S T U D I A G E O M O R P H O L O G I C A C A R P A T H O - B A L C A N I C A
vol. LV, 2021: 89–97 PL ISSN 0081-6434

GRZEGORZ HACZEWSKI, JÓZEF KUKULAK (KRAKÓW)

POSSIBLE ROLE OF STREAM PIRACY IN EVOLUTION OF DRAINAGE NETWORK IN PASMO POŁONIN: THE ROZTOKI STREAM VALLEY (BIESZCZADY WYSOKIE, POLISH CARPATHIANS)

Abstract: Stream piracy is proposed to explain unusual relief of two neighbouring valleys in the Bieszczady Mountains, SE Poland. The Muczny Stream for more than 2 km of its headwater course is an underfit stream and the upstream continuation of its former valley is traceable in the present-day Roztoki Stream. The Roztoki Stream broke through its former right bank along a zone of a large tectonic fault, where disintegrated and displaced rocks provided routes for water escape by sapping toward the San valley. The barrier was weakened and destroyed by groundwater sapping, mass wasting on its distal side and headward erosion at the outflows of the escaped water. The gradient of the stream increased, resulting in incision of bedrock in the stream's lower course and in construction of an alluvial fan whose size is exceptional for the area. Headward erosion created a deeply incised channel, outstanding in narrowness and depth among the other stream channels in the area. Incision of this channel, in turn, provoked capture of a nearby eastward stream that had been flowing straight to the San in a broad gentle valley. Headward erosion after the capture led to incision of a deep and narrow channel in the bottom of this old gentle valley.

Keywords: stream piracy, landform analysis, drainage system, relief evolution, bedrock control, Bieszczady Mts.

INTRODUCTION

Evolution of fluvial systems in the south of Poland is well studied, owing to numerous studies by L. Starkel (1965, 1988, 1995, 2001), his students and collaborators (Szumański 1982; Starkel et al. 1982, 1996; Kaszowski, Kotarba 1987). These studies were largely based on analyses of fluvial sediments, their age and spatial relations between various generations of the fluvial and other sediments (Starkel, Gębica 1995). These methods prove less productive in the higher parts of the Carpathians, where valleys have been in large part carved by erosion and sediments tend to be preserved as scarce relics, often hardly datable (Henkiel 1969; Tokarski 1975). Progressive deepening of the valleys destroys older landforms and interpretation of relief evolution often needs to be based on inconclusive evidence. According to A. Henkiel (1977, 1982, 1997), the fluvial network in the Bieszczady Wysokie Mountains has been undergoing gradual rearrangement from drainage directed to the northwest, along the structural grain of the area, to the northward drainage, with increasing role of transverse valleys. Such transformation must have involved many instances of stream piracy, shifting streams to neighbouring drainage basins, across water divides. One of classical models of stream piracy (Crosby 1937) involves dissection of a water divide by headward erosion of streams whose channels lie lower than those of the captured rivers. Activity of the capturing stream usually plays the leading role in this process. D.T. Pederson (2001) pointed out that groundwater sapping may in some cases play decisive role in water escape across a water divide, hence the captured river may become the active player in the process. We present here our interpretation of the evolution of a node in the drainage network where the two variants of stream piracy followed one another.

Several locations of supposed past stream captures in the Bieszczady Wysokie have been pointed out by A. Henkiel (1982, 1997) and K. Pękala (1971, 1997). K. Pękala suggested that the present-day headwater section of the Muczny Stream was used by the lower course of the Roztoki Stream. This interpretation raised some concern because no stream obviously capable of capturing the Roztoki Stream by headward erosion seemed to be ever present on the other side of the water divide.

METHODS

We have collected field data in the two valleys during our work for the Detailed Geological Map of Poland, sheets Dźwiniacz Górny and Ustrzyki Górne (Haczewski et al. 2017a, b). Additional detailed fieldwork was conducted while supervising a series of master theses realized in the valley of the Roztoki Stream. Analysis of the relief for the purpose of this paper was done on topographical maps 1:10,000 and on LIDAR images available at www.geoportal.gov.pl. A 25 m long line of 7 hand drillings up to 1.8 m deep was made by one of the authors (J. Kukulak) on the water divide between the Roztoki Stream and the Muczny Stream across the supposed ancient valley bottom.

CHARACTERISTICS OF THE VALLEYS OF THE ROZTOKI AND MUCZNY STREAMS

The Roztoki and Muczny streams drain a section of the Pasmo Połonin range toward the major valley of the San River that extends parallel to the range northeast of it (Fig. 1). The relief of the valleys of both streams departs from the characteristics of most other valleys draining this range toward the San River. The other valleys are mostly deep, V-shaped, and run roughly perpendicular to the Pasmo Połonin range and the San valley.

The uppermost course of the Muczny Stream for about 2 km is a low discharge underfit stream in a wide, trough-shaped moderately deep valley running SE-NW, parallel to the structural grain of the Pasmo Połonin range. Farther downstream it receives two major left tributaries that make it a bigger stream, though the valley widens there only slightly. Below the junctions with these two streams the relief of the valley is highly altered by a landslide that dammed the stream and impounded the valley at ca. 11,500 BP for several hundred years, leaving a thick cover of lacustrine and deltaic sediments (Haczewski, Kukulak 2004). Downstream from the partly preserved landslide dam the Muczny Stream receives another left tributary from the south and turns north down to the San River.

The description of the Roztoki stream is presented separately for the two main branches of the stream: the eastern one labelled Roztoki I in Figures 2 and 3, and the western one, labelled Roztoki II.

Roztoki II occupy a steep-sided V-shaped valley with bedrock exposures in the bottom downstream from the place where headwater section clearly ends at the confluence of three smaller streams, where the valley breaks through a series of thick, steeply dipping resistant sandstone beds running across the valley, with cascades in the main channel marking a knick point in the stream's long profile (Fig. 2B). Downstream of the connection with Roztoki I the valley is generally similar, though its eastern slope is heavily affected by landslides over the whole length of this section. The lowest parts of the left, western slope are extremely steep, unusual for the V-shaped stream valleys in the Bieszczady Mountains. The depth of the narrow incision increases downstream and it attains 70 m below the saddle on the left slope behind which the Muczny stream valley begins.

Roztoki I occupies a broader valley with relatively gentle slopes and a narrow and deep, steep-sided channel incised in its axial part. Two markedly flattened ledges extend along the valley on each of its slopes, more distinct on the eastern slope. Though dissected by numerous tributaries, they can be traced over a long distance and their elevation above the stream channel increases

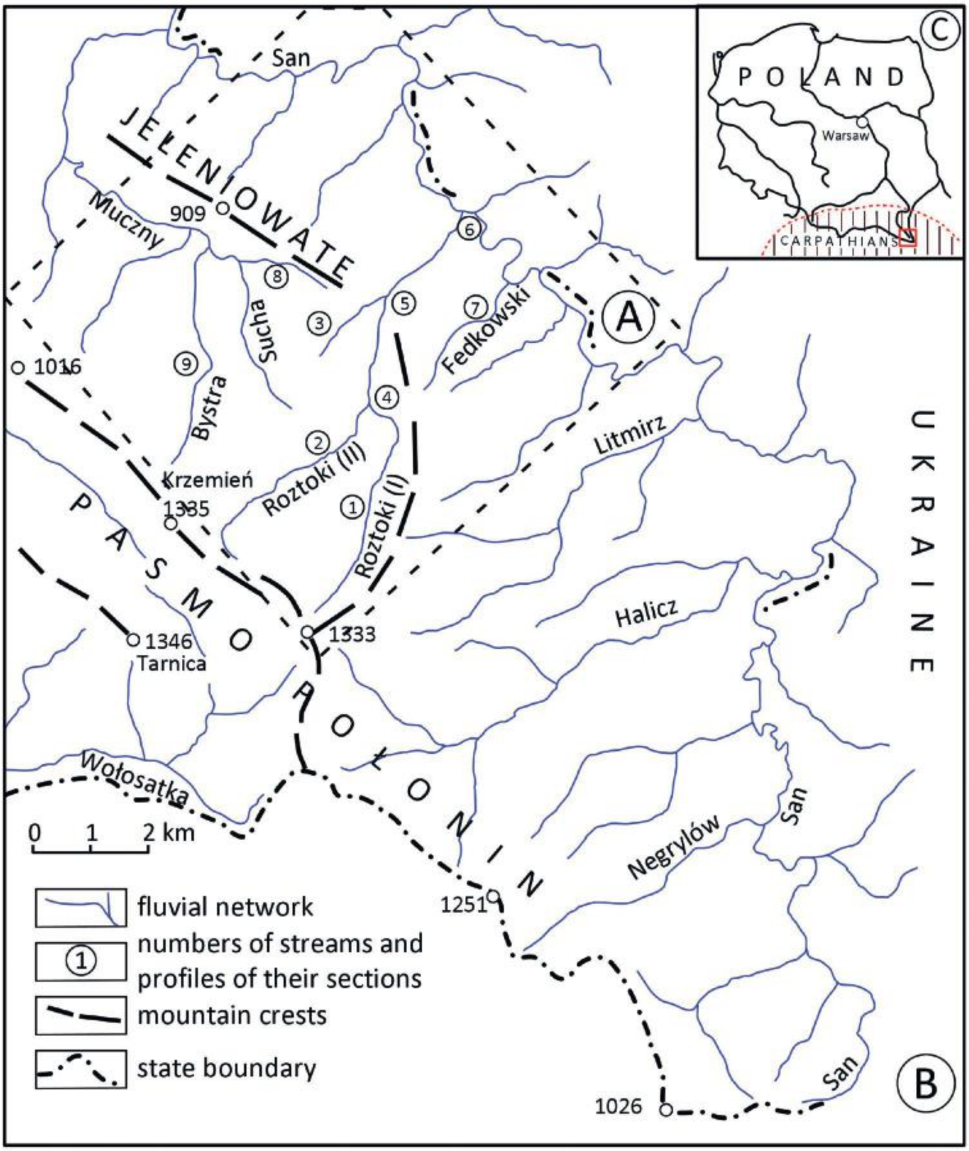

Fig. 1. Location of the study area in Bieszczady (A) and Poland (B)

gradually downstream. They are separated by a step that rises in height from 5–6 m in the upper part of the valley to 10–15 m in the lower part, below the sharp westward turn toward the junction with Roztoki II. These ledges are from more than ten to a few tens of metres wide and they narrow gradually upstream up to disappearance at altitude of ca 900 m (Fig. 2C). The higher ledge (I) is elevated 15–20 m above the stream level in the upper part of

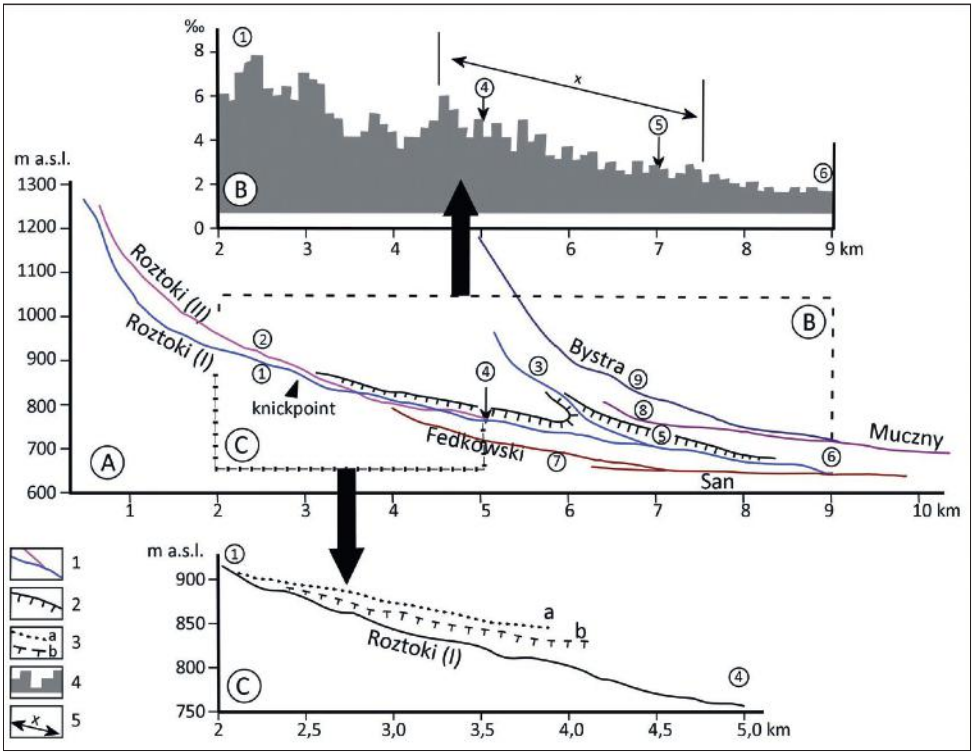

Fig. 2. Cartometric parameters of the studied streams: A – longitudinal profiles of the streams; B – gradient of the whole Roztoki stream determined from reading every 200 m; C – long profile of Roztoki (I) and relics of two positions of its ancient bottom; 1 – studied fragments of valley network, 2 – deep incisions in valley bottoms, 3 – relics of ancient positions of the valley bottom (a, b), 4 – stream gradient (in promilles), 5 – stream sections with steep gradient (x)

the valley and rises to 45 m at its downstream end. The lower level is elevated ca. 35 above the stream at its downstream termination, where it extends to the right-hand ridge crest at altitude 825 m at the place where the stream turns west to its junction with Roztoki II. Northward from this turn, in prolongation of the upper course of the stream, extends the valley of the Fedkowski Stream, lacking a funnel-shaped head, typical of stream valleys in the area. It is wide from the start and follows downstream with a uniform, mature long profile.

Downstream from the place where the Muczny valley begins on the western side, the valley of Roztoki enters extensive, flat alluvial fan of the Roztoki Stream. The fan is 1.4 km long and widens downstream to 400 m passing laterally without a contrast in relief into alluvial terrace of the San. The fan has a uniform slope of 26‰ over all its length and its upper surface is flat.

The river follows the western margin of the fan and is incised to the depth of 9–8 m at the apex and 6–5 m in the distal part. In the proximal part the stream is incised up to 7 m into bedrock overlain by 1–1.5 m of gravel. In the distal part the whole depth of the channel is cut into gravel.

DISCUSSION

Underfit streams, such as the headwater section of the Muczny Stream, are usually interpreted as eroded by a stream much larger than the one that flows there now. A natural candidate for such larger stream is the upper course of the Roztoki Stream, as was suggested by K. Pękala (1997). As an important evidence in support of this interpretation he noted the presence of densely packed gravel with clasts up to 30 cm in size on the water divide between the Roztoki and Muczny streams. We did not succeed finding this gravel during our field work. All the boreholes across the supposed ancient valley bottom encountered only clays produced by weathering of bedrock and no gravel. We assume that the gravel found by K. Pękala could be present in a small relic of ancient fluvial terrace preserved away from the present-day valley axis. It could also be brought for construction of forest railway tracks in the twenties of the 20th century, and may be now hidden below the asphalted road that follows the route of the rail.

Traces of two phases of ancient valley bottom are visible in the valley of Roztoki I in the form of the ledges, better preserved on the eastern slope. Their continuation is not present in the lowermost, westward trending section of the valley but may be found instead in the valley of the Fedkowski Stream. No clear relics of ancient valley bottom could be found in the valley of Roztoki II. They could be destroyed by incision of the valley after the capture and by mass movements in the section below the junction of Roztoki I with Roztoki II.

Stream piracy is usually effected by headward erosion of the capturing stream. Though the slope of the San valley north of the suggested former water divide on the right side of the Roztoki valley (Fig. 3) lied some 50–70 m lower than the ancient bottom of Roztoki valley, no likely candidate for dissecting the divide by headward erosion can be seen north of the divide. We suggest instead that the diversion of the stream could occur by action of the Roztoki Stream whose water dissected the water divide largely by the process groundwater sapping, percolation along a zone of fragmented and displaced rocks in the zone of the Roztoki Fault. The fault cross-cuts the ancient water divide along the present-day course of the Roztoki. This sharply bounded zone of disintegrated, displaced and mixed fault rocks was clearly exposed (Fig. 4) during the construction of the road from the Muczny valley

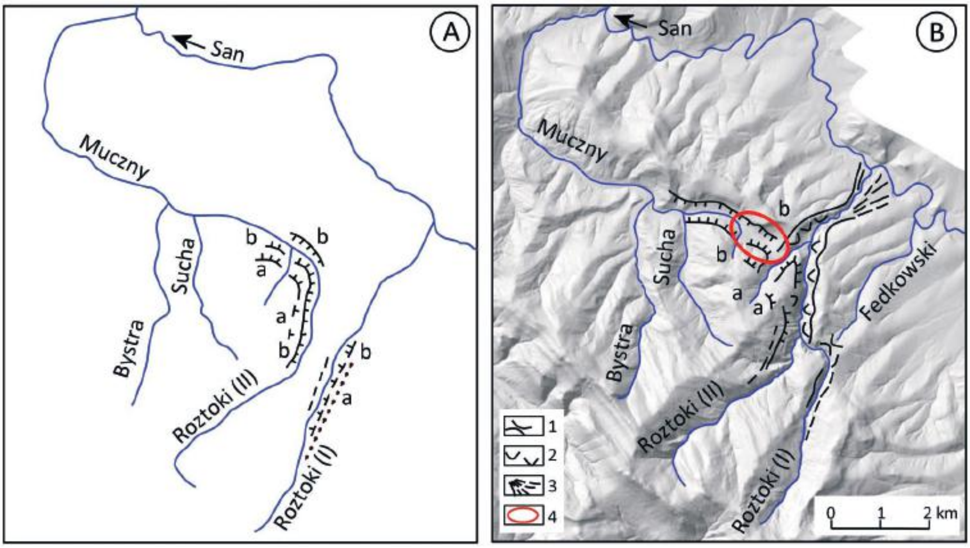

Fig. 3. Modification of the drainage network in the Roztoki and Muczny basins: A – Roztoki II flowing west to the Muczny valley and Roztoki I flowing north to the Fedkowski valley; B – Roztoki captured to the San valley and Roztoki I captured by Roztoki II; 1 – pass, 2 – slopes affected by landslides, 3 – alluvial fan, 4 – valley with underfit stream

Fig. 4. Western boundary of the fault zone in the Roztoki valley in 1971 (southward view)

to the San valley. The fault zone is still present in the bedrock of the east slope of the Roztoki below the junction of Roztoki I and Roztoki II and downstream to the apex of the Roztoki fan. Water escape from the valley bottom through the fault zone led to seepages and mass movements on the side of the San valley, undermining the water divide. When the water course became finally diverted from the Muczny valley toward the San valley, the gradient of Roztoki Stream increased leading to accelerated deepening of the valley bottom. It was probably then that Roztoki I, earlier flowing toward the Fedkowski valley became captured by Roztoki II, possibly with a significant role of gravitational mass movement on the unstable eastern slope of Roztoki valley. When the two streams united, their increased power favoured incision of the valley bottom and headward erosion, resulting in exceptionally deep and narrow ravine. The large-scale erosion supplied abundant debris for construction of the fan of the Roztoki Stream.

CONCLUSIONS

The unusual features in the relief of the upper course on the Muczny valley and of the Roztoki valley – underfit stream, extremely narrow and steep channel of the Roztoki Stream, strikingly large alluvial fan of the Roztoki Stream – are best explained by a step in drainage rearrangement from subsequent to transversal, as proposed by A. Henkiel (1977, 1982, 1997), involving the Roztoki Stream breaking to the San valley along a line of tectonic fault and later capture of its present-day right tributary.

REFERENCES

Crosby I.B., 1937. *Methods of stream piracy*. The Journal of Geology 46, Chicago, 465–486.

Haczewski G., Bąk K., Kukulak J., 2017a. *Szczegółowa Mapa Geologiczna Polski 1:50,000, arkusz 1069 - Dźwiniacz* Górny (M-34-106-D). Państwowy Instytut Geologiczny – Państwowy Instytut Badawczy, Warszawa.

Haczewski G., Bąk K., Kukulak J., 2017b. *Szczegółowa Mapa Geologiczna Polski 1:50,000, arkusz 1068 – Ustrzyki Górne(M-34-106-D).* Państwowy Instytut Geologiczny – Państwowy Instytut Badawczy, Warszawa.

Haczewski G., Kukulak J., 2004. *Early Holocene Landslide-Dammed Lake in the Bieszczady Mountains (Polish East Carpathians) and its Evolution*. Studia Geomorphologica Carpatho-Balcanica 38, 83–96.

Henkiel A., 1969. *Rozwój rzeźby dorzecza Strwiąża (Karpaty Wschodnie)*. Annales UMCS, sec. B, 24, 99–148, (in Polish).

Henkiel A., 1977. *Rzeźba strukturalna Karpat fliszowych*. Annales UMCS, Sec. B, 32–33, 37–88, (in Polish).

Henkiel A., 1982. *O pochodzeniu kratowej sieci rzecznej Beskidów Wschodnich*. Czasopismo Geograficzne 53, 19–27, (in Polish).

Henkiel A., 1997. *Mikroregiony geomorfologiczne Bieszczadów polskich*. Annales UMCS, sec. B, 52, 9, 133–145, (in Polish).

Kaszowski L., Kotarba A., 1967. *Charakterystyka morfodynamiczna koryta Sanu koło Myczkowiec*. Studia Geomorphologica Carpatho-Balcanica 1, 53–72, (in Polish).

Pederson D. T., 2001. *Stream piracy revisited: a groundwater-sapping solution*. GSA Today 2001, 4-10.

Pękala K., 1971. *Elementy rzeźby przedczwartorzędowej w dolinie górnego Sanu w Bieszczadach*. Annales UMCS, sec. B, 26, 220–230, (in Polish).

Pękala K., 1997. *Rzeźba Bieszczadzkiego Parku Narodowego*. Roczniki Bieszczadzkie 6, 19–38, (in Polish).

Starkel L., 1965. *Rozwój rzeźby polskiej części Karpat Wschodnich (na przykładzie dorzecza górnego Sanu)*. Prace Geograficzne IGiPZ PAN, 50, 1–160, (in Polish).

Starkel L., 1988. *Historia dolin rzecznych w holocenie*. [in:] L. Starkel (ed.) *Przemiany* środowiska *geograficznego Polski*. Ossolineum, Wrocław, 87–107, (in Polish).

Starkel L.,1995. *Evolution of the Carpathian valleys and the Forecarpathian Basins in the Vistulian and Holocene.* Studia Geomorphologica Carpatho-Balcanica 29, 5–40.

Starkel L., 2001. *Historia doliny Wisły od ostatniego zlodowacenia do dziś*. Monografie IGiPZ PAN 2, 1–263, (in Polish).

Starkel L., Gębica P., 1995. *Evolution of river valleys in Southern Poland during the Pleistocene-Holocene transition*.Biuletyn Peryglacjalny 34, 177–190.

Starkel L., Kalicki T.,Krąpiec M., Soja R., Gębica P., Czyżowska E., 1996. *Hydrological changes of valley floors in upper Vistula basin during the last 15 000 years*. [in:] L. Starkel (ed.) *Evolution of the Vistula river valley during the last 15,000 years, part VI*. Geographical Studies, Special Issue 9, IGiPZ PAN, 7–128.

Starkel L., Klimek K., Mamakowa K., Niedziałkowska E., 1982. *The Wisłoka river valley in the Carpathian foreland during the Lateglacial and Holocene*. [in:] L.Starkel (ed.) *Evolution of the Vistula river valley during the last 15,000 years*. Geographical Studies IGiPZ PAN, Special Issue 1, 41–56.

Szumański A., 1982. *The evolution of the lower San river valley during the late glacial and the Holocene.* [in:] L. Starkel (ed.), *Evolution of the Vistula river valley during the last 15,000 years*. Geographical Studies IGiPZ PAN, Special Issue 1, 57–78.

Tokarski A.K., 1975. *Geologia i geomorfologia okolic Ustrzyk Górnych (polskie Karpaty Wschodnie.* Studia Geologica Polonica, 48, 1–92, (in Polish).

Grzegorz Haczewski
Józef Kukulak
Institute of Geography
Pedagogical University of Kraków
Podchorążych 2, 30-084 Kraków
e-mail of the corresponding author: jkukulak@up.krakow.pl