energy of 0—2 m/km^2 characteristic of the fluviatile and eolic surfaces described in the foregoing constitutes here only 11% of the area (Fig. 3). This character of the relief energy can be attributed to the effect of the

material of the loessial rock, the intense linear carving effect of small streams, and the deflationary action of the wind.

4. The southeastern part of *Mezőföld* represent another type of relief, the *Imperfect plain* which is an area of 1300 km^2. (Fig. 4.) The closer hachures of the map indicate clearly the generally higher relief energy, while the wide range of relief indexes shows the varienty and sharp division of the relief. 69% of the surface has a relief energy of 10—50 m/km^2, and its distribution within this can be said to be fairly even. (33% of the area has a relief energy of 10—20 m, 22% of it 20—30 m, and 14% of it 30—50 m/km^2). There are here already values exceeding 50 m, though they constitute only 6%. On the other hand relief indexes between 0—4 m are characteristic of only 2% of the area.

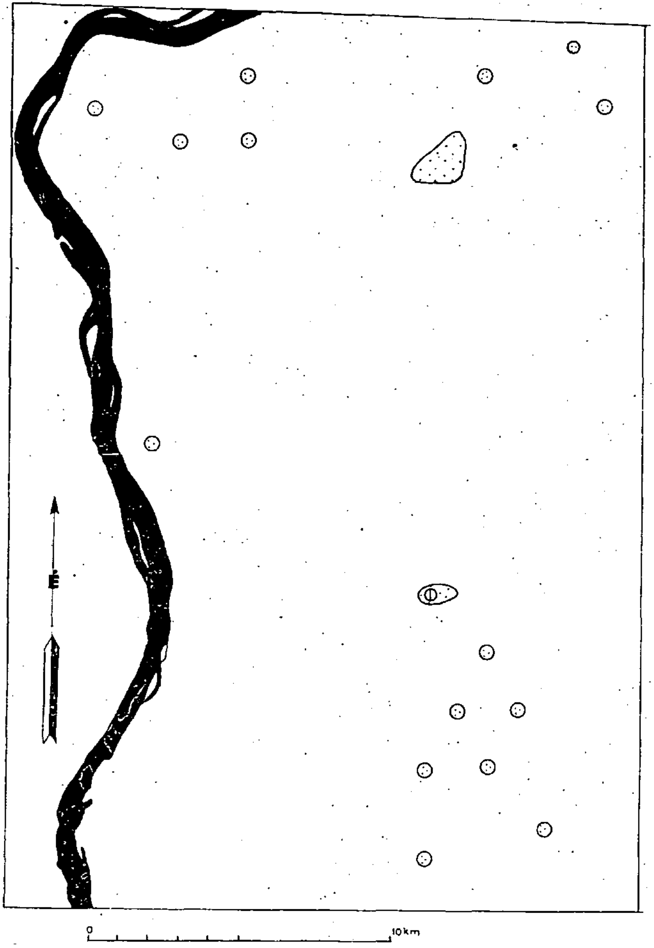


Figure 1. Relief energy map of an alluvial flood plain on the left bank of the Danube.

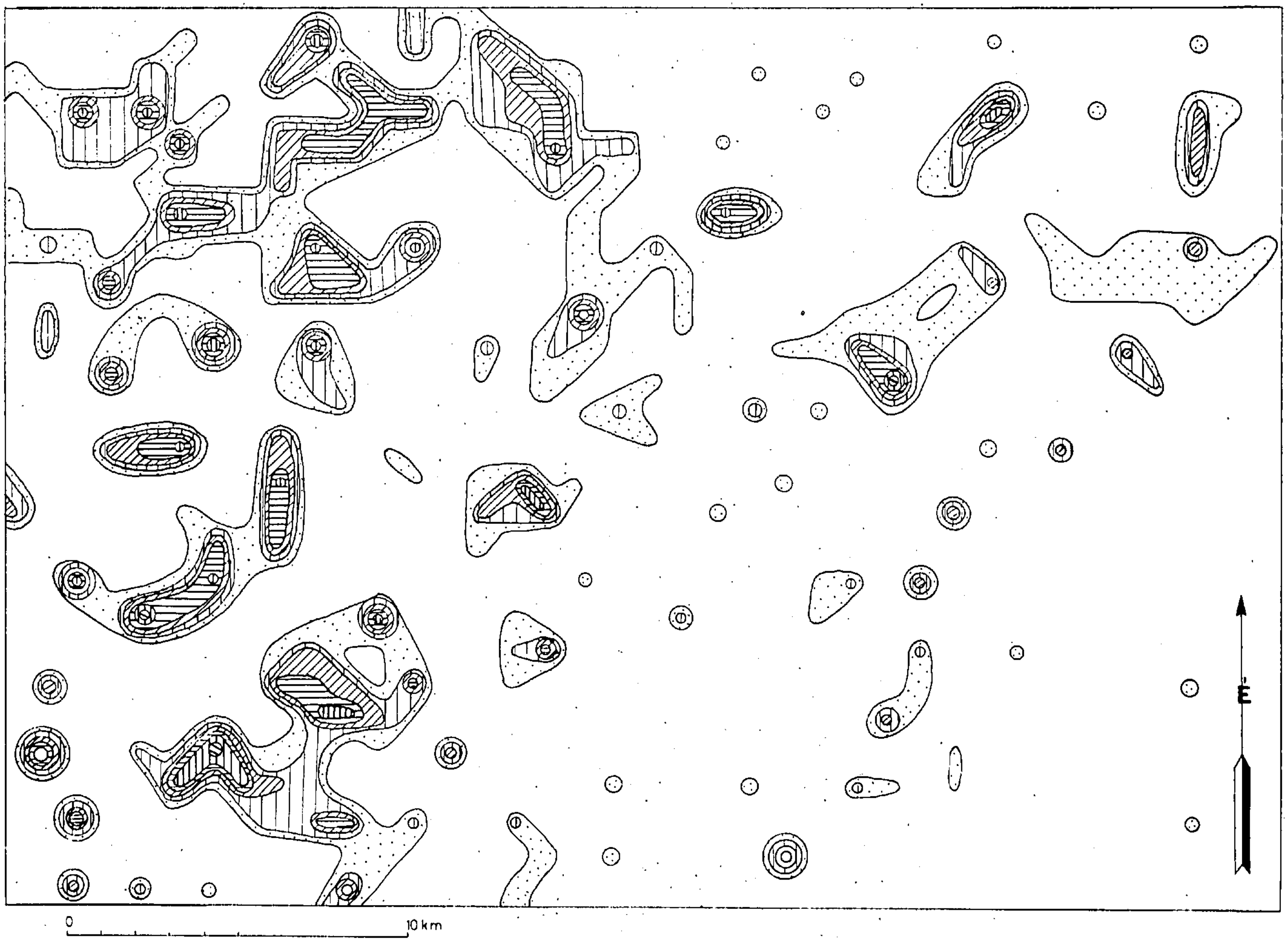


Figure 2. Relief energy map of a land with drift-sand in the Danube-Tisza interfluve

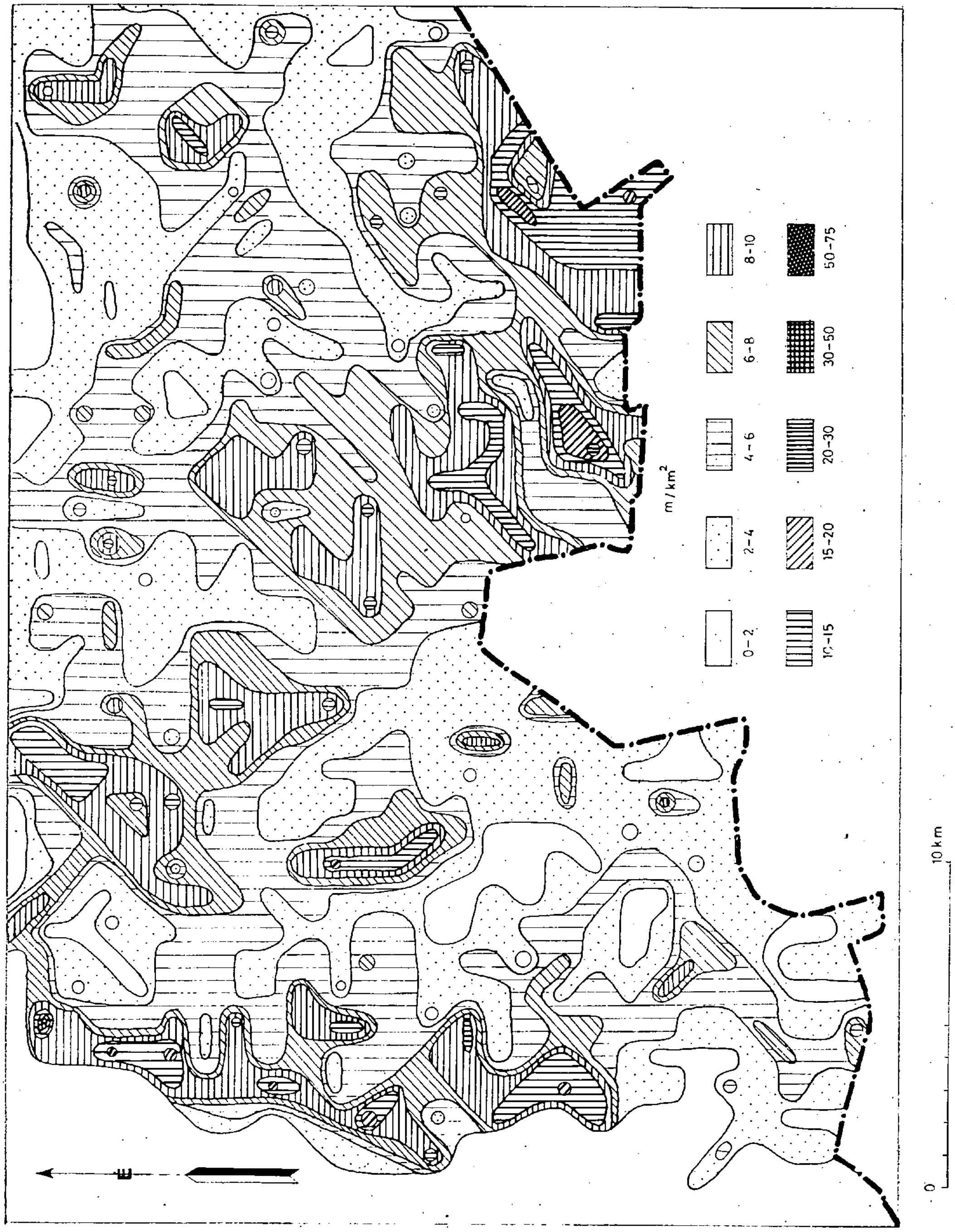


Figure 3. Relief energy map of a loessial area of Bácska.

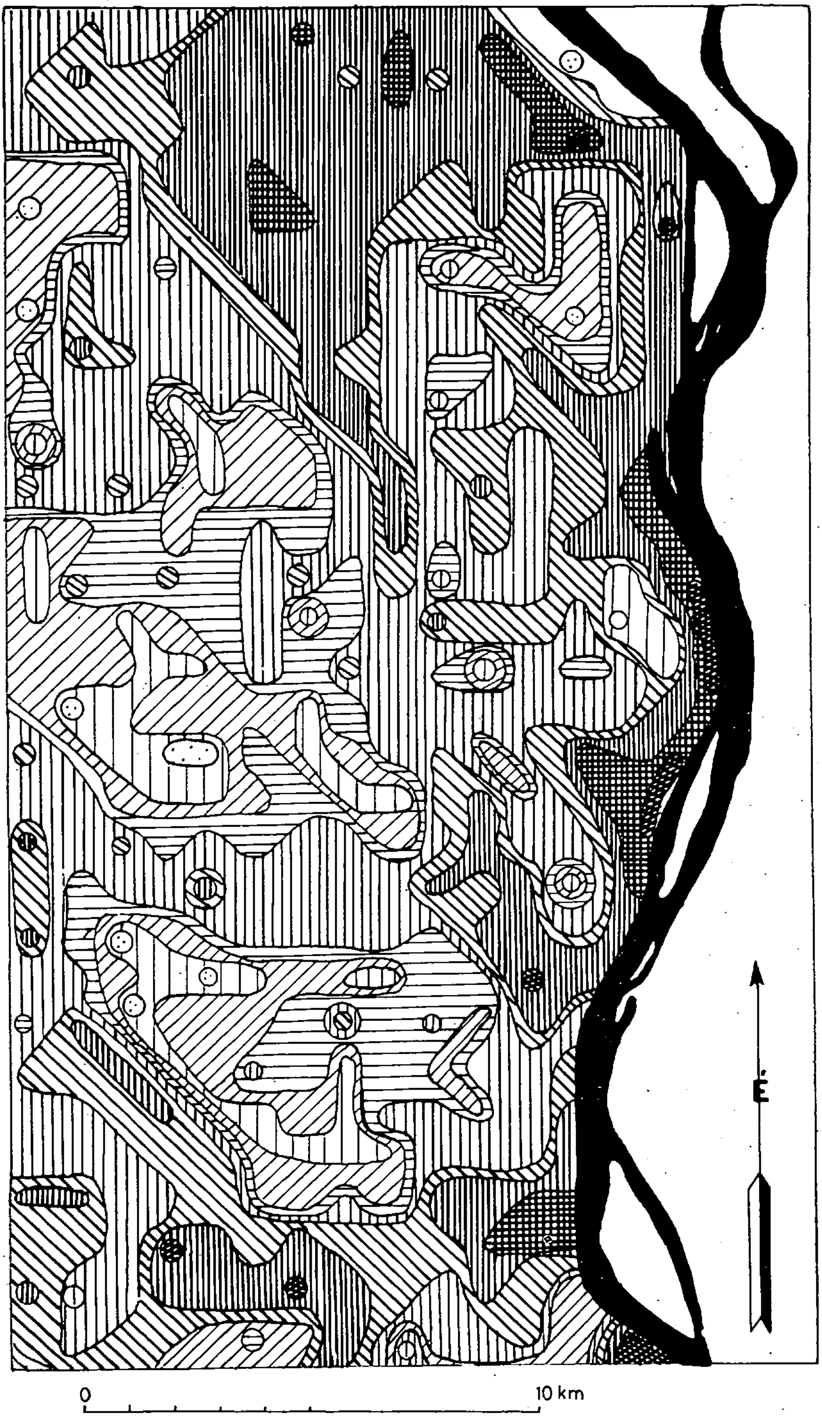


Figure 4. Relief energy map of the southeastern part of Mezőföld.

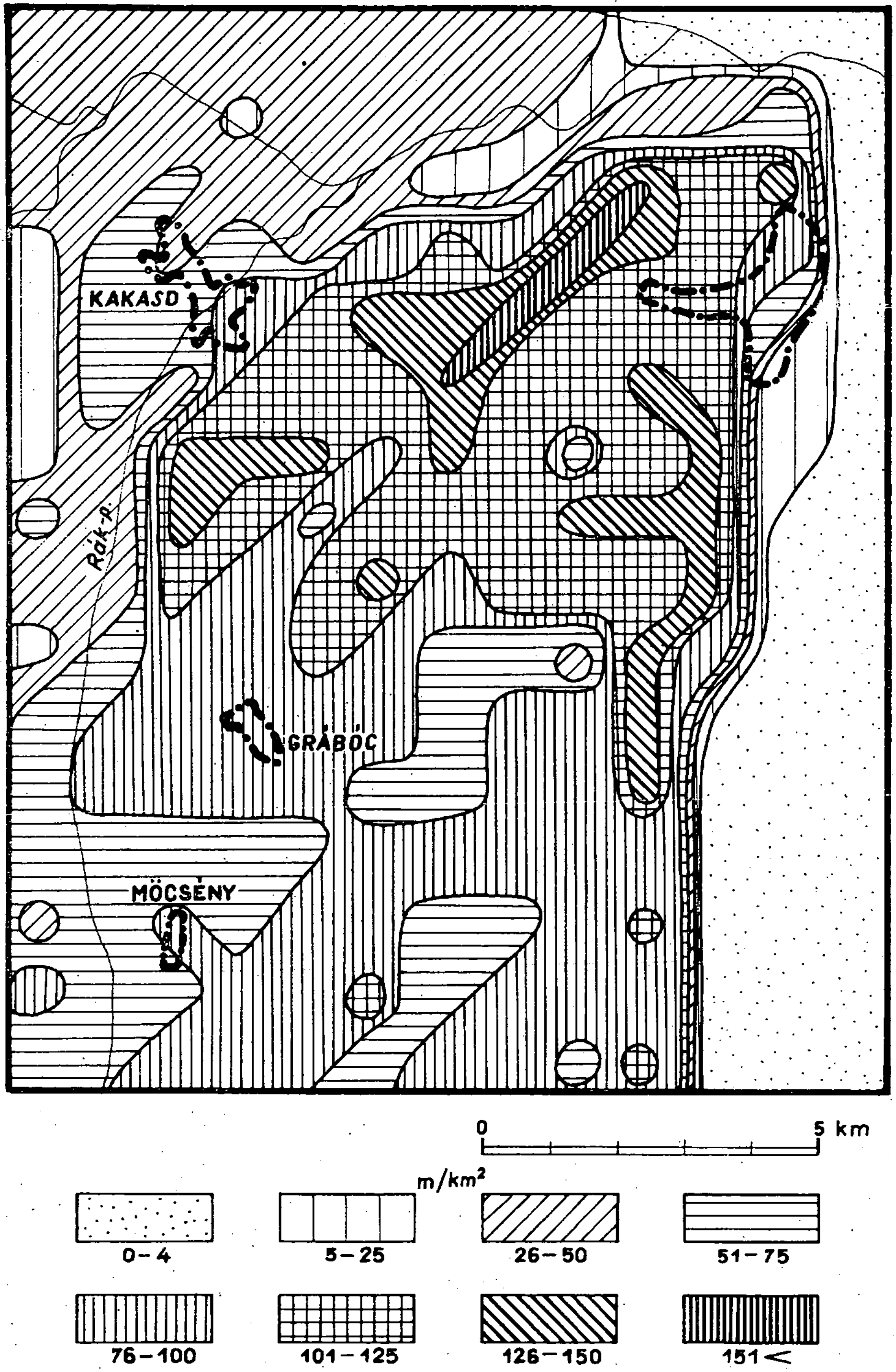


Figure 5. Relief energy map of the hilly area of Szekszárd.

5. The relief energy conditions of *hilly country* are shown in the relief, the *Imperfect plain* which is an area of 1300 km^2. Fig. 4. The closer sdanubia (Fig. 5). The land surface covered by a 20—40 m thick layer of loess and made up of Pannonic clay, sand, and sand-stone rocks was cut up into irregular pieces and raised to different elevations by tectonic movements in the Pleistocene epoch, while the northern and eastern peripheral parts of the hilly area sank stepwise along parallel faults. The small streams of the area have steep gradient and thus they have contributed with their intense linear erosive action to the division of the terrain. As an example characteristic of the density of the network of valleys the area of Parászta valley may be mentioned the 2,5 km^2 catchment basin of which is dissected by 14 lateral valleys.

In this hilly area the trend of the patches with identical relief energy values are determined first of all by the structure lines; the magnitude of the relief energy by the absolute elevation of the area (150—300 m altitude above sea-level) or the magnitude of the tectonic movements of the crust. The distribution of the relief energy here is as follows: In 77% of the area values of 30—125 m/km^2, in 10% of the area indexes of 10—30 m, in 13% of the area more than 125 m/km^2 are characteristic. Lower than 10 m values of relief energy are not found in the whole area. The largest portion of the area belongs to the 75—100 m/km^2 category constituting 27%.

6. The *relief type of medium high mountains* is represented by the relief energy map of the Börzsöny mountain (Fig. 6), and the relief energy distribution characteristic of this type of relief is presented on the basis of the evaluation of the Börzsöny and Mátra mountains (see columns 6 and 7 of Table 2). The mountain area to be evaluated was marked off from the area of the foothills along the 100 m/km^2 iso-relief energy line.

Both mountains were formed approximately at the same time and in the same way. Multiphase neogenic vulcanism was followed by intense erosion; then at the end of the Pliocene epoch uneven elevations along the tectonic faults gave the mountains their present form. The character of uplifted eroded mountains can easily be read from the relief energy map and the steep outlines of the eroded parts, at different heights can be seen from the closeness of the iso-relief energy lines. Owing to similar genetics, rock structure, and absolute altitude. the relief energy shows similar distribution (the highest points being 939 m for the Börzsöny and 1015 m for the Mátra). The largest part of the mountain areas (76—85%), can be found in the relief index range of 100—250 m/km^2, the categories between 150—250 m/km^2 being the most heavily represented (47—49%).

Analysis of the relief energy map details and of the distribution of relief energy proves convincingly that the relief energy maps constructed with a network of 1 km^2 meshes expose the qualitative differences of the character of the different relief types in necessarily exaggerated form, thereby drawing attention to the factors determining or influenc-

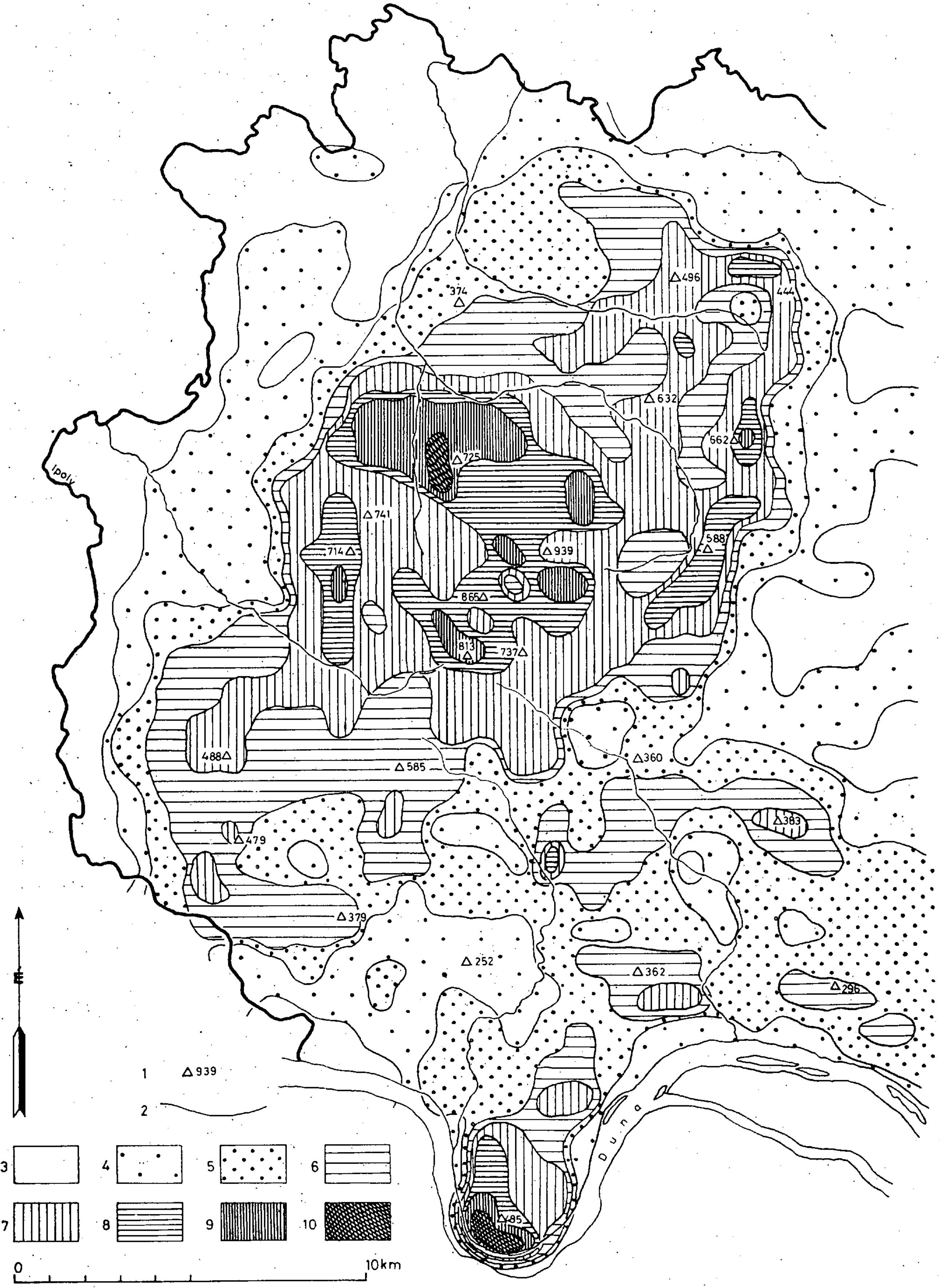


Figure 6. Relief energy map of the Börzsöny mountain (S. Láng 1959.)

ing surface development. The percentage distribution of the relief energy indexes points out also the quantitative differences in the development of the landscape. In this respect the relief energy map provides better information than even detailed hypsometric maps. Therefore analysis and comparison of it with different kinds of special physical geographic maps as well as statistical analysis of the distribution of the relief energy indexes are indispensable for modern dynamic physical geographic landscape evaluation.

On the basis of his experience *the author proposes:*

(1) the general use of maps constructed with a network of 1 km^2 meshes for the purposes of relief energy investigations,

(2) the use of value categories determined on the basis of statistical evaluation of relief indexes referred to 1 km^2 which characterize the different types of relief better. For instance: the term ”perfect plain” could be applied to an area 90% of which has less than 10 m/km^2 relief energy. The ”imperfect plain” would be an area, two-thirds of which has 10—50 m/km^2 relief energy. The hilly country would be an area, two-thirds of which has 30—125 m/km^2 relief energy, and the medium highmountain an area, two-thirds of which at least has 100—250 m/km^2 relief energy.

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