VERIFICATION OF AGE OF UNPAIRED TERRACES OF THE ĽUPČIANKA STREAM (NORTHERN SLOPES OF THE NÍZKE TATRY MTS., WESTERN CARPATHIANS)

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Abstract

The Ľupčianka Stream, rising from the core of the Nízke Tatry Mts. (NTM), flows to the Liptovská kotlina Basin (LKB), where it joins the Váh River valley. Its accumulations are developed in form of terraces and terraced fans. The paper focuses on verification of age of unpaired terraces on the contact zone between the NTM and the LKB, as the opinions on their age differ. The procedure is based on analysis of terrace sediments consisting of observation of lithology and stage of weathering as well as terrace base detection. Within the field research, ~13 m vertical difference between the terrace bases was identified. Based on applied analyses together with previous investigations, terraces were classified as T-IVa (left-bank) and T-III (right-bank terrace), which is traditionally correlated with younger Mindel and Pre-Riss. Usage of numerical dating would improve the age verification. Neotectonic activity is recorded in morphoposition of remnants as well.

Keywords: Western Carpathians, Nízke Tatry Mts., Ľupčianka Stream, river terrace, gravel analysis

Introduction

The Ľupčianka Stream rises from the crystalline core of the Ďumbierske Tatry (western subunit of the Nízke Tatry Mts. (NTM)), in the Prašivá part (Mazúr, Lukniš, 1978) at an elevation of ~1605 m a.s.l. and flows generally towards the north. It enters the Liptovská kotlina Basin (LKB), a subunit of the Podtatranská kotlina Basin at an elevation of ~590 m a.s.l., where the staircase of terraced fans on both banks is developed along its course. In general, younger generations of terraced fans (T-II and T-III) are preserved on the right bank, whereas older generations of fans (T-IV, T-V and T-VI) cover the left bank of the valley. Terraced fans of the Ľupčianka Stream join the Váh River terraces (Droppa, 1970; Gross, 1979).

Within this study, the focus is put on the analysis of unpaired terraces of the Ľupčianka Stream in the contact zone of the NTM and the LKB (Map 1). The terraces are situated on both banks of the stream, from which the right-bank terrace is situated apparently lower compared to the terrace remnant on the left-bank.
Regional settings and state of the art

According to Regional geological subdivision of Slovakia (Vass, 1988), the western part of the NTM belongs to the Core mountains Area and the Zone of Ďumbierske Tatry. The pre-Cenozoic basement consists of the Paleozoic basement and Mesozoic sedimentary sequences belonging to the Veporic and Tatric Unit. The Fatric Unit (Lower Triassic–Middle to Upper Cretaceous) and Hronic Unit (Carboniferous–Lower Cretaceous) nappes occur in north-western part. The Paleogene fill of the adjacent LKB is represented by flysch Subtatric Group (Paleocene–Oligocene) (Gross, 1979; Lexa et al., 2000).

From neotectonic point of view, the NTM, as a Quaternary horst, are in relation to the LKB limited by margin-bounding faults, which is recorded in facets, travertines, linearity of slopes and other features (Maglay et al., 1999; Littva, 2017). Regarding the study area is situated on the contact zone of the NTM and the LKB, its neotectonic evolution could be controlled by regional stress field changes of both morphostructures. The character of these changes in both units has a very similar trend of evolution (Pešková, Hók, 2008; Littva, Hók, 2014). It is in line with Gross (1980), who determined marginal faults of the LKB as older, while transverse faults continuing along the valleys to adjacent mountains as younger. Neotectonic activity of marginal and transverse faults within the study area was estimated by Maglay et al. (2011b) and Vitovič, Minár (2018) as well.

Within the Western Carpathians, classification of river terraces was unified by Halouzka (1986) and Maglay et al. (2011a). Concerning the study area, several previous investigations of the mentioned terrace remnants were conducted. However, opinions on the age and classification of the terraces differ. The left-bank terrace in relative elevation 35 m was mentioned by Vitásek (1932), but without any age estimation. Droppa (1970) classified the right-bank terrace to T-III (older Riss), with its base ~14 m, while the left-bank was assigned to T-IV (younger Mindel), with the base ~37 m above the Ľupčianka Stream. The thickness of the accumulation was estimated to 2–3 m (right-bank) and 2–5 m (left-bank terrace). The measurements and classifications of Droppa (1972) and Vaškovský (1980) are very similar. Terraces are classified to T-IV (with base ~632–638 m a.s.l.) and T-III (~610–615 m a.s.l.), resulting in relative elevation of ~35–39 m and ~13–16 m and vertical difference between the bases ~22–23 m. Within the marginal concern, the terraces were studied also by Gross (1979), who interpreted their age as Riss (right-bank) and Mindel (left-bank terrace). Detailed extent of the sediments was obtained in engineer-geological survey, but without age assessment (Páleník, 1988). Official geological mapping was carried out by Biely et al. (1992), who classified both terrace remnants as T-IIa (younger Riss). According to Littva (2017), character of the terrace sediments points to the identical age on both banks, which implies neotectonic dislocation of the terrace remnants.
Remnants of terrace T-III preserved along the Ľupčianka Stream have a stratigraphic importance too, as they connect the Váh River terraces and the glacial deposits of distal moraine in the Nízke Tatry Mts. (Vitásek, 1932; Droppa, 1970; Vaškovský, 1980).

The main object of the paper is to verify the age of the terraces, represented by their classification. Consequently, the verification of age enables to evaluate the possible tectonic control over the unpaired terrace distribution of the studied area.

Map 1 A: Location of the Ľupčianka Stream within Slovakia. B: A more detailed view on the Ľupčianka Stream and study area. Settlements in the map: LM: Liptovský Mikuláš, RK: Ružomberok. C: A detailed view on the studied terraces within the study area. Position of studied terraces and faults is according to Páleník (1988), the rest of deposits is in line with Biely et al. (1992)
Methods

To fulfil the object of the paper, analysis of the accumulations in line with Vitovič, Timko (2018) was conducted. The field research was carried out in June 2019. Besides of gravel analysis, the position of terrace bases together with thickness of accumulation was observed as well. The terrace bases were detected in manually excavated outcrops on both remnants (at the Site 1 and 2, Map 1 C), whereas the thickness of accumulation was identified only on the right-bank terrace (Site 2). To identify the position of terrace bases and surfaces, the GPS device (Garmin eTrex Touch 35), hypsometers (Skywatch Geos 11) together with topographic maps (1:10,000) were utilized. The altitude was derived from digital elevation model (inferred from vectorized contours of 1:10,000 topographic map of Slovakia) and confirmed by Google Earth-derived altitude. The thickness of accumulation was estimated with measuring-tape.

Within the analysis of terrace gravel, selected attributes of clasts were evaluated. To compare the accumulations, 154 clasts from the left-bank (Site 1) and 164 clasts from the right-bank (Site 2) terrace were analysed. The clasts were collected from 0.1–0.3 m (Site 1) and 0.7–1 m (Site 2) relative elevation from the bases. Visual macroscopic analysis of randomly collected gravelly fraction was conducted, based on observation of lithology as well as total stage of weathering of granitoid clasts, regarding that granitoid group of rocks is generally the most numerous within the Váh River terraces (Vitovič, Timko, 2018). To verify the classification of terraces, comparison of total stage of weathering with the Váh River terraces was carried out.

Results

The left-bank terrace remnant has an approximate size 450 x 100 m, whereas the right-bank remnant 700 x 120 m. Based on mentioned approaches, the elevation of terrace bases and surfaces was inferred (Figure 1). Elevation of the valley bottom reaches from ~597 m a.s.l (in the vicinity of the Site 2) to ~599 m a.s.l (in the vicinity of the Site 1). The elevation of the right-bank terrace surface (at the site of outcrop, Figure 2) is ~612 m a.s.l., the base is located ~2.3 m under the terrace edge, which results in ~13 m relative elevation of the base above the recent valley bottom. Fluvial sediments, covered with soil (0.8 m) are ~1.5 m thick. Considering small spatial variability in terrace morphology within the study area, the same relative elevation of the base (~13 m) is presumed in the place of cross-section line as well. On the left bank (Figure 3), the terrace base was detected at an elevation of 625 m a.s.l., resulting in ~26 m relative elevation above the valley bottom. The thickness of the accumulation wasn’t detected due to thick cover of slope deposits. In order to depict the terrace in a cross-section, the same thickness
of terrace deposits as on the right bank was utilised. To sum up, ~13 m the vertical difference between the bases was estimated. The bases of both terraces are formed by Paleogene limestone of Borové formation.

Accumulations of both terrace remnants consist mostly of gravelly and sand fraction of a stream-bed facies, while fine-grained sediments of floodplain facies weren’t detected. The results of partial analyses are visualized in Graph 1, 2 and 3. Granitoid (46 %), silicic (27 %) and carbonate (19 %) rocks belong to the most numerous groups at the Site 1. Small portion of metamorphic (5 %) and sandstone (3 %) rocks occur as well. Metamorphic rocks are represented mostly by gneiss, less by amphibolites. Here, small occurrence of paleovulcanites (1 %) was detected as well. They come from very tiny areals of Cretaceous vulcanites occurring in its catchment (Biely et al., 1992). On the opposite bank, granitoid (78 %), silicic (12 %) and carbonate (7 %) rocks are dominant as well. Portion of metamorphic (1 %) and sandstone (1 %) rocks is reduced, whereas paleovulcanites weren’t detected at all. Metamorphic rocks are represented by gneiss and mylonite clasts. Differences in lithological composition are apparent (Graph 1). The most apparent difference is in portion of granitoid, quartzite and limestones rocks. Left-bank terrace accumulation contains lower portion of granitoid, but higher portion of all other rock types. On the right-bank terrace, an increasement of carbonates was noticed in lower part of accumulation closer to its base. In both accumulations, the most numerous is granitoid group, therefore, it was applied in comparison of stage of weathering.

The difference in the total stage of weathering (W) between the terraces is only slight (Graph 2 and 3). The portion of rocks in selected weathering stages is similar. The most significant difference is only in portion of second and third group (47.7 vs. 38.0 % and 25.0 vs. 32.4 %).

Figure 1: Simplified geological cross-section of the Ľupčianka Stream valley. Identified vertical difference between terrace bases is ~13 m, whereas difference inferred from previous investigations (Droppa, 1972; Vaškovský, 1980) is ~23 m (see Discussion)
Graph 1: Lithology of terrace gravel. Numbers in columns are referred to portions (in %). Explanation to numbers in legend, types of rocks: 1: granitoid (granite, granodiorite), 2: silicic (quartzite, quartz and quartzite conglomerate), 3: carbonate (limestone, dolomite), 4: sandstone (Paleogene, Permian), 5: volcanic (paleobasalt, paleoandesite), 6: metamorphic (amphibolite, gneiss, mylonite)

Graph 2: Portions of granitoid rocks (n=71) in selected stages of weathering from the Site 1. The value of the total stage of weathering (W) is in the right corner

Graph 3: Portions of granitoid rocks (n=128) in selected stages of weathering from the Site 2. The value of the total stage of weathering (W) is in the right corner
Graph 4: Comparison of values of total stage of weathering (W) between the Váh River terraces (white dots) and the Ľupčianka Stream terraces (colourful dots). Modified and specified according to Vitovič, Timko (2018). Denoted range of selected W values is inferred from the measurements of the Váh River terraces.

Figure 2: Outcrop in right-bank terrace at the Site 1. Geologic hammer for a scale (June 2019)

Figure 3: View on the left-bank terrace surface (June 2019)

Source: author
Discussion

Whereas the elevation of the right-bank terrace base detected in this study is nearly in entire accordance with the previous measurements (Droppa, 1970, 1972; Vaškovský, 1980), the opinions on elevation of the left-bank terrace base markedly differ. Moreover, the thickness of the right-bank terrace accumulation measured in this study is in partial concert with Droppa (1970) too. Thus, discrepancies in base elevation can arise from different approaches in measurement and field research (terrace base detection) as well. In spite of some skills in field research (e.g. Vitovič, Timko, 2018) and in detection of terrace bases (e.g. Vitovič, Minár, 2018), taking into account that more measurements of the left-bank base elevation imply its higher position (~632–638 m a.s.l.), elevation identified by this study (~625 m a.s.l.) has a lower credibility. Therefore, more credible value of the left-bank base elevation at Site 1 is ~638 m a.s.l., resulting in vertical difference between the terrace bases ~23 m.

Concerning differences in lithology, they can be caused by various reasons, e.g. by changes of source area of the stream (e.g. river piracy) or by different age of the accumulation. With erosional rivalry between catchments of the Ľupčianka Stream and Lúžňanka Stream, mentioned by Littva (2017), progressing headward erosion of the Ľupčianka Stream would transport not only more granitoid rocks (from crystalline core of the NTM), but as well as quartzites (from Lúžna Formation). Therefore, in this case, the changes of catchment source area wouldn’t cause the significant differences in lithology. This implies that lithology variations of the clasts could be caused rather by time-related changes. In this case, the higher portion of silicic rocks together with lower portion of granitoid rocks would result from selective weathering. But as it was detected by Vitovič, Timko (2018), the portions of the rock types don’t always correlate with age of terrace. Moreover, the differences in rock composition can be influenced by collection of gravel from slightly different elevation from terrace bases at the Site 1 and 2. The attribute which better correlates with the age of terraces is the total stage of weathering (Vitovič, Timko, 2018). On the other hand, the difference in stage of weathering of the granitoid clasts (Graph 2 and 3) is not extremely significant. In spite of that, the W values lie within the range of selected terraces of the Váh River (Graph 4). Values of weathering (W) of terrace T-III ranges from 218,9 to 237,5, while values relating to terrace T-IVa range from 240,4 to 268,9. Thus, based on the values of total stage of weathering of the Váh River terraces, right-bank terrace can be assigned to terrace T-III (which is in concert with many of investigations), whereas the left-bank remnant can be assigned to terrace T-IVa (identical with T-IV according to Droppa (1970, 1972) and Vaškovský (1980) after reclassification and unification). In spite of the suggestion to avoid Alpine morphostratigraphy in terrace classification (Šujan, 2015), an approximate assessment is carried out in
deference to traditional approach within the Western Carpathians. Nevertheless, we accept that numerical dating would considerably increase exactness of classification. Regarding the traditional classification of river terraces of the Western Carpathians (e.g. Halouzka, 1986), the age of the right-bank terrace remnant (T-III) is presumed to Pre-Riss Glacial Stage, while the left-bank remnant (T-IVa) to younger Mindel Glacial Stage. Applying Nordic stratigraphy (Halouzka, 1986; Menning, Hendrich, 2016), Pre-Riss can be correlated with Saalian complex (Fuhne Stadial) and younger Mindel with Elsterian Complex (younger Elster).

Regarding the difference in relative elevation of the Ľupčianka Stream terrace T-III in the LKB (north of Partizánska Ľupča village), which is ~11 m (Droppa, 1970) and ~13–14 m in study area, influence of neotectonic activity along the marginal fault is presumed. However, lower position in downstream reach can be caused by ground tilting as well. Considering the unpaired preservation of terraced fans along the Ľupčianka Stream (Droppa, 1970; Gross, 1979), which resulted from tectonic activity along the transverse fault continuing to the mountains, vertical difference between terraces (~22–23 m) can be partially controlled by neotectonics as well. Neotectonic activity of the transversal fault is proved by presence of travertines in the NTM and the LKB (Bešeňová village) as well (Kovanda, 1971; Gross 1980).

**Conclusion**

In current research, the analysis of unpaired terraces of the Ľupčianka Stream in the contact zone of the NTM and the LKB was carried out to verify their age. The field research associated with the analysis of terrace sediments was applied together with compilation of previous investigations. Based on the results of partial analyses and regarding the previous studies of terraces and neotectonic settings, the terrace remnants were classified as terrace T-IVa (left-bank remnant) and T-III (right-bank remnant). According to traditional Alpine morphostratigraphy, the terraces can be considered as record of valley bottom development during younger Mindel Glacial Stage (left-bank) and Pre-Riss Glacial Stage (right-bank remnant). To determine the precise age of the sediments, numerical dating (e.g. cosmogenic nuclides method) should by applied. Attributes of morphoposition of studied terraces are presumed to record the neotectonic activity of marginal and transverse fault as well.

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