SHAPE OF FLUVIAL PEBBLES IN SURFACE AND SUBSURFACE KARST STREAM FROM MORAVIAN KARST, CZECH REPUBLIC

OBLIKA FLUVIALNI PRODNIKOV V POVRŠINSKIH IN PODZEMELJSKIH KRAŠKIH VODOTOKIH NA MORAVSKEM KRASU, ČEŠKA REPUBLIKA

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Jaroslav Kadlec: Oblika fluvialnih prodnikov v površinskih in podzemeljskih kraških vodotokih na Moravskem krasu, Češka republika

Voda s kraških področij pogosto teče skozi jame, kjer se hidravlične razmere močno razlikujejo od površinskih. Na Moravskem krasu je avtor primerjal različne stopnje zaobljenosti prodnikov, ki jih prenašajo tokovi na površju in v podzemlju. Za študijo so bili izbrani recentni prodniki v Bili vodi in Punkvi. Dolžina površinskega teka je 18.5 km, podzemni tek pa je dolg 6 km. Skupno je bilo izmerjenih 960 prodnikov iz greywacke (velikost od 16 do 31.5 mm). Spremembe v obliki in zaobljenosti prodnikov v sedanjem vodotoku zanesljivo kažejo odvisnost fluvialnega drobirja od hidravličnih lastnosti okolja.

Ključne besede: kraški vodotok, fluvialni prodniki, oblika, zaobljenost

Abstract UDC 556.34:553.628

Jaroslav Kadlec: Shape of Fluvial Pebbles in Surface and Subsurface Karst Stream from Moravian Karst, Czech Republic

Streams draining karst areas often flow through caves which have significantly different hydraulic parameters than surface channels. The Moravian Karst yields a possibility of comparing different degrees of reworking of pebbles transported by streams in surface and subsurface environments. For the study of the reworking of fluvially deposited pebbles, modern sediments of the Bila Voda and Punkva Rivers were chosen. The length of the surface stream is 18.5 km; the subsurface stream is 6 km long. 960 pebbles of greywacke (size interval 16-31.5 mm) were measured in total. The changes in shape and roundness of pebbles in the modern stream channel persuasively demonstrated the dependence of reworking of clasts of fluvial sediments on the hydraulic conditions of the environment.

Key words: karst stream, fluvial pebbles, shape, roundness

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The karst environment is characterised by its unique hydrologic conditions. Streams draining karst areas often flow through caves which have significantly different hydraulic parameters than surface channels. The hydraulic conditions of the environment have a dominant influence on the means of transport and reworking of pebbles of fluvial sediments. The length of transportation and the degree of reworking of fluvial clasts depend on the kinetic energy of the flow. The energy of water increases either due to higher flow velocity or due to the increase in water amount. These processes are caused by higher water levels during spring thaw. Flood stages may also be occasionally caused by high rainfall in different periods of the year.

Several authors have studied the shape of pebbles in superficial streams and the level of their reworking (e.g. Sneed and Folk, 1958; Mills, 1979). Pebbles deposited by underground karstic streams were also investigated (e.g. Bull, 1978; Kranjc, 1981). Kranjc (1989, pp. 51- 54) published a data set characterizing reworking of pebbles in a subterranean river flowing through the Škocjanske Jame and Kačna Jama Caves. The set is complemented by three samples of a psephite collected from a surface stream at different distances in front of the caves. However, significant differences between reworking of pebbles in the surface stream and the underground stream are not apparent.

Moravian Karst yields a possibility of comparing different degrees of reworking of pebbles transported by streams in surface and subsurface environments. The common feature of rivers flowing through the Moravian Karst is the fact that the larger part of their catchment area is formed by non-karstic rocks of Lower Carboniferous age. On the boundary with the Devonian limestones of the Moravian Karst, the flows sink underground and continue through caves.

For the study of the reworking of fluvially deposited pebbles, modern sediments of the Bila Voda River were chosen. This stream originates in the Drahanska Vrchovina Upland 2 km southwest of Protivanov village. It flows through the Lower Carboniferous greywackes, siltstones and shales of the Protivanov and Rozstáni formations. Most of the pebbles transported by the Bila Voda River consist of fine - to medium-grained greywackes (83-98%), siltstones and shales are present in a much smaller scale (9-17%) and quartz can be found exceptionally in the psephitic fraction. The Bila Voda River originates 640 m a.s.l. and the length of its surface stream to the northern margin of the Moravian Karst is 18.5 km. South of the village of Holstejn, the stream sinks underground to the Rasovna Cave. It drops 30 m vertically and continues through the cave systems (Fig. 1.). In the Amaterska Jeskyne cave, the Bila Voda merges with a stream which sinks underground in the Sloupsko-Sosuvske caves. It is the Luha Creek and its tributaries. Waters of these two streams continue as the Punkva River through the Amaterska Cave towards the Macocha Chasm and Punkevni Caves. The subterranean river resurges on the bottom of the Pusty Žleb valley. Punkva continues 13 km on the surface and meets the Svitava River on the southern margin of the town of Blansko.

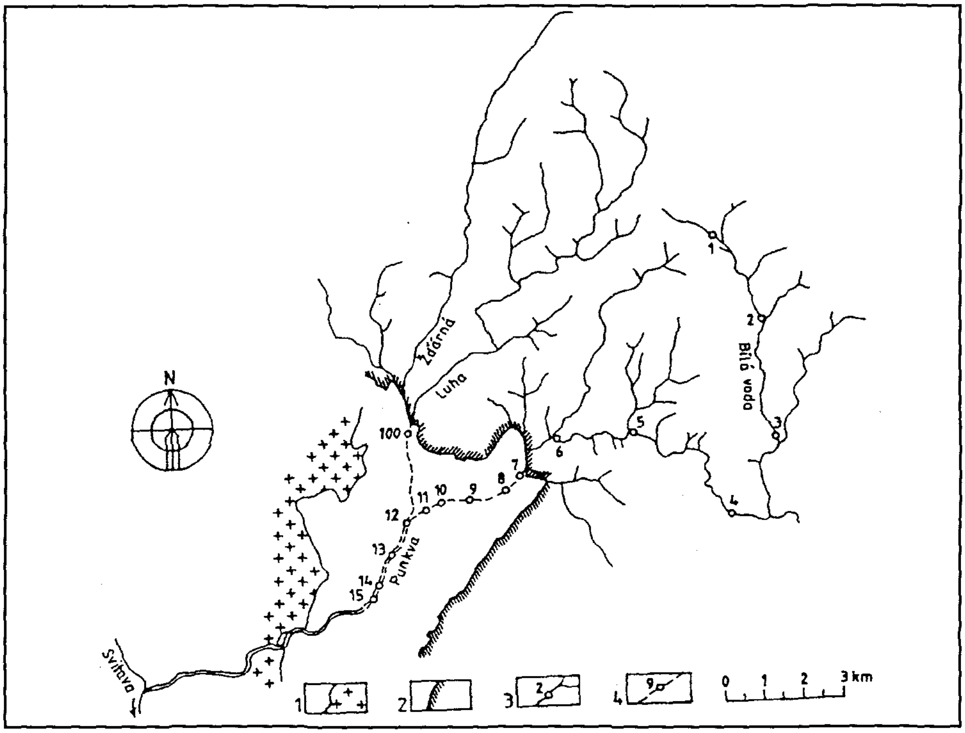

Fig. 1: The northern part of the Moravian Karst; 1 - boundary between Devonian limestones and Proterozoic Brno massiv, 2 - boundary between Devonian limestones and Lower Carboniferous non-karstic sediments, 3 - surface stream with a sampling point, 4 - subsurface stream with a sampling point

Sl. 1: Severni del Moravskega krasa; 1 - meja med devonskimi apnenci in proterozojskim masivom Brna, 2 - meja med devonskimi apnenci in spodnje karbonskimi nekraškimi sedimenti, 3 - površinski tok in mesto vzorčevanja, 4 - podzemeljski tok in mesto vzorčevanja

Reworking of the clasts during transportation both in the surface and underground channels of the Bila Voda and Punkva Rivers is expressed by the roundness and shape of the pebbles. Each sample consisted of 60 pebbles of greywacke from the size interval 16-31.5 mm (Ø = -4 to -5). Eight samples were collected in the surface channel and another eight in the caves. 960 pebbles were measured in total.

Roundness is determined by the ratio of the diameters of the largest and smallest circle drawn into the plane of the pebbles' largest projection (Dobkins and Folk, 1970). The resultant roundness of the suite of 60 pebbles is calculated as a weighted average. Weights are determined by the above average abundance in each bin of the roundness distribution. Figure 2-B shows that roundness in the surface flow gently rises downstream (samples 1-7). In places where short tributaries carrying less reworked pebbles enter the Bila Voda River, the roundness drops (samples 2, 4, 7). The profile of the flow rapidly changes its character at the ponor of the Bila Voda (Fig. 2-A). The hydrodynamic potential of the river increases and so does the rate of reworking of the pebbles. This is also caused by the specific hydraulic conditions of an underground environment. The stream flows through narrow places, often without open air surface, at an increased velocity. Another increase in the pebble roundness occurs after the confluence with the Luha Creek which transports more reworked clasts. The pebbles in a sample of fluvial sandy gravels collected in front of the ponor at Sloup (sample 100) are more rounded than those found in front of the sink of the Bila Voda River near Holstejn (Fig. 2-B). The steeper profile of the Luha increases the hydrodynamic potential of the flow causing higher roundness of clasts.

It is not possible reliably to determine the roundness of pebbles in the surface flow of the Punkva from its resurgence in the Pusty Žleb valley to its confluence with the Svitava River. Limestone and granitoid clasts dominate in the channel and it is not possible to collect a psephitic sample with the necessary amount of greywacke pebbles. This part of the Punkva surface stream is graded with the same slope as that of the Bila Voda from its spring to the sink in the Rasovna Cave (Fig. 2-A). One can thus assume that the roundness of pebbles in the surface flow of Punkva gently rises in the same manner as in the Bila Voda in the part represented by samples 1 to 7.

The shape of pebbles is determined by the ratio of all three axes and calculated by a formula used by Dobkins and Folk (1970). The resultant value is once again a weighted average of 60 values. Weights are determined from the above average abundance in each bin of the distribution. Positive values represent a rodlike pebble shape, negative values an oblate shape. An obvious trend in flattening of pebbles can be seen from the source of the Bila Voda downstream (Fig. 2-C, samples 1-7). In places where short tributaries bring less reworked clasts, rodlike pebbles are more abundant (samples 2,4,7). Continuous flattening downstream results from shortening of the shortest axes

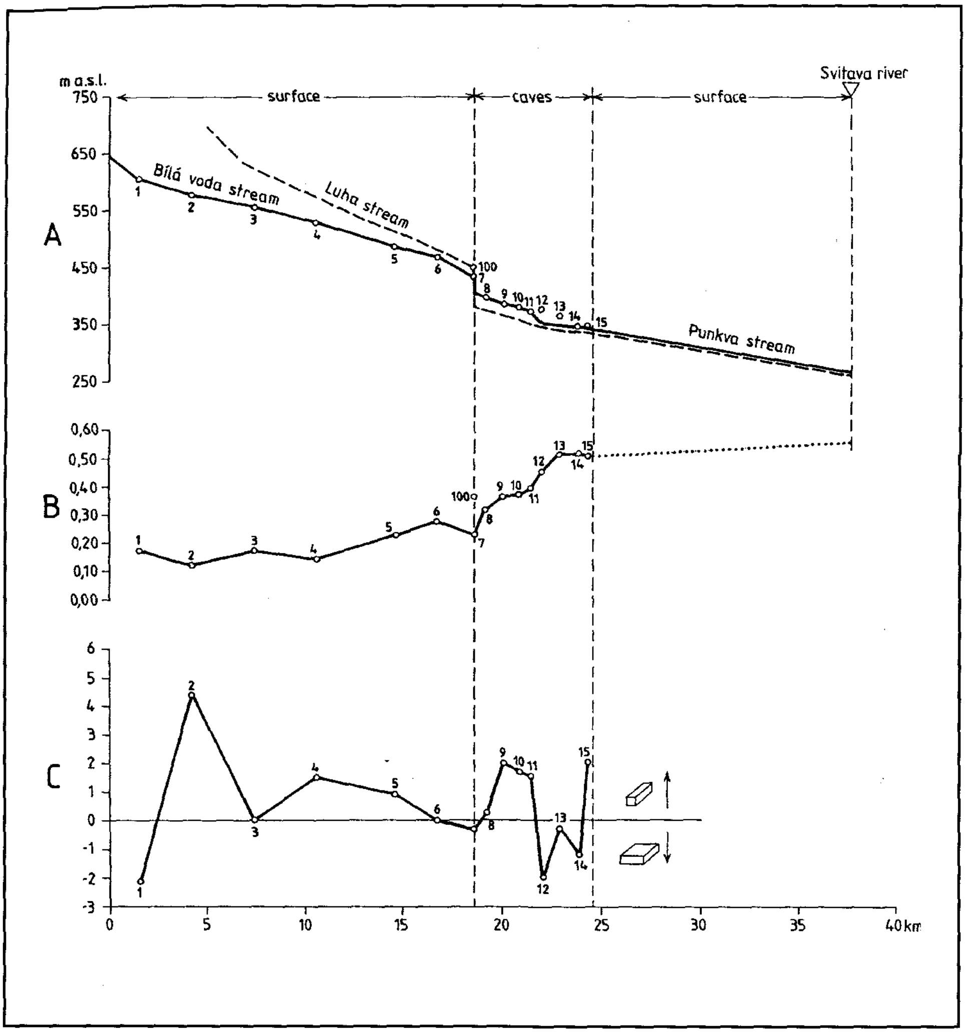

Fig. 2: A - gradient curves of the Luha, Bila Voda and Punkva rivers with sampling points, B - roundness of the pebbles, C - shape of the pebbles

Sl. 2: A - strmec rek Luha, Bila voda in Punkva z vzorčevalnimi mesti, B - zaobljenost prodnikov, C - oblika prodnikov

(S). This is caused by sliding of pebbles along the bottom of the channel. The flux pushes the clasts to the bottom by a force opposite to hydraulic lift (Blatt et al., 1972, p. 108). The same force causes imbrication of pebbles.

On the margin of the Moravian Karst where the Bila Voda sinks underground, hydraulic conditions change. In the karstic caverns which often form narrow channels, water flows with increased velocity often without a free air surface. The fluvial greywacke pebbles from the initial part of subterranean stream have significantly rodlike shapes (samples 9,10). The Bila Voda flows through several long narrow siphons connecting the caves. The increased velocity in the underground channels lowers the pressure (Dreybrodt, 1988, Kranjc, 1989). The clasts are not being forced to the bottom of the channel, they rotate around their long axes (L) and obtain a rodlike shape. The next segment of the active stream channel is mostly unknown as it is situated 10-20 m below the Amaterska Jeskyne cave which consists of vast flood passages probably active still in the Holocene. In some of the extremely spacious passages, the hydraulic conditions were similar to those of a surface channel. In such segments of the underground stream, the pebbles of greywacke were rapidly flattened due to decrease in water velocity and increase in pressure (samples 11,12,13). The last part of the underground flow of the Punkva River is formed by narrow channels and a 400 m long siphon between the Amaterska and Punkevni Caves. The pebbles become rodlike again due to the previously described mechanism (samples 14,15).

The changes in shape and roundness of pebbles in the modern stream channels of the Bila Voda and Punkva Rivers persuasively demonstrate the dependence of reworking of clasts of the fluvial sediments on the hydraulic conditions of the environment.

ACKNOWLEDGEMENT

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Povzetek

Voda s kraških področij pogosto teče skozi jame, kjer se hidravlične razmere močno razlikujejo od površinskih. Dolžina transporta in stopnja preoblikovanja fluvialnega kamninskega drobirja sta odvisni od kinetične energije vode, ta pa od hitrosti toka in od pretoka. Na Moravskem krasu so bile v okviru študije primerjane različne stopnje zaobljenosti prodnikov, ki jih prenašajo tokovi na površju in v podzemlju. Za študijo so bili izbrani recentni prodniki v Bili vodi in Punkvi. Njuna glavna značilnost je velik delež porečja na normalnem svetu, ob prehodu na devonske apnence pa reki ponikata in tečeta dalje pod zemljo. Dolžina površinskega teka je 18.5 km, podzemni tek pa je dolg 6 km. Skupno je bilo izmerjenih 960 prodnikov iz greywacke (velikost od 16 do 31.5 mm). Spremembe v obliki in zaobljenosti prodnikov v sedanjem vodotoku zanesljivo kažejo odvisnost fluvialnega drobirja od hidravličnih lastnosti okolja. Tako v zaobljenosti kot v obliki se pokažejo bistvene razlike med prodniki iz površinske in tistimi iz podzemeljske struge. Ponorna cona je tisti del rečne struge, kjer se lastnosti prodnikov najhitreje spremene.