Neotectonic activity of the Pravno fault in the area of the Žiar Mts.

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Neotektonická aktivita pravnianskeho zlomu v oblasti pohoria Žiar

Abstract: The paper presents neotectonic interpretation of the Pravno fault in the Horná Nitra Basin and the Žiar Mts. which is located in central Slovakia. The investigated area, belonging to the Tatra-Fatra Belt, has complicated structure and can be characterized by Neogene horst-and-graben faulting. The Pravno fault is the tectonic structure of the NW–SE direction and it is observable mainly in the southern edge of the Žiar Mts. The total length of the observed fault is 19.84 kilometers. The fault as significant morphostructural feature is pronounced between villages of Pravenec and Ráztočno. The Lelovce Formation (Pontian–Pliocene) are the youngest deposits, which have been clearly disrupted by the Pravno fault. To obtain reliable evidence of the neotectonic activity were used morphostructural parameters, longitudinal valley curves, slope, aspect, horizontal and vertical curvature of landforms, mountain-front sinuosity and measure faceted slopes of the mountain-front which clearly indicate that the SW edge of the Žiar Mts. represented by the Pravno fault is tectonically predisposed morphostructural discontinuity. The fault was active primarily in the Neogene period, especially during the Badenian and Sarmatian. The Pravno fault (south-eastern segment) have partly eroded faceted surfaces, and suggest that this segment of fault was not significantly activated during neotectonic period. Faceted surfaces are occasionally covered with debris slope sediments and rounded. In the course of the Pravno fault, Pliocene-Quaternary alluvial fans are rarely developed. The slope map refer to sensitive fault interface, but it is not such strong and distinct as in the case of the Malá Magura fault. Finally, the Pravno fault is most probably neotectonic structure of the Central Western Carpathians.

Key words: Western Carpathians, Žiar Mts., Horná Nitra Basin, Turiec Basin, Pravno fault, neotectonics, tectonic geomorphology

1. Introduction and survey research

The study area of the Žiar Mts. and its neighbourhood is located in the western part of the Central Western Carpathians (Fig. 1). The Žiar Mts. is a part of "core" mountains and forms the asymmetric horst structure with the NW–SE direction. The total length of the studied portion of mountains is 16 km and width approximately 6 km. The north side of the mountains is bordered by the Turiec Basin and from the south side by the Horná Nitra Basin.

The Turiec Basin is located north of the Žiar Mts. and is extending in the NNE–SSW direction. It is about 40 km long and 10 km wide (Fig. 1). The basin is a westward dipping halfgraben with sedimentary fill attaining thickness up to 1200 m (Killenyi & Šefara, 1989). The Horná Nitra Basin is a typical intramontane basin of the Western Carpathians which is elongated in the N–S direction. Orographically, the basin belongs to the Tatra-Fatra belt of the Central Western Carpathians (Fig. 1) and represents Neogene depression on the upper reaches of the Nitra River. Recent basin surface was formed by processes of erosion and accumulation during the Late Pliocene and Quaternary (e.g., Vojtko et al., 2011). Streams and a number of smaller tributaries disintegrated the original valley floor to low ridges and shallow valleys that make lowland.

The principal aims of this paper were morphostructural and neotectonic research of fault structure related to the neotectonic period. Our investigation was predominantly focused to the Pravno fault, because of its morphostructural and geological expression.

2. Geological and tectonic setting

The geological structure of the region is composed of the palaeo-Alpine tectonic units (Tatric, Fatric, and Hronic units) which are covered by post-nappe sequences of the Central Carpathian Palaeogene Basin, Neogene sediments of the intramontane basins and volcanic to volcaniclastic formations of the Vtáčnik and Kremnické vrchy Mts. (Fig. 2). The palaeo-Alpine units are emerged on the surface in the Žiar Mts. and submerged beneath the Palaeogene and Neogene sedimentary successions (Šimon et al., 1997[a,b]).

The crystalline basement of the Tatric Unit is composed of various granitic rocks (e.g., Plašienka et al., 1997; Kohút et al., 2004), related to the Variscan orogeny (Kráľ & Štarková, 1995). The Mesozoic Ráztočno cover unit which consists predominantly of Jurassic to Lower Cretaceous sequence. The Fatric Unit is represented by the Zliechov (deep water) succession with stratigraphic range from Middle Triassic to Albian. Occurrence of the Hronic Unit is restricted to the southern margin of the Žiar Mts. and contains Permian to Triassic facies (e.g., Šimon et al., 1997[a,b]).

Manuscript received 12 March 2013
Revised version accepted 21 May 2013

acta geologica slovaca, 5(2), 2013, 117 – 127

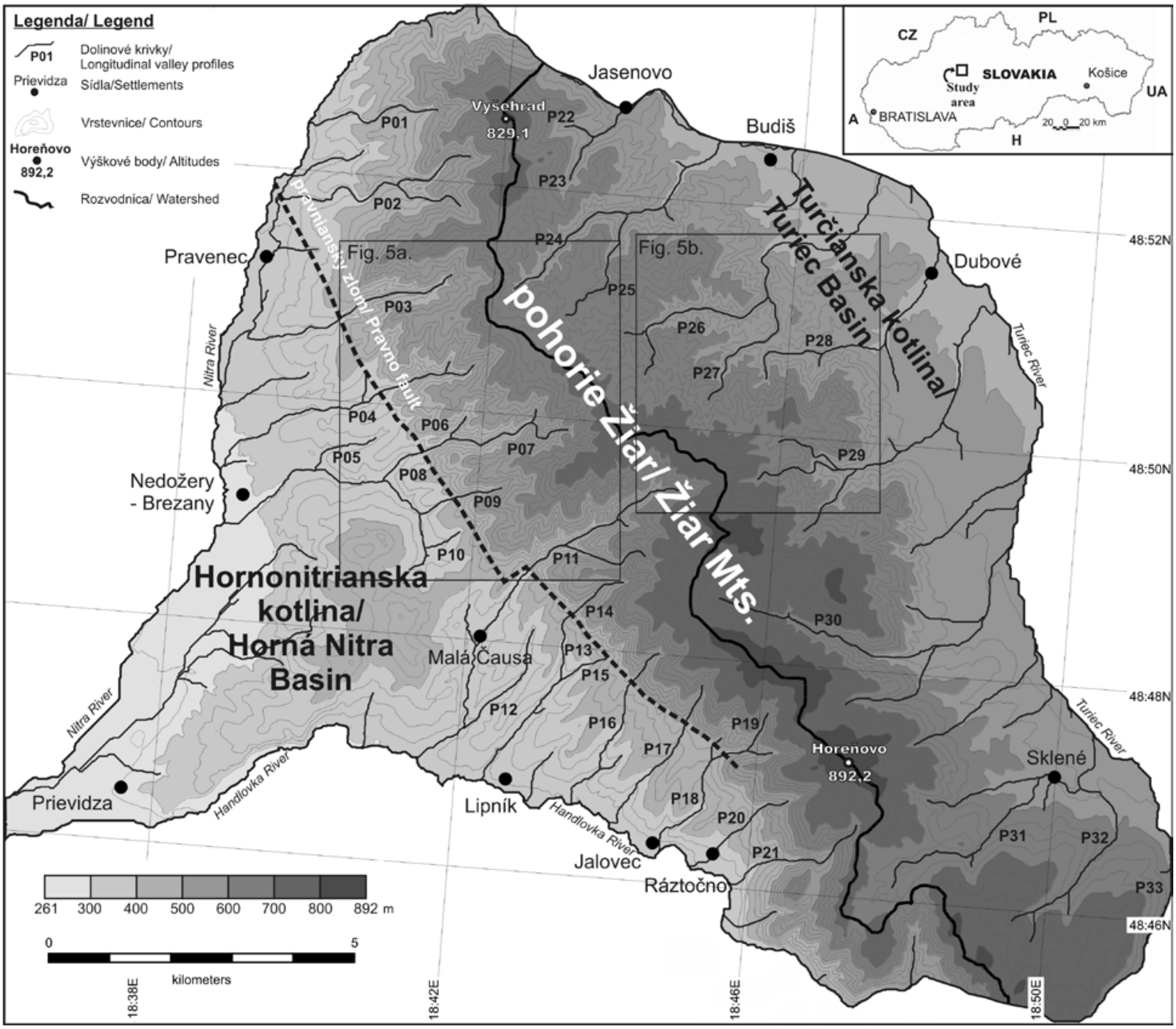

Fig. 1. Elevation map of the Žiar Mts. area.
Obr. 1. Hypsometrická mapa Žiaru a okolia.

Geology of the investigated area is due to the faulting rather complicated and can be characterized by Neogene horst-and-graben structure (Nemčok & Lexa, 1990). The most important and impressive structure of the study area is so-called the Pravno fault which generally separates crystalline rocks of the Žiar Mts. from the Palaeogene and Neogene successions of the Horná Nitra Basin.

Tectonically, the area is formed in two main stages that reflect palaeo-Alpine and neo-Alpine evolution. The palaeo-Alpine stage can be characterized by the late Early Cretaceous collision and orogenic processes which resulted to the nappe stacking of the Tatric, Fatric, and Hronic units (e.g., Plašienka et al., 1997; Frontzheim et al., 2008). Disintegration of nappe structure was carried out during the Cenozoic era predominantly by faulting. During the Neogene, the study area was reorganized to the horst-and-graben structure (Nemčok & Lexa, 1990; Šimon et al., 1997[a]).

The Žiar Mts., predominantly built by crystalline rocks is irregularly triangular horst which is bounded by margin faults. The current structure reflects the Neogene Alpine tectonic processes associated with the formation of the Carpathian arc. The Žiar Mts. is significantly segmented into individual parts with different movement tendency. Individualization and exhumation of the Žiar Mts. began in the Late Palaeogene and Early Miocene. The timing of the exhumation was proved by apatite fission track data from granitic rocks which yielded ages of 24–34 Ma (Danišík et al., 2008) or 46–52 Ma (Kováč et al., 1994), respectively. As a result of activity along the margin faults are different coarse grained sediments filling the basins derived from the source area of the Žiar Mts. They have character of gravity flow sediments in the form of deposited alluvial cones at the edge of the mountains, for example the Budiš Member of the Martin Formation (Upper Sarmatian–Pannonian) (Sládek & Bizubová, 2008; Kováč et al., 2011).

3. METHODS

Morphostructural analysis is a method covering a wide range of particular steps. The topographic data, precise Digital Terrain Model (DTM) and other DTM-derived data were used during the identification process of the tectonically-controlled landforms. The DTM used in this study was derived from vectorized contours of the general maps of Slovakia at a scale of 1:10,000 with cell size of 5 m in the S-JTSK (Datum of Uniform Trigonometric Cadastral Network) coordinate system by the GRASS-GIS and Quantum GIS software (*Athan et al.*, 2011, GRASS Development Team, 2012). These obtained data were used for whole range of morphostructural analysis presented therein. For broader view, the Shuttle Radar Topography Mission (SRTM) data and geological data from the geological maps at a scale of 1:50,000 were also used.

Morphostructural parameters, such as elevation, slope, aspect, horizontal and profile curvatures, were computed from the DTM. *Elevation* was used for spatial views of absolute altitudes of the study area. *Slope* shows dip direction of hillside from horizontal level within the range of 0–90°. Another morphostructural parameter was slope exposure *(aspect)*, which can take values from 0° to 360° (azimuth). The aspect map was constructed with the intervals which were divided into eight classes with an individual interval of 45°. As additional parameters were used *vertical and horizontal curvatures* which display the curvature in the vertical and horizontal direction respectively, which means that these parameters are sensitive to changes of landform curvature in vertical or horizontal plane.

Longitudinal and transverse river valley profiles were constructed based on the DTM with cell sizes of 5×5. The longitudinal river profiles (LRPs) were analyzed as most commonly practiced. Their quantified parameters are used to compare different drainage systems and, specifically, to identify the response of neotectonic activities in the drainage basins (Hack, 1973; Zuchiewicz, 1980, 1991, 1995, 1998; Seeber & Gornitz, 1983; Bull & Knuepfer, 1987; Demoulin, 1998; Ruszkiczay-Rüdiger et al., 2009; Vojtko et al., 2012). Data were obtained from the DTM using the GRASS-GIS software which traces a flow through a least-cost pathway in an elevation model. In this study, normalized LRPs because the advantage of these profiles is the direct comparison of valleys with different lengths and absolute gradients because they are dimensionless were used. These normalized LRPs were applied to describe the geomorphic response of rivers in regions with active tectonics (Zuchiewicz, 1991, 1998; Demoulin, 1998; Ruszkiczay-Rüdiger et al., 2009; Vojtko et al., 2012). The construction of normalized LRPs is shown in Fig. 3. The profile has significantly downward course along the entire profile without significant changes for low or no activity in the watershed. If profile contains knick points it can indicate

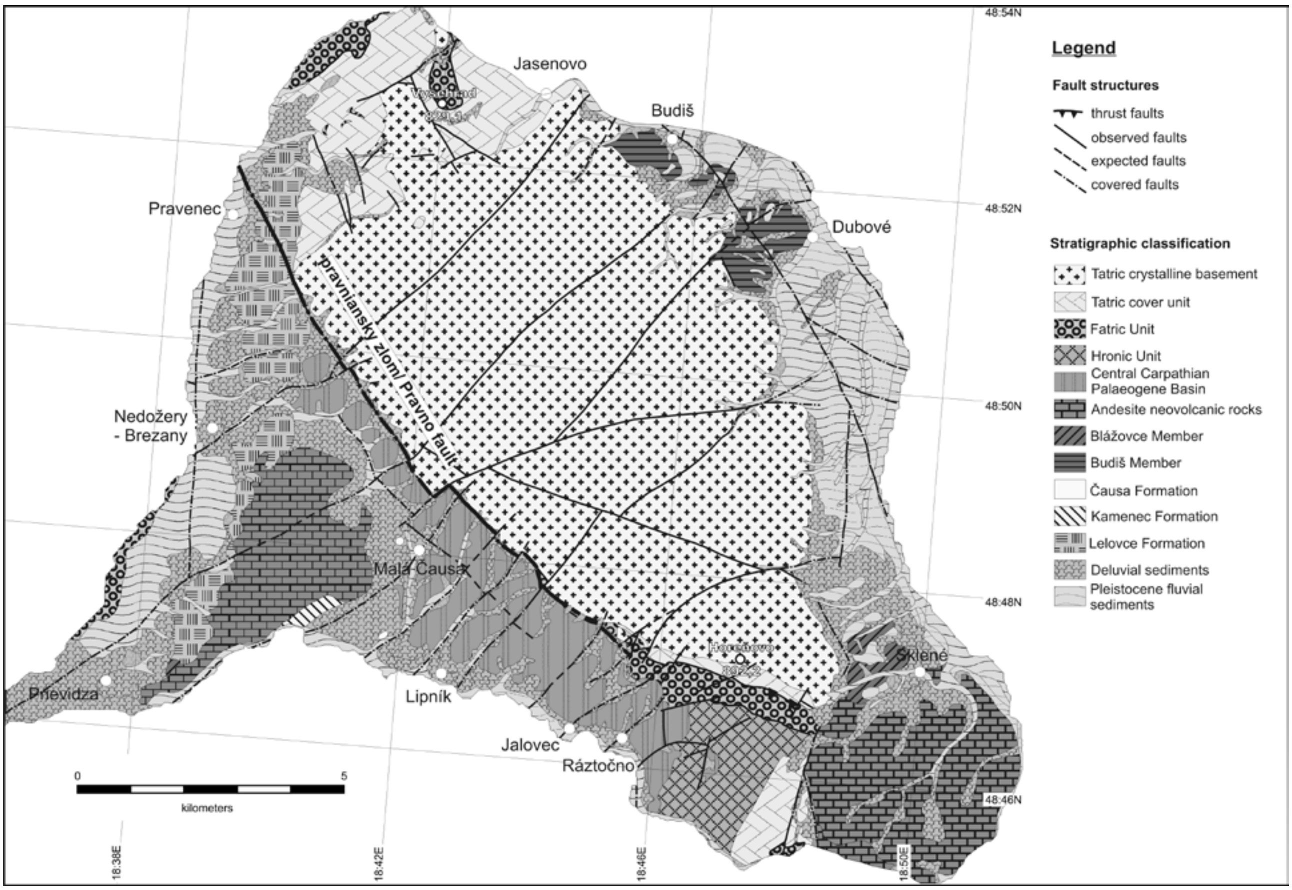

Fig. 2. Geological sketch map of Horná Nitra Basin and the Žiar Mts. with main fault structures.

Obr. 2. Účelová geologická mapa Hornonitrianskej kotliny a pohoria Žiar s hlavnými zlomovými štruktúrami.

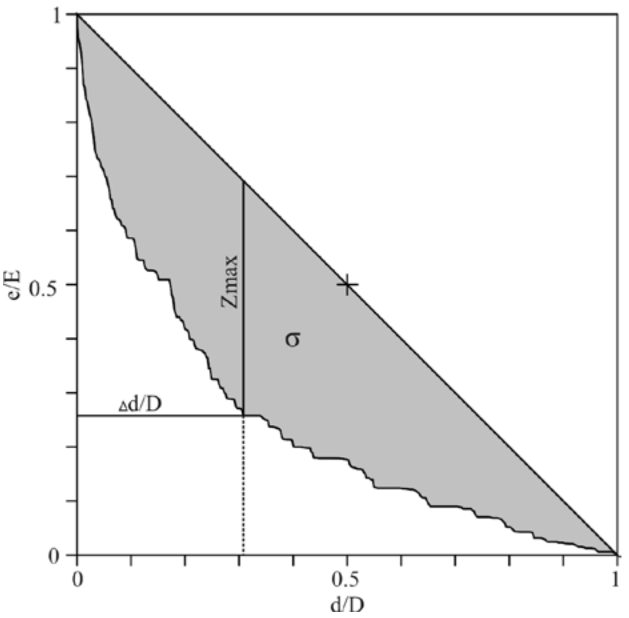

Fig. 3. Normalized longitudinal river valley profile. The abscissa is d/D, where D is the profile length and d is the distance of the individual data points from the valley summit or watershed at one end of the profile. The ordinate represents normalized elevation to the absolute gradient along the valley (e/E). Normalized LPRs characterize the degree of grading of a river where z_{max} is the maximal concavity on graph, and Δd/D is the normalized distance between z_{max} and the source. The area on the plot between the valley profile and the straight line connecting the source and the outlet of the valley is the concavity index (σ) in percent. Theoretically, this index lies between 0.0 (0%) and 0.5 (100%). Higher values indicate a more concave profile or a more highly graded river.

Obr. 3. Pozdĺžne dolinové krivky. d/D je úsečka, kde D je dĺžka profilu a d je vzdialenosť jednotlivých bodov od vrcholu údolia alebo rozvodnice na jednom konci profilu. Súradnice predstavujú normalizované výšky na absolútnu gradientu pozdĺž údolia (e/E). Normalizované LPRs charakterizuje mieru triedenia rieky kde z_{max} predstavuje konkávnosť na grafe, a Δd/D určuje vzdialenosť medzi z_{max} a zdrojom. Oblasť na grafe medzi profilom údolia a diagonálou spájajúcou najvyšší a najnižší bod povodia predstavuje konkávnosť (σ) v percentách. Teoreticky, tento index leží medzi 0,0 (0%) a 0,5 (100%). Vyššie hodnoty znamenajú viac konkávne profily alebo zrelšie rieky.

faulting or markable lithological competence in the study area. Steep knick points in profile usually refer to normal fault (decreasing movement), reverse fault (rearrangement of profile), and occasionally strike-slip fault (lateral movement in the valley).

Transverse river valley profiles provide useful information about the geometry of the valley. Low values indicates intense undercutting valley and uplift, which are characteristic for narrow valley with high walls (V-shape), high values are characteristic for shallow valleys (U-shape), where the dominant erosion of side wall of the valley expanded and reduces the ridges separating the different valleys. Profiles of the valley are made from the foothill towards upstream, but since the process of degrading the shape of the valley takes time to progress deeper into the valley. The profiles have made as close to the foothill and approximately 1 km upstream. By comparing the values obtained from the NE and SW sides, the most probably the SW edge of the mountains was controlled by active tectonics. The NE edge of the mountains seem to be relatively stable.

The present morphometric analysis is based on the calculation of the most commonly used geomorphic indices such as the mountain front sinuosity (S_{mf}), the ratio of valley floor width to valley height (V_f) and cross section of the valley (V_r). The V_f and V_r indexes are related to the shape of the valleys. Broad-floored valleys have relatively high values of V_f/V_r index that is associated to low uplift rates, while V-shaped valleys have low V_f/V_r values (close to 0) corresponding to rapidly incising valleys (Bull & McFadden, 1977). Mountain-front sinuosity (S_{mf}) reflects ratio of the erosion processes that disrupt the linearity of the foothills and tectonic processes that it supports on the contrary. The linearity of the mountain front (*S-index)* was quantified and introduced by the slightly reinterpreted *S-index*, introduced by Bull & McFadden (1977) using the formula: $S = L_{mf}/L_s$, where L_{mf} is the total length of the considered segment of the mountain front, and L_s is the length of abscissa, which connects the end points of the considered segment of the mountain front. Tectonically active mountain ranges have sinuosity close to 1, while the index approaching 2 and higher is more characteristic for multiple foothills with low tectonic activity (Vojtko et al., 2011).

4. RESULTS

4.1. The Pravno fault

The Pravno fault is NW–SE striking fault structure which is steeply inclined to the SW. Towards NW passes through the northern edge of the HNB to the Strážovské vrchy Mts. where gradually disappear in the Tatric crystalline. On the contrary SE continuation of the boundary ends on faults of Štiavnica caldera, east of Handlová. Along the fault trace, there was no travertine found related to faulting. The Lelovce Formation (Pontian–Pliocene) is the youngest deposits, which have been clearly disrupted by the Pravno fault. The total length of the observed fault is 19.84 kilometers. The fault is partly segmented by the NE–SW oriented faults (e.g., Brezany, Necpaly, and Háj faults).

4.2. Morphostructural parameters

Based on DTM data, morphostructural parameters were calculated and expressed by using maps of elevation, slope, aspect, horizontal and vertical curvature. (Figs. 1 and 4a,b,c,d). These parameters were used for reconstruction of neotectonic evolution of the study area.

The elevation map was constructed using the DTM data where the lowest point in the study area is lying near Prievidza town and has altitude of 260 m asl. On the contrary, the highest point in the investigated area is Horeňovo mount (892 m asl.). The Žiar Mts. form an elevated horst structure which separates the Turiec and Horná Nitra basins. Based on hypsography, the Horná Nitra

Tab. 1. Measured values of all longitudinal river valley profiles. Note: the marks of watershed column: HNB – the south-western hillside of the Žiar Mts., the Nitra River catchment; TB – the north-eastern hillside of the Žiar Mts., the Turiec River catchment. For further information see Fig. 3 and text.

Tab. 1. Namerané hodnoty všetkých pozdĺžnych dolinových kriviek. Vysvetlivky: kódy pre stĺpec "watershed" znamenajú: HNB – juhozápadná časť Žiaru, povodie rieky Nitra; TB – severovýchodná časť Žiaru, povodie rieky Turiec. Poznámka: vysvetlenie ostatných symbolov je na Obr. 3 a v texte.

Profile	D	Zmax	K	σ	Down	Watershed
3	0.34	0.22	0.15	13.99	36.01	HNB
4	0.29	0.23	0.17	14.53	35.47	HNB
5	0.23	0.13	0.09	7.45	42.55	HNB
6	0.75	0.17	0.12	9.10	40.90	HNB
7	0.38	0.26	0.18	15.74	34.26	HNB
8	0.72	0.06	0.04	2.23	47.76	HNB
9	0.28	0.21	0.15	11.91	38.09	HNB
10	0.36	0.08	0.06	4.48	45.52	HNB
11	0.3	0.20	0.14	11.79	38.21	HNB
12	0.76	0.06	0.04	1.91	48.09	HNB
13	0.69	0.07	0.05	3.37	46.63	HNB
14	0.29	0.14	0.10	9.13	40.87	HNB
15	0.45	0.10	0.07	5.91	44.15	HNB
16	0.55	0.11	0.08	6.68	43.32	HNB
17	0.66	0.10	0.07	5.00	45	HNB
18	0.76	0.09	0.07	3.84	46.16	HNB
19	0.32	0.21	0.20	13.95	36.05	HNB
20	0.44	0.16	0.11	9.23	40.77	HNB
Average	0.48	0.14	0.1	8.35	41.66	
22	0.37	0.27	0.19	16.20	33.8	TB
23	0.46	0.17	0.12	10.42	39.58	TB
24	0.65	0.11	0.07	4.90	45.1	TB
25	0.52	0.26	0.18	11.46	38.54	TB
26	0.24	0.18	0.13	0.00	41.14	TB
27	0.23	0.18	0.13	8.59	41.41	TB
28	0.40	0.31	0.22	18.00	32.00	TB
29	0.64	0.19	0.13	9.20	40.80	TB
30	0.93	0.05	0.03	1.12	48.79	TB
Average	0.49	0.19	0.13	8.88	40.13	

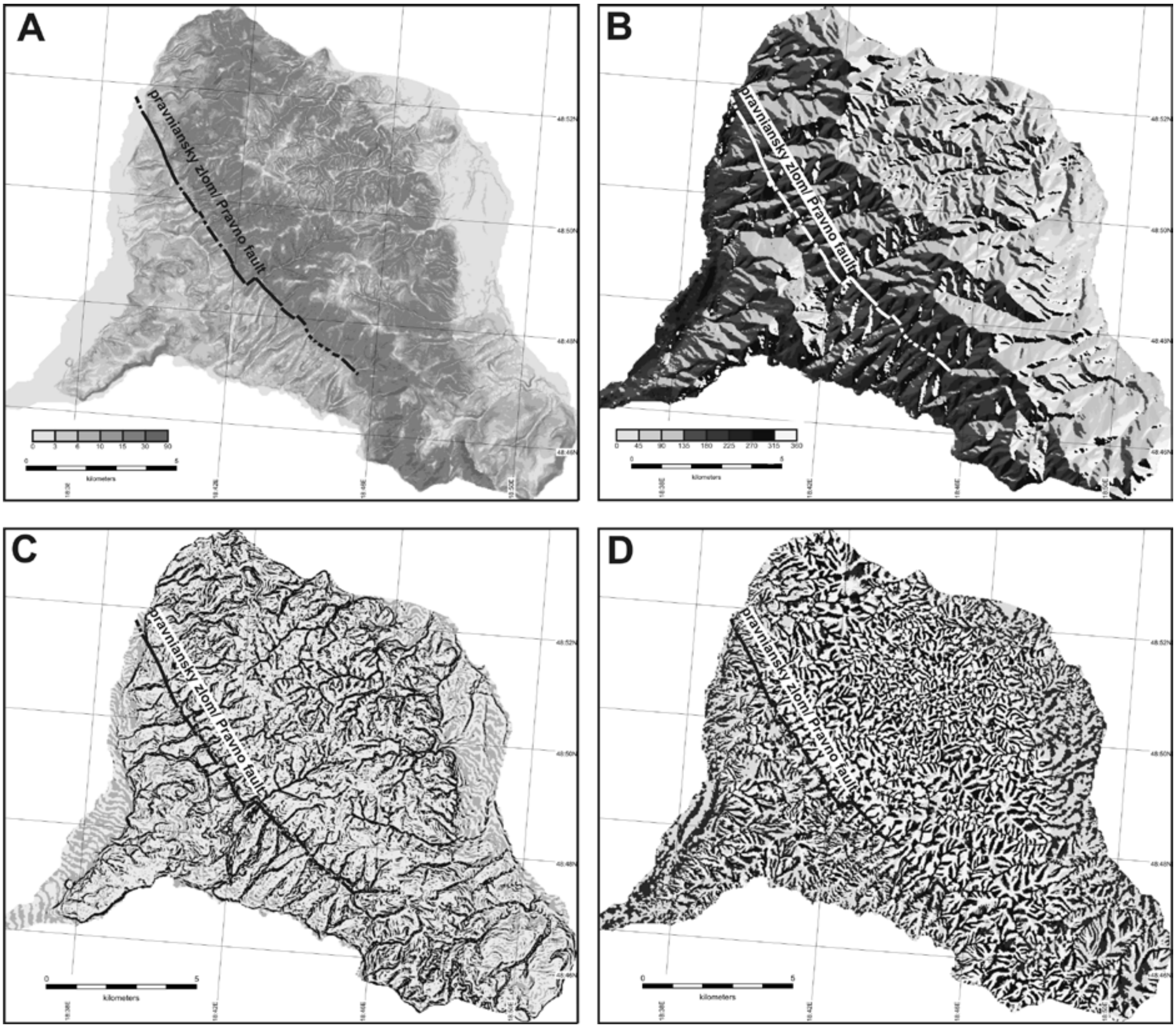

Fig. 4. Morphostructural parameters of territory displayed in following maps. a) map of slope; b) map of slope exposure (aspect); c) map of vertical curvature; d) map of horizontal curvature.

Obr. 4. Morfoštruktúrne parametre územia zobrazené v nasledujúcich mapách. a) mapa sklonov svahov; b) mapa expozície svahov; c) mapa vertikálnej krivosti; d) mapa horizontálnej krivosti.

Basin has 200 m lower altitude than the Turiec Basin. Altitudinal differences between mountain and adjacent basins cause an asymmetry of the Žiar Mts. This is proved also by asymmetric strike of the central ridge of the mountains which is located in the southern portion of this mountain (Fig. 1).

In the study area, the slope range varies between 0–61°. Spatial distribution of slope inclination is very heterogeneous which is well-visible on the slope map (Fig. 4a). The largest slopes are concentrated along the south-east mountain front of the Žiar Mts. that immediately adjacent to the Horná Nitra Basin where the slope values range from 15 to 61°. Conversely, the NE part of the Žiar Mts. has generally smaller slope than the SW part, which usually reach values of 10–30°.

The high slope of SW part of the Žiar Mts. is most probably caused by a combination of the active downward movement of the Pravno fault and renewed backward erosion in the Žiar Mts. Valleys located in this part of the territory are deeply eroded in the shape of the letter "V", with steep side slopes indicating a dominant deep backward erosion of the valleys. Conversely, NE part of the Žiar Mts. is made of longer less cutting valleys where the dominant factor is erosion-denudation (lateral erosion). Adjacent slopes of these valleys are less steep than the SW edge of the mountain indicating that these valleys have a balanced gradient. The course of the Pravno fault strictly separates this morphostructural parameter, while SW from the fault are dominating slopes about 0–10° unlike from NE part where the inclination is between 20–61°. It can be said that the slope map is a significant manifestation of the Pravno fault.

Another important phenomenon that the slope map captures are aligned surfaces. The largest aligned surfaces in the Žiar Mts. are located in the ridge part of the mountain and represents middle-mountain range (Kováč et al. 2011). These aligned surfaces of middle-mountain range can be observable from Vyšehrad mount (829 m asl.) to Horeňovo mount (892 m asl.).

Based on the aspect map, the study area can be divided into two distinct parts along watershed in the Žiar Mts. ridge (Fig. 4b). The area north-east of the watershed (NE part of the Žiar Mts. and the Turiec Basin) is represented by the dominance of slopes oriented generally to NE direction (ranges 315–360° and 0–135° respectively). On the contrary, the area located south-west of the watershed (SW part of the Žiar Mts. and the Horná Nitra Basin) is characterized by a strong dominance of slopes with the azimuth to the southwest (135–315°).

The maps of horizontal and vertical curvatures were used to test the manifestation of the SW and NE mountain fronts in the landforms of the Žiar Mts. respectively. The Pravno fault breakthrough changes of these parameters significantly and the SW block is represented with higher degrees of vertical and horizontal curvatures unlike the NE block where again lower degree of curvatures occurred (Fig. 4c,d).

4.3. Longitudinal valley curves

The method of longitudinal valley curves graphically expresses gravity conditions to the west and east of the Žiar Mts. (Fig. 5). The analysis has been successfully used to identify the tectonic deformation of the study area (based on topographic profile changes), but also to study aimed to predict the development of valley systems. The profile calculations have been performed mainly by the GRASS-GIS software.

Gradient ratios of all valleys reflect the real values, which are continuous curves with downward course. The average angle of these curves is 9.77° in the Horná Nitra Basin and 2.64° in the Turiec Basin which is indicating a significant difference in overall geomorphology and the neotectonic evolution of the Žiar Mts. The curve at the Pravno fault is not significantly decreasing process; therefore the high activity of the fault during the Pliocene to Quaternary is not so significant. The curves along the entire profile are without significant changes at or near the strike of the Pravno fault. The average length of valley curves is significantly different on both sides of the Žiar Mts., on the southwest side reaches ~1963 m and on the northeast side ~3103 m.

4.4. The ratio of height and width of the valley

Using the method of the ratio of height and width of the valley, the valley profile was measured parallel to the foot of the mountain providing useful information about the geometry of the Pravno fault and valley of the Turiec River. The V_f index value is about 0.5 and V_r approximately 2.0. River system has characteristics of parallel and rectangular network, individual valleys are more or less parallel to each other.

Fairly high levels were measured, which are characteristic of shallow U-shaped valleys. Lateral erosion prevailed here. The valley profiles were measured as close to the foot of the Žiar Mts. upstream of Turiec and Nitra lateral flow. By comparing the values obtained from different mountain foothills and from different parts of the same mountain foothills is assumed that part of the Žiar Mts. foothills were controlled by active tectonics before Pliocene-Quaternary period, and which are now relatively stable.

4.5. Mountain front sinuosity

Mountain front sinuosity and rate of facets are parameters that can be in the case of the Pravno fault used between Nitra River and Ráztočno valley. Mountain front sinuosity points to a slightly divided foot of mountain, which was (is) controlled by tectonic activity of fault. Total length of the Žiar Mts. foothills is 14.15 km; length of the Pravno fault is 12.03 km, which implies that the sinuosity value is 1.18 (active fault system). In the case of faceted mountain foothills is possible to say that the fault edges (facets) of the Pravno fault are significantly eroded, degraded material from the source area is rounded, but still form a significant visible relief on the digital terrain model, as well as aerial and satellite imagery. Ridge and bottom of the mountain are rounded and faceted surfaces reach 15–24°. Based on the classification by Bull (2008), the faceted surface of the Pravno fault is in Class 2 to 3 (typically for small to moderate active fault system). It can be defined as the planar surfaces with shallow valleys extended in a short distance to the facet as valley extended more than 0.7 horizontal distances between the base and the top facets.

5. INTERPRETATION AND DISCUSSION

The Pravno fault is geomorphologically distinct fault structure of the NW–SE direction which was also one of the arguments for the neotectonic investigation. During this investigation some new more or less reliable evidence of neotectonic activity of this fault were obtained (i.e. faulting during the Pliocene and Quaternary period, the last 5.33 Ma).

Since 1985, only a few earthquakes with local magnitude in size 3, based on archived material obtained from the Geophysical Institute had been recorded in this area (Cipciar et al., 2009). These results can be assessed that it is a less active seismogenic area. Another major argument used to prove a weak neotectonic activity on the Pravno fault is the absolute absence of alluvial fans located at the foothills of the Žiar Mts. This argument can be accepted partially, because the fault structure does not separate the Neogene basin fill of the HNB from the Žiar Mts. It means that it is not a typical mountain-front fault but the fault passing through ongoing foothills. On the other hand, morphostructural parameters that were analyzed, such as longitudinal valley curves, slope, aspect, horizontal and vertical curvature of landforms, mountain-front sinuosity and measure faceted mountain foothills suggest that the south-western edge of the Žiar Mts. represented by the Pravno fault has tectonically predisposed morphostructural discontinuity. These contrast landforms on the edge of the mountain could arise through a combination of erosion-denudation processes, but it had to be involved in the formation of active tectonics (i.e. active movement of the fault in the Pliocene to Quaternary period). Based on these characteristics, it is possible to characterize the Pravno fault at least as active and potentially active neotectonic structure (cf. Marko et al., 2005; Plencner, 2005). Recent activity on the

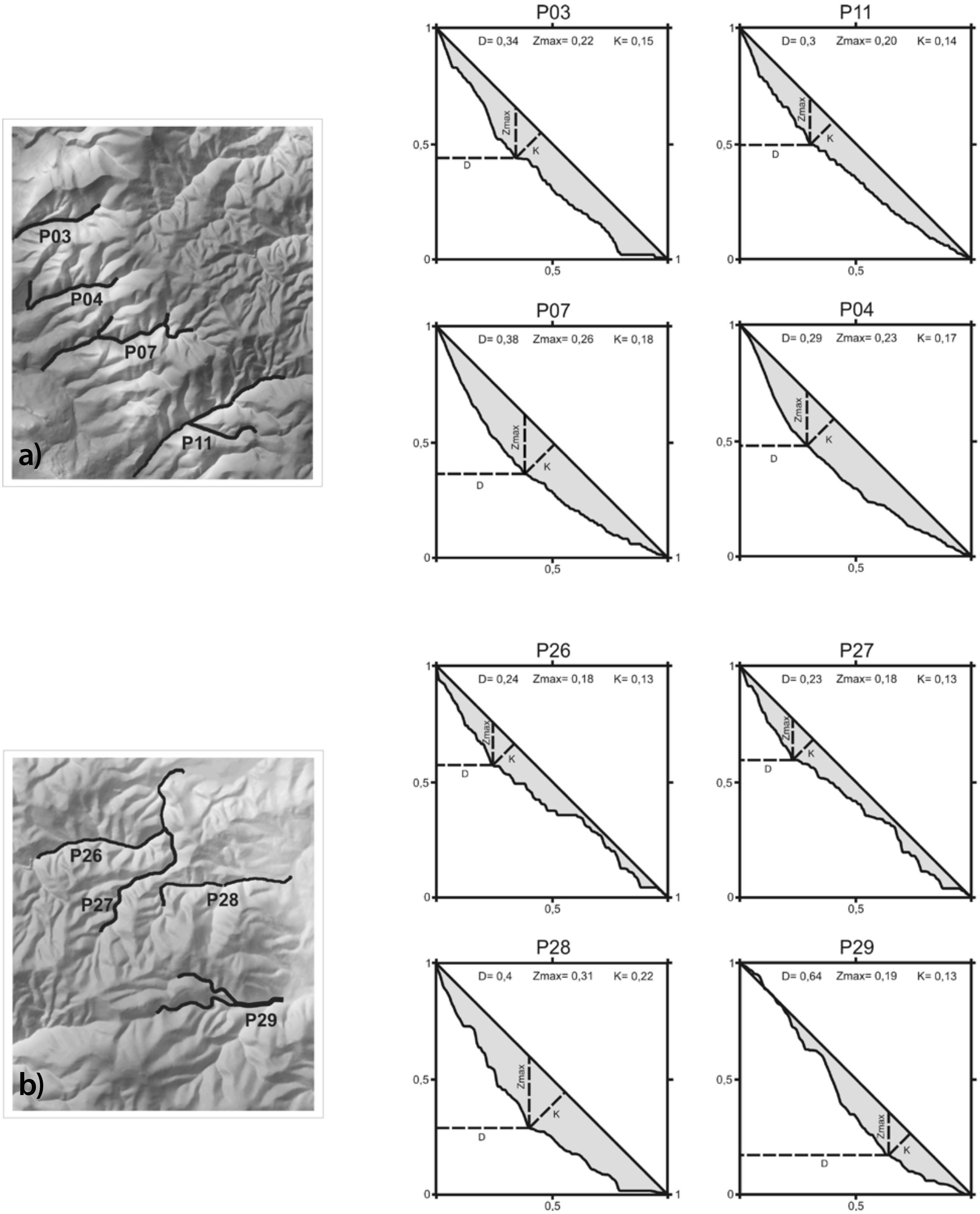

Fig. 5. Longitudinal river valley profiles. a) the western hillside of the Žiar Mts. (Nitra River watershed), NW–SE direction; b) the eastern hillside of the Žiar Mts. (Turiec River watershed), NW–SE direction.

Obr. 5. Pozdĺžne dolinové krivky. a) západný svah pohoria Žiar (povodie rieky Nitra), smer SZ–JV; b) východný svah pohoria Žiar (povodie rieky Turiec), smer SZ–JV.

fault was partially confirmed by geophysical measurements VES (vertical electrical sounding), PEE (pulsed electromagnetic emission), DEMP (dipole electromagnetic profiling), VLF (very long-wave method), SP (spontaneous polarization), and magnetics emanometria (radon) (Vojtko et al., 2011). The geophysical results indicate that the Pravno fault has a different character as the Malá Magura fault. The Pravno fault shows signs of fault without a single touch of a wider area, and the authors suggest that it is the vertical motion at the fracture (Marko et al., 2005). Methods were confirmed by a sharp transition between the Žiar Mts. rocks and Cenozoic sediments. PEE method shows slightly increased intensity of mechanical stress in the slope of the Žiar Mts. rocks. The content of radon in soil air has a slight variation, while in the rock mass is slightly higher than in the sediments. The contact point increase in radon content in soil gas was not observed, suggesting the low-permeability of gas in these places (Vojtko et al., 2011).

Resurrection of older landforms refers to the youngest tectonic exhumation of the mountain during Pliocene and Quaternary (Bizubová et al., 2005; Sládek & Bizubová, 2008).

The important evidence of older landforms is the area of saddle near Vyšehrad in the NW portion of Žiar Mts. where the Neogene sediments were preserved. The Žiar Mts. was covered and then partially exhumed from beneath the Neogene sediments on contact with surrounding basins (Sládek, 2007). Indirectly this could indicate systems of flat surfaces in the near or distant surroundings. Direct evidence of overlapping mountains with the Neogene sediments could be remnants of the sediments in the saddles, valleys or near flat surfaces. These statements are based on two hypotheses. The first hypothesis assumes drainage from the Turiec Basin to the south of the Horná Nitra Basin area through the Vyšehrad saddle at the end of the Neogene and Early Quaternary (Bizubová, 2002). According to the second hypothesis the Žiar Mts. is geologically old but geomorphological relatively young mountain range, suggesting that there may be at least partially covered with Lower Neogene sediments (e.g., Kováč et al., 2011).

The Middle Sarmatian to Pliocene, probably until the Quaternary, the compression component of palaeostress field rotated from the NE–SW to NNW–SSE direction. Significant vertical displacements (horst-and-graben structure) and signs of lateral movement during the faulting were observed (Hók et al., 1995; Marko, 2012). It is presumed, that the neotectonic palaeostress field can be characterized by NE–SW compression and perpendicular tension (e.g., Vojtko et al., 2011, Marko, 2012).

6. CONCLUSIONS

The principal aims of this work was to identify neotectonic activity of the Pravno fault using the methods of tectonic geomorphology that were confronted with earlier published as well as archival data. The Pravno fault is the tectonic structure of the NW–SE direction and it is observable from the Tužiná Valley to the neovolcanites of the Kremnica Mts. on the south-eastern side. Its continuation north-westwards and south-eastwards began unclear. The total length of the observed fault is 19.84 km. The fault as significant morphostructural anomaly is pronounced between the villages of Pravenec and Ráztočno. The Lelovce Formation (Pontian–Pliocene) is the youngest deposits, which have been clearly disrupted by the Pravno fault.

The fault was active primarily in the Neogene period, especially during the Badenian and Sarmatian. The Pravno fault (south-eastern segment) has partly eroded faceted surfaces, and suggests that this segment of fault was not significantly activated during neotectonic period. Facet surfaces are occasionally covered with debris slope sediments and rounded. In the course of the Pravno fault, Pliocene-Quaternary alluvial fans are rarely developed. The slope map refers to important changes along the strike of the fault but it is not as strong and distinct as in the case of the Malá Magura fault. The Pravno fault is most probably neotectonic structure of the Central Western Carpathians.

Acknowledgement: The work was financially supported by the Research and Development Agency under the contracts No.APVV-0625-11 & APVV ESF-EC-0006-07 and by the VEGA agency under contracts Nos. 1/0587/11 and 1/0712/11.

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Resumé: Pohorie Žiar je situované v západnej časti Centrálnych Západných Karpát. Podľa regionálno-geologického členenia patrí pohorie Žiar do pásma jadrových pohorí. Zo severnej strany je pohorie ohraničené Turčianskou kotlinou a z južnej strany Hornonitrianskou a Handlovskou kotlinou (Obr. 1). Všetky tri kotliny patria do vnútrohorských kotlín Centrálnych Západných Karpát. Študované územie je odvodňované riekou Nitra na západe, riekou Handlovka situovanou na juhu územia a riekou Turiec na východe a severe územia. Hornonitrianska a Turčianska kotlina ako medzihorské celky orograficky patria do fatransko-tatranskej oblasti subprovincie vnútorných Západných Karpát (Obr. 1). Predstavujú členité zníženiny na hornom toku rieky Nitry a Turca respektíve. Obidve kotliny majú výrazne pretiahnutý tvar v S–J smere, pričom súčasný povrch kotliny sa vytváral eróznymi procesmi koncom pliocénu a počas pleistocénu.

Na geologickej stavbe územia regiónu sa podieľajú kryštalinikum tatrika, mezozoikum (tatrikum, fatrikum, hronikum), paleogéne sedimenty podtatranskej skupiny, neogénne sedimenty, vulkanity a kvartérne uloženiny (Obr. 2). Kryštalinikum a mezozoikum sú súčasťou príkrovovej stavby centrálnych vnútorných Karpát, a to tatrika, fatrika a hronika. Na povrch vystupujú na severe i na juhozápade Žiaru.

Územie charakterizuje hrasťovo-prepadlinová stavba neogénneho veku. Zlomy s veľkou vertikálnou amplitúdou rozčleňujú región na hlavné bloky, zvyčajne naklonené (rotované), ktoré sa zlomami s menšou vertikálnou amplitúdou ďalej členia na segmenty. Pravniansky zlom v jeho jv. segmente oddeľuje kryštalinikum pohoria Žiar od sedimentov mezozoika, paleogénu a neogénu. V sz. pokračovaní, zlom pravdepodobne oddeľuje sedimenty pliocénu (lelovské súvrstvie) od sedimentov kvartéru.

Zámerom práce bolo testovať neotektonickú aktivitu pravnianskeho zlomu pomocou metód tektonickej geomorfológie a morfoštruktúrnej analýzy. Výsledky týchto analýz slúžia na poznanie základnej morfoštruktúrnej stavby predmetného územia a vysvetlenie histórie jej vývoja.

Pomocou softwérových aplikácií bolo možné upraviť morfoštruktúrne parametre a získať požadované výsledky v podobe grafických výstupov (Obr. 3, 4a-d). Na základe výškopisných údajov z hypsometrickej mapy môžeme konštatovať, že Hornonitrianska kotlina je oproti Turčianskej kotline približne o 200 m nižšie položená. Poukazuje to na rýchlejšiu subsidenciu alebo eróziu Hornonitrianskej kotliny ako v oblasti Turčianskej kotliny. Na mape sklonov svahov je prejav pravnianskeho zlomu výrazný. Vysoké hodnoty sklonov svahov SV od pravnianskeho zlomu sú spôsobené pravdepodobne kombináciou aktívneho poklesového pohybu na zlome a obnovenej spätnej erózie v pohorí. Doliny nachádzajúce sa v tejto časti územia sú hlboko rezané v tvare písmena „V" so strmými bočnými svahmi, čo poukazuje na dominantnú hĺbkovú a spätnú eróziu v dolinách. Naopak SV časť pohoria Žiar je tvorená dlhšími menej zarezanými dolinami kde je dominantným erózno-denudačným činiteľom laterálna erózia. Priľahlé svahy týchto dolín sú menej strmé ako na JZ okraji pohoria čo poukazuje na to, že tieto údolia majú vyrovnaný

spád. Priebeh zlomu striktne oddeľuje tento morfoštruktúrny parameter, pričom JZ od zlomu dominujú sklony od 0–10° na rozdiel od SV časti kde sú sklony od 20–61°. Na základe expozície svahov môžeme študované územie rozdeliť pozdĺž rozvodnice na dve rozdielne časti. Územia SV od rozvodnice (SV časť Žiaru a priľahlá Turčianska kotlina) je reprezentované dominanciou svahov orientovaných generálne na SV (interval 315–135°). Naopak, územie situované JZ od rozvodnice (JZ časť Žiaru a priľahlá Hornonitrianska kotlina) sa vyznačuje výraznou dominanciou svahov exponovaných generálne na JZ (135–315°). Hodnoty spádnicovej a vrstevnicovej krivosti sú veľmi nízke v oblasti kotlín, naopak v pohorí Žiar nadobúdajú oveľa výraznejšie hodnoty. SV okraj pohoria Žiar má difúzny prechod do Turčianskej kotliny (najmä medzi Veľkou dolinou a údolím Jasenice) na rozdiel od JZ pohoria reprezentovaného pravnianskym zlomom. Pozdĺž zlomu dochádza k výraznej, skokovitej zmene týchto parametrov. V prípade facetovania horského úpätia je možné konštatovať, že zlomové hrany (facety) pravnianskeho zlomu sú významne erodované, degradáciou materiálu zo zdrojovej oblasti sú zaoblené, no stále tvoria výrazný reliéf viditeľný na digitálnom terénnom modeli ako aj na leteckých a družicových snímkach. Hrebeň aj úpätie sú zaoblené a sklony facetovaných plôch dosahujú 15–24°. Na základe klasifikácie podľa práce Bull (2008), sa facetované plochy nad priebehom pravnianskeho zlomu zaraďujú do triedy 2 až 3. Je možné ich definovať ako planárne povrchy s plytkými údoliami rozšírených v krátkej vzdialenosti vo facetách až ako údolia rozšírené viac ako 0,7 horizontálnej vzdialenosti medzi bázou a vrcholom facety. Metóda pozdĺžnych dolinových kriviek poukazuje na výrazný rozdiel v celkovej morfológii a vývoji pohoria Žiar (Tab. 1, Obr. 3,5). Krivka v mieste priebehu pravnianskeho zlomu nemá výrazne klesajúci priebeh, preto sa nepredpokladá výrazná aktivita zlomu v pliocénnom a najmä kvartérnom období. Pomocou metódy pomeru šírky a výšky údolia boli namerané relatívne vysoké hodnoty, ktoré sú charakteristické pre plytké údolia tvaru U. Prevládala tu bočná erózia, ktorá rozširovala steny údolia a znižovala hrebene oddeľujúce jednotlivé údolia. Na záver je možné konštatovať, že pravniansky zlom patrí medzi potenciálne neotektonicky aktívne až aktívne zlomové štruktúry CZK.