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Morphometric investigation of dolines in Bükk mountains

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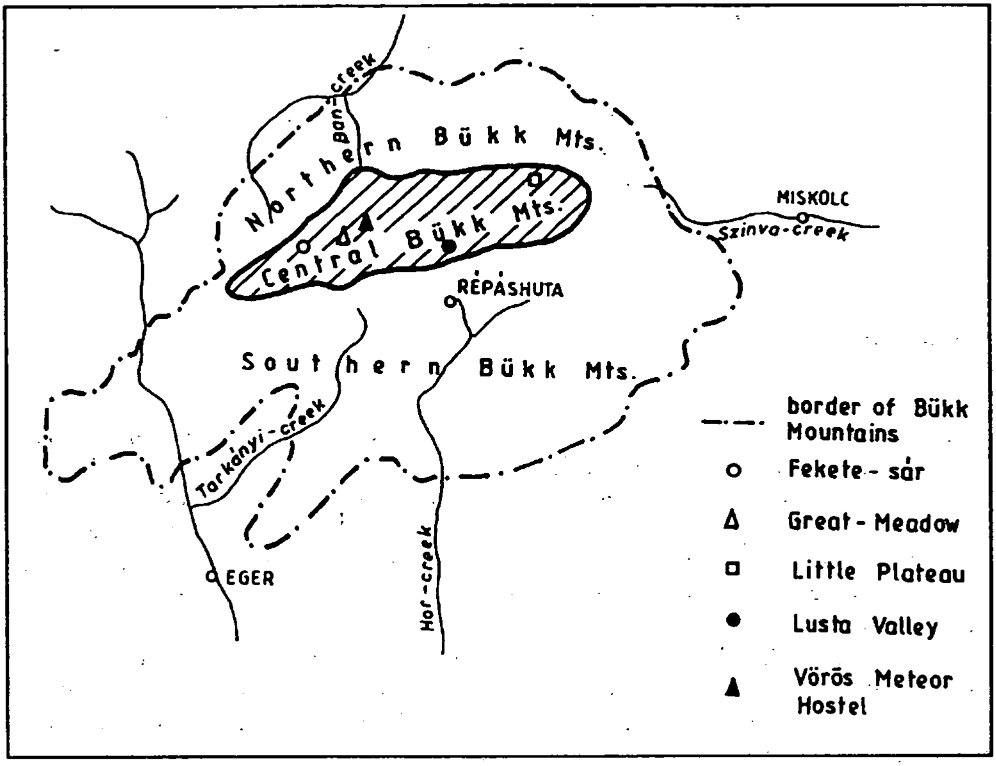
INTRODUCTION

The content of geomorphology, its methods as well as the aim of the investigation have significantly changed in last decades. These changes developed in accordance with social claims for engineering geomorphology, landscape ecology and model investigations. The fundamental question of each new conception is the exact terrain measurement and evaluation. Terrain classification based on its quantitative analysis followed former descriptive terrain evaluation. This effort was the basis of the elaboration of the morphometric methods.

Morphometry follows the theoretical and the practical investigations. The morphometric terrain analysis is significant from theoretical point of view, because with the help of morphometry the landscape elements can be studied with optional accuracy, which is always defined by the required aim of the study.

The dolines are the characteristic forms of the karst process and there were some experiments to analyze their morphometric properties. Veress, M. and Péntek, K. (1988) examined the so called "ideal dolines" (ideal=symmetrical) which can be derived from the original doline by certain topological transformations. With mathematical methods applied, they typified these ideal dolines and they did not take the variety of dolines in accordance with aspect into consideration. On the basis of the location of the inflexion point of slope, they divided the dolines into two groups: dolines which develop into doline (in the original sense), and the second type of dolines including dolines developed into sinkhole. Other authors investigated the development of dolines from a quantitative point of view. The development and the shapes of different slopes significantly differ from each other depending on the intensity of microbiologic processes carried out in the soil determined by the aspect. We also have to take these differences into consideration at the classification. Williams,P.W. (1989) called attention to the importance of the asymmetrical development of dolines.

During this study, we have carried out the morphometric analysis of 27 dolines located in Bükk Mountains. The groups of dolines (Map 1) can be found on region of Fekete-sár (9 dolines), on Little Plateau (10), on the surrounding of Vörös Meteor Hostel (5), on Great Plateau (2) and on Lusta valley (1). The aim of this study was to find a method to re-evaluate the fundamental ideas of both above mentioned conceptions.



Map 1 Location of the investigated dolines

METHODS

For the classification of dolines, we had to choose parameters which describe both vertical and aspective properties exactly. The application of mathematical statistics seemed to be the most favourable method. In the first stage, we considered dolines as the fundamental unit of the measurement, but we were not able to find parameters which can represent the shape of dolines in every aspect because of the spatial variation. A second problem was the comparison of shape of different dolines, because using variables with more than 2 dimensions the shapes cannot be compared with each other.

Both problems can be solved if we choose the "slices" of a given doline as a unit of the statistical investigation instead of the whole doline. Each of these slices are 1 m thick and delimited by the contour lines.

We supposed that the dolines can be well represented with their slices and this supposition can be proved by the following facts: the T(x) function, applied to dolines, expresses difference in the top and bottom area of the slice x, can be well approached by exponential function; $\mathbf{T(x)=l{*}e^{\mu x}}$ (Veress,M. - Péntek,K. 1988). Then the ratio of T(1) and T(2), where T(1) and T(2) are the top and bottom areas of the given slice, can be expressed by the following way:

$$\frac{T(1)}{T(2)}=\frac{T(x_0+1)}{T(x_0)}=\frac{l*e^{\mu(x_0+1)}}{l*e^{\mu(x_0)}}=e^{\mu}$$

consequently the value of the T(1)/T(2) ratio is independent from variable x_0, therefore it can be explained as a value well expressing the vertical development of the given doline.

In our statistical examinations, we have used parameters which express the vertical development or the aspects of the dolines. We did not use variables in which these above mentioned properties are represented at the same time.We used the following parameters to express the vertical development:

- ln(T(1)/T(2)), where T(1) and T(2) are the top and bottom areas of the slice,
- K(1)/K(2), where K(1) and K(2) are the top and bottom perimeters of the slice.

To describe aspects of the dolines, it is expedient to investigate the shortest and longest directions of extension. Since in the case of the mapped dolines, these parameters coincided with the most important aspects (N,E,S,W), we used the following parameters:

- αN, αS, αE, αW, where αA means the steepness of slope (A aspect)

The location of the deepest point of the doline is characteristic with respect to the shape of the doline and its location can be very important from the point of view of the development of doline (Zámbó,L. 1986, Williams,P.W. 1989). Therefore we examined the characteristic formation of the distances from this point (or from its rectangular projection on slice) in accordance with the aspect, i.e. the values of N-S and W-E eccentricity had been considered at the classification:

- eccNS= N/N+S;
- eccEW= E/E+W,

where N,S,E,W mean the distance from the location of the deepest point in the given aspect on the given level. We can calculate from these parameters the value of extension of the given slice:

- extension = (N+S)/(E+W).

Each slice can be characterised by vectors expressed with the above mentioned parameters. Spatial groups of these vectors represent same slices, consequently they can represent slices the same origin. The structure of groups can be examined by the complete method of the test sites. The most important task is the determination of those factors which are responsible for the differences between the groups. This problem can be solved with the help of discriminate analysis between the groups.

RESULTS

According to the results of the complete method, we can say that the samples can be divided into two groups (A,B) and one of them can be also divided into two subgroups (A_1,A_2). The simplified picture of the final dendogram can be seen in Fig. 1. The most important difference between the group A and B is that the elements of group B represent only the lower 1 or 2 slices of the dolines, while group A contains the upper slices. The elements of group A_1 and A_2 can be well distinguished from each other according to their

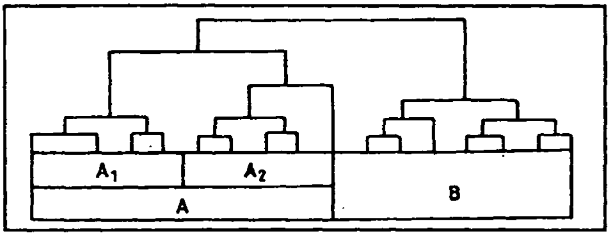


Figure 1 Sketch dendrogram of the investigated slices of dolines

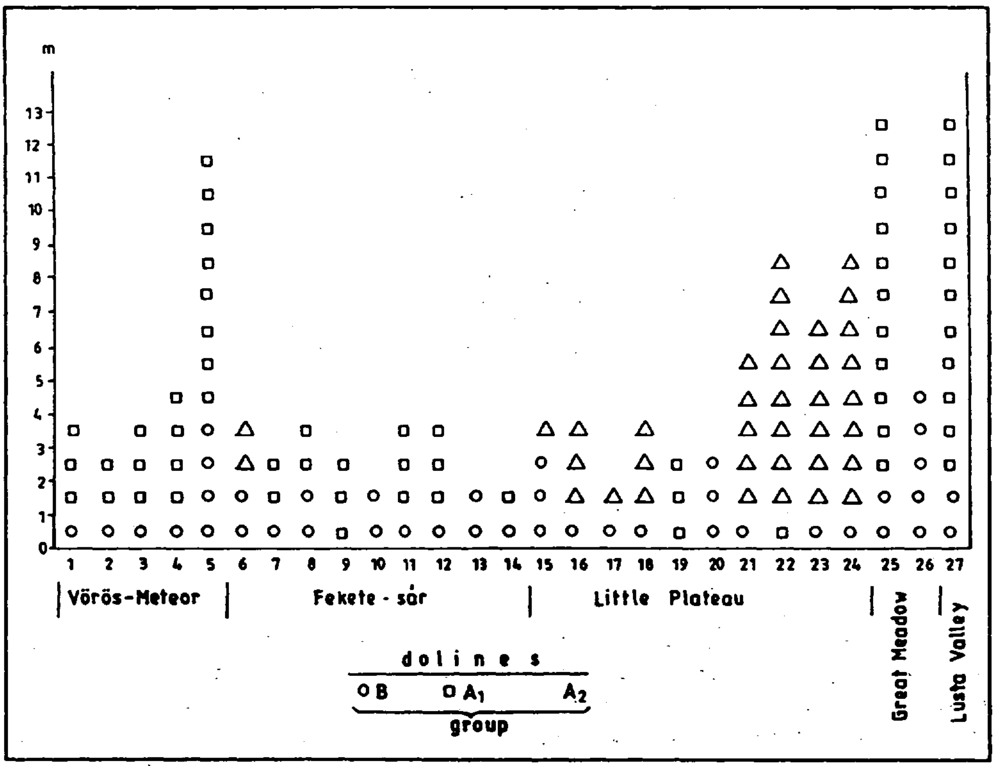


Figure 2 Groups of slices based on complete method

geographical locations. Subgroup A_1 includes the slices of dolines situated on Kis-mező. We summarized (Fig.2) the arrangement of slices due to the results of the complete method. Since the complete method referred the slices of the dolines to the same groups without exception we supposed that in the chosen space of parameters, the slices well represent the dolines statistically.

According to the results of the investigation we can say that the most important morphological difference appears between the lower and the upper slices. On basis of the results of the discriminate analysis, the reason for this fact is in the parameter ln(T(1)/T(2)) and K(1)/K(2), which characterizes the vertical development of dolines.

The values of both parameters are much greater than those of samples in group B, i.e. at the bottom of the doline the decrease of the area and the parameter is greater. It is in connection with the fact that the bottom of the doline can be concerned as an alluvial surface, where the development is rather lateral as vertical (Jakucs,L. 1971, Zámbó,L. 1986). If we investigate the number of slices in a given doline in group B, then we can conclude to the direction of the development of doline (doline or sinkhole). In this manner, dolines No. 5 (at Vörös Meteor Hostel) and No. 26 in Great Meadow (Nagy-mező) fall into group I, while doline No. 9 (Fekete-sár) falls into group II.

We determined the parameters to distinguish subgroups of group A by discriminate analysis. From this point of view, the most important parameters were the eccEW, the αE as well as the extension. The eccEW and the αE are significantly correlated with each other (0.71) and they show that there is a significant difference in the state of development on the eastern and the western slopes (especially on the eastern slope) in group A_1 and A_2. This fact is more conspicuous if we represent the values of eccentricity in a N-S-E-W coordinate system (Fig. 3). In the case of group A_1, the dolines are elongated in eastern

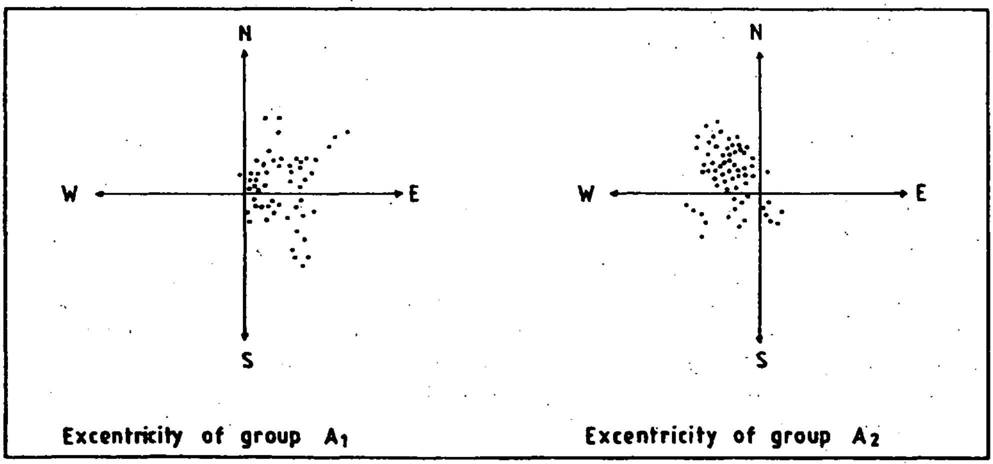


Figure 3 Characteristic values of excentricity of subgroup A_1 and A_2
(Origin is at the point (0.5,0.5))

direction, while there is not significant differences in N-S direction. In the case of group A_2, definite western and northern eccentricity can be determined. This latter property is well correlated with the fact that, due to the microbiological processes appeared in the soil, the western and northern slopes (eastern and southern aspect) of the dolines develop in faster rate (Keveiné Bárány, I. - Mezősi,G. 1978).

The value of extension was also used to distinguish these subgroups. Almost in all case, the following interesting facts can be claimed:

(1) from the bottom to the top, the values of north-southern extension decrease gradually,

(2) in the case of the dolines situated on Kis-fennsík (Little Plateau), the extension will be east-western definitely at a given altitude, while in other cases it remains north-southern.

In Fig. 4 we represented 6 different characteristic curves of extension depending on the depth. In our opinion, the reasons for the initial north-southern extension can be (a) the local tectonical factors and (b) local morphological factors. At higher levels, the differences in microclimatical conditions can become effective on distinctive slopes and due to the effect of these differences, the values of the initial north-southern extension decrease gradually. In the case of dolines, measured in Soros-töbör (töbör=doline) (Little Plateau), the reason for the lack of the north-southern extension is the east-western tectonic alignment of the valley.

SUMMARY

The morphometric classification of the dolines from 5 different areas of Bükk Mountains has been done with the help of the methods of mathematic statistics. We cut the dolines into 1 m thick slices by the contour lines and these slices were the fundamental units of our statistical investigation.

The results show that the doline slices well represent the original shape in the chosen space of parameters. The weighting of the vertical and aspect parameters was difficult in the morphometric classification of dolines. We can say that the most significant differences are in the bottom slices and the slices found above them. The ratio of them can refer to the development of the doline. If we take the differences (connected with the orientation of the slopes) into consideration a more detailed classification will be possible.

In the first case, general regularities of the doline development are the determining factors, while in the second case, the local tectonical, petrological, ecological and morphological parameters play a significant role in doline development.

Further investigations are necessary (1) to define the reason for the distinctive development of the dolines on Little Plateau), and (2) to find the reason for the regular change in the extension connected with the depth.

We would like to thank Dr. Márton Veress making his data from his field measurements and mapping available for us.

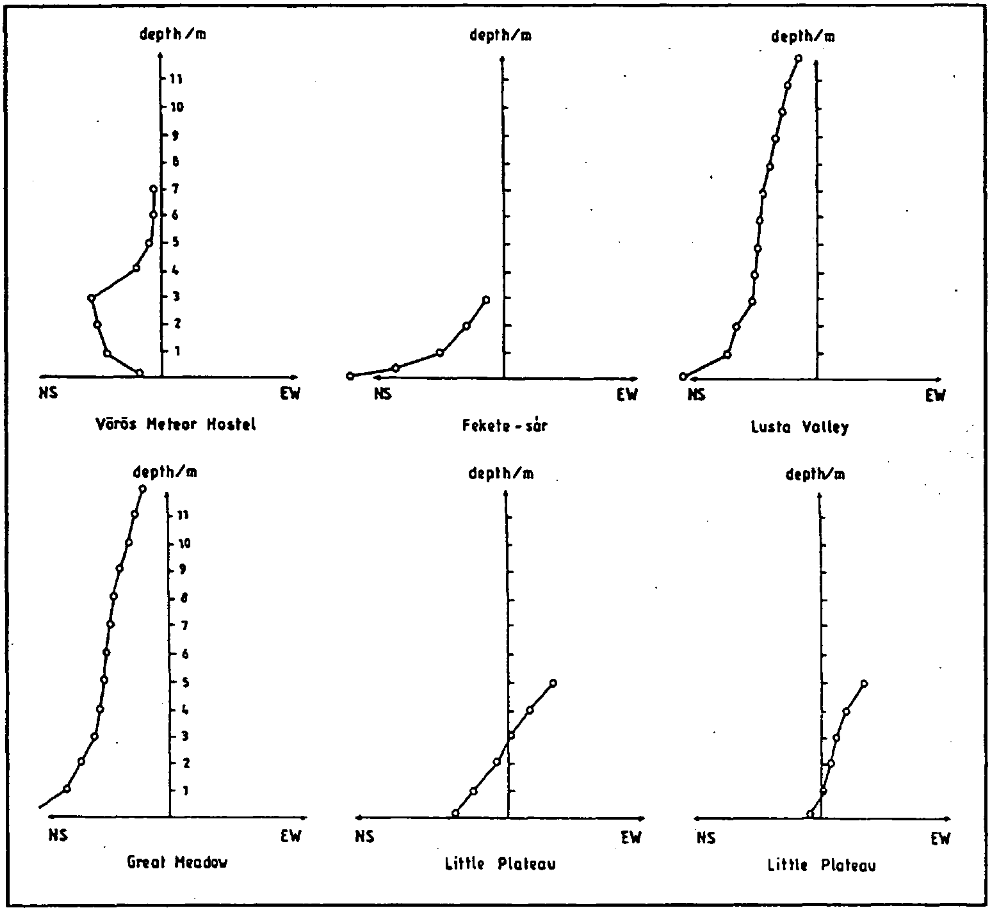


Figure 4 Connection between the extension and depth

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