Large-scale relief of the Slovak Karst and Aggtelek Karst (Gömör–Torna/Gemer–Turňa Karst) – a DEM-based study

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Abstract

The surface of the Gömör–Torna/Gemer–Turňa Karst (GTK) was largely formed by Pannonian or Pliocene pediplanation. Although this surface has been dissected by subsequent tectonic and fluvial processes, the present karst plateaus still preserve large pieces of this once homogeneous surface. GIS-based statistical methods have been used to calculate exact aspects and slopes of the relict surfaces using the Shuttle Radar Topography Mission digital terrain model (SRTM DTM). Topographic swath profiles proved to be especially useful in the analysis, because top levels of the relief are marked in these profiles thus facilitating the identification and quantitative characterisation of these relict surfaces.

Analysis results show that a general 1° slope is valid for most of the GTK. This very low slope angle is typical for particular karst plateaus as well as for long north to south cross-sections covering the whole karst area. Based on the smooth-filtered DTM the largest, most homogeneous surfaces (Plešivská plateau, Silická plateau) have a dominant south–south-western aspect, many other plateaus have southern aspect, whereas peripheral plateaus slope towards the margins. Uplift resulted in a uniform tilt in the western part of the area including the Slovenské rudohorie (Slovak Ore Mts.) found north of the GTK, while in the central and eastern zones the blocks uplifted to different elevations and their tilts are more varied. In these zones, the Slovenské rudohorie are above the elevation trend of GTK, therefore a fault step also separates these morphological units.

The origin of Slaná (Sajó) and Štítnik (Csetnek) valleys (east and west of Plešivská plateau) is debatable in the literature. Taking into consideration the good fit of topographic trends on opposite sides of valleys, vertical faulting can be excluded, therefore superimposition/antecedence could be the dominant process although tectonic preformation certainly had some influence in case of Štítnik valley. Before the tectonic uplift of GTK or in its early phase, water courses flowing in north to south direction existed in the central parts. Traces of these flows are observable in the present relief around Jablonovské sedlo (saddle) and Derenk.

Keywords: Gömör–Torna/Gemer–Turňa Karst, Aggtelek Karst, Slovak Karst, digital terrain analysis, tectonic geomorphology, swath analysis, Quaternary landform evolution.

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Introduction

Gömör–Torna/Gemer–Turňa Karst (GTK) is situated in a transitional position between the uplifting Carpathian mountain ranges (here: Slovenské rudohorie/Gömör–Szepesi-érchegység) and the subsiding Pannonian Basin that determine its landform evolution. The present relief largely consists of karst plateaus sharply outlined by steep slopes. Plateaus (further „p.") are separated from each other by deeply cut valleys and basins *(Figure 1).* This is particularly true for the northern, large plateaus (Plešivská p., Silická p., etc.), while the southern parts (e.g. Aggtelek p.) are more dissected and the proportion of flat areas is limited. The karst terrain is predominantly built up of middle and upper Triassic karstifiable rocks, the most extensive being the Wetterstein Limestone and Dolomite, but Gutenstein Limestone and Dolomite as well as Steinalm Limestone are also widespread. Structurally, the GTK consists of overlying nappes studied in details by previous geologic research (e.g. Less, Gy. 1998; Mello, J. 1996, 1997).

Due to the varied surface and underground landforms of the karst terrain the area has been the object of extensive geomorphological studies (Gaál L. 1997; Hevesi A. 1991; Jakál, J. 1975; Jakucs L. 1956; Láng S. 1955; Mazur, E. 1973; Mezősi G. 1984; Móga J. 1998; Sásdi L. 1990; Telbisz, T. 2001; Telbisz, T. and Móga, J. 2005; Telbisz, T. *et al.* 2006; Veress, M. 2008; Zámbó, L. 1998). The present relief of the karst plateaus is so homogeneous that researchers unanimously state the one-time existence of a large, uniform pediplanation surface. However, there are different views about the age of pediplanation. Slovak authors (Gaál, L. and Bella, P. 2005 and references therein) suggest Pannonian age, whereas certain Hungarian geographers (Láng, S. 1955; Mezősi, G. 1984; Zámbó, L. 1998) mention Pliocene age for the pediplanation. In the wake of pediplanation most part of the area became covered in a varied thickness by the coarse-grained Poltar Gravel (Borsod Gravel in Hungarian terminology), which was deposited here by rivers arriving from the northern mountainous territory. Meanwhile the GTK uplifted in several phases. During the Attic phase of Pliocene only the northern parts uplifted and fluvial incision took place there. Later on uplift stopped and subsidence followed. As a result gravelly sediments accumulated exceeding 100 m thickness in the Slaná (Sajó) and Štítnik (Csetnek) valleys as well as in the Rožňava (Rozsnyó) basin (Gaál, L. and Bella, P. 2005; Petrvalská, A. 2010). Uplift recommenced during the Pleistocene that led to the erosion of non-karstifying covering rocks giving place to karstification in a growing extent.

The relict surface conserved by the karst plateaus is characterized by southern aspect and 2–5° slope angles according to Jakucs, L. and Móga, J. (2002), Sásdi, L. (1990) and Zámbó, L. (1998). Some data about the relative displacements of particular blocks is given by Sásdi, L. (1990).

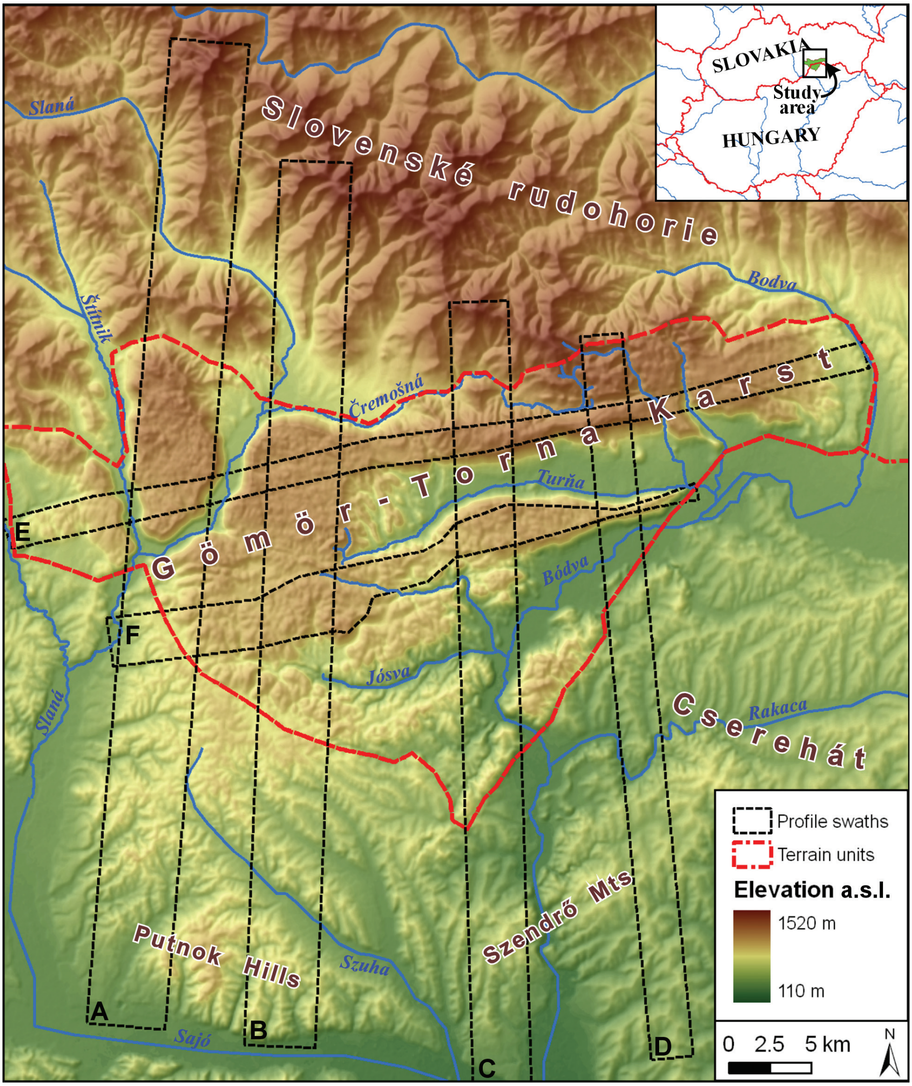

Fig. 1. Shaded and stretch-colored DEM of the study area with the terrain units of *Fig. 3* and swath locations of *figs 5* and *6*. Inset map shows the location of the study area

In spite of the wealth of geomorphological studies, digital terrain analysis of the GTK has not yet been carried out. In fact, part of the study area, the Plešivská p. was investigated by means of digital elevation models by Telbisz, T. *et al.* 2009. Another pediment surface, not far from the venue of the present study, Bükkalja was also investigated by digital terrain analysis (Vágó, J. and Hegedűs, A. 2011).

Quantitative analysis of the relief can be more precise and diverse using digital terrain models (DTMs). Characteristic levels in elevation, generalized cross-sections, slope and aspect values of single pixels and larger units can be determined that may provide important supplementary data for a better understanding of Quaternary landform evolution of the area. It is the aim of this paper.

Methodology and data

For the analysis, Shuttle Radar Topography Mission digital terrain model (SRTM DTM) was used (see e.g. Rabus, B. *et al.* 2003). It has approximately 90 m horizontal resolution, which is absolutely suitable for the morphometric study of the plateaus. This resolution implies that slope angles calculated from the SRTM data underestimate the real ones, however, in this study mostly long slopes are considered, which are not biased. Beside standard slope and aspect maps derived from the DTM, mainly topographic profiles were used in the analysis. Instead of using simple line-based profiles, swath profiles were constructed. Swath profiles reflect elevation data of a wider zone by calculating minimum, mean and maximum elevation values at a certain distance from the startline. This method has a widespread application in tectonic geomorphology (e.g. Fielding, E.J. 1996; Korup, O. *et al.* 2005; Kühni, A. and Pfiffner, O.A. 2001), since it is more reliable than arbitrary line-based cross-sections. The maximum curve of the swath profile shows the elevation of mountain tops and ridges, therefore it provides a good approximation of the relict surface. The mean curve eliminates the noise effects of particular, „irregular" minor landforms, whereas the minimum curve detects the elevation of valley bottoms.

The characteristic slopes of the studied surfaces were calculated from trendlines fitted to swath profiles. This method really gives the general trend of the surface as opposed to calculating the mean of pixel slope angles that is rather a measure of surface dissection. The basic units of the analysis were karst plateaus, which were outlined on the DTM-derived slope map *(Figure 2).* Surface slope values abruptly changed at 8° slope, therefore this limit was used as a boundary. Furthermore, plateau boundaries were finely corrected taking lithology into consideration (after Less, Gy. *et al.* 1988; Mello, J. 1996, 1997), and elevation position as well. Basin-like karstified plains such as Jósvafő p. and Silická Brezová polje were excluded from the plateau analysis. The extensive Silická p. was divided into several pieces based on internal topographic boundaries. The delimitation of units was problematic in the southern areas due to the highly dissected surface. Here, the too small subunits were merged into larger pieces (e.g. Aggtelek p.). Another problem arose in finding the eastern boundary of Jasovská p., because this plateau descends eastwards gradually. Finally,

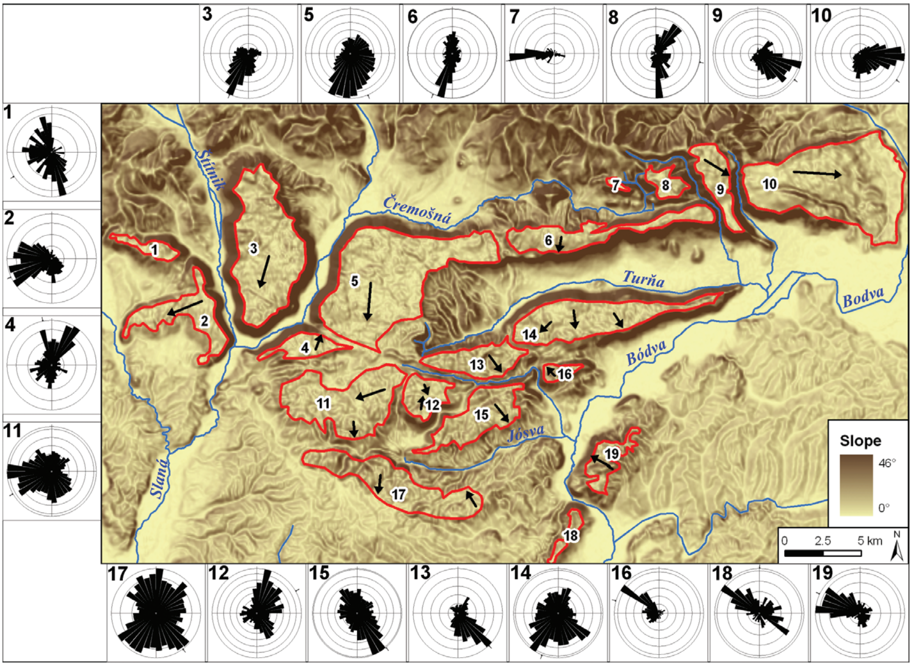

Fig. 2. Slope map of the Gömör–Torna Karst with plateau boundaries and generalized aspect roses. Arrows indicate the locally dominant aspect. Numbers indicate plateaus with reference to *Table 1*.

the plateau limit was extended to the Bodva (Bódva) river based on lithology since Wetterstein Limestone blocks outcrop even next to the river.

Altogether, 19 plateaus were identified, whose data are summarized in *Table 1.* The largest plateaus according to the above criteria are Silická p. and Jasovská p. with an area of more than 47 km^2, and the third one is Plešivská p. with 33 km^2. The smallest though topographically clearly identifiable plateau is Žl'ab Mt. with 0.6 km^2 surrounded by the tributaries of Čremošná (Csermosnya) stream.

An important goal of the present study was to determine the dominant aspects of plateaus as objectively as possible. To avoid the biasing effects of minor landforms, even the SRTM DTM was smoothed by a 450 m radius median filter in this analysis. From the smoothed DTM rose diagrams were constructed using pixel aspect values and these diagrams are suitable for the analysis of large scale aspects of plateau surfaces *(Figure 2).* Characteristic aspect directions were also marked in *Figure 2* as arrows. The exact location of arrows, though simplified for the sake of visibility, were set based on the aspect map (which is not published here).

Table 1. Dominant aspect and trendline slope data of the plateaus

Plateau name	Area (km^2)	Dominant aspect	Swath azimuth	Trendline slope
1. Jelšavská/Jolsvai p.	3.0	NNW, SSE, W	260	1.26
2. Koniarska/Konyárt p.	11.7	WSW	245	4.77; 1.22
3. Plešivská/Pelsőci p.	33.0	SSW	205	1.45 (1.6; 2.88; 0)
4. Bučina/Bikk p.	5.2	NNE	215	0
5. Silická/Szilicei p.	47.6	S	190	-0.09; 2.91
6. Horný/Felső Mt.	13.3	SSW	195	1.32; 2.19
7. Žľab/Mészkő Mt.	0.6	W	-	-
8. Bôrčianska/Barkai p.	3.4	NE, S	175	0; 4.22
9. Zádielska/Szádelői p.	8.0	SE	130	2.15; 7.28; 0
10. Jasovská/Jászói p.	47.1	E	95	0.6; 3.64
11. Kečovská/Kecső-Haragistya p.	23.9	E, SE, S	250	1.36; 0.24
12. Nagyoldal	6.2	NNE, SE	200	0.8; -3.88
13. W-Alsó Mt.	9.8	SE	135	4.06; 0; 4.72
14. E-Alsó Mt.	21.3	SW,S,SE	175	0.51
15. Szinpetri p.	13.2	SSE	150	0.86
16. Páska-bükk	1.9	NE	120	-5.29
17. Aggtelek p.	20.7	NW-NE, SW-SE	180	1.23
18. Rudabánya Mts.	2.1	NW, SE	-	-
19. Szalonna Mts.	5.5	WNW	-	-

Trendline slopes were calculated from swath profiles with azimuths given in this table. In case of compound surfaces, several trend slopes are given in an approximately N–S order. Exception is Plešivská p., where the first value refers to the entire plateau. Slope values were not calculated for 7 (too small) and 18, 19 (too narrow)

Results

Elevation and slope distributions

At first, the whole study area (as in *Figure 1*) was distributed into three large units: Slovenské rudohorie, GTK and southern hills (this latter unit comprises the hilly landscapes found south of the GTK, namely Putnok Hills, Szendrő Mts. and parts of Cserehát). These units were compared using the statistical distributions of the two most important terrain parameters, elevation and slope *(Figure 3).* The transitional position of GTK is reflected in the elevation histograms. At first, it is surprising that the most frequent elevation categories in the GTK histogram are related to relatively low levels (150–160 m; 190–200 m and 260–270 m a.s.l.) that is due to the largely extensive low-elevation valley bottoms belonging to the GTK (Bódva, Turňa and Slaná, respectively). These levels are very similar to the dominant 180–240 m of the southern hills. Higher up, there are peaks at 340–350 m elevation, which is the characteristic level of Aggtelek p. and at 530–590 m elevation, which is the most frequent level of the southern part of Plešivská p., Silická p., Alsó Mt., Nagyoldal, Jelšavská p., southern part of Zádielska p., central part of Jasovská p. The proportion of

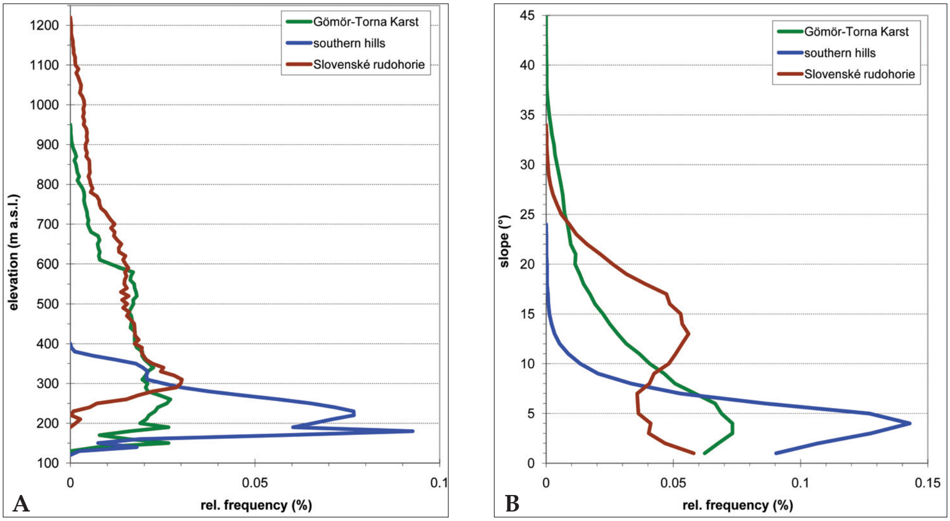

Fig. 3. General terrain characteristics of the study area. The boundaries of the three units (Slovenské rudohorie, Gömör–Torna Karst and the southern hills, including Putnok Hills, Szendrő Mts. and parts of Cserehát) are shown in *Fig. 1.* – A = Elevation distribution; B = Slope distribution

areas even higher abruptly decreases and is markedly less than in the Slovenské rudohorie. A less significant peak is however present at 690–700 m elevation due to the northern part of Plešivská p., Horný Mt. and the western part of Jasovská p.

The elevation distributions of each plateau are presented in *Figure 4.* This clearly supports the flatness of most plateaus, since in most cases, half of the terrain (the part represented by the box in *Figure 4*) is generally found within a 40 m high elevation range. Nevertheless, some exceptions exist from this rule: Jasovská p. (10), which gradually lowers towards the east, Zádielska p. (9) having a 200 m drop towards south and the very extensive Plešivská p. sloping towards south–south-west (3). In turn, the largest Silická p. has a strikingly narrow elevation range. Furthermore, based on this figure, it is clear, that the highest level is represented not by Plešivská p. as it is mentioned by some authors erroneously (Zámbó L. 1998) but by the north–eastern plateaus, namely the tiny Žl'ab Mt. (7) and Bôrčianska p. (8) being the highest and Horný Mt. (6) as well as Zádielska p. (9).

Slope histograms *(Figure 3b)* also discriminate the three main units. The characteristic 4° slope of the southern hills means that in spite of the intense fluvial dissection, the slopes of this morphological unit are gentle. The comparison of Slovenské rudohorie and GTK slope histograms clearly demonstrate the main characteristics of karst terrains, i.e. the GTK is the „leader" both

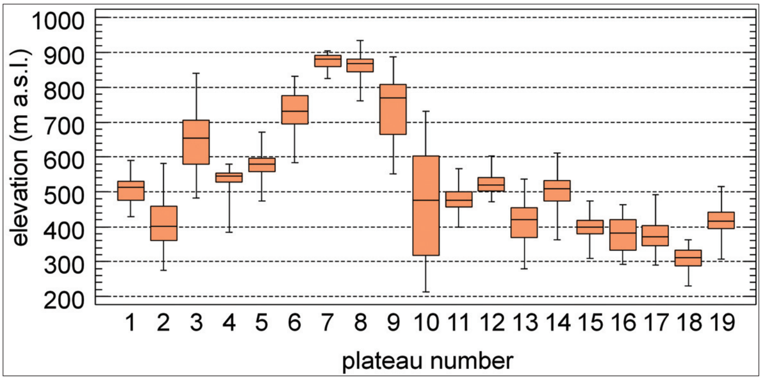

Fig. 4. Comparison of plateau elevation distributions (boxes represent the interquartile range; whiskers the full range; the box-dividing line is the median). For plateau numeration see *Table 1.*

in the gentle slope (<9°) category (due to the wide valley bottoms and plain plateaus) as well as in the steepest slope (>24°) category, which is in turn due to the steep plateau edges and gorge valley sides. On the contrary, in the medium slope categories, the Slovenské rudohorie, which are of predominantly fluvially formed have higher proportions.

Dominant aspect and slope trends of the plateaus

In most cases, aspect rose diagrams *(Figure 2)* provide a well-interpretable dominant direction. Nevertheless, the picture is more complicated where the plateau is dissected by larger valleys not removed by the DTM-smoothing (e.g. Aggtelek p.), because valley side aspects are also represented in the rose diagrams, therefore angle categories rectangular to the original flow directions are emphasized. Similarly, in case of too narrow plateaus (e.g. Rudabánya Mts.), aspect directions at right angle to the strike are more pronounced due to the regression of edge slopes.

The surface of the two largest plateaus (Plešivská p. and Silická p.) and Horný Mt. basically slope towards south–south-west. Marginal plateaus generally slope outwards. In the north-west, Jelšavská p. and Koniarska p. slope towards west–south-west, however it is not the main direction in the Jelšavská rose diagram, because north–north-west and south–south-east directions overcome this, probably due to the narrowness of the plateau. In the north–east, Zádielska p. and Jasovská p. face to east–south–east and east, respectively. In the south–west, Kečovská-Haragistya p. slopes towards west–south–west, whereas in south-east the easternmost part of Alsó Mt. faces south-east. Thus, based on the aspect analysis, the aforementioned plateaus seem to have preserved the large-scale morphology of the pediplanated surface.

„Irregular" dominant aspects are found in Rudabánya Mts. and Szalonna Mts. (both slope towards north–west) as well as in Bučina p., the southern part of Nagyoldal (oriented towards north–north-east) and in the eastern part of Aggtelek p. (towards north–north-west). Smaller exceptions are Páska-bükk (towards north–west), Žl'ab Mt. (towards west) and Bôrčianska p. (towards north–east).

Minor irregularities can be explained by former valleys, but major anomalies are more likely of tectonic origin, especially the relatively flat Bučina p. and Nagyoldal could have a north–north-eastern tilt relative to other units. Tectonic tilt could also produce the north-western aspect of Szalonna Mts. and Rudabánya Mts.

Swath profiles parallel with the main directions inferred from the rose diagrams were created for each plateau (except the smallest Žl'ab Mt. as well as Rudabánya and Szalonna Mts., which are not interpretable in this context). Trendlines were fitted to these profiles and the general slopes of plateaus were calculated from the trend. Swath azimuths and trendline slopes are given in *Table 1.* Some plateaus can be divided into several parts based on slope trends, in these cases, several slope values are provided in an approximate north to south order.

Negative values mark that the slope is opposite to the swath azimuth. These data make up an essential part of the present surface analysis. Based on these data, it is stated that the general slopes are typically very gentle (lower than is usually mentioned in the above cited papers), between 0.5° and 1.5°. Significant deviations from these values are considered anomalies, which require explanation.

Negative values refer to plateaus already mentioned in the previous paragraph (Nagyoldal, Páska-bükk) and suggest either tectonic tilt (Nagyoldal) or the existence of a former valley (Páska-bükk), perhaps both. Beside negative values, there are zero slopes as well, marking large, almost flat terrains, particularly the northern part of Silická p., but other examples are the southern part of Plešivská p., Bučina p., northern part of Bôrčianska p., southern part of Zádielska p. and western part of Alsó Mt. Supposedly, these zero-slope surfaces were influenced by differential tilting during Quaternary tectonic uplift.

On the contrary, one may find relatively steep (ca 3–7°) intraplateau steps in the Koniarska p., Jasovská p., southern part of Plešivská p., southern part of Silická p., Bôrčianska p., Zádielska p. and the western part of Alsó Mt. The first two examples are due to the relatively steep outside lowering of GTK. The other examples are linked to tectonic lines (Pasková/Páskaháza–Silica/Szilice line, Miglinc-Čremošná line and Derenk depression).

Topographic swath profile analysis

Long swath profiles (with 40–60 km length) were created to study the large-scale uniformity of slopes in GTK *(Figure 5).* Four swath profiles *(Figure 5A–D)* have nearly north to south directions and trend from the Slovenské rudohorie to the southern valley segment of Sajó.

In the westernmost profile *(Figure 5A)* it is observed that the level of Turecká (Török-hegy) and even the elevation of Babiná (Bábaszék) fits well to the northern extension of the Plešivská p. trend. Taking it into account, the relatively low elevation of Lučice ridge can be explained by differential erosion only and tectonic segmentation is not evident in this swath. The southern continuation of the Plešivská p. trend fits even better to the surface down to the line of Dlhá Ves (Gömörhosszúszó). Amazingly, the Slaná valley is hardly detectable in the maximum curve that proves the similarity of top levels at both sides of the valley. The longscale validity of slope trendline suggests that this zone moved as a large unit during tectonic uplift. The general 1.28° slope of the trend is well within the slope range of individual plateaus. Again, this fact supports the tectonic unity of the western swath down to Dlhá Ves. Nevertheless, south of it the karstifiable rocks are covered, and the maximum curve becomes almost horizontal. This implies that since the last sedimentation, this area has escaped tectonic tilting and only slight uplift took place here causing the remarkable fluvial dissection observable in the DTM as well *(Figure 1).* The relief is increased only in the southernmost part of the profile, where the Putnok Hills stand out with erosional residues of the Poltár (Borsod) Gravel sediments that once covered the whole area. In turn, the mean and minimum curves show slightly decreasing southward trends.

The second swath profile *(Figure 5B)* shows some similarities to the first one, but there are several different details. Considering the karst area of this section it is also possible to recognise a trend though the fit is not as good as in the westernmost swath. The northern continuation of the trend slightly shoot over Rákoš (Rákos) Mt. but given the uncertainties it is supposed that this could be part of the same palaeosurface. In contrast, the elevation of Skalisko (Nagy-kő) is much higher than the estimation from the trend that suggests a separated, higher-rate tectonic uplift of Slovenské rudohorie in this section. The karst terrain ends with a sharp north-facing cliff at Čremošná valley. The aforementioned striking flatness of Silická p. is also discernible in the swath profile and its northern parts are found below the trendline. Opposedly, the also flat and faintly north-facing Nagyoldal is above the trend. In fact, it seems that Silická p. and Nagyoldal share a common and flatter trend. At the southern end of open karst, just south of Aggtelek p., there is a drop in the maximum curve, but the decreasing trend is observed down to about 40 km along the profile, from where the surface becomes constant. Therefore, in this swath, the

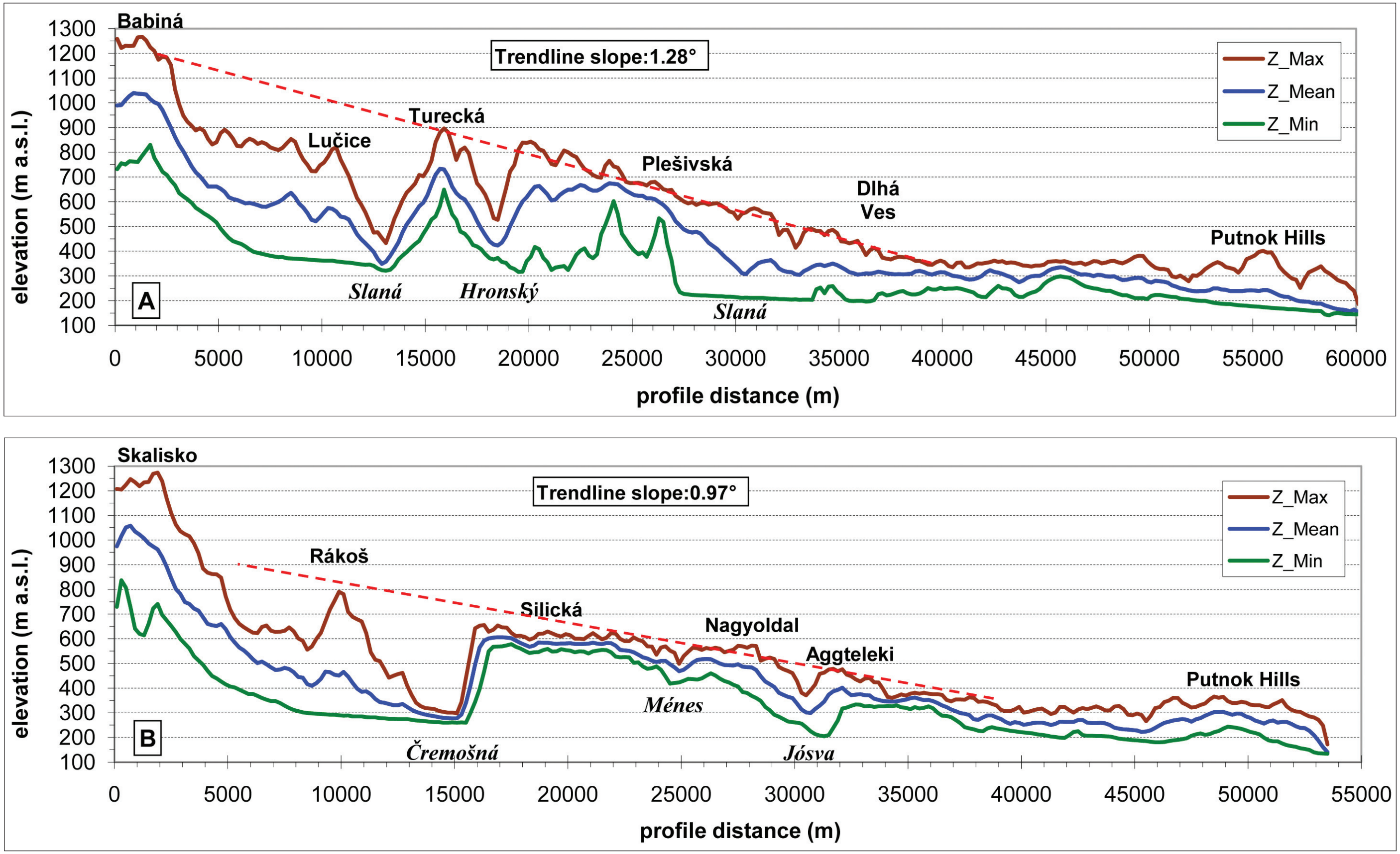

Fig. 5. Swath profiles across the study area (~N–S profiles: A, B, C, D; ~WSW–ENE profiles: E, F). Red, dashed lines are elevation trendlines fitted to the maximum curve. For profile locations see *Fig. 1*.

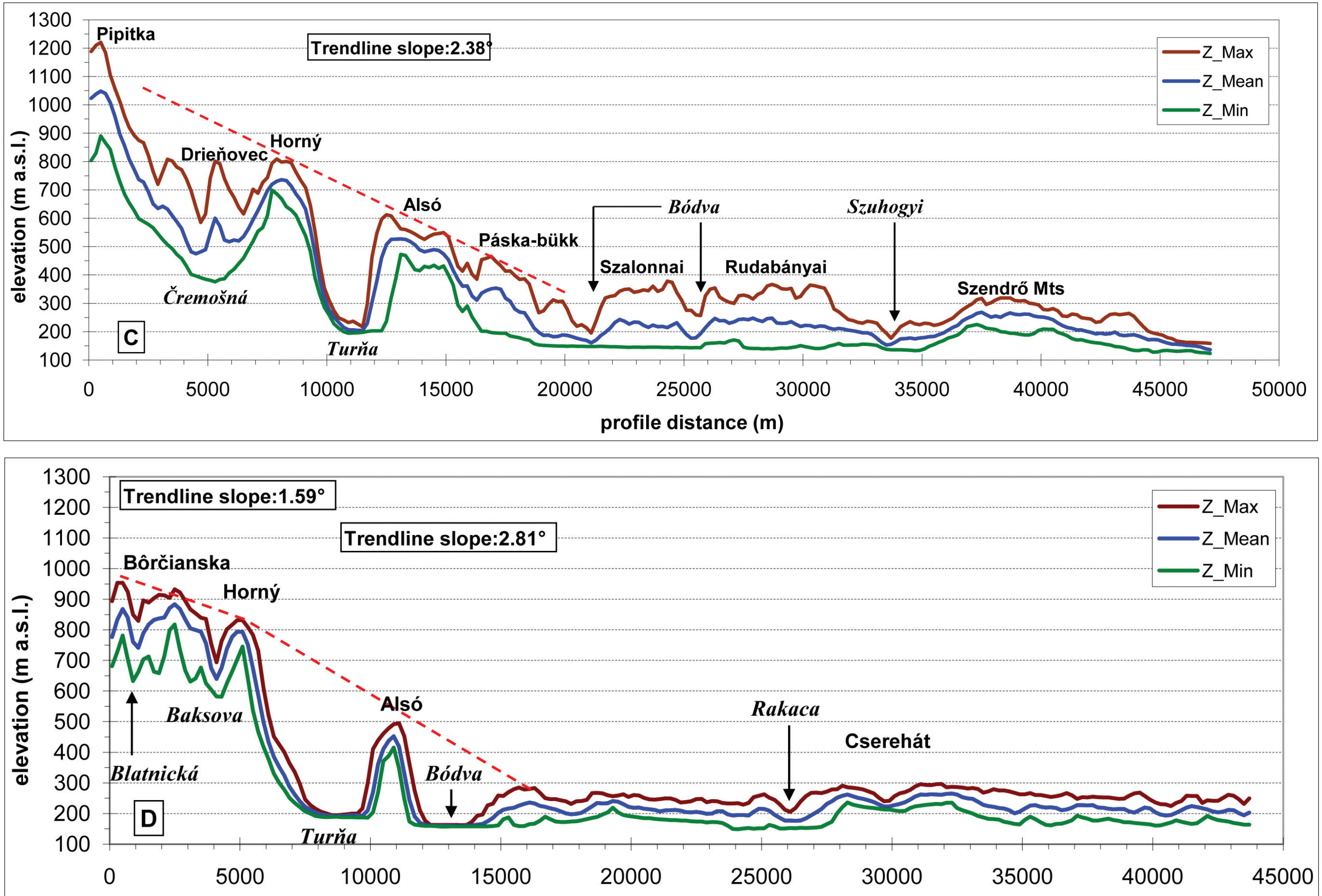

Fig. 5. Continuation

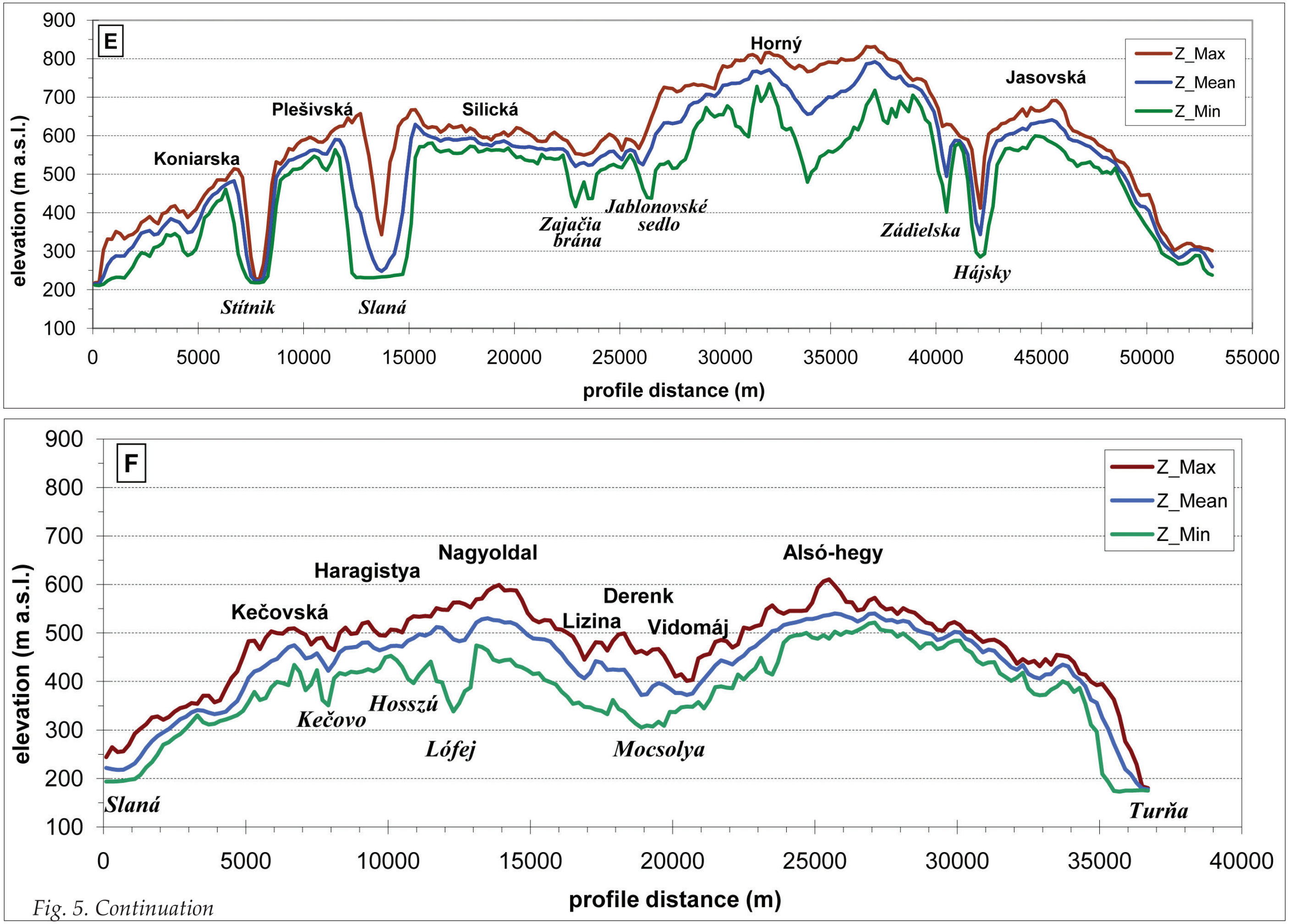

Fig. 5. Continuation

change in surface trend does not coincide with the boundary of open karst. The general 0.97° slope of the karst terrain is also within the plateau slope range, but it is somewhat lower than the value of the westernmost swath. The smaller Ménes and larger Jósva valleys are largely rectangular to the swath and are clearly detectable in all the three curves.

The third swath profile *(Figure 5C)* is more different. The trend fitted to Horný Mt., Alsó Mt. and the southern slope of Páska-bükk results in 2.36° general slope. This value is steeper than the individual values of Horný Mt. and Alsó Mt. (see *Table 1*). However, the northern extension of the trend does not reach the Pipitka (Pipityke) level that suggests again a separate and higher-rate uplift of Slovenské rudohorie.

On the contrary, the Drienovec (Som-hegy) top level (built up of Dachstein Limestone and separated from Horný Mt. by the tributaries of Čremošná) is well below the trend. All of these facts indicate that the blocks found north and south of Turňa valley as well as the Slovenské rudohorie block had differential uplift and the northern blocks were elevated to higher level than in the western segment of GTK. Three steps (Pipitka, Drienovec–Horný, Alsó Mt.–Páska-bükk) and a trough (Turňa) can be recognised within this swath. The trend is abruptly finished south of Páska-bükk and the mean curve shows three slightly southward sloping units (Szalonna Mts., Rudabánya Mts., Szendrő Mts). It should be noted that the given swath profile is somewhat misleading for the Szalonna Mts., because only the western margin of the mountains fall within the swath and Szalonna Mts. are in fact higher then Rudabánya Mts.

The easternmost swath profile *(Figure 5D)* is similar to the previous one. Two separate trends are valid for the top level of Bôrčianska p.–Horný Mt. and for the Horný Mt.–Alsó Mt.–Bódva left bank Triassic limestone hills. The steep slope (2.81°) of the latter trend also supports the separate tectonic uplift of Horný Mt. and Alsó Mt. In the north, the Blatnicka (Szár-patak) valley formed at lithological-structural boundary and the Baksova (Baksa) valley formed along a fault line are clearly observable in all the three curves. The extreme flat accumulation plains of Turňa and Bódva valleys, formed in tectonic depressions, are also detected. Cserehát Hills are somewhat more dissected but can be largely characterized as a uniform surface, slightly sloping southward and divided into two segments by the Rakaca valley.

The two last swath profiles *(Figure 5E* and *F)* are oriented ca west–south–west to east–north-east. They were constructed in order to visualize west–east differences between the karst plateaus and to outline the cross-section of active and inactive valleys flowing in a north to south direction.

In the northern swath profile *(Figure 5E)* it is observed that relief trends are continued at the opposite sides of Štítnik, Slaná and Hájský (Áji) rivers. This observation excludes uplift differences (but not horizontal faulting) between valley sides along these river sections, thus diminishing the importance of tectonic preformation. So superimposition/antecedence could be the dominant process in the formation of these valley sections. Nevertheless, tectonic preformation certainly had some influence in case of Štítnik valley (where covered faults are marked in the geologic map by Mello, J. 1996) and cave phases during the development of Hájský valley are not excluded either. On the other hand, abrupt topographic changes are unambiguously present east of Jablonovské sedlo and west of Zádielska valley.These topographic steps are in agreement of the previously mentioned higher-rate uplift of Horný Mt. and indicate that tectonic preformation was important in the formation of these valleys. It is noted that Jablonovské sedlo (Szoros-kő-nyereg) and Zajačia brána (Nyúlkapu) are probably the elevated and dried out remnants of palaeovalleys, therefore they are to be considered wind gaps. The two ends of the swath profile reflect the western and eastern lowering of GTK margins. A slight east–south-east sloping of Silická p. is also discernible. A local minimum artefact is present in the minimum (and partly in the mean) curve at Horný Mt. because the plateau narrows here extremely that is not perfectly followed by the swath boundary, therefore pixels of lower elevation at the edge of the plateau are also represented in the swath profile.

The southern swath profile *(Figure 5F)* portrays a more or less symmetric, truncated convex profile, sloping towards the margins. The open karst terrain has a gentle slope only (from Nagyoldal to Kečovská p. and the Alsó Mt. towards the east), while the edges of the karst plateau are characterised by steeper slopes. In the western end of the profile down to the Slaná river there is a gentler slope section, which is a covered karst terrain.

In the middle of the profile, the Derenk depression is probably of tectonic origin. Incisions that are observed mainly in the maximum curve (Kečovo/Kecső, Lizina, Vidomáj) indicate north to south oriented palaeovalleys. Other valleys (Hosszú, Lófej), which are absent in the maximum curve are rather of regression origin.

Conclusions

At present, the large-scale general slope of GTK in a north to south cross-section is ca 1°. This value is typical of most individual plateaus and of the general profile of the study area. Consequently, if pre-uplift surface is considered, an even gentler slope must be inferred, i.e the area had to be almost flat during pediplanation.

Due to the flatness of the terrain, the river pathways flowing through the area were hardly constant and flow directions could be very different from those of the present-day water courses except where inherited by superimposition. According to the swath profile analysis, the Jablonovské sedlo and Zajačia brána as well as incisions above Lizina-source and Vidomájpuszta could be potential water pathways. Further research should focus on the analyis of the former drainage network.

The uplift of the GTK had a somewhat changing style from the west towards the east. In the western segment the surface was tectonically uplifted and tilted as a single unit including the Slovenské rudohorie peaks, although differential erosion removed more material from the rudohorie section. Rivers (Štítnik, Slaná) formed superimposed/antecedent valleys in this segment.

On the contrary, in the central and eastern segments of the GTK, the Slovenské rudohorie had a separate and higher-rate uplift that created a tectonic step between the mountains and the karst terrain. In addition, in this part of the area, differential uplift took place even within the GTK, the northeastern blocks (Horný Mt., Zádielska p., Bôrčianska p., Žl'ab Mt.) experienced the most intense elevation whereas local subsidence (Rožňava basin, Turňa valley, Derenk depression, Jósvafő p., Bódva valley) also contributed to the increase of large-scale relative relief. There are several subareas with almost zero slope (the most extensive being the northern part of Silická p.); in these cases a slight northward tilt is supposed.

The hilly region south of GTK has a largely uniform, almost plain maximum surface suggesting that tectonic tilting was insignificant within this region since the last sedimentation. However, as a response to the slight uplift, the landscape was strongly dissected by fluvial processes.

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