

Utilization of Geoinformatic Methods in the Morphometric Analysis Case Study on a Mesa from Hungary: the Somló Hill*

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Key words: dry valley, morphometry, contour line section index, GIS, Somló Hill

Abstract. Somló situated on the Little Hungarian Plain (*Kisalföld*), represents an ideal territory for geomorphologic and morphometric analysis. In the course of the research, the aim was to work out an unambiguous descriptive method applicable to the two types of derasional valleys of the sample territory. Therefore, the already existing traditional geomorphologic results, as well as statistical and geoinformatic techniques were utilized.

In the first stage of the analysis, the characteristic features of each section of the contour lines—crossing the dry valley—were examined. The average contour line section index (CLSI) and the standard deviation of each young and old valley was defined, according to which the valleys belonging to these two groups as well as the morphometrically different valleys could be separated from each other. The extent and location of change observable in the cross-section of valleys was also described.

In the second stage of the research, the characteristic inclination of the valleys was analyzed. According to the maximum values of the normal distribution projected on the slopes of the valleys, it was also possible to distinguish the old and young derasional valleys. The valleys with characteristic values different from that of the above mentioned two groups were revealed as well.

Introduction and Aims

Somló Hill (432 m) is situated on the Little Hungarian Plain, in the western part of Transdanubia, in Hungary (Fig. 1). Its major building rocks are easily eroding sediments of Lake

Pannon deposited in the Central Paratethys. The lake retreated from the research area approximately 9–9,5 million years ago (Magyar et al., 1999). The deposits consisting of clays and sands were covered by hard, resistant basalt, which protected them from the effects of the exogenic processes.

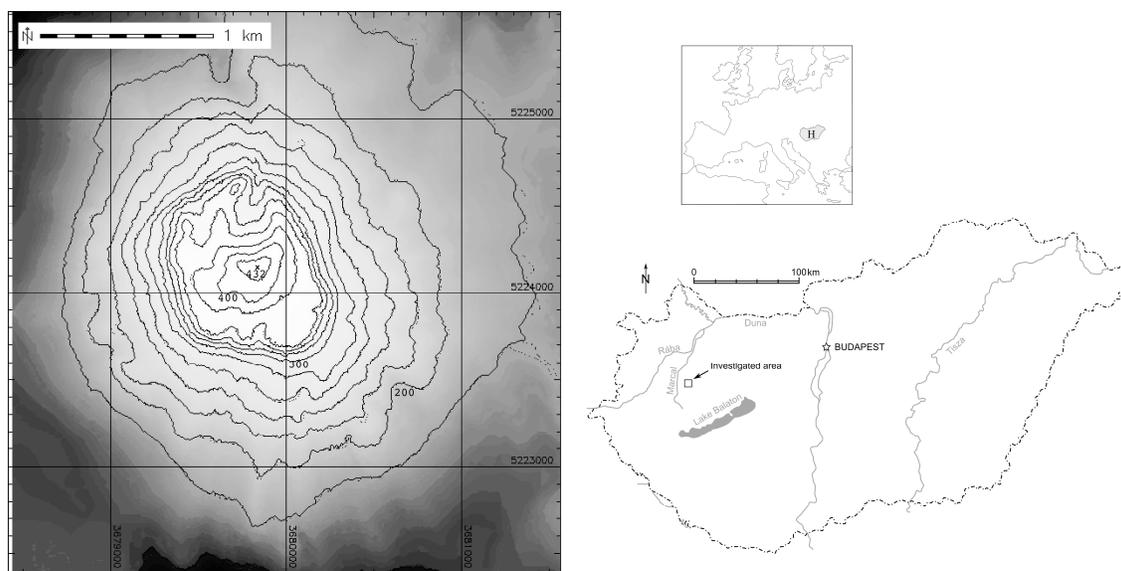


Fig. 1. Location of the study area. (UTM coordinates)

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The duration of the Somló's volcanic activity is still doubtful. The researches based on absolute dating (Balogh et al., 1982, 1987; Borsy et al., 1986; Pécskay et al., 1995; Wijbrans et al., 2007) define the period lasting for 3,5 million years. The relative chronological interpretations (Varga et al., 2004, Schweitzer, 1997) and the latest geomorphologic observations (Kovács, 2008) calculate with an older volcanic activity dating back minimum 5 million years. These latter examinations and results were utilized in this research.

After the basalt volcanic activity had finished, the hill grew high above its environment, and on it developed two generations of derasional valleys. These valleys represent a special group of dry valleys. They were formed by sheet erosion and mass movements, under a Pleistocene periglacial climate. This study utilises this term originating from Pécsi (1964/a, b, 1997) as well.

The young derasional valleys developed on the deposits of Lake Pannon, resulting from Pleistocene periglacial processes. The old derasional valleys were deflation hollows incised in the basalt mesa (Kovács, 2008), and were formed after their dissection under periglacial climate alike (Fig. 2).

Morphometric parameters and evolution of derasional valleys were particularly investigated in the last 50 years in Hungary. Cross-sections, slope maps and geomorphologic sketches were made (Kéz, 1956, Marosi, 1965, Szilárd, 1965, Pécsi, 1962, 1997), though their detailed description and analytic morphometric examination is still not completed. However derasional valleys play an important part in flash foods (Czigány, et al. 2008). They cover more than 60% of Hungary's surface (Pécsi, 1997).

In the course of the research, the authors' aim was to work out an unambiguous descriptive method applicable to the two types of the dry valleys of the sample territory, using traditional geomorphologic results (geomorphologic map), statistical and geoinformational techniques.

Methods

In this work the 6.0 version of the Grass GIS software was utilized, which was run in a Debian Linux environment. The contour lines of the topographic map of the research area to a scale of 1 : 10 000 were digitalized on-screen, using the *v.digit* routine of Grass 6.0. The resulting vector lines were rasterized using the *v.to.rast* routine.

Grass 6.0 creates a raster elevation map from a rasterized contour map using the *r.surf.contour* routine. To determine the elevation of a point on a contour map, we could interpolate its value from those of the two nearest contour lines (uphill and downhill). The *r.surf.contour* routine linearly interpolates between contour lines (Ehlschlaeger, 2007). On the topographic maps used contour lines are indicated every 2.5 meter, therefore the theoretical breaking down of the resulting elevation map includes 5x5 meters. The geomorphologic map of the Somló was constructed based on the above mentioned topographic map, thus its digital version could be compared with the elevation map of the hill. The young and the old derasional valleys represented on the geomorphologic map were distinguished and grouped using the *r.reclass* routine.

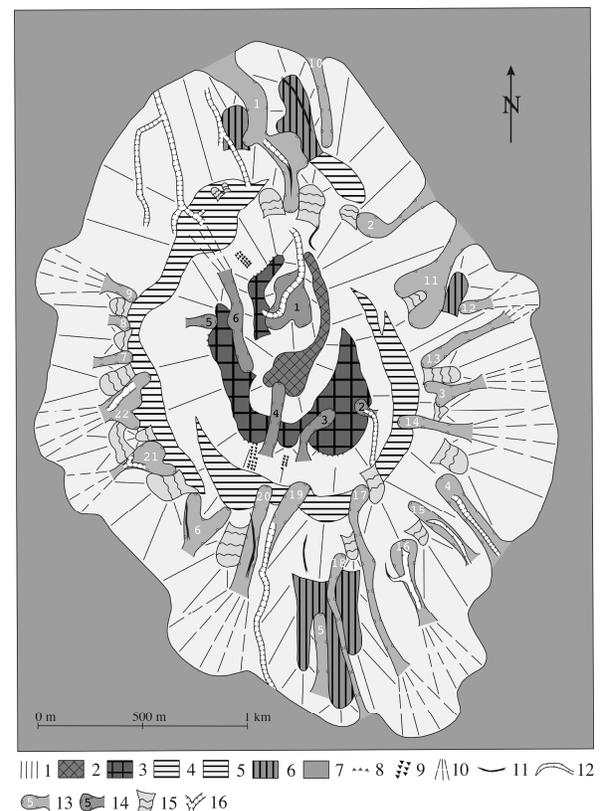


Fig. 2. Geomorphological map of Somló Hill and Id. numbers of the derasional valleys

1 = slopes undistinguished; 2 = top region of the mesa;
 3 = mesa; 4 = higher level of pediment; 5 = lower level of pediment; 6 = interfluvium; 7 = alluvium; 8 = columnar basalt;
 9 = debris flow; 10 = debris cone; 11 = gully; 12 = ravine;
 13 = young derasional valley and Id. number; 14 = old derasional valley and Id. number; 15 = landslide; 16 = defile
 (After: Kovács 2008)

In the first stage of analysis, the characteristic features of each section of the contour lines—crossing the derasion valley—were examined (Fig. 3). The geomorphologic map was completed by the projection of the rasterized map of contour lines, and the data were measured on this version. Subsequent to the input and run of the “*d.measure - m >>*” routine, the length of the contour lines in the

valleys was measured with the mouse, and listed into a file. The second step was to define the length of the straight line between the incoming and outgoing point of the contour lines. These two kind of measurements were repeated in every case of contour lines crossing a derasional valley. Beside the length of the measured sections, the elevation values of each contour line were also indicated.

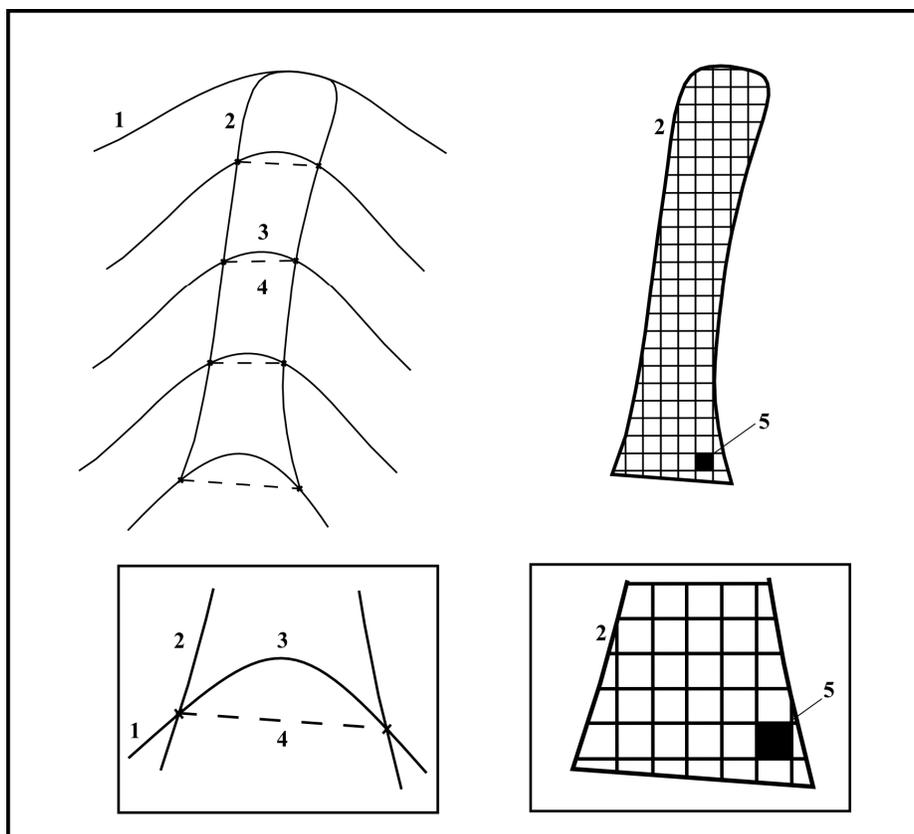


Fig. 3. Components of the contour line section index (CLSI) and characteristic inclination of valleys methods.
 1 = contour line; 2 = border of the derasional valley according to the geomorphological map; 3 = contour line section between the incoming and outgoing point of the contour line; 4 = straight line between the incoming and outgoing point of the contour line; 5 = one pixel of the derasional valley, which represents the slope category of the derasional valley.

The data related to each derasional valley were organized into a chart: the elevation values of the contour lines crossing the valley were combined with the length of the given contour line in the valley, as well as with the length of the straight line between the incoming and outgoing point of the contour line. From the quotient of these two values, the contour line section index (CLSI) belonging to the contour lines crossing the valleys was calculated. This process was repeated in the case of every valley. The CLSI characteristic for each valley was added and averaged, and their standard

deviation was defined. The CLSIs were illustrated on graphs, so they became comparable with each other.

In the second stage of the research (second method), the characteristic inclination of the valleys was analyzed. Using the *r.slope.aspect* routine, the slope map of the Somló Hill was constructed. This routine used to determine slopes uses a 3x3 neighbourhood around each cell in the elevation file (Shapiro et al., 2006). The slope map was reclassified using the *r.reclass.rules* routine, so that the slope angles were grouped every 3 degree.

(Therefore the area with a gradient between 0 and 3 degrees got an identification number 1, those with a gradient between 4 and 6 got an identification number 2 etc.).

From the geomorphologic map, the derasional valleys were distinguished using the *r.reclass.rules* routine, so that they should get the value 1 during the reclassifying process, while the other landforms got NULL (= no data). With the use of the *r.clump* routine, different values were connected to each valley. From the resulting map the valleys were distinctly selected using the *r.reclass.rules* routine. These were multiplied one by one with the already described slope map, using the *r.mapcalculator* routine. The maps representing the slope categories of each valley were reported back using the *r.report* routine, so that the area (in hectares) connected to the given slope category as well as the territory of the valley were saved into a file.

For every valley, the ratio (in percentage) of each slope angle related to the area of the valley, their average value, as well as their standard deviation were defined. The results were compared with a normal distribution, and they both were displayed on a single graph.

Results

In the course of the research, the CLSIs of 19 young and 6 old valleys were examined (Fig. 4). The investigation of the young valleys numbered 17, 18 and 22 could not be completed due to their special morphologic location. The defile running in valley Id. 22, as well as the incorrect location of the valleys Id. 17 and 18 on the geomorphologic map could mislead the results of the measurements and also the consequences related to the young derasional valleys.

<i>CLSI of young derasion valleys</i>				
Valley ID	Min.	Max.	Average	Standard dev.
1	0.43	1.02	0.77	0.16
2	0.68	1.02	0.89	0.1
3	0.74	0.98	0.88	0.07
4	0.67	0.98	0.78	0.07
5	0.81	0.98	0.92	0.05
6	0.88	0.99	0.95	0.03
7	0.88	1	0.95	0.04
8	0.83	0.96	0.91	0.04
9	0.88	0.99	0.94	0.03
10	0.79	1	0.93	0.07
11	0.54	0.99	0.89	0.12
12	0.90	0.98	0.95	0.03
13	0.79	1.02	0.93	0.06
14	0.68	0.98	0.89	0.07
15	0.64	1.00	0.83	0.84
16	0.58	1.01	0.83	0.12
19	0.87	1.04	0.94	0.05
20	0.81	1.03	0.93	0.05
21	0.67	1.00	0.81	0.08
Average	0.74	1.00	0.89	0.11
Standard dev.	0.12	0.02	0.06	0.18

<i>CLSI of old derasion valleys</i>				
Valley ID	Min.	Max.	Average	Standard dev.
1	0.30	1.01	0.71	0.23
3	0.44	0.98	0.74	0.17
4	0.61	0.96	0.87	0.09
5	0.95	0.99	0.98	0.01
6	0.39	0.93	0.67	0.16
Average	0.54	0.97	0.79	0.13
Standard dev.	0.26	0.03	0.13	0.08

Fig. 4. Common CLSI of the young and old derasional valleys

The CLSIs of the contour lines present in the young derasional valleys vary between 0.43-1.04, while that of the old derasional valleys have a value between 0.07-1.01. Based on the average value of the contour lines in the valleys, the distinct CLSIs characteristic for each valley have a value of 0.89 in the case of young derasional valleys, accompanied by a low standard deviation of 0.11. This value becomes 0.79 in the case of old derasional valleys, with a standard deviation of 0.17. In the case of young valleys, the above mentioned value primarily resulted from the CLSIs above 0.8; lower values occurred only in the valleys Id. 1 and 4. The old valleys have a CLSI below 0.8; the valleys Id. 4 and 5 represent exceptions.

Because of the spatial restrictions of the study, there is no possibility to introduce the CLSIs of every valley; therefore the results of the investigation are exemplified on some characteristic instances. The morphologic features of the young valleys are best represented by the derasional valley Id. 20 (Fig. 5): its high average CLSI (0.93) is accompanied by a standard deviation of 0.05. The CLSIs of each contour lines vary between 0.81 and 1.03.

Among the CLSIs characteristic for the young valleys, the indexes of the valley Id. 1 (Fig. 6) did not fit into the line: their average value is 0.77 and the standard deviation 0.16. Regarding the CLSI-graph of the valley, it becomes evident that below and above the altitude of 200 m the indexes show a lower standard deviation, according to which two parts of the valley could be differentiated: the section below 200 m was named 1A, while the section above 200 m was named 1B. The average CLSI of the new valley section became 0.86 in the case of 1B, which is characteristic for the young valleys. The validity of the differentiation is also proven by the outcome of a low standard deviation. The 1A valley section has features of old valleys, though its values are even lower: the average CLSI is 0.61; while the standard deviation is 0.14.

The average CLSI (0.87) and standard deviation (0.09) of the old derasional valley Id. 4 is not in compliance with the typical values of old valleys (0.79 average of CLSI, standard deviation above 0.1). Nevertheless, with the graphic representation of every index of the valley (Fig. 7), a tendency of the CLSIs became obvious, which unambiguously groups them into this category. The values of the CLSIs continuously decrease from 380 m to 360 m, then take the value of 0.6, and increase again towards lower altitudes. The values of the valley above 380 m equal that of the young derasional valleys. The average value (0.98) of valley Id. 5 fits the least into the CLSIs of the old derasional valleys (Fig. 8). This value is accompanied by an exceptionally low standard deviation of 0.01.

The investigation aiming at the exploration of the slope categories of the valleys was completed in all the cases of the 22 young and the 6 old valleys. The graphic representation of the normal distribution of the young derasional valleys (Fig. 9) made it evident that nearly all of them show a distorted value. The valleys were characterised by maximum values of 0.0418-0.0254, and by a low standard deviation (0.01). Only the valleys Id. 5, 10 and 17 meant an exception.

The valleys Id. 5 and 10 were exceptional because of their low maximum value (0.0121) and the distinctively low standard deviation (0.003 and 0.004). The young valley Id. 17 showed an atypical picture as well, with a maximum value of 0.0535; and a standard deviation of 0.02. Real normal distribution was detectable only in this valley.

In the case of old derasional valleys, every valley showed a distorted normal distribution (Fig. 10). The maximum values taken by the curve varied between 0.0536 and 0.0418, their standard deviation was 0.02 – except for the valleys Id. 2 (maximum value of 0.0321; standard deviation of 0.01) and 5 (maximum value of 0.0804; standard deviation of 0.01).

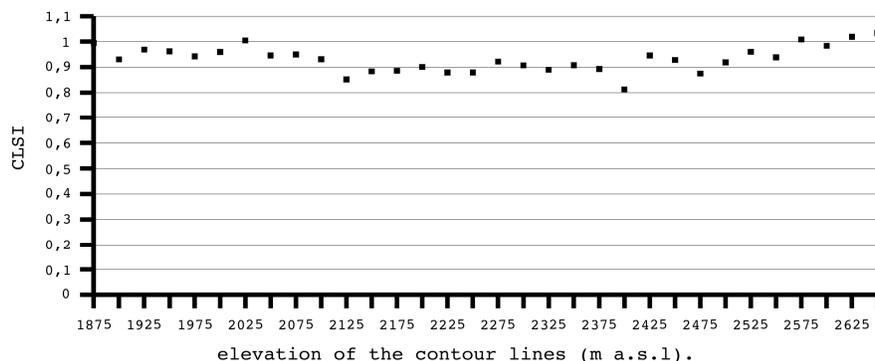


Fig. 5. CLSI of the young derasional valley Id. 20

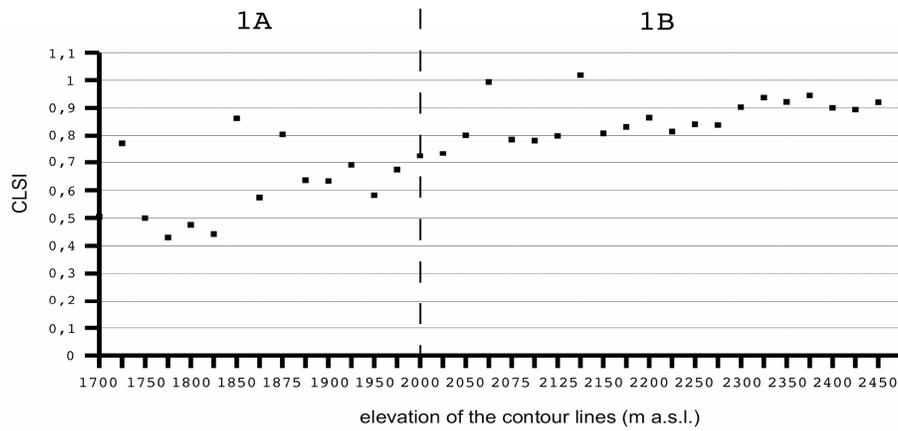


Fig. 6. CLSI of the young derasional valley Id. 1

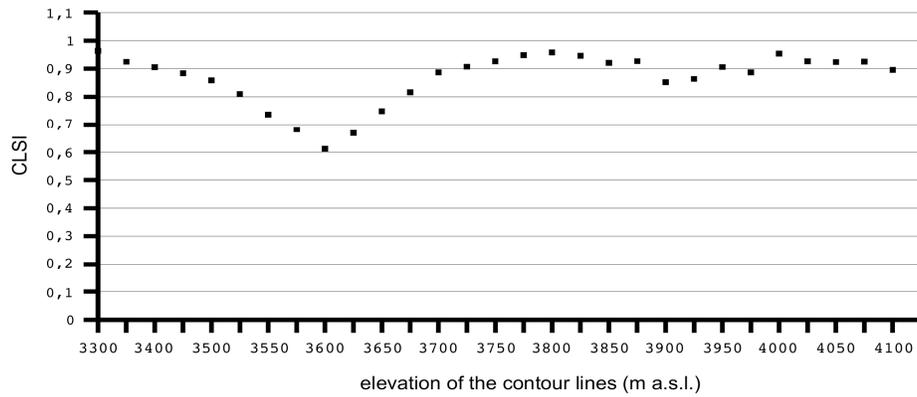


Fig. 7. CLSI of the old derasional valley Id. 4

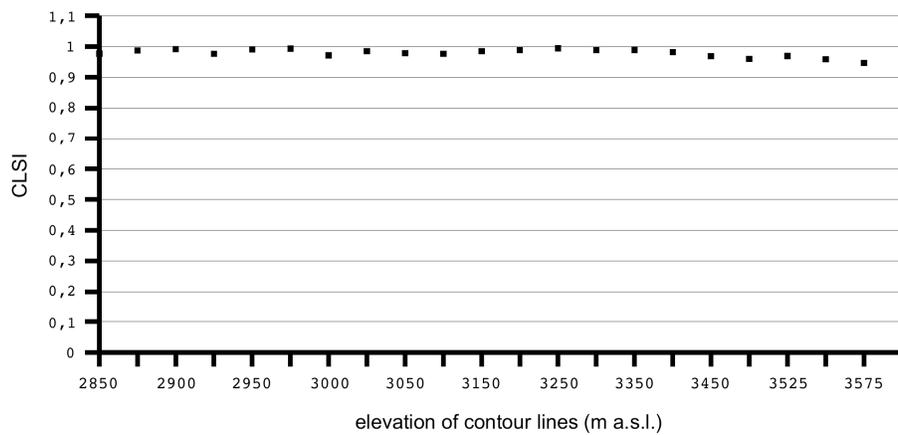


Fig. 8. CLSI of the old derasional valley Id. 5

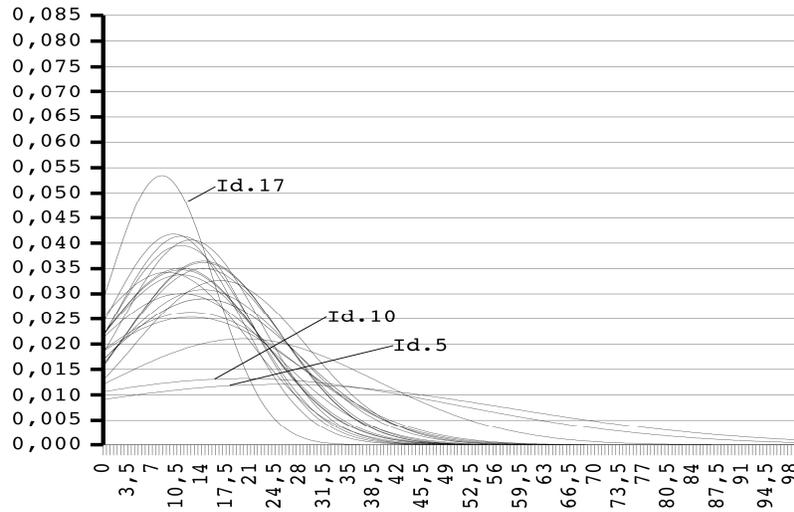


Fig. 9. Normal distribution of the slopes of the young derasional valleys

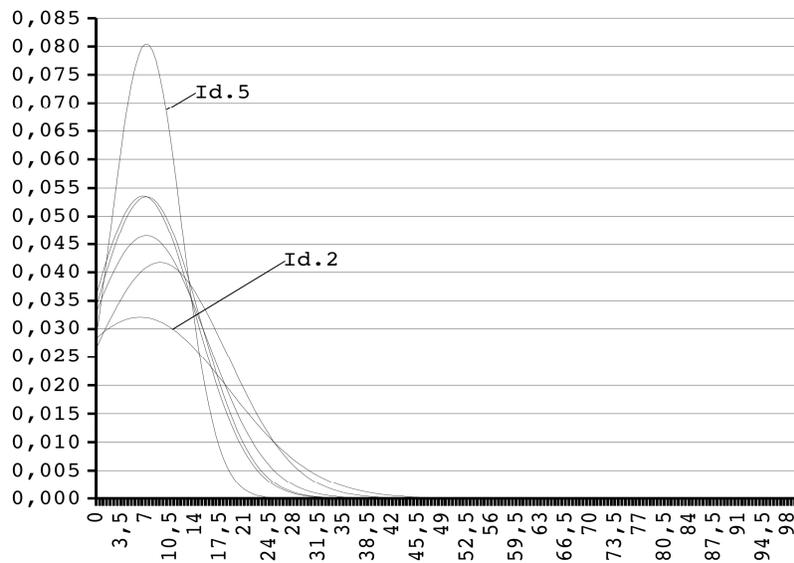


Fig. 10. Normal distribution of the slopes of the old derasional valleys

Discussion

The CLSIs are the index numbers of the cross-section of the valley. The longer the contour line section related to its chord, the lower is the CLSI. The lower the CLSI at a given point, the larger is the determined cross-section of the valley. According to the factors of the index, the shape of the valley (V-shaped or bowl-shaped) can not be defined in the research area, only its extension can be concluded.

The CLSIs observed in the valleys and having a value 1 or more mean, that at the given valley section, the length of the contour line in the valley

equals or is shorter than the length of the straight line between the incoming and outgoing point of the contour line. The latter unambiguously refers to a measurement mistake. In the former case, we can realize a completely plain territory. Such sections can be observed only at the lower or upper ending of the valleys. The mistakes occurring at the construction of the geomorphologic map – primarily during the generalization process – as well as an inaccurate manual measurement can result in such an error. Therefore, either these sections are not part of the valley – thus the geomorphologic map is incorrect –, or the sections are part of the valley, but

the measurement is mistaken. The above mentioned values rarely occur (only once in the case of old derasional valleys), so they did not influence the precision of the statistical connections. The value of 0.43 is considerably low, which refers to a valley section of a significant extension. Similarly low values occur mainly in cases of old valleys.

The young valleys with a high CLSI (above 0.8) and low standard deviation (0.11) can be well differentiated from the old derasional valleys, which are characterized by a low CLSI (below 0.8) and a high standard deviation. The young valleys are plain, bowl-shaped forms, typical derasional valleys, which are distinguished by low CLSIs. The high CLSI and its low standard deviation value proves the fact that the valleys are even, longitudinal hollows, in which – besides some exceptions – sections with significantly different values do not, or just rarely occur. Among the young valleys, Id. 20 best exemplifies this type of valley. The already mentioned differences were revealed by the examinations; therefore their accurate location is also described.

Anomalies of this kind are observable in the case of the young valley Id. 1. Based on the CLSIs the valley was divided into two sections. The distinct valley sections show more consistency individually – this fact is also proven by the low standard deviation of section 1B. The discussed section took the value characteristic for young valleys. Section 1A has CLSI values even lower than the old valleys, and its standard deviation is high as well. According to the results of geomorphologic mapping (Kovács, 2008) it can not belong to the old valleys, thus its formation can surely be dated back to the Pleistocene (i.e. it is a young valley). Nevertheless, the shape of the valley can be significantly influenced by the rock quality as well as by many other factors. Therefore the described method is able to reveal the extent and location of the anomalies to be found in the cross-sections of valleys, though it can not inform us about their origin and accurate characteristics.

The old valleys are distinguished by significantly lower average CLSIs (below 0.8) and higher standard deviations (0.13). The high CLSIs can be explained by the relatively deeper valleys. The high standard deviation of the valleys refers to their varied morphology. This diversity, which is observable in almost every case of old valleys, is especially noteworthy on the graph of the old valley Id. 4. The CLSIs reach their minimum after continuous decrease at the lower section of the valley, and then start to increase again, until they take the value characteristic for young valleys. This

phenomenon is also explained by the results of the traditional geomorphologic mapping. The old derasional valleys occur at their upper sections as plain, bowl-shaped hollows. Their CLSIs almost exclusively equal the values of the young valleys. At lower altitudes, reaching the basalt mesa, the valleys turn into V-shaped forms, and even incise into the basalt nappe. The decrease of the CLSI noteworthy in the case of the old valley Id. 4 is caused by this valley section and by the incision itself. Thus the method revealed a considerable morphometric change and also its location in the case of old valleys. Nevertheless, one fact cannot be ignored, namely that the low CLSIs measured in old valleys (plain, bowl-shaped upper valley section) equal the values of the young valleys, though have fundamentally different genetics. So the research found equal results for two formations of essentially diverse genetics, but of analogous morphologic parameters.

Similar results occurred in the case of the old derasional valley Id. 5 as well. The average CLSI of the valley is 0.98, which refers to an even more insignificant form than the young valleys have (very mild, shallow surface hollow). Its standard deviation is considerably low (0.01), therefore the valley is consistent and there are no detectable morphometric changes. According to the field researches – and despite its present-day morphologic parameters – it is definitely an old valley, filled up and nearly completely covered by the debris originating from the basalt nappe, which caused its shallow form.

The investigation of the normal distribution of the valleys' slopes was carried out in each valley. Based on the maximum values of the normal distributions, the categories of young and old valleys could be constructed once again. The maximum values of the young valleys varied between 0.0418 and 0.0254, while those of the old valleys between 0.0418 and 0.0536. Related to the defined value limits, some valleys showed differences again.

The valleys Id. 5 and 10 were distinguished based on their lower maximum and extremely low standard deviation. Their values moved on a wide range, several values occurred with a low frequency. The valley Id. 17 is prominent among the other valleys because of its outstanding maximum value and real normal distribution. The comparison with CLSI researches is possible only in the cases of valley Id. 5 and 10, for valley Id. 17 it could not be examined. The valleys at that location did not show any difference from the average values.

Compared with the maximum values of the old valleys, Id. 2 and 5 had lower values. The

exceptional valley Id. 5 was already realized during the former CLSI-investigation, since it had values characteristic for the young valleys. Its high maximum value can be explained by its filled up position (significantly even, shallow bowl-shape).

The research was also able to distinguish two types of derasional valleys. Nevertheless, it only provides little basic information about the morphometry, and tells nothing about the genetics. The comparison of the results of the two investigations showed only one coincidence.

Summary

The average CLSIs, as well as the standard deviation of both young and old valleys were defined, according to which it was possible to distinguish the members of these two groups, and to list the morphometrically different valleys. As the most characteristic example for young valleys, valley Id. 20 was introduced. In the case of the old valley Id. 4, the method revealed the exact location of the dissimilar valley sections and the extent of divergence.

The average CLSI of some valleys differed from the average value of the two groups. The separated young valley Id. 1 could be divided into two valley sections according to its CLSIs. In the case of the old valley Id. 5, it was achievable to reveal values different from the average.

The CLSI served as a kind of index characteristic for the cross-section of the valley, based on which it was possible to specify the changes and differences from the average in the cross-sections of the valleys. The index provided

information about their proper location, and also about the extent of change. Nevertheless, it is incapable to define the shape of the given valley section, or to reveal the reasons for the development of different sections. Therefore, it is necessary to continue the field researches, as well as to apply the additional means of the traditional geomorphologic mapping.

The analysis of the slope categories of the valleys represented a novel point of view in this study. According to the maximum values of the normal distribution projected upon the slopes of the valleys, it was also made possible to distinguish the young and old derasional vales. The study exposed the valleys with values different from the characteristic features of these two groups (young valleys Id. 5, 10 and 17; old valleys Id. 2 and 5).

The comparison of the results of the two methods showed agreement in the case of the old derasional valley Id. 5, thus the necessity of its further investigation was pointed out by both methods simultaneously. Therefore, these techniques are able to complete the comparative and analytic investigation of basic morphometric features of valleys, as well as to assist the geomorphologic mapping.

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