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Progressive evolution of the Bodva drainage basin (SE West Carpathians, Slovakia)

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Abstract

This contribution presents the results of a detailed study of the Bodva drainage basin (SE Slovakia) situated in the SE periphery of the West Carpathian dome-like mega-morphostructure. Its relative short distance from the asymmetrical top of this dome (in the Tatra Mts.) accelerates more dynamic geomorphic processes in the studied area. It can be used as a good example of the progressively developing drainage basin. The Bodva drainage basin has extended its area at the expense of neighbouring Slaná and Hnilec drainage basins. A potential piracy activity has been determined by a strong watershed barrier effect, with the exception of the Slovenský kras karst, where we assume a possible underground type of piracy inside of the karst plateaus. We have identified a short watershed segment bordering the Bodva and Hornád drainage basin in the eastern part of the studied area with regressive evolution. The upper segment of Ida valley could be captured into the Hornád drainage basin.

There is a very specific geomorphological network in the studied area. A very rare or missing valley network has developed in the Slovenský kras karst. It is substituted by underground karstic (cave) network. The Bodva drainage basin consists of two relatively equivalent valley systems of the Bodva and Ida rivers. Both are characterized by a specific crescent ground plane. It is a result of local morphotectonics - the Slovenský kras horst uplifting and the Turnianska partial graben subsiding. We can predict capturing of the Čremošné brook (left tributary of the Slaná river) into the Bodva River through the Zádielska dolina valley controlled by this very active local morphostructural evolution.

Key words: geomorphological network, river piracy, the Bodva drainage basin

1. Introduction

During the neotectonic period, the geomorphic network (network of valleys and inter-valley ridges) composition has been controlled not only by climatic changes, but also by the morphostructural evolution. Rising of the dome-like mega-morphostructure of the West Carpathians after the Lower Badenian (Mazúr, 1979) has started the process of the older geomorphological network transformation to a new one. The older networks disappear and younger ones adapted to new conditions replace them. Transformation is always gradual and delayed following to climatic and morphostructural changes. This is the reason why the individual drainage basins also consist of segments corresponding to non-existing conditions. Their share is diminishing while younger segments of networks are being created in accordance with the contemporary morphoclimatic and morphostructural conditions. Usually, several generations of valley network segments can be identified within one drainage basin, which is due to the cyclic nature of geomorphological development.

This article presents the results of analyses of the Bodva drainage basin. There are three main aims: a) to identify wider regional reasons of the progressive evolution of the studied area, b) to determine the relationship order to the neighbouring basin according to the level of the watershed barrier effect and c) to specify inner morphostructural properties inside of the basin recorded in the valley network composition.

2. Methods

This contribution presents the results of several analyses interpreting some relevant properties of valleys and inter-valley (watershed) networks. These analyses have been done in several Slovak Carpathian drainage basins: Poprad (Lacika, 1998 and 2000), Slaná (Lacika, 2001a) and Hnilec (Lacika, 2001b).

Analyses of geomorphological networks are conducted in two fundamental ways: paleo-reconstructions and predictions. They are applicable to the knowledge of the history of the morphostructural development of the given territory as encoded in the spatial arrangement, density and elevation of these networks. Its prognostic application - forecasting of the developmental trend of geomorphological networks - is also important; it is in fact identification of areas where developmental changes are expected and may change the future erosion-denudation character of the given territory.

The data for analysis of geomorphological networks are obtained from the basic topographical maps with contour line grid, in the case of the Slovak Carpathians from maps at a scale of 1:25 000 which depict practically all elements of these networks - valleys and inter-valley ridges and which are sufficient. The grid consisting of linear signs tracing their axes is preserved in an analysable form even after a 6- or 8-fold diminution.

2.1. Analysis of valley networks

The geomorphological network is analysed and the following attributes of its elements are studied: hierarchy, textures, density, linearity and asymmetry. Hierarchisation of the network elements is carried out pursuant to Strahler method (1952). The analysis of network element texture takes into account different patterns, for example valleys arranged into tree- or fan-like forms, grid, parallel rectangular, radial or other textures. The identified textures are indicators of certain morphostructural properties of the given territory. The density of network elements is calculated as the sum of valley or ridge axes in squares with an area of 1 square kilometre (in $km \cdot km^{-2}$). Measurements do not have to be done in the whole research territory. They are carried out in selected areas with a relatively homogeneous density. Delimitation of such areas is done visually according to obvious change of the quantity of delineated valley or ridge axes. Linearity of network elements is a specific property of valley or ridge segments, which indicate the presence of linear morphostructural divides. Linearity of network elements means visual joining of valley or ridge segments arranged in lines. Not only valleys or ridges within one partial basin, also the segments of adjacent basins are joined into lines. Within manifestations of network element asymmetry, three types of this attribute of valley or ridge networks were identified: ground plan, profile longitudinal and profile altitudinal types.

2.2. Analysis of dividing ridges

Dividing ridge is a place of "fight" of two adjacent basins for the territory. Headward erosion and in certain circumstances also lateral erosion contribute to the shift of the watershed to the side of the less "aggressive" basin. The watershed is pushed back which causes a reduction or regressive development of this basin. The development of the opposite basin side is progressive, its area is expanding. Apart from a progressive shift of the watershed, there also occurs a radical transformation of the valley network over the watersheds by means of piracy. Piracy is the result of different altitudinal positions of erosion bases of the opposite valleys. The valley with a lower situated erosion base is predestined to capture a part of the basin with a higher situated erosion base. The extent of the shift of the basin or even of piracy depends on the rate of the barrier effect of the corresponding extent of the watershed. The barrier effect was identified by means of the following morphometric parameters: sea level altitude, relative altitude and arrangement of isobasites. The sea level altitude of the watershed is only an auxiliary criterion for the assessment of the rate of its barrier effect. It helps to locate important culminations at watershed, bottom culminations (saddles) and upper culminations (tops). The date indicating the relative altitude of basins as related to the nearest local erosion basis is more valuable. The point of the valley network where valleys of the third order meet and following that the valley had acquired a higher hierarchical position was chosen as local erosions basis. The map of isobasites compiled after Filosofov (1960), and the map by Zuchiewicz (1981) were successfully used in morphostructural research and finally in accordance with Lacika (1993,1997,1998 and 2000), Lacika, Gajdoš (1997) and Lacika, Urbánek (2000) provide a suitable auxiliary database which helps to assess the rate of the barrier effect in the basin. The largest barriers, as well as the weakened spots of the barrier effect are clearly represented on these special morphometric maps. The arrangement of isobasites (elevation and density) suggests the course of the axis of principal morphostructural units, i.e. ridges and valleys. High isobasites delimit the main barriers. Important saddles often cause disintegration of isobasite networks, important valleys with tectonic history manifest by curvature of otherwise comparatively straight isobasites.

3. Results

3.1. Morphostructural position

The geomorphic network (network of valleys and inter-valley ridges) composition has been controlled not only by climatic changes but also by the morphostructural solution during the neotectonic period. Rising of the dome-like mega-morphostructure

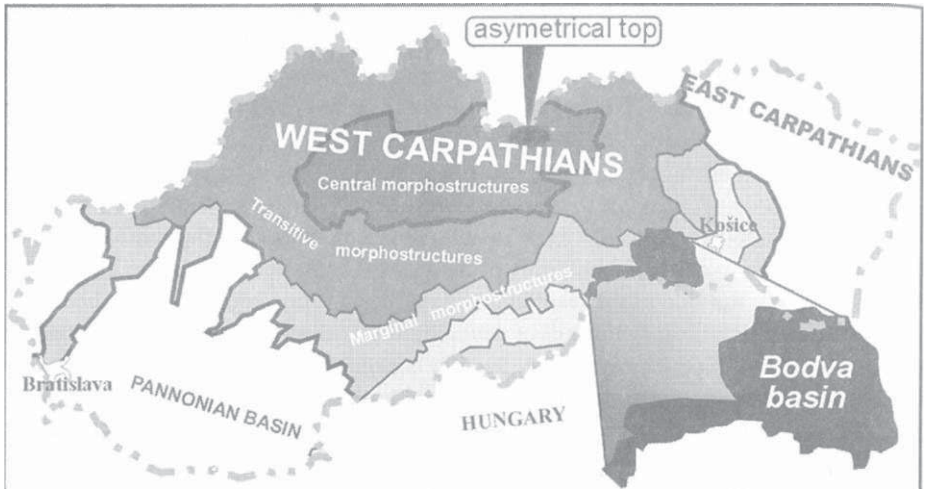

Fig. 1 Morphostructural position of the Bodva drainage basin

of the West Carpathians (Fig. 1) after the Lower Badenian (Mazúr 1979) has started the process of the older geomorphologic network transformation to a new one. The older networks disappear and younger ones adapted to new conditions replace them. Transformation is always gradual and delayed following to climatic and morphostructural changes. This is the reason why the individual drainage basins also consist of segments corresponding to non-existing conditions. Their share is diminishing while younger segments of networks are being created in accordance with the contemporary morphoclimatic and morphostructural conditions.

3.2. Morphostructural properties

The studied part of the Bodva drainage basin has been very differentiated from morphostructural point of view. It consists of contrast mosaics of partial morphostructures. The upper part spreads into the massif of the positively developing Volovské vrchy Mts with their highest massifs of Kojšovská hoľa and Pipitka, which are situated at more than 500 m above the neighbouring Košická kotlina basin. The Holička massif is about 500 m lower than the Kojšovská hoľa massif. The Slovenský kras karst represents the most important morphostructure within the drainage basin. Jakál (2001) described it as a partial morphostructure created by uplifting of the originally vast planation surface and its dissection into a system of individual karst plateaus.

They are basic morphostructural units of horst type (Jakál, 1975, 2001). The Slovenský kras karst has developed as positive (uplifting) morphostructure, which has, became a strong high barrier forcing the Bodva River to flow away. The Košická kotlina basin represents the next pivotal morphostructure. It has mostly developed as subsiding morphostructure. This negative evolution started at the end of the Palaeogene. It shapes the main local erosion base within the Bodva drainage basin. There are specific morphostructures of graben type in the Košická kotlina basin - Turnianska

Fig. 2 Mouthing of the Zádielska dolina valley (Photo J. Lacika)

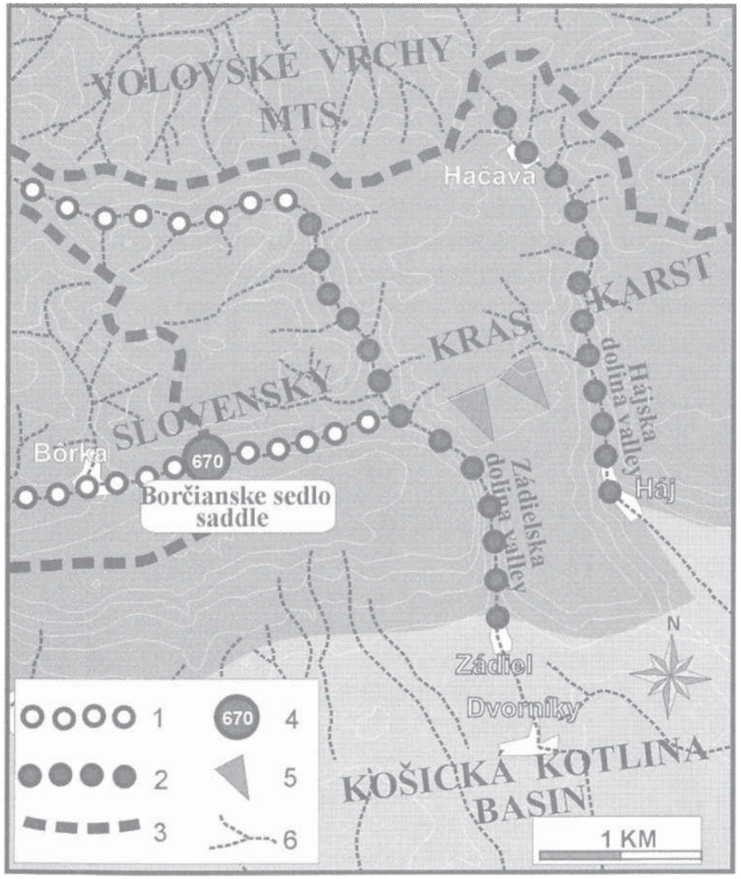

Fig. 3 Geomorphic scheme of the Zádielska dolina and Hájska dolina valleys: 1 - older valley segments, 2 - younger valley segments, 3 - watershed, 4 - saddle (altitude), 5 - slope dissected step-like karst plateaus, 6 - valley network

kotlina partial basin. According to Vass et al. (1994) the Turnianska kotlina partial basin has a peculiar lithology reflecting its tectonic and paleogeographic history. It has been tectonically very intensively destroyed by fold and fault tectonics. The most important is the youngest W - E fault system active during the Pliocene and Pleistocene periods. According to Vass et al. (1994), its activity is young, but their origin old. The faults controlled the uplifting of the Slovenský kras karst and the subsidence of the Turnianska kotlina basin and caused a strong erosion of the depression river network (Vass et al., 1994). The W - E faults bordered the Jasovská planina plateau from the south along the cave system of the Skalistý potok brook (Hochmuth, 1989). The step-like profile of this cave could be interpreted as Quaternary uplifting of the plateau and as corrosion-erosional base subsiding in the Turnianska kotlina basin. According to Jakál (1975, 2002), the specific origin of this basin is a result of inversion evolution. An increasing morphostructural contrast between karst plateaus and the flat basin bottom caused an intensive erosion removing gravels of the Pontian Poltár Formation during the Valachian neotectonic phase (Pliocene-Quaternary). There are massive proluvial accumulations at the mouthing of the Zádielská dolina and Hájska dolina valleys. It is another evidence of the dynamic morphostructural evolution of the eastern part of the Slovenský kras karst, which is more intensive than in the west of this karst area (Jakál, 2002).

3.3. Valley networks

The studied valley network (Fig. 4) has several specific properties. Firstly, its atypical ground plan is shaped like a pear fruit. Its upper part is wide, while the lower one narrows down. The fan drainage pattern is the most frequent there. The nodes positions are related to tectonic lines bordering mountains and the Košická kotlina basin. Lukniš

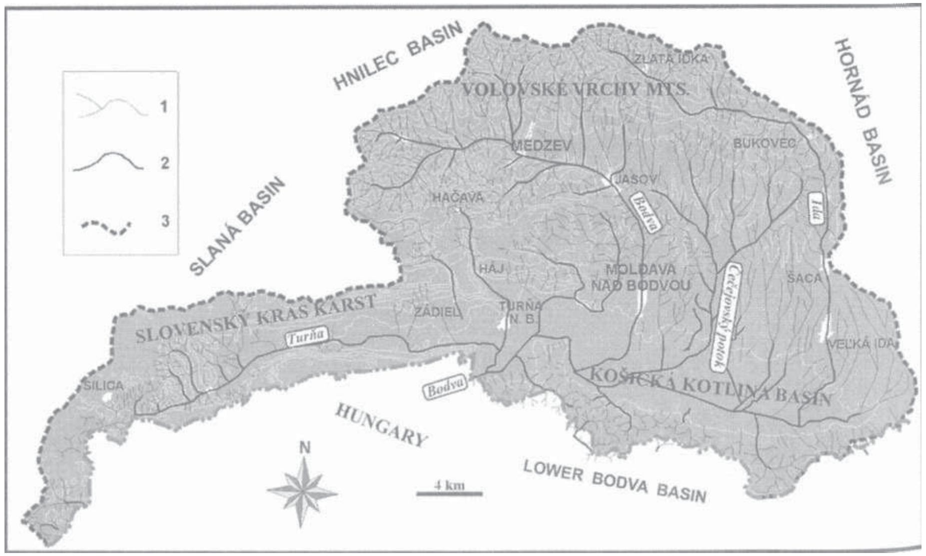

Fig. 4 Valley texture of the Bodva drainage basin: 1 - valley axis of the 1st and 2nd order, 2 - valley axis of at least the 3rd order, 3 - watershed of the Bodva drainage basin

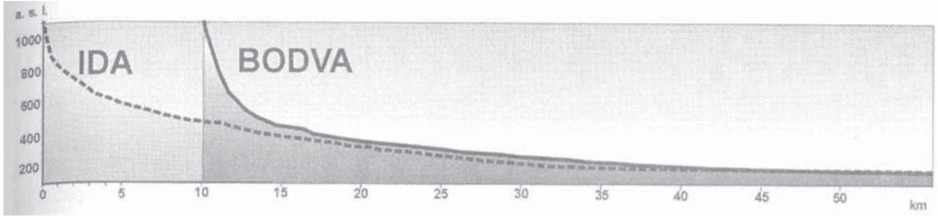

Fig. 5 Comparative longitudinal profiles of the Bodva and Ida valleys

Fig. 6 The upper part of the Bodva drainage basin from the Jasovská skala rock near the Jasov (Photo J. Lacika)

(1972) called attention to the distinctly condensed valley network near the subsiding area of Turňa nad Bodvou. This concentration was caused by a horst uplifting. The Bodva, Ida and Čečejovský potok rivers with a crescent ground plane shape are directed towards this node. Originally, however, they flowed parallel to the south. The Ida river has created a divergent fan drainage pattern due to river channel removing.

There are two dominant valleys in the Bodva drainage basin: that of Bodva and that of Ida. We have identified a fast increase of the valley hierarchy to the 5th level (according to Strahler's method, 1952) and keeping it in a very long segment. It is interesting, that the Bodva does not reach the 6th level, which is reached by its tributary Ida. The analysis of the longitudinal profiles has shown the Ida valley's dominancy in the drainage basin (Fig. 5). It has a more developed (more concave) curve of its analysed profile.

There is a very different valley network density in the studied drainage basin. This parameter changes from the value near to zero in the karst areas to more than 3-5 km $\cdot$km^{-2}. The low density in the Slovenský kras karst can be found on the surface only, the normal density is underground in cave and fissures networks.

Hochmuth and Barabas (2001) described a specific segment of the valley network in the Jasov village area (Fig. 6). They analysed the segment of the Bodva valley flowing of the Jasovská planina plateau. The Bodva is considered as "recipient" of karst hydrology of the Medzevská pahorkatina hilly land with a very small density of the valley network. The authors assume the presence of karst covered by the Neogene and Quaternary sediments.

The ground plan asymmetry has been identified in the Ida valley. The river flowing in the eastern margin of the studied basin has a more developed left (inner) side of tributaries. We can see a sort of linearity effect in this area (see Fig. 4), which indicates a probable morphostructural line.

The karst morphology is characteristic for the Bodva valley near the Jasov village. According to (Droppa 1965), this river flowed underground and formed the Jasovska jaskyňa cave. The river water used the system of tectonic fissures to penetrate in the interior of the Jasovská skala rock. The fissures follow the W - E direction. It is the same as the Bodva river channel orientation. Fluvial deep erosion created 5 cave levels, the highest one situated at 30 m above and the lowest one at 6 m under the present Bodva channel. The same periodical cycle was identified by Roth (1937) in the Domica cave.

3.4. Watersheds

The Bodva drainage basin as a component of the Slaná drainage basin integrates into the main valley near to the mouth (in Hungary). There is a high morphological barrier of the Slovenský kras karst on the western side of the studied drainage basin bordering it from the upper Slaná drainage basin. The altitude of the watershed can be only hardly recognized on the karst plateau and it varies from 350 m (SW of the Silická planina plateau) to 832 m (the Horný vrch plateau). It is about 300-600 m higher than the bottom of the Turnianska kotlina basin. We can assume subterranean piracy (explanation by Lauder 1968) in this area, which decreases the real level of the barrier effect of the Slovenský kras karst.

We identified a short watershed segment (Fig. 7), which could be transformed by a real surgical piracy close to the Borčianske sedlo saddle (670 m a.s.l.). According to Lacika (2001a), this saddle is situated 190 m above the Zádielska dolina valley and 90 m above the Čremošná valley. This topography allows to assume the future capturing of Čremošná brook (just Slaná's left tributary) to the Bodva drainage basin (through Blatnický potok brook in the Zádielska dolina valley). The Borčianske sedlo is a locality of possible surface river piracy.

There is a very low barrier effect of the watershed segment bordering the Bodva and Hornád drainage basins in the Košická kotlina basin. It appears from 20 to 100 m above the local erosion base, higher towards the Hornád valley side (Fig. 7). The watershed topographic properties and the distinct ground plan asymmetry of the Ida valley allow to assume river piracy there. We identified two localities manifesting this kind of evolution. They are situated close to Bukovec and Hýľov villages on the border of the Volovské vrchy Mts. and the Košická kotlina basin. Due to piracy, the Bodva drainage basin will lose the upper Ida valley. Lukniš (1972) wrote about the tendency to bifurcate of Ida river.

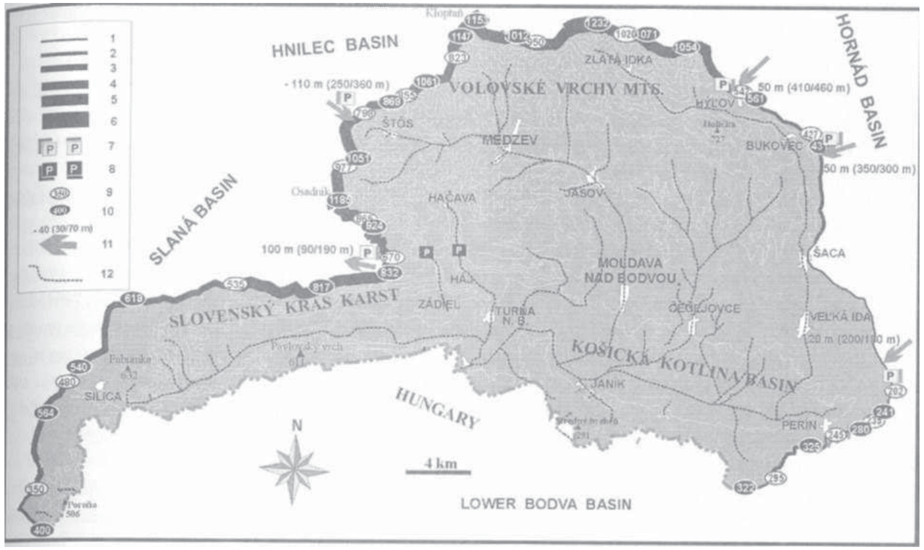

Fig. 7 Indicators of the watershed barrier effect of the Bodva drainage basin: **1** - watersheds at an altitude below 300 m, **2** - watersheds at 301-500 m a.s.l., 3 - watersheds at 501-700 m a.s.l., **4** - watersheds at 701-900 m a.s.l., **S** - watersheds at 901-1,100 m a.s.l., 6 - watersheds over 1,100 m a.s.l., 7-potential piracy (line position shows direction of the assumed river capturing), **8** - real piracy (line position shows direction **of** the river capturing), **9** - saddle and its altitude, **10** - summit and its altitude, **11** - direction of the watershed migration (opposite erosion base levels vertical difference), **12** - valley axis of at least the 3rd order

4. Conclusion

The studied Bodva drainage basin is progressively developing at the expense of the neighbouring Slaná and Hnilec drainage basins. It is spreading its area by reducing the neighbouring ones. A gradual replacing of the watershed toward the regressive Slaná and Hnilec drainage basins prevails. The piracy is determined by the mostly high barrier effect of the watershed. It is massive and high. The Slovenský kras karst barrier effect is lower, as subterranean piracy may occur underground inside of the karst plateau. There is a local tendency of regressive evolution of the studied area through the watershed bordering the Bodva and Hornád drainage basins. It is a local phenomena, but with probable more wider consequences (losing of the upper Ida valley).

Acknowledgements

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PROGRESÍVNY VÝVOJ POVODIA RIEKY BODVA
(JUHOVÝCHOD SLOVENSKÝCH ZÁPADNÍCH KARPÁT)

Résumé

Kompozícia geomorfologických sietí (sietí dolín a medzidolinových chrbtov) sa pretvára pod vplyvom morfoštruktúrnych a morfoklimatických zmien. Dochádza k jej transformácii. Starú sieť nahrádza nova odpovedajúca zmeneným podmienkam. Obvykle možno v jednom povodí identifikovať niekoľko generácií segmentov dolinových sietí, čo je odrazom cyklickej povahy geomorfologického vývoja. Nové povodia sa vyvíjajú progresívne, rozširujú sa na úkor susedných regresívne sa vyvíjajúcich povodí.

Tento príspevok prezentuje výsledok detailného výskumu slovenskej časti povodia Bodvy, ktorá je príkladom prevažne progresívne sa vyvíjajúceho sa povodia. Dané povodie je situované na juhovýchodne periférium západokarpatskej megaklenby, ktoré je vďaka asymetrickej polohe jej centra (situovaného do oblasti Tatier) geomorfologicky veľmi dynamické (obr. 1). Jeho dynamika spočíva v pomerne krátkej vzdialenosti medzi centrom a okrajom klenby resp. krátkej vzdialenosti medzi najvyšším a najnižším bodom pozdĺžneho profilu hlavnej doliny povodia. Povodie Bodvy sa progresívne vyvíja voči susedným povodiam Slanej (na západe) a Hnilca (na severe). Prejavuje tu tendenciu rozšírenia svojej rozlohy na ich úkor. Podľa analýzy rozvodia sa nám javí aktuálnejšie rozširovanie viac cestou horizontálneho zatláčania rozvodného chrbta spätnou eróziou ako riečnym pirátstvom. Riziko riečneho pirátstva je determinované pomerne vysokým bariérovým efektom (výškou a šírkou) rozvodného chrbta (obr. 7). V prípade rozhrania medzi povodím Bodvy a Slanej, ktorým sú planiny Slovenského krasu, však možno predpokladať, že jeho bariérovosť je v krasovom podzemí značne oslabená. Je tu predpoklad tzv. podpovrchového pirátstva v zmysle Laudera (1968). Voči povodiu Hornádu susediacom na severovýchode a východe, je povodie Bodvy v regresívnom vývoji. Príčina má lokálnu povahu, ale dôsledok tohto vývoja môže byť regionálne širší. Speje k tomu, že by povodie Bodvy mohlo perspektívne prísť o hornú časť povodia Idy v prospech povodia Hornádu. Pirátstvu zatiaľ bráni vysoká bariérovosť rozvodného chrbta. O budúcom pirátstve možno uvažovať len cez Borčianske sedlo (670 m), kde sa dá predpokladať načapovanie potoka Čremošná do povodia Bodvy cez Blatnický potok v Zádielskej doline (obr. 2 a 3). K pirátstvu speje aj horný tok Idy, ktorý by sa mohol stať súčasťou povodia Hornádu.

Vnútorné usporiadanie geomorfologickej siete povodia Bodvy je veľmi špecifické (obr. 4). Prvá špecifičnosť spočíva v tom, že pomerne veľká časť povodia je krasová, v dôsledku čoho na planinách Slovenského krasu absentuje povrchová dolinová sieť. Nahrádza ju podzemná sieť riečnych jaskýň. Spätosť povrchovej a podzemnej siete je markantná v okolí Javova (obr. 6), kde sa rieka Bodva účastnila na tvorbe cyklicky sa vyvíjajúcej Jasovskej jaskyne (Droppa 1965). Druhým špecifikom povodia sú kompozícia a tvar hlavných dolín. Okrem osovej doliny Bodvy sa tu vyvinula takmer rovnocenná dolina Idy. Obe sú charakteristické pôdorysom s nápadným oblúkom, ktorý je výsledkom formovania mladých lokálnych morfoštruktúr v povodí. Ohnutie zapríčinila individualizácia kvartérnej Turnianskej priekopovej prepadliny. S jej vznikom súvisí aj špecifický vývoj Zádielskej a Hájskej doliny. V horných častiach sa zachovali segmenty staršej siete, nižšie sú mladšie tiesňavovité segmenty formované pod vplyvom subsidencie Turnianskej prepadliny.